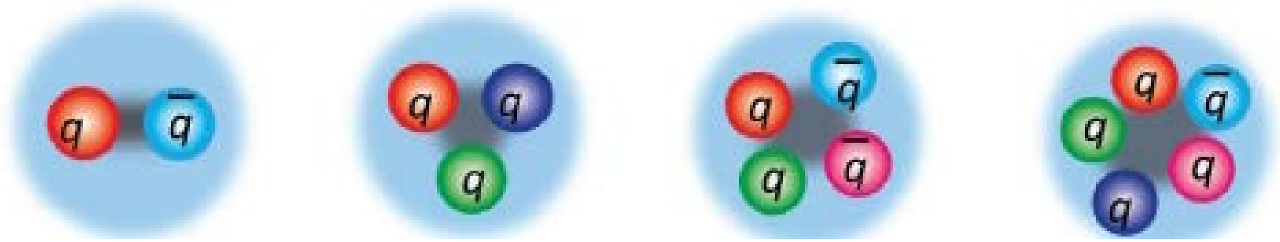
FÍSICA HADRÓNICA



VNIVERSITAT DE VALÈNCIA

IFIC
INSTITUT DE FÍSICA CORPUSCULAR

FÍSICA HADRÓNICA, INTERACCIONES FUNDAMENTALES Y FÍSICA NUCLEAR

PROYECTOS : FPA2013-47443-C2-1-P, FPA2016-77177-C2-1-P (Coordinados)
PrometeoII/2014/066

COMPONENTES DEL GRUPO

V. Vento : CU, FT (IP Proyecto Nacional 2014-2016)

S. Noguera : CU, FT (IP Prometeo)

P. González : CU, FT (IP Proyecto Nacional 2016-2018)

J. Vijande : TU, FAMN (50%)

V. Pagura : Contrato Investigador Doctor Junior, UV

M. Rinaldi : Contratado Proyecto, CSIC

TEMAS GENERALES DE INVESTIGACIÓN

Estructura Hadrónica

V. Vento , S. Noguera, P. González, J. Vijande, V. Pagura, M. Rinaldi

Universidad de Salamanca (A. Valcarce, T. Fernández-Caramés)
Università degli Studi di Peruggia (Italia) (S.Scopetta)
INFN (Italia) (M. Traini)
IPNL (Francia) (J. M. Richard)
Universidad Nacional de La Plata (Argentina) (C. García Canal, D. Gómez Dumm)
CONICET (Argentina) (T. Tarutina)
Laboratorio TANDAR (Argentina) (N. Scoccola)
Instituto Politécnico Nacional (Méjico) (A. Courtois, H. Garcilazo)
Chungnam National University (Corea del Sur) (B-J. Park)
Chungbuk National University (Corea del Sur) (H-J. Lee)

Monopolos Magnéticos

V. Vento

Universidad Nacional de La Plata (C. García Canal, L. Epele, H. Fanchioti)
MoEDAL

ESTRUCTURA HADRÓNICA

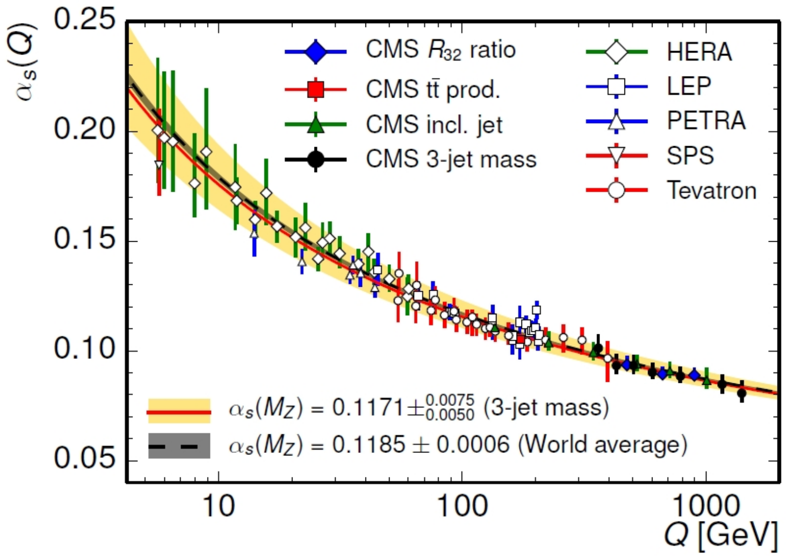
QCD

$$L_{\rm QCD} = -\frac{1}{2}\,{\rm tr}\,G^{\mu\nu}G_{\mu\nu} + \sum_{f=u,\ldots,b} \bar{q}_f\,(i\not{D} - m)\,q_f$$

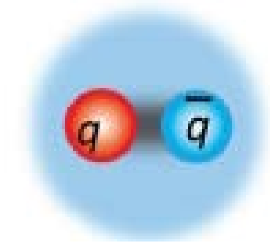
$$\begin{aligned} G_{\mu\nu} &= \partial_\mu A_\nu - \partial_\nu A_\mu - ig[A_\mu, A_\nu] \\ D_\mu &= \partial_\mu - igA_\mu \end{aligned}$$

Running parameter : g Libertad Asintótica, Esclavitud Infraroja

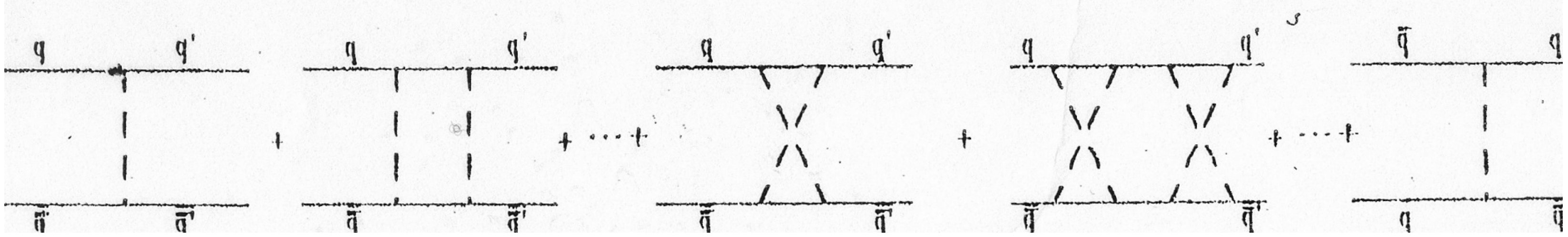
$$\alpha_s = g^2/4\pi$$



Bethe-Salpeter Equation



$$(p_q\partial - m_q)\Psi_{q\bar{q}}(p;P)(p_{\bar{q}}\,\partial - m_{\bar{q}}) = \frac{1}{(2\pi)^4}\int K(p,p';P)\Psi_{q\bar{q}}(p';P)d^4p'$$



1. Static Approach

$$K(p,p';P) = K(\overrightarrow{q} = \overrightarrow{p} - \overrightarrow{p}') = V(\overrightarrow{q})$$

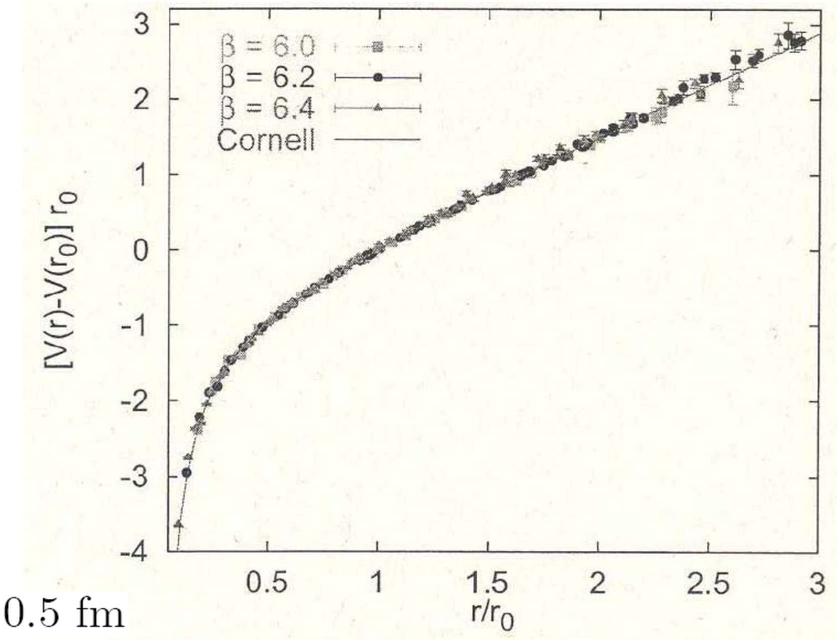
Fully nonrelativistic approach (Schrödinger equation)

$$\left(m_q + \frac{\overrightarrow{p}_q^2}{2m_q} + m_{\overline{q}} + \frac{\overrightarrow{p}_{\overline{q}}^2}{2m_{\overline{q}}} - M\right)\phi(\overrightarrow{p}) = -\frac{1}{(2\pi)^3}\int V(\overrightarrow{q})\phi(\overrightarrow{p}')d^3p'$$

$$\phi(\overrightarrow{p}) = \int \Psi_{q\overline{q}}(p;P=0)dp^0$$

Nonrelativistic Quark Model

Quenched static potential from Lattice - QCD



$r_0 \approx 0.5$ fm

$$V_{st}(r) = \sigma r - \frac{\kappa}{r} + C$$

G. S. Bali, Phys. Rep. 343,1 (2001)

Cornell potential:

$$V_C(r) = \sigma r - \frac{k}{r} + C$$

Good description of heavy quarkonia up to meson-meson thresholds.

E. Eichten et al., Phys. Rev. D 21 (1980) 203

Multiquark Structures

Dibaryons (qqqqQQ): Cornell potential + CM

Color + Antisimmetry

$$V = -\frac{3}{16}\sum_{i<j}\tilde{\lambda}_i.\tilde{\lambda}_j\left(-\frac{a}{r_{ij}} + b\,r_{ij} + \frac{c}{m_i\,m_j}\left(\frac{\mu}{\pi}\right)^{3/2}\exp(-\mu\,r_{ij}^2)\,\boldsymbol{\sigma}_i.\boldsymbol{\sigma}_j\right)$$

$$S_1 = (000)\ ,\quad S_2 = (011)\ ,\quad S_3 = (101)\ ,$$
$$S_4 = (110)\ ,\quad S_5 = (111)\ .$$

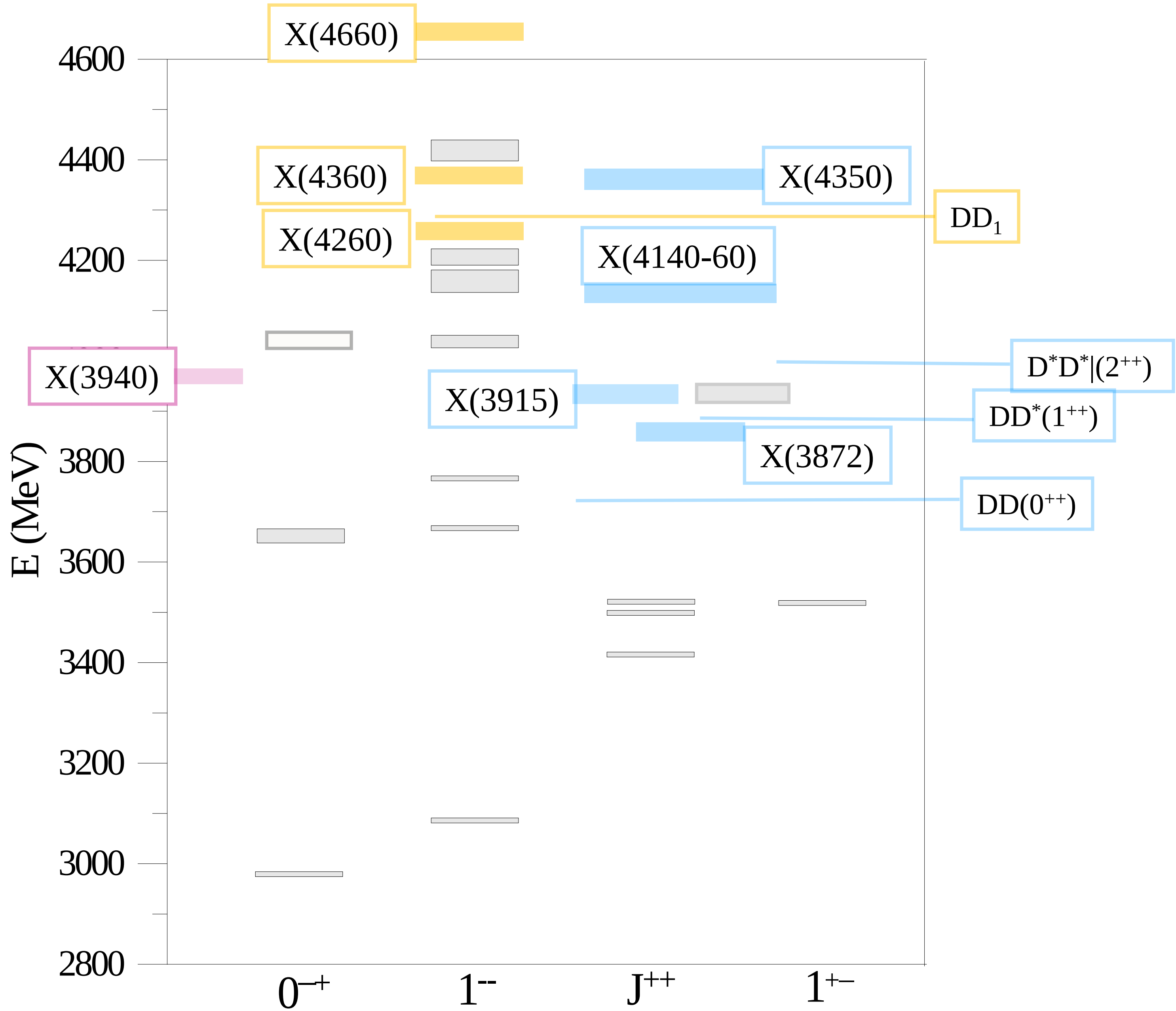
$$C_1 = (666)\ ,\quad C_2 = (6\bar{3}\bar{3})\ ,\quad C_3 = (\bar{3}6\bar{3})\ ,$$
$$C_4 = (\bar{3}\bar{3}6)\ ,\quad C_5 = (\bar{3}\bar{3}\bar{3})\ .$$

Color-spin vector	E (GeV)	
C_1S_1	3.079	
C_2S_1	2.829	
C_3S_4	2.831	
C_2S_2	3.030	
C_3S_3	3.030	
C_3S_5	2.908	
C_1S_2	2.995	
C_4S_3	2.835	
C_4S_4	3.080	
C_4S_5	3.016	
C_5S_3	2.891	
C_5S_4	2.997	
C_5S_5	3.034	
Coupled	2.767	
Thresholds	2.570	2.630

J. Vijande, A. Valcarce, J.-M. Richard, and P. Sorba
Phys. Rev. D **94**, 034038 (2016)

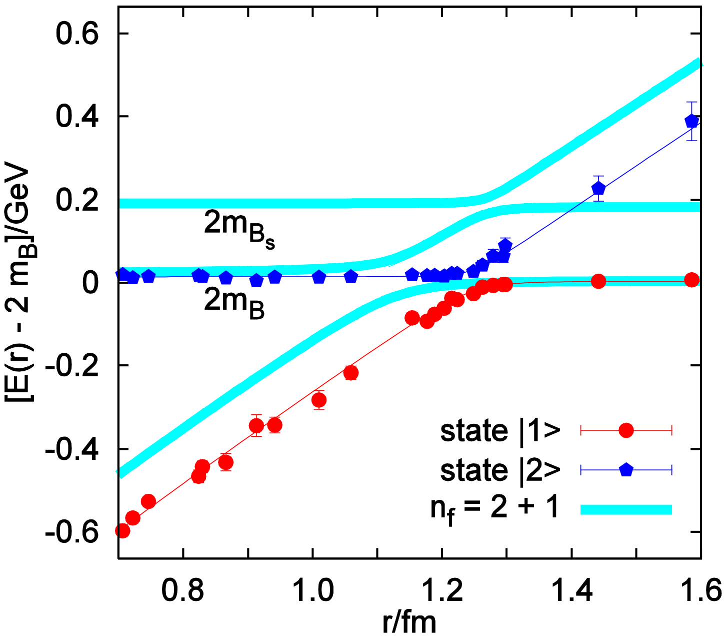
No bound state is found

New Charmonium

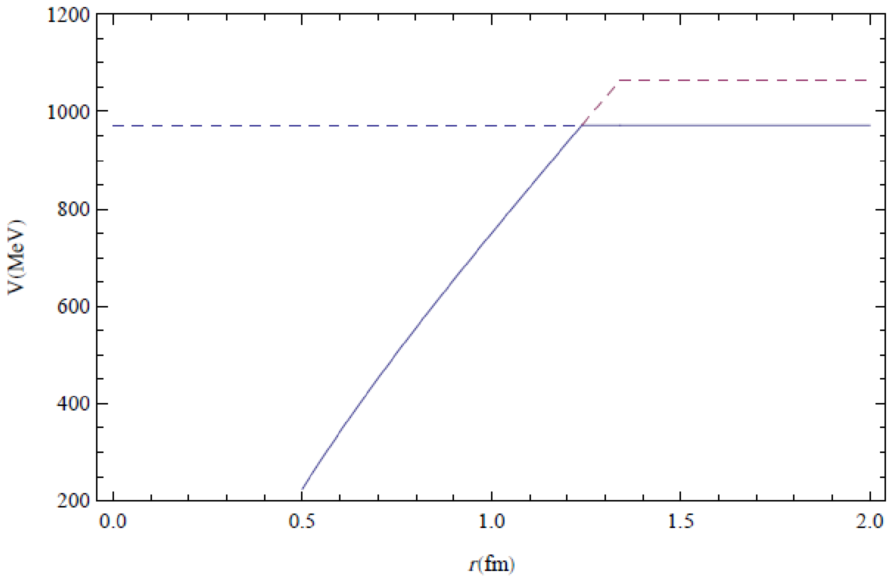


X states : Close-below or Above their First S-wave M-M Threshold

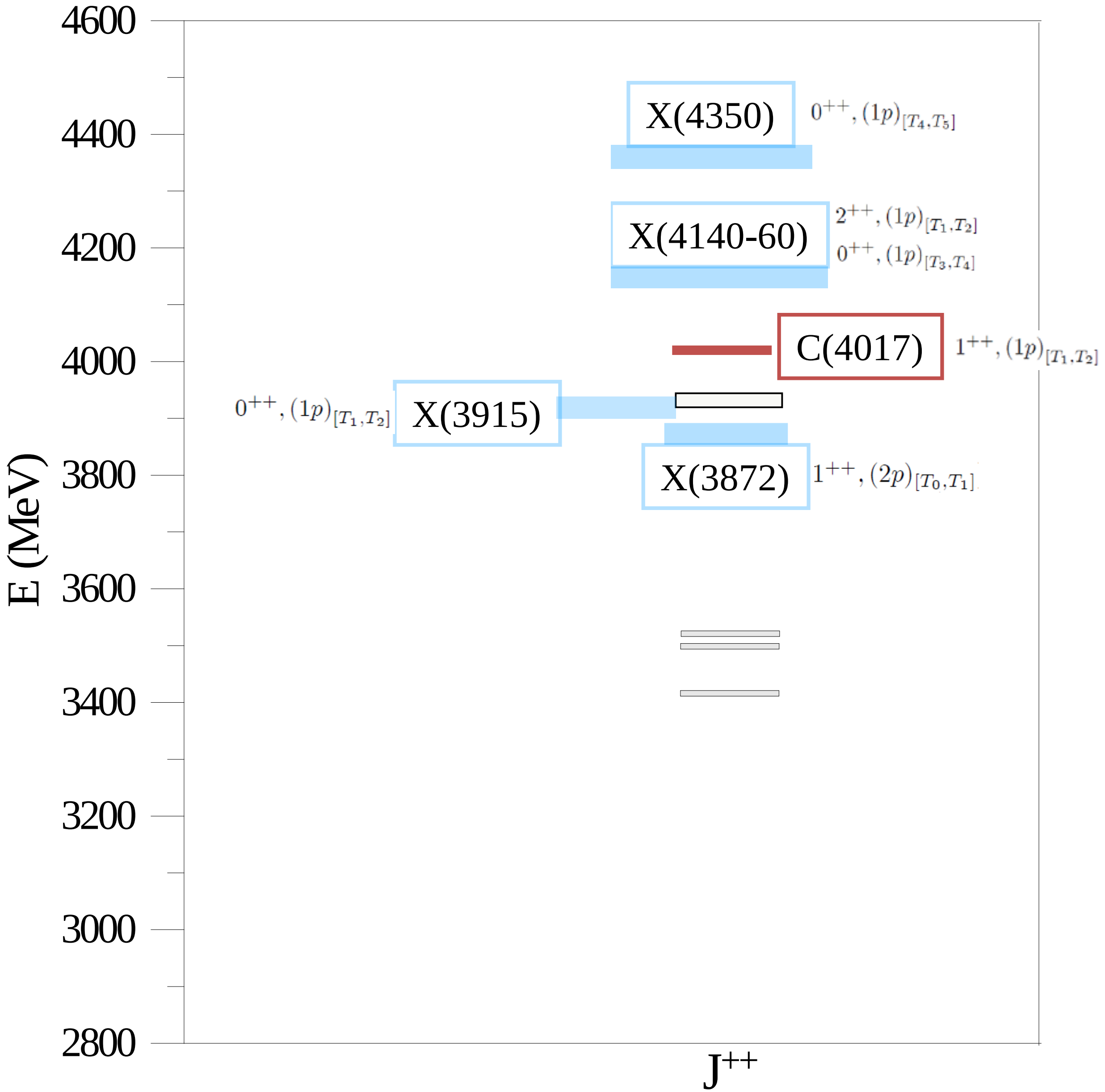
Unquenched static potential from Lattice - QCD



G. S. Bali *et al.*, PRD 71, 11453 (2005)



Cornell potential modulated by thresholds



P. González. , Phys. Rev. D92, 014017 (2015)

2. Effective Field Theory Approach

NJL Model : Model of QCD in the chiral limit, quark condensate (SSB), no confinement, extra UV cutoff.

$$\mathcal{L} = \bar{\psi}(i\partial\!\!\!/ - m_0)\psi + G\left[(\bar{\psi}\psi)^2 + (\bar{\psi}i\gamma_5\psi)^2\right]$$

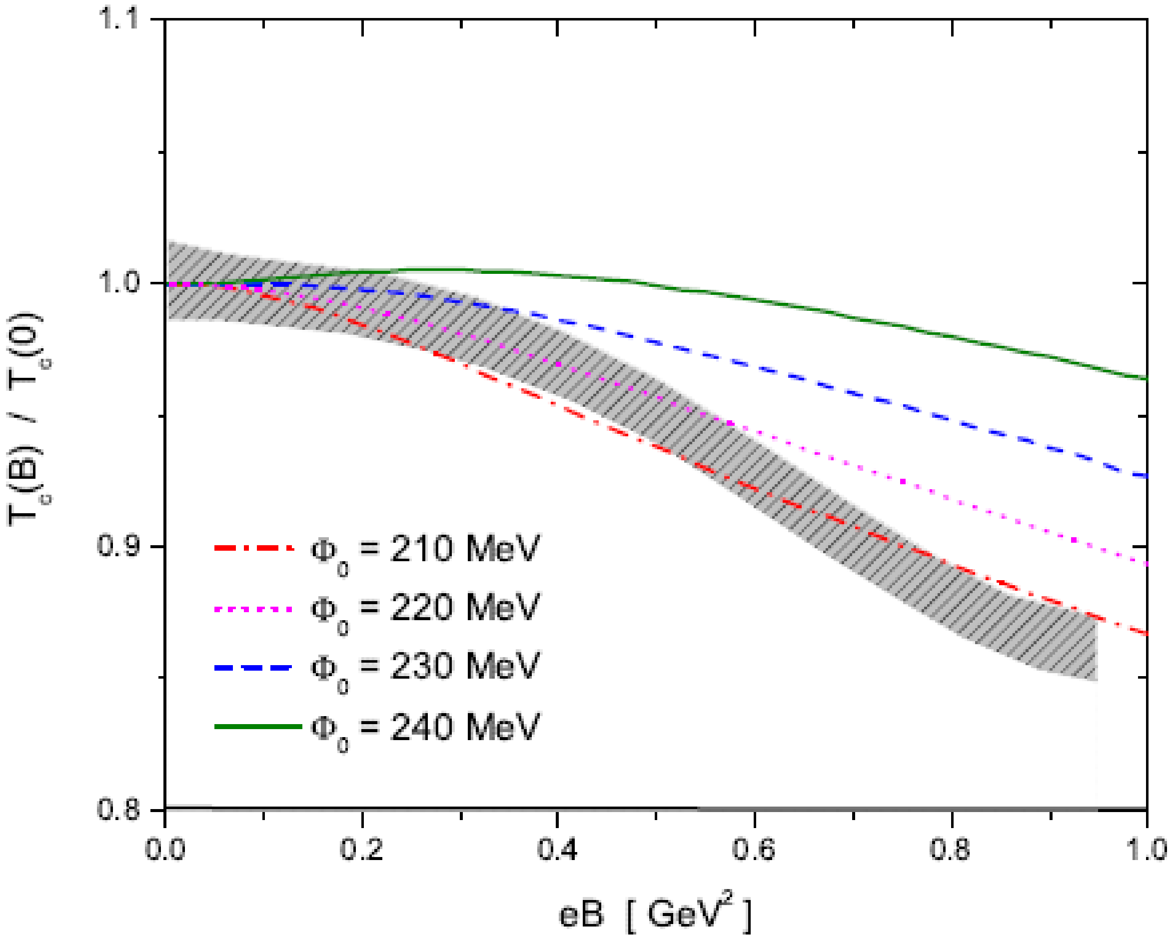
Non-local NJL Model

$$\mathcal{L} = \bar{\psi}(x)\left(-i\partial\!\!\!/ + m_c\right)\psi(x) - \frac{G}{2} j_a(x) j_a(x)$$

$$j_a(x) = \int d^4z\, \mathcal{G}(z)\, \bar{\psi}(x + \frac{z}{2})\, \Gamma_a\, \psi(x - \frac{z}{2}) \qquad \Gamma_a = (1\!\!1, i\gamma_5\vec{\tau})$$

Confinement imposed by the structure of the quark propagator plus restriction to single color states, no need of extra cutoff.

Inverse Magnetic Catalysis in Non-local NJL Model



V. Pagura, D. Gómez Dumm, S. Noguera, N. N. Scoccola, **arXiv:1609.02025**

Pion structure with the Non-local NJL Model

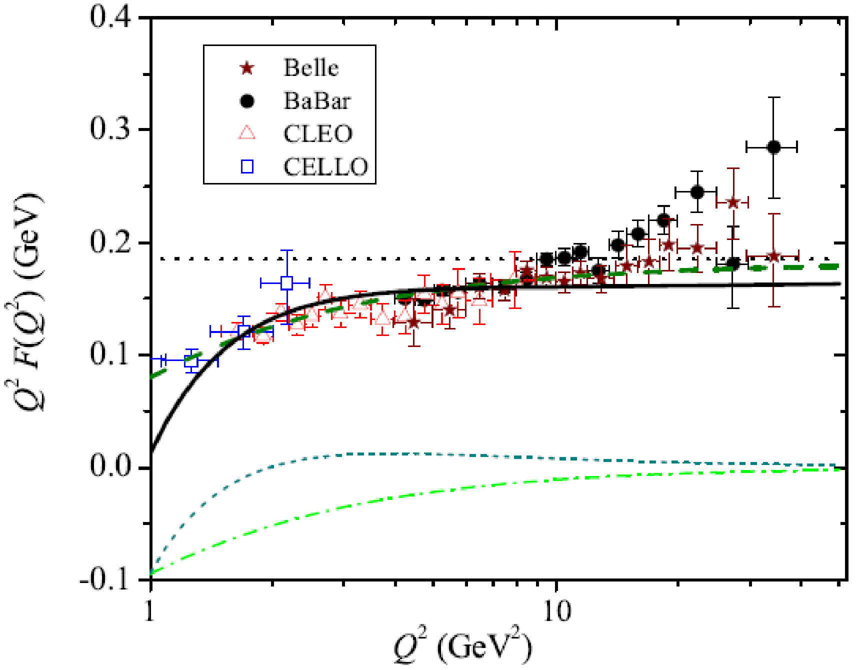
The model reproduces the phenomenological values of the pion mass and pion decay constant. It provides the structure (FF, TFF…) at a certain hadronic momentum scale. QCD evolution connects it to higher momentum (deep hadron structure: PD, GPD, TFF…).

D. Gómez Dumm, S. Noguera, N. N. Scoccola, Phys. Rev. D89, 054031 (2014)

$$\pi^0 \to \gamma\gamma^*$$

$$F(Q^2) = \frac{\sqrt{2} f_\pi}{3\,Q^2} \int_0^1 dx\, T_H(x, Q^2, \mu)\, \phi_\pi(x, \mu)$$

$$\phi_\pi(x) = \frac{2\sqrt{2}\, N_c\, g_{\pi q\bar{q}}}{f_\pi} \int \frac{dw\, d^2k_T}{(2\pi)^4}\, F(w, x, k_T)$$



Extension to the eta structure in progress

3. Light Front Hamiltonian Approach

Cuantificación de QCD a “light front time” fijado.

La descripción de un hadrón para un “light front time” fijado es independiente del observador Lorentz.

$$x^+ = x^0 + x^3, \qquad x^- = x^0 - x^3$$

$$(H_{LF} - M^2)|M\rangle = 0 \qquad H_{LF} = P^-P^+ - P_\perp^2$$

Conjunto infinito de ecuaciones integrales acopladas para las componentes de la función de onda en el espacio de Fock.

$$F_M(q^2) = \sum_n \prod_{j=1}^{n-1} \int dx_j d^2\mathrm{b}_{\perp j} \exp\left(i\mathrm{q}_\perp \cdot \sum_{j=1}^{n-1} x_j \mathrm{b}_{\perp j}\right) \left|\psi_{n/M}(x_j, \mathrm{b}_{\perp j})\right|^2$$

Las funciones de estructura y otras distribuciones probabilísticas de partones en DIS se obtienen a partir de los módulos al cuadrado de las funciones de onda que son invariantes bajo “boosts”.

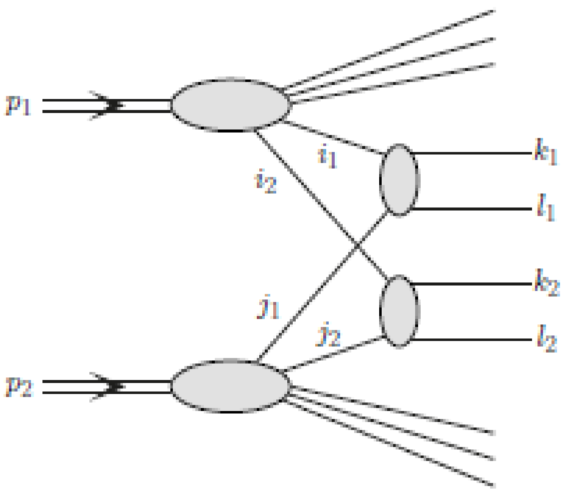
LFQM

$$|N, J, J_n = +1/2\rangle = \psi_{0,0}(\xi)\,\mathcal{Y}^{(0,0)}_{[0,0,0]}(\Omega)\,\frac{\chi_{MS}\phi_{MS} + \chi_{MA}\phi_{MA}}{\sqrt{2}}$$

$$(M_0 + V)\psi_{00}(k_\xi) = \left(\sum_i^3 \sqrt{\vec{k}_i^2 + m^2} - \frac{\tau}{\xi} + \kappa\xi\right)\psi_{00}(k_\xi) = M\psi_{00}(k_\xi)$$

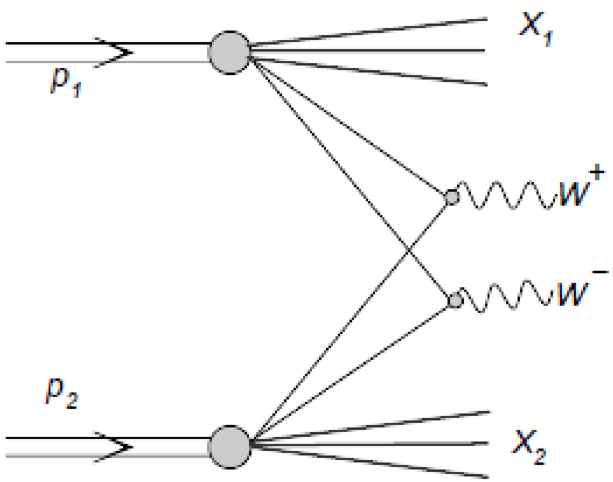
$$\xi = \sqrt{\vec{\rho}^{\,2} + \vec{\lambda}^{\,2}} \qquad k_\xi = \sqrt{2(\vec{k}_1^2 + \vec{k}_2^2 + \vec{k}_1 \cdot \vec{k}_2)}$$

Double Parton Scattering Cross Section from a Light Front Quark Model



$$\sigma^{DPS}(pp \to c\bar{c}c\bar{c}X) =$$

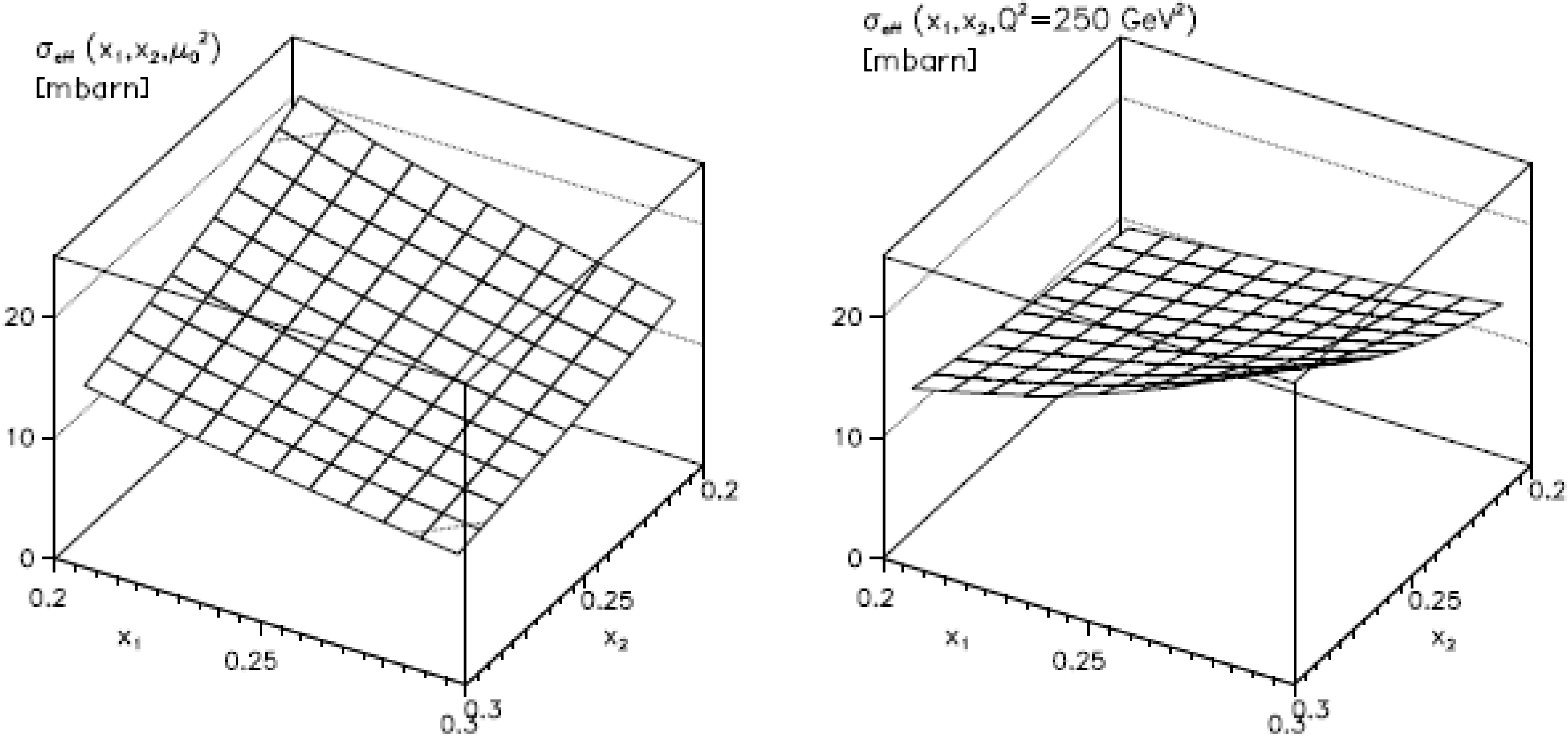
$$\frac{1}{2\sigma_{eff}}\sigma^{SPS}(pp \to c\bar{c}X_1)\cdot\sigma^{SPS}(pp \to c\bar{c}X_2)$$



Experiments compatible with constant σ_{eff}

$$\sigma^{pp}_{double}(x_1, x'_1, x_2, x'_2, \mu_1, \mu_2) = \frac{m}{2} \sum_{i,j,k,l} \int D_{ij}(x_1, x_2; \mathbf{k}_\perp, \mu_1, \mu_2)\, \hat{\sigma}^A_{ik}(x_1, x'_1)\, \hat{\sigma}^B_{jl}(x_2, x'_2) \times D_{kl}(x'_1, x'_2; -\mathbf{k}_\perp, \mu_1, \mu_2) \frac{d\mathbf{k}_\perp}{(2\pi)^2} .$$

$$\hat{\sigma}_{ij}(x, x') = C_{ij} \bar{\sigma}(x, x')$$



$\mu_0^2 \simeq 0,1 \ \mathrm{GeV}^2$

M. Rinaldi, S. Scopetta, M. Traini, V. Vento, Phys. Lett. B752, 40 (2016)

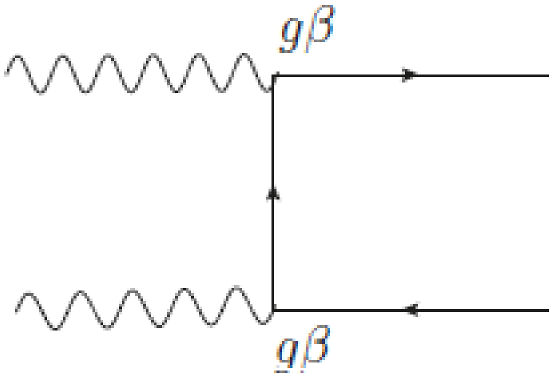
MONOPOLOS MAGNÉTICOS

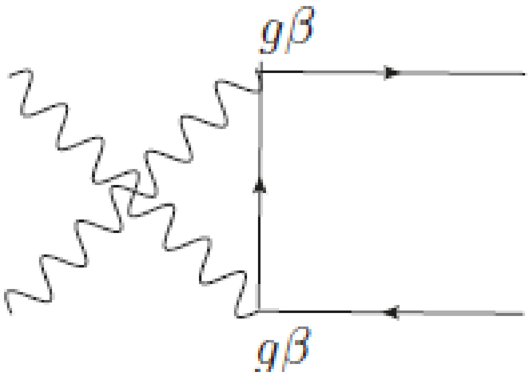
$$\begin{aligned}
\nabla \cdot \vec{E} &= 4\pi\rho \\
\nabla \cdot \vec{B} &= 4\pi\rho_m \\
-\nabla \times \vec{E} &= \frac{1}{c}\frac{\partial \vec{B}}{\partial t} + \frac{4\pi}{c}\vec{j}_m \\
\nabla \times \vec{B} &= \frac{1}{c}\frac{\partial \vec{E}}{\partial t} + \frac{4\pi}{c}\vec{j}
\end{aligned}$$

$$g = N\frac{\hbar c}{2e}$$

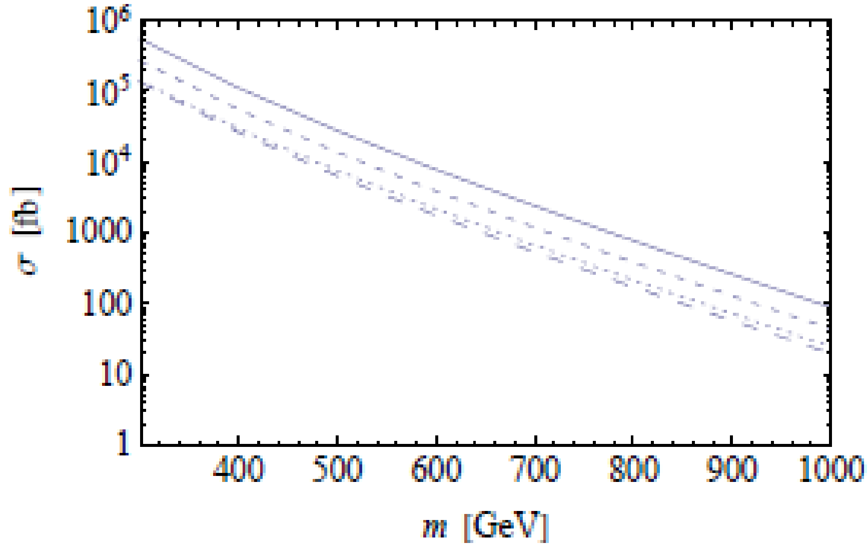
MONOPOLIUM

LHC





$$\sigma(\gamma\,\gamma \to m\overline{m}) = \frac{\pi\, g^4\,(1-\beta^2)\,\beta^4}{2\,m^2}\left(\frac{3-\beta^4}{2\beta}\log\left(\frac{1+\beta}{1-\beta}\right) - (2-\beta^2)\right)$$



L. Epele, H. Fanchioti, C. García Canal, V. Mitsou, V. Vento, Eur. Phys. J. Plus 127, 60 (2012)

FUTURO INMEDIATO

Double Parton Scattering from Quark models, Light Front Formalism and AdS/CFT
V. Vento, M. Rinaldi

Quark-Antiquark potential from Schwinger Dyson equations
V. Vento, P. González

Heavy quarkonia transitions from a Generalized Screened Potential model
P. González

η-γ and η'-γ transition form factors in a nonlocal Nambu-Jona-Lasinio model
S. Noguera

Hadronic matter under extreme conditions of temperature, density and/or magnetic field in the context of Nambu-Jona Lasinio type effective models
S. Noguera, V. Pagura

Exotic states and the hadron spectra
J. Vijande

FIN