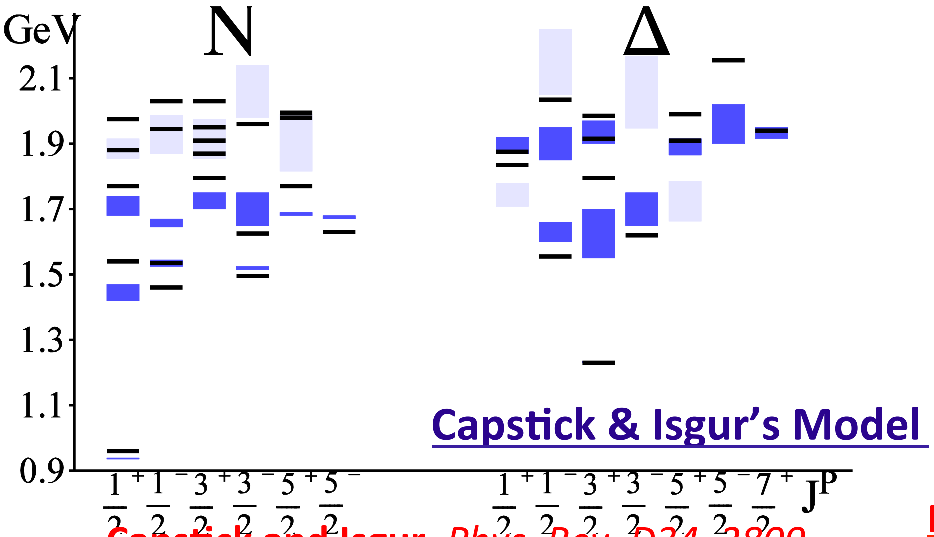
NINPHA

E. Santopinto
INFN
Genova
CdS, July 2015
santopinto@ge.infn.it

Models for the nucleon structure

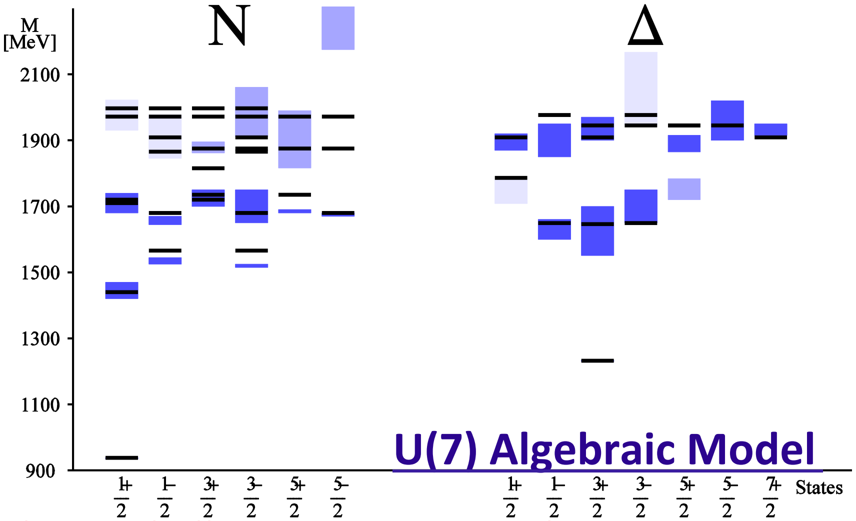
state of the art

Non strange spectrum



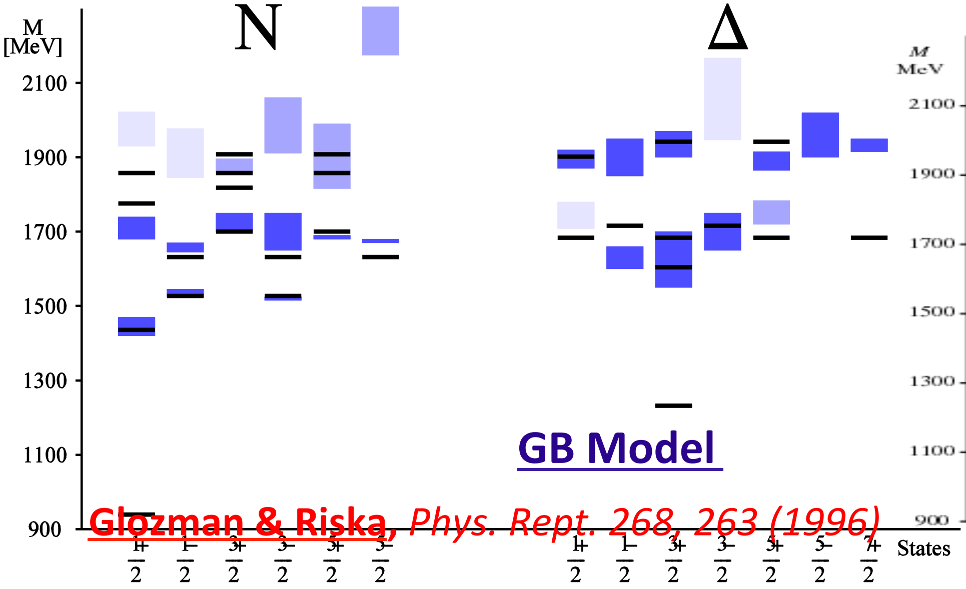
Capstick & Isgur's Model

Capstick and Isgur, *Phys. Rev. D34, 2809.*



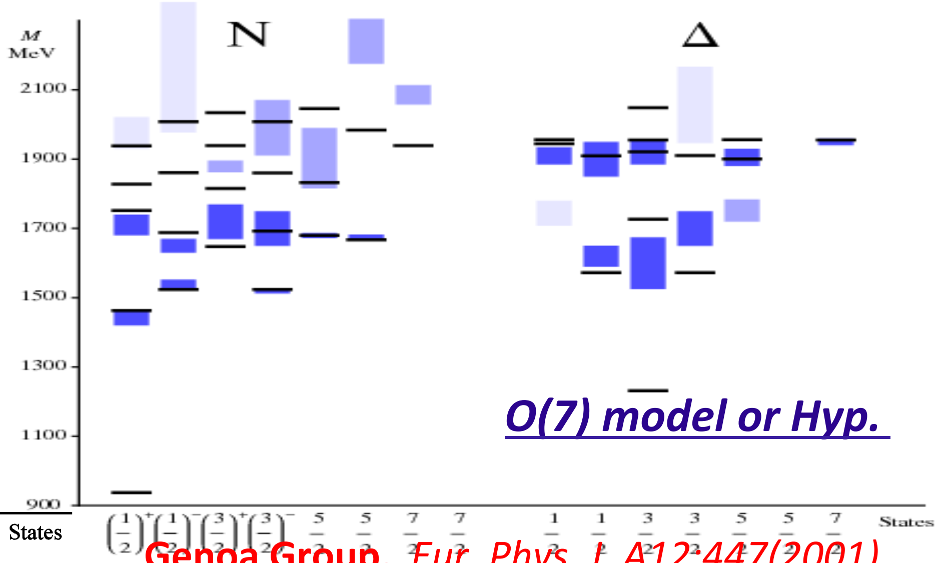
U(7) Algebraic Model

Bijker, Iachello, Leviatan, Ann. Phys. 236, 69 (1994)



GB Model

Glozman & Riska, *Phys. Rept. 268, 263 (1996)*



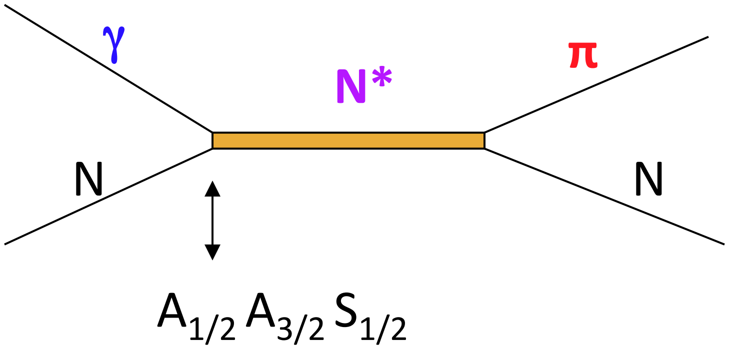
O(7) model or Hyp.

Genoa Group, *Eur. Phys. J .A12:447(2001)*

The helicity amplitudes

HELICITY AMPLITUDES

Extracted from electroproduction of mesons



Definition

$$A_{1/2} = < N^* \; J_z = 1/2 \mid H^{T}_{em} \mid N \; J_z = -1/2 > \qquad \S$$

$$A_{3/2} = < N^* \; J_z = 3/2 \mid H^{T}_{em} \mid N \; J_z = 1/2 > \qquad \S$$

$$S_{1/2} = < N^* \; J_z = 1/2 \mid H^{L}_{em} \mid N \; J_z = 1/2 >$$

N, N^* nucleon and resonance as 3q states

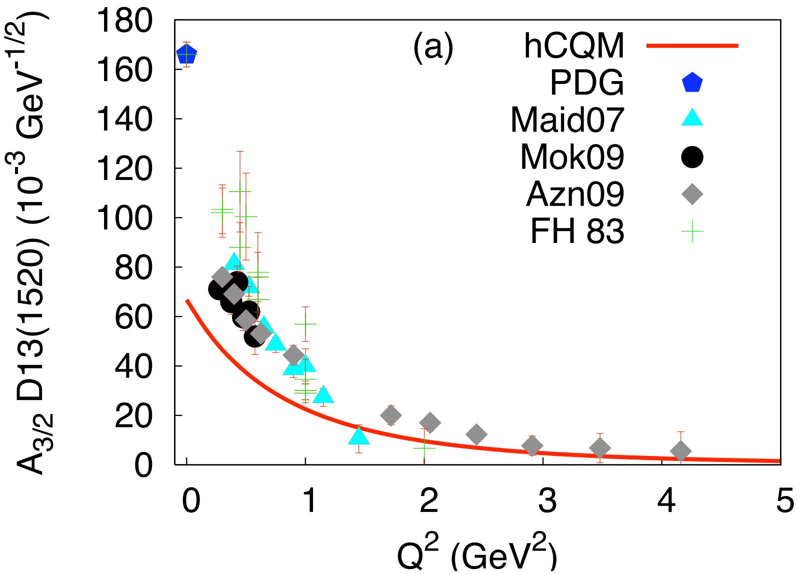
H^{T}_{em} H^{l}_{em} model transition operator

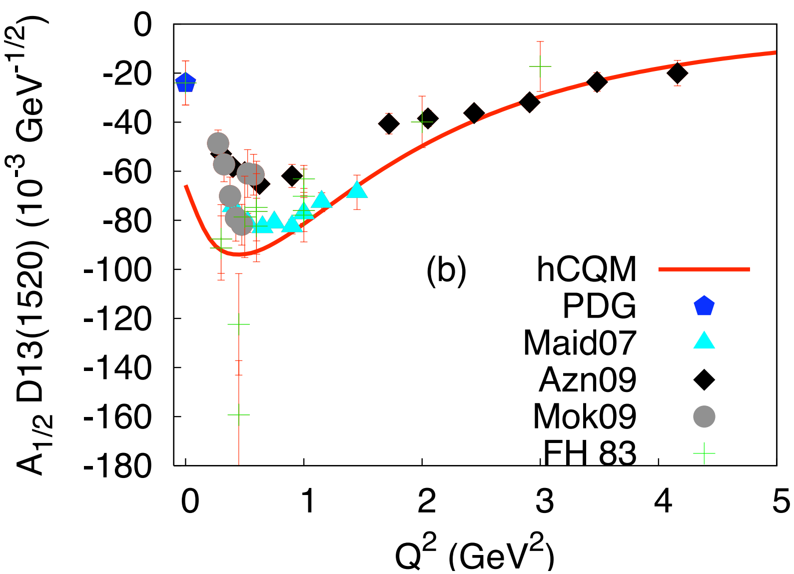
§ results for the negative parity resonances:
M. Aiello, M.Giannini, E. Santopinto J. Phys. G24, 753 (1998)

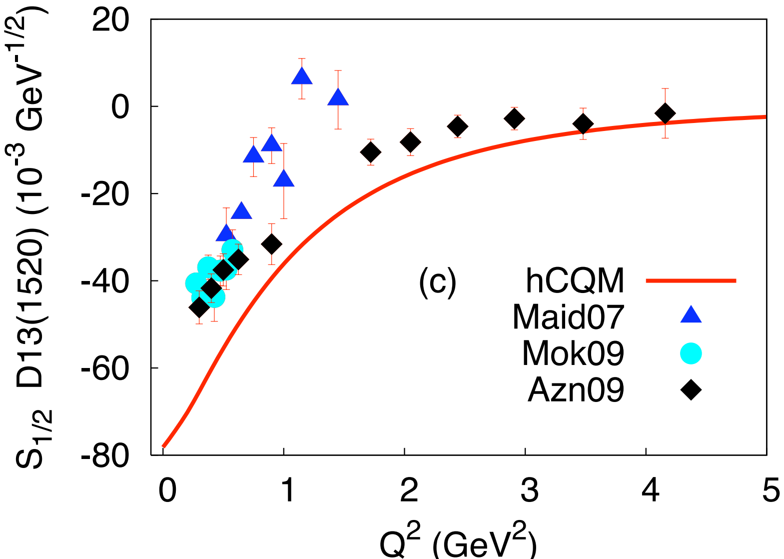
Systematic predictions for transverse and longitudinal amplitudes
E. Santopinto et al. , Phys. Rev. C86, 065202 (2012)

Proton and neutron electro-excitation to 14 resonances

N(1520) $3/2^-$ transition amplitudes

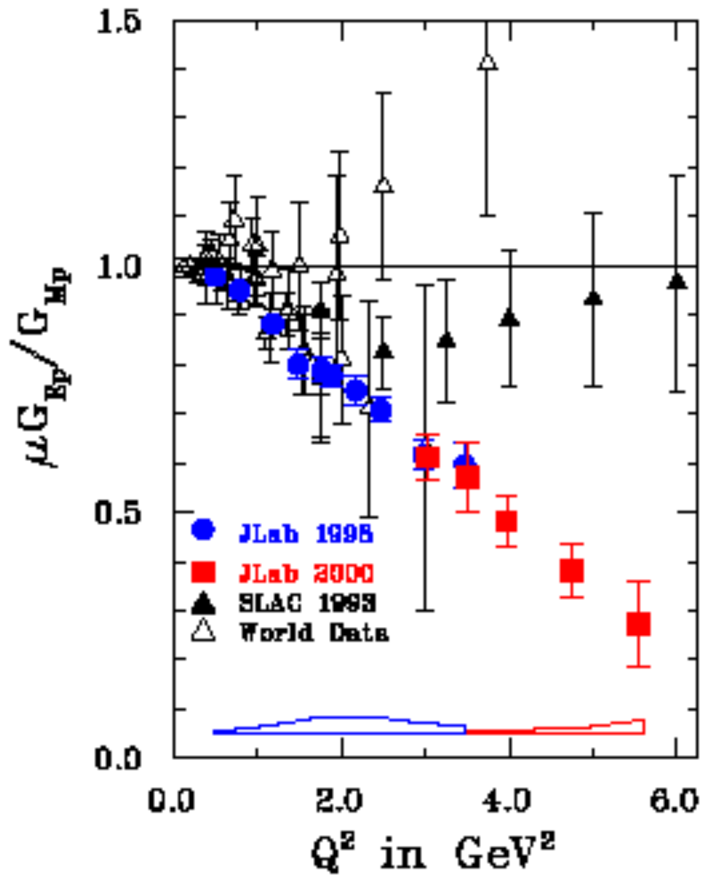






E. Santopinto et al.,
Phys. Rev. C86,
065202 (2012)

The nucleon elastic form factors



- elastic scattering of polarized electrons on polarized protons

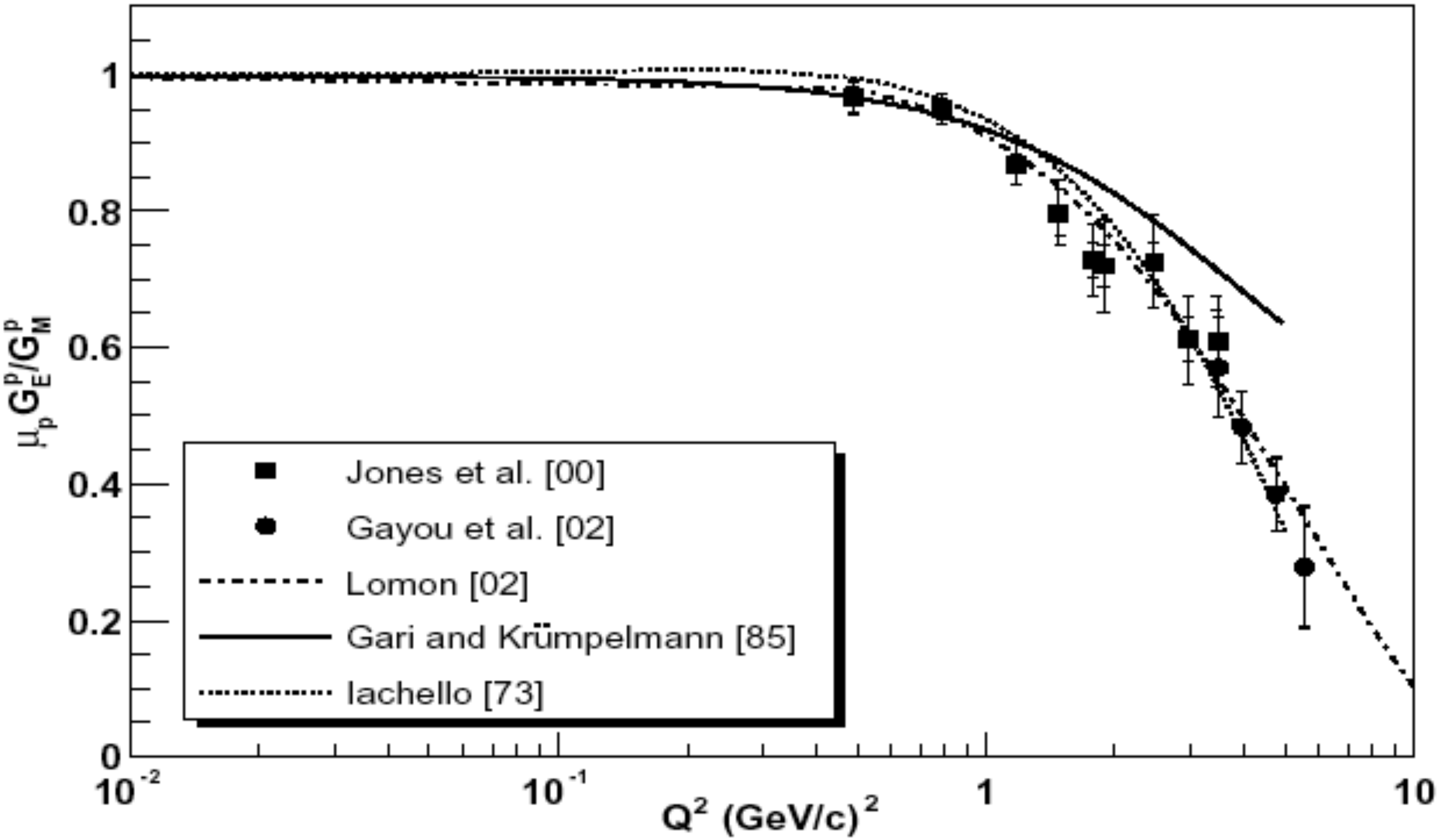
- measurement of polarizations asymmetry gives directly the ratio G^p_E/G^p_M

- discrepancy with Rosenbluth data (?)

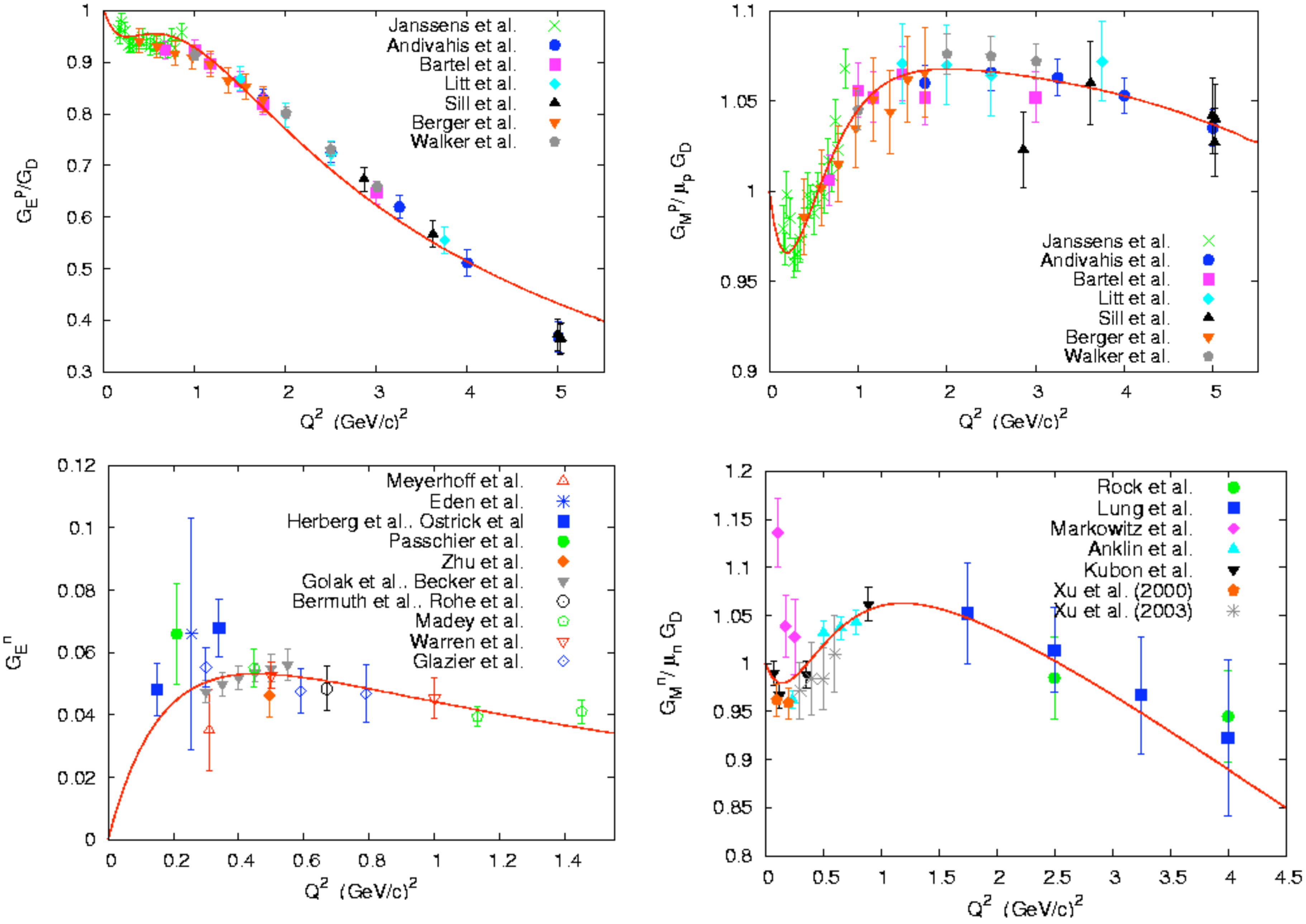
- linear and strong decrease

- pointing towards a zero (!)

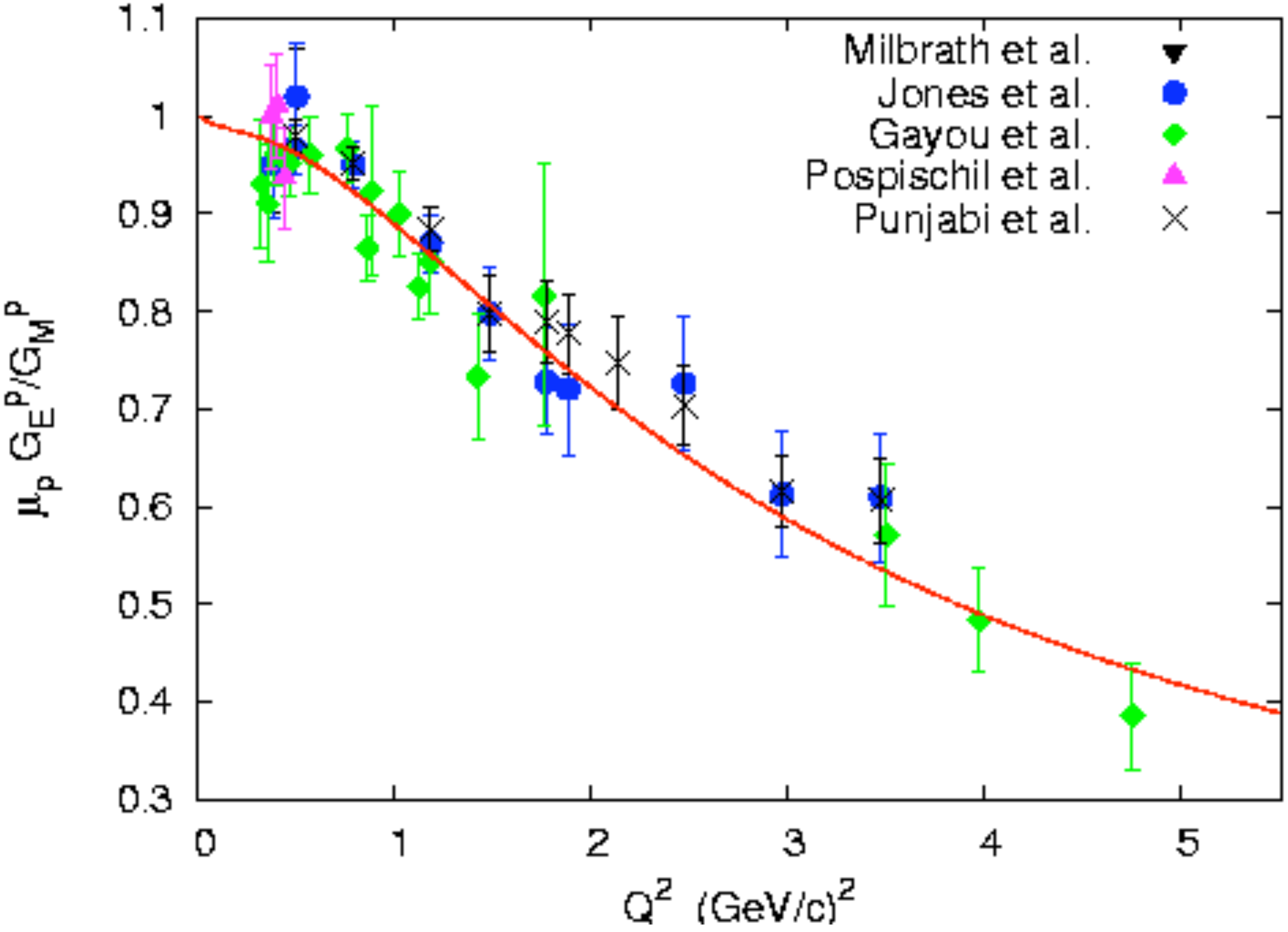
- new data (jan 2010) seem to confirm the behaviour

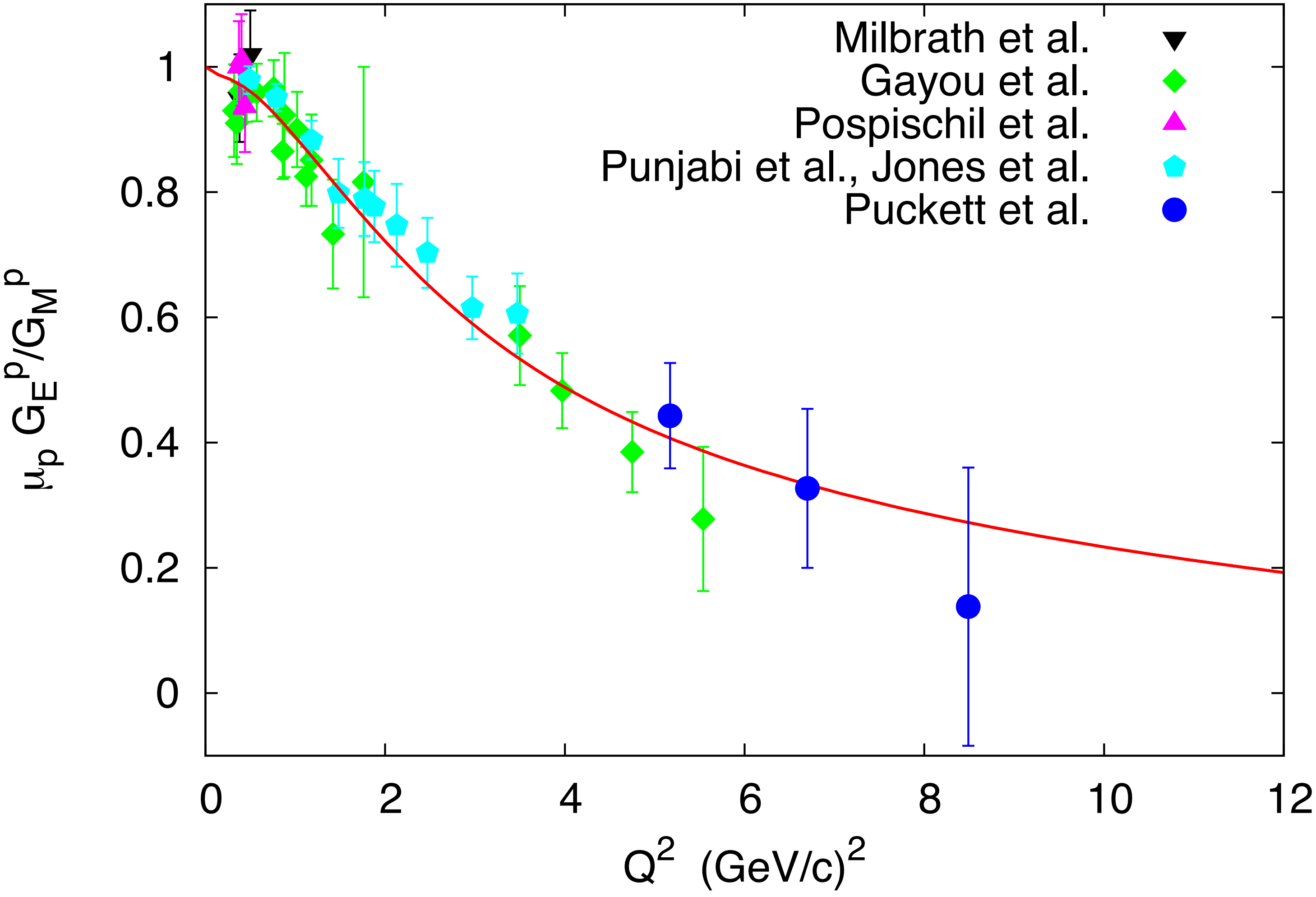


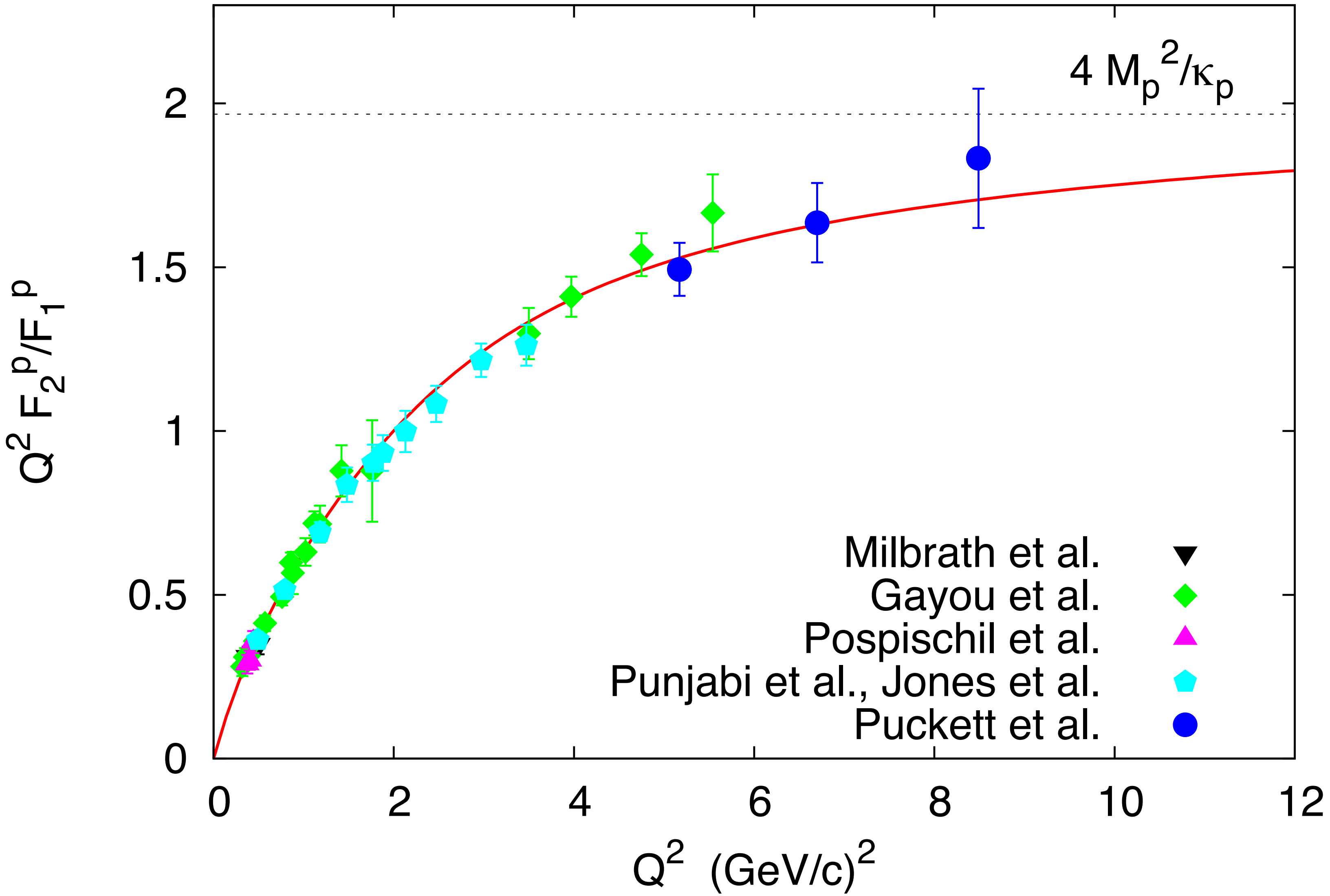
$\mu_p G_E^p / G_M^p$
Q^2 (GeV/c)^2
0
0.2
0.4
0.6
0.8
1
10^{-2}
10^{-1}
1
10
Jones et al. [00]
Gayou et al. [02]
Lomon [02]
Gari and Krümpelmann [85]
Iachello [73]

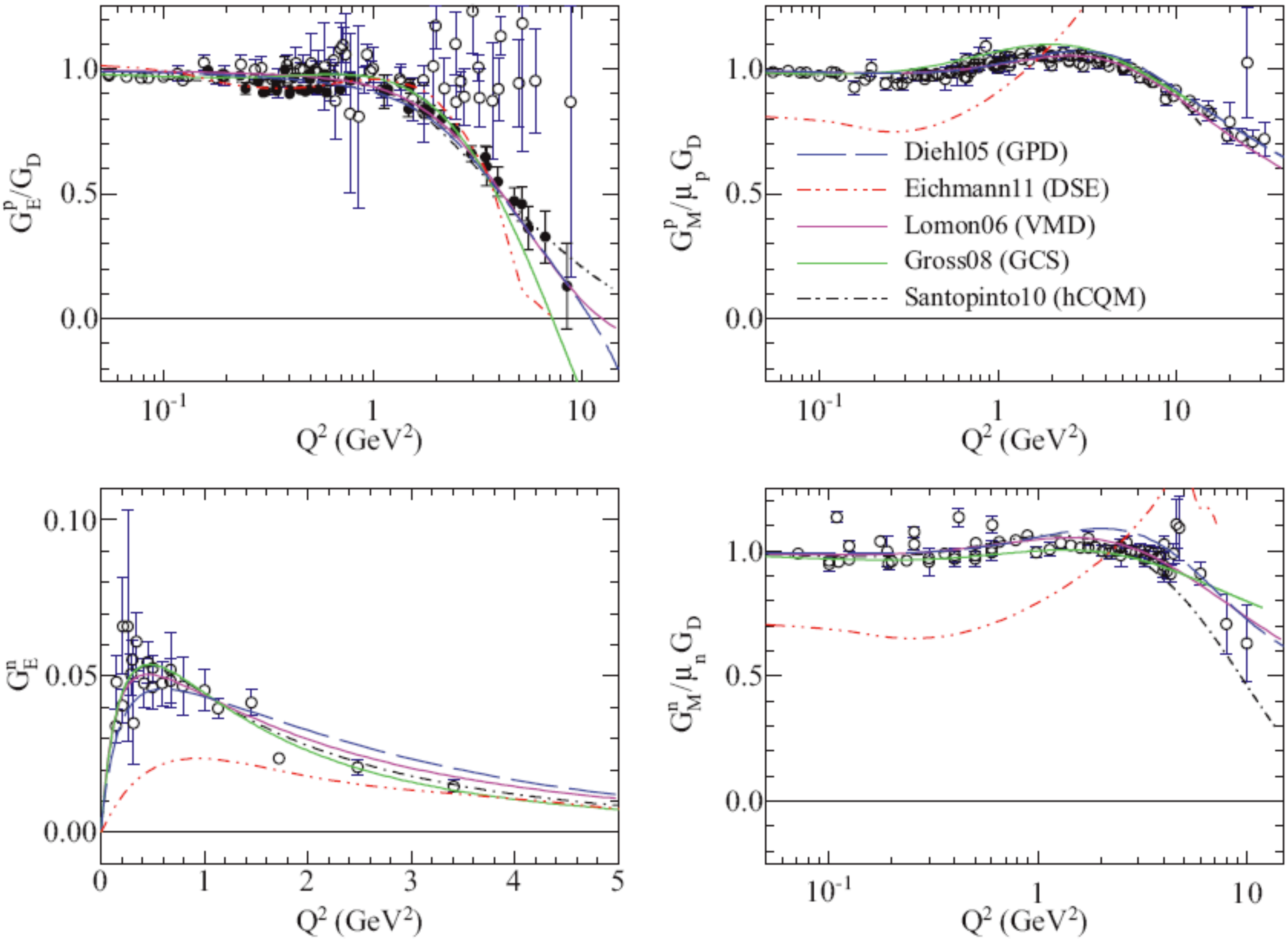


Genoa group, Phys. Rev. C76, 062201 (2007)


Milbrath et al. ▼
Jones et al. ●
Gayou et al. ◆
Pospischil et al. ▲
Punjabi et al. ×
$\mu_p G_E^p/G_M^p$
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
1
2
3
4
5
Q^2 (GeV/c)^2


Milbrath et al.
Gayou et al.
Pospischil et al.
Punjabi et al., Jones et al.
Puckett et al.
$\mu_p G_E^p/G_M^p$
Q^2 (GeV/c)^2
0
0.2
0.4
0.6
0.8
1
0
2
4
6
8
10
12


$4\ M_p{}^2/\kappa_p$
$Q^2\ F_2{}^p/F_1{}^p$
$Q^2\ (\mathrm{GeV/c})^2$
0
0.5
1
1.5
2
0
2
4
6
8
10
12
Milbrath et al. ▼
Gayou et al. ◆
Pospischil et al. ▲
Punjabi et al., Jones et al. ⬟
Puckett et al. ●


G_E^p/G_D
1.0
0.5
0.0
10^{-1}
1
10
Q^2 (GeV^2)
$G_M^p/\mu_p G_D$
Diehl05 (GPD)
Eichmann11 (DSE)
Lomon06 (VMD)
Gross08 (GCS)
Santopinto10 (hCQM)
G_E^n
0.10
0.05
0.00
0
2
3
4
5
$G_M^n/\mu_n G_D$

- The hyp model seems to provide realistic wave functions

- The main reason is the O(7) dynamical symm.

Solvable model H=f(C_2(O(7)) analytical model !!!

- ➢ energy levels, w. fs and observables all expressed analytically
- ➢ Right power low behavior for form factors and transition f.f.

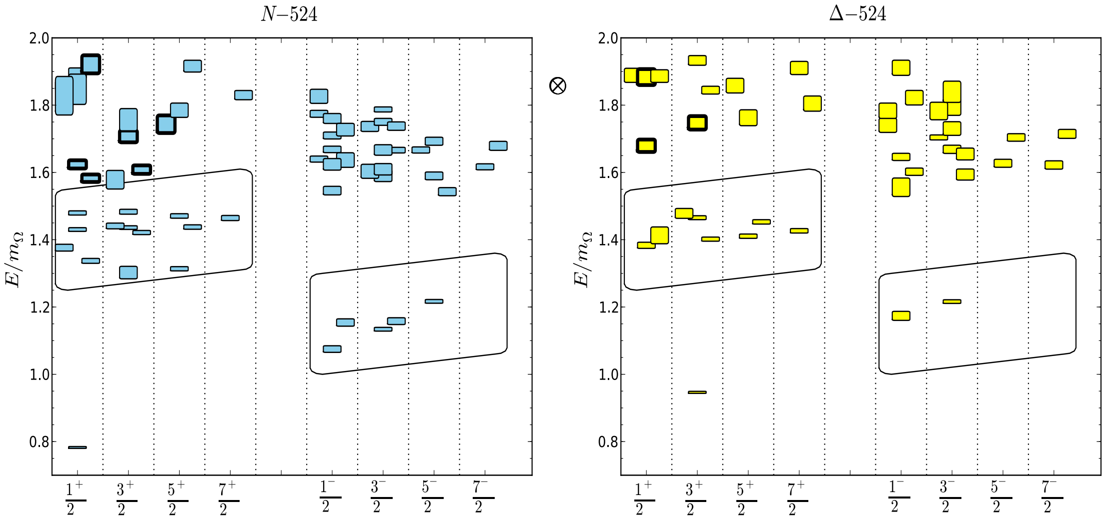
Good results due to semplicity

E. Santopinto, F. Iachello, Eur. Phys. J. A **1**, 307 (1998) ; Bijker, Iachello, Santopinto, J.Phys. A (1998)

LQCD results: SU(6)× O(3) QM states up to ≈2.2 GeV

J. J. Dudek, R. G. Edwards

Phys.Rev. D85 (2012) 054016



HYBRIDS

Exotic spectroscopy

Hybrids levels

- For $J_g=1$ (lowest energy) we can have two gluelumps states: $J_g^{PC}=1^{+-}$, 1^{--}
- Coupling the gluelump with the quark-antiquark state with $L_Q=0$ and $S_Q=0,1$ we get

in the first case: $J^{PC}=1^{--}$ for $S_Q=0$

$J^{PC}=0^{-+}, 1^{-+}, 2^{-+}$ for $S_Q=1$

in the second case: $J^{PC}=1^{+-}$ for $S_Q=0$

$J^{PC}=0^{++}, 1^{++}, 2^{++}$ for $S_Q=1$

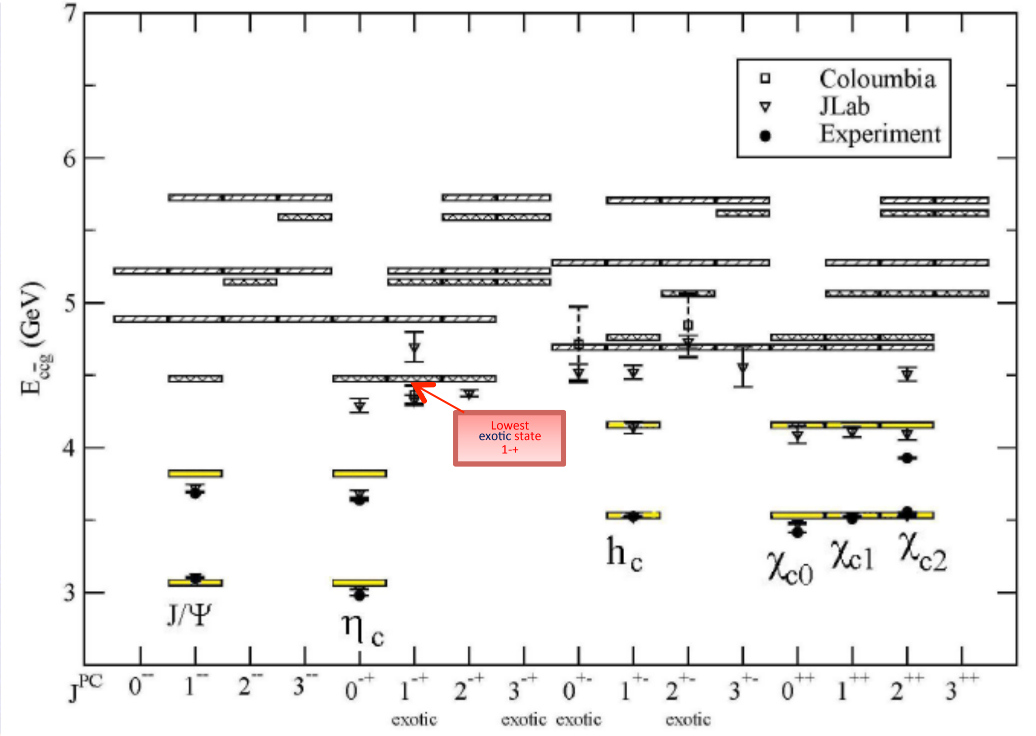
the hybrid with exotic quantum numbers 1^{-+} appear in this lowest multiplet

$J_g^{PC}=1^{+-},\ 1^{--}$

Hybrids spectrum

$J_g^{P_g}$	This work [GeV]	J^{PC}	Lattice [14] [GeV]
1^+	4.476	$0^{-+}, 1^{-+}, 2^{-+}, [1^{--}]$	4.291(48),4.327(36),4.376(24), [?]
1^-	4.762	$1^{+-}, 2^{++}, [0^{++}, 1^{++}]$	4.521(48),4.508(48), [?,?]
2^+	5.144	$1^{-+}, [2^{--}, 2^{-+}, 3^{-+}]$	4.696(103), [?,?,?]
2^-	5.065	$2^{+-}, [1^{++}, 2^{++}, 3^{++}]$	4.733(42), [?,?,?]

Spectrum: normal charmoniums (yellow boxes) and charmonium hybrids (dashed boxes) confronted with experimental and lattice data

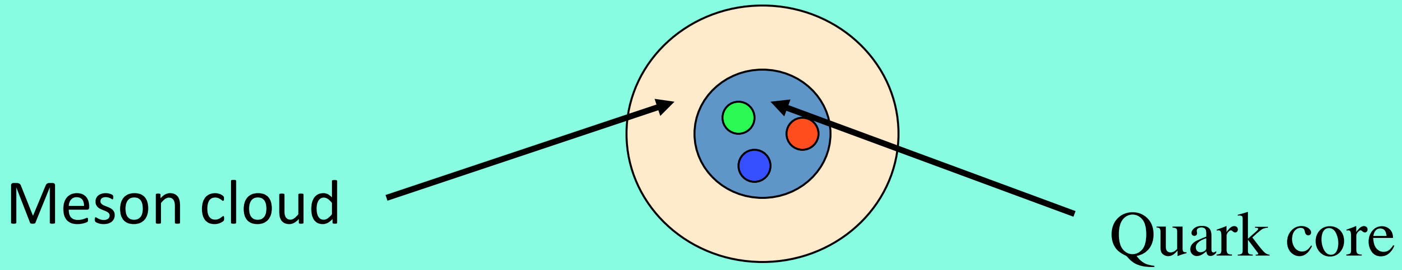


Unquenching of hadron models

- emerging picture:

  quark core plus (meson or sea-quark) **cloud**

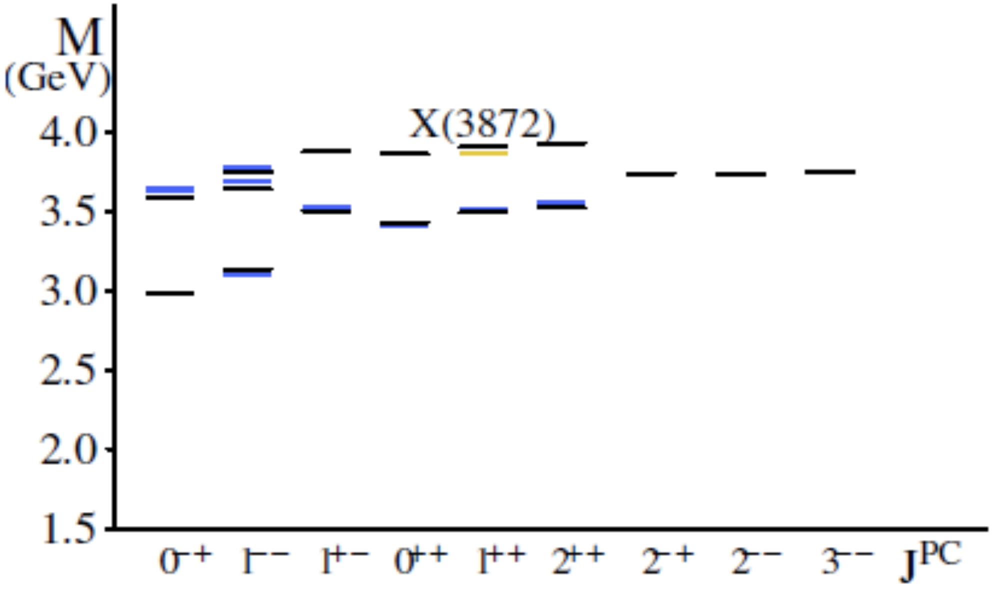
$$| \psi_A \rangle = \mathcal{N} \left\{ | A \rangle + \sum_{BClJ} \int d\vec{K}\, k^2 dk \; | BC\vec{K}\, k\, lJ \rangle \frac{\langle BC\vec{K}\, k\, lJ \mid T^\dagger \mid A \rangle}{M_A - E_B - E_C} \right\}$$



UQM: charmonium spectrum with self-energy corr.

Ferretti, Galata' and Santopinto, Phys. Rev. C 88, 015207 (2013)

State	J^{PC}	$D\bar{D}$	$\bar{D}D^*$ $D\bar{D}^*$	$\bar{D}^*D^*$	$D_s\bar{D}_s$	$D_s\bar{D}_s^*$ $\bar{D}_sD_s^*$	$D_s^*\bar{D}_s^*$	$\eta_c\eta_c$	η_cJ/Ψ	$J/\Psi J/\Psi$	$\Sigma(E_a)$	E_a	M_a	$M_{exp.}$
$\eta_c(1^1S_0)$	0^{-+}	–	-34	-31	–	-8	-8	–	–	-2	-83	3062	2979	2980
$J/\Psi(1^3S_1)$	1^{--}	-8	-27	-41	-2	-6	-10	–	-2	–	-96	3233	3137	3097
$\eta_c(2^1S_0)$	0^{-+}	–	-52	-41	–	-9	-8	–	–	-1	-111	3699	3588	3637
$\Psi(2^3S_1)$	1^{--}	-18	-42	-54	-2	-7	-10	–	-1	–	-134	3774	3640	3686
$h_c(1^1P_1)$	1^{+-}	–	-59	-48	–	-11	-10	–	-2	–	-130	3631	3501	3525
$\chi_{c0}(1^3P_0)$	0^{++}	-31	–	-72	-4	–	-15	0	–	-3	-125	3555	3430	3415
$\chi_{c1}(1^3P_1)$	1^{++}	–	-54	-53	–	-9	-11	–	–	-2	-129	3623	3494	3511
$\chi_{c2}(1^3P_2)$	2^{++}	-17	-40	-57	-3	-8	-10	0	–	-2	-137	3664	3527	3556
$h_c(2^1P_1)$	1^{+-}	–	-55	-76	–	-12	-8	–	-1	–	-152	4029	3877	–
$\chi_{c0}(2^3P_0)$	0^{++}	-23	–	-86	-1	–	-13	0	–	-1	-124	3987	3863	–
$\chi_{c1}(2^3P_1)$	1^{++}	–	-30	-66	–	-11	-9	–	–	-1	-117	4025	3908	3872
$\chi_{c2}(2^3P_2)$	2^{++}	-2	-42	-54	-4	-8	-10	0	–	-1	-121	4053	3932	3927
$c\bar{c}(1^1D_2)$	2^{-+}	–	-99	-62	–	-12	-10	–						
$\Psi(3770)(1^3D_1)$	1^{--}	-11	-40	-84	-4	-2	-16	–						
$c\bar{c}(1^3D_2)$	2^{--}	–	-106	-61	–	-11	-11	–						
$c\bar{c}(1^3D_3)$	3^{--}	-25	-49	-88	-4	-8	-10	–						



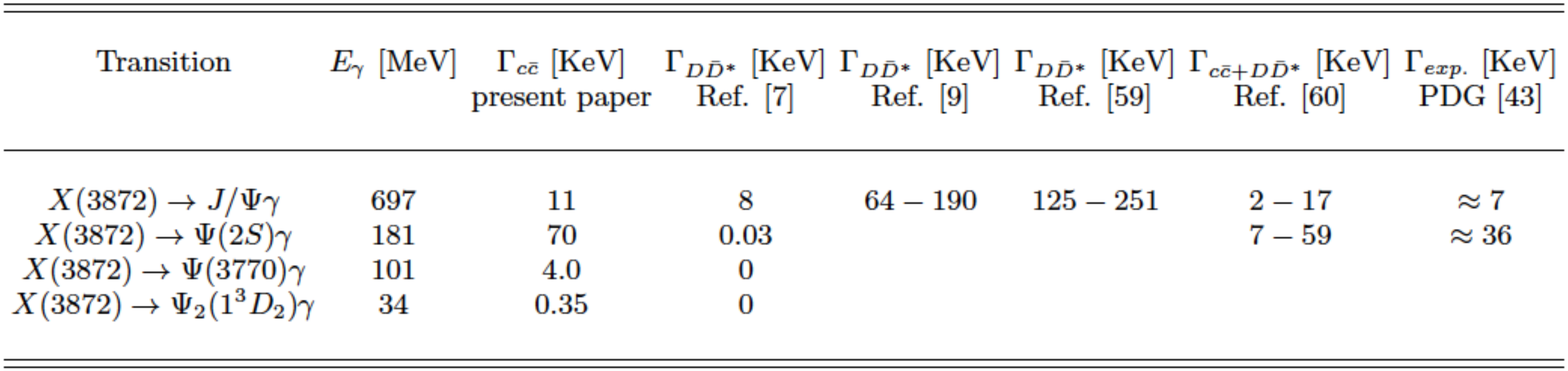
Interpretation of the X(3872) as a charmonium state plus an extra component due to the coupling to the meson-meson continuum

Ferretti,Galatà, Santopinto, **Phys.Rev. C88 (2013) 1, 015207**

- UCQM results used to study the problem of the **X(3872)** mass, meson with $J^{PC} = 1^{++}$, 2^3P_1 quantum numbers
- X(3872) very close to D bar-D* decay threshold
- Possible importance of continuum coupling effects?
- Several interpretations: pure c bar-c
- D bar-D* molecule
- tetraquark
- c bar-c + continuum effects
  - need to study strong and radiative decays to uderstand the situation

Radiative decays

Ferretti,Galatà,Santopinto,Phys.Rev. D90 (2014) 5, 054010



Transition	E_γ [MeV]	$\Gamma_{c\bar{c}}$ [KeV] present paper	$\Gamma_{D\bar{D}^*}$ [KeV] Ref. [7]	$\Gamma_{D\bar{D}^*}$ [KeV] Ref. [9]	$\Gamma_{D\bar{D}^*}$ [KeV] Ref. [59]	$\Gamma_{c\bar{c}+D\bar{D}^*}$ [KeV] Ref. [60]	$\Gamma_{exp.}$ [KeV] PDG [43]
$X(3872) \to J/\Psi\gamma$	697	11	8	64 – 190	125 – 251	2 – 17	≈ 7
$X(3872) \to \Psi(2S)\gamma$	181	70	0.03			7 – 59	≈ 36
$X(3872) \to \Psi(3770)\gamma$	101	4.0	0				
$X(3872) \to \Psi_2(1^3D_2)\gamma$	34	0.35	0				

[7] Swanson: molecular interpretation
[9] Oset: molecular interpretation
[59]-[60] Faessler : molecular ; ccbar +molecular

The Molecular model does not predict radiative decays into $\Psi(3770)$ and $\Psi_2(1^3D_2)$-→ Possible way to distinguish between the two interpretations

Quasi two-body decay $X(3872) \to D^0(\bar{D}^0\pi^0)_{\bar{D}^{0*}}$

Ferretti,Galatà,Santopinto,Phys.Rev. D90 (2014) 5, 054010

$$\Gamma_{\bar{D}^{0*}} < 2.1 \text{ MeV} \qquad \Gamma_{\bar{D}^{0*}} = 0.1 \quad \text{MeV}$$

$$\Gamma_{X(3872)\to D(\bar{D}\pi)_{\bar{D}^*}} = 0.50 - 0.62 \text{ MeV} \,, \quad M_{X(3872)} = 3871.85 \text{ MeV}$$

$$\Gamma_{X(3872)\to D(\bar{D}\pi)_{\bar{D}^*}} = 0.54 - 0.75 \text{ MeV} \,, \quad M_{X(3872)} = 3871.95 \text{ MeV}$$

Experimental results:

$\Gamma_{X(3872)\to D^0\bar{D}^{0*}} = 3.9^{+2.8+0.2}_{-1.4-1.1}$ MeV PDG Aushev et al. [Belle Coll.], Phys. Rev. D **81**, 031103 (2010)

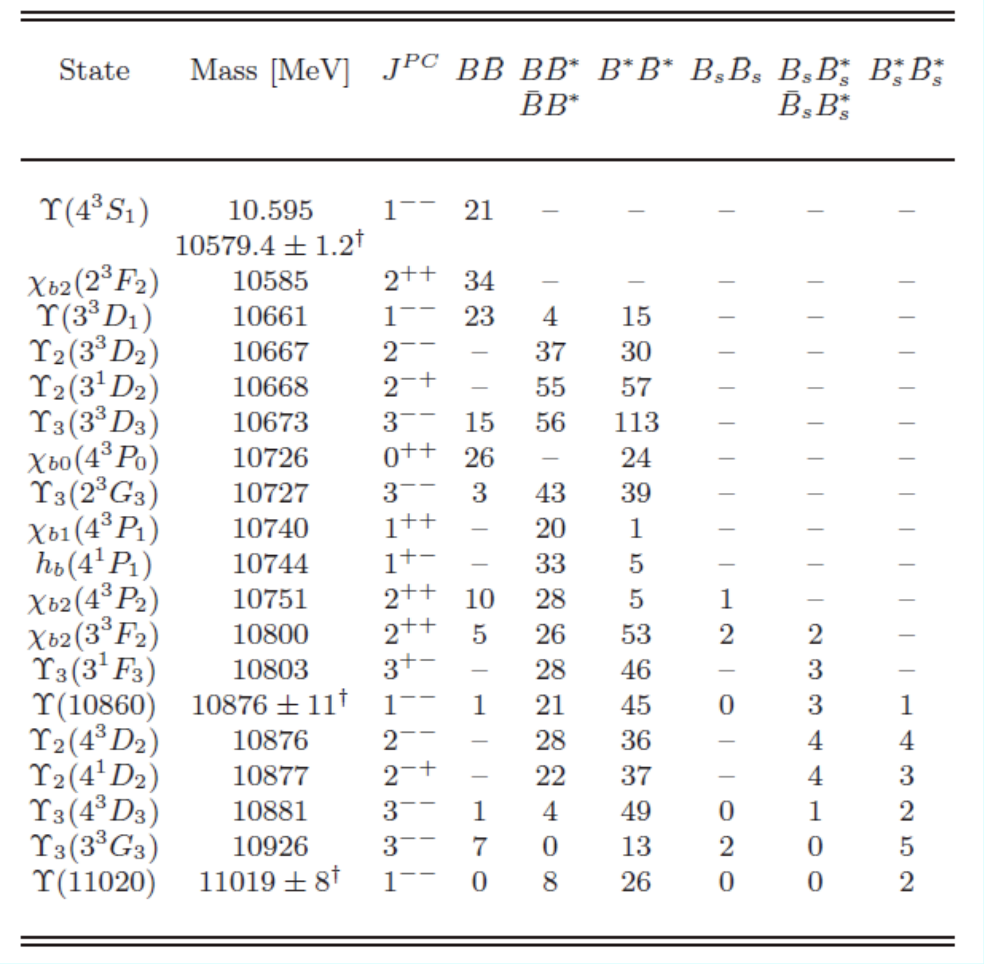
$\Gamma_{X(3872)\to D^0\bar{D}^{0*}} = 3.0^{+1.9}_{-1.4} \pm 0.9$ MeV PDG Aubert et al. [BABAR Coll.], Phys. Rev. D 77011102(2008)

- **Prompt production from CDF collaboration in high-energy hadron collisions incompatible with a molecular interpretation**
- meson-meson molecule: large (a few fm) and fragile
- See: Bignamini et al., Phys. Rev. Lett. **103**, 162001 (2009); Bauer, Int. J. Mod. Phys. A **20**, 3765 (2005)

Bottomonium Strong Decays

Ferretti, Santopinto, Phys.Rev. D90 094022 (2014)

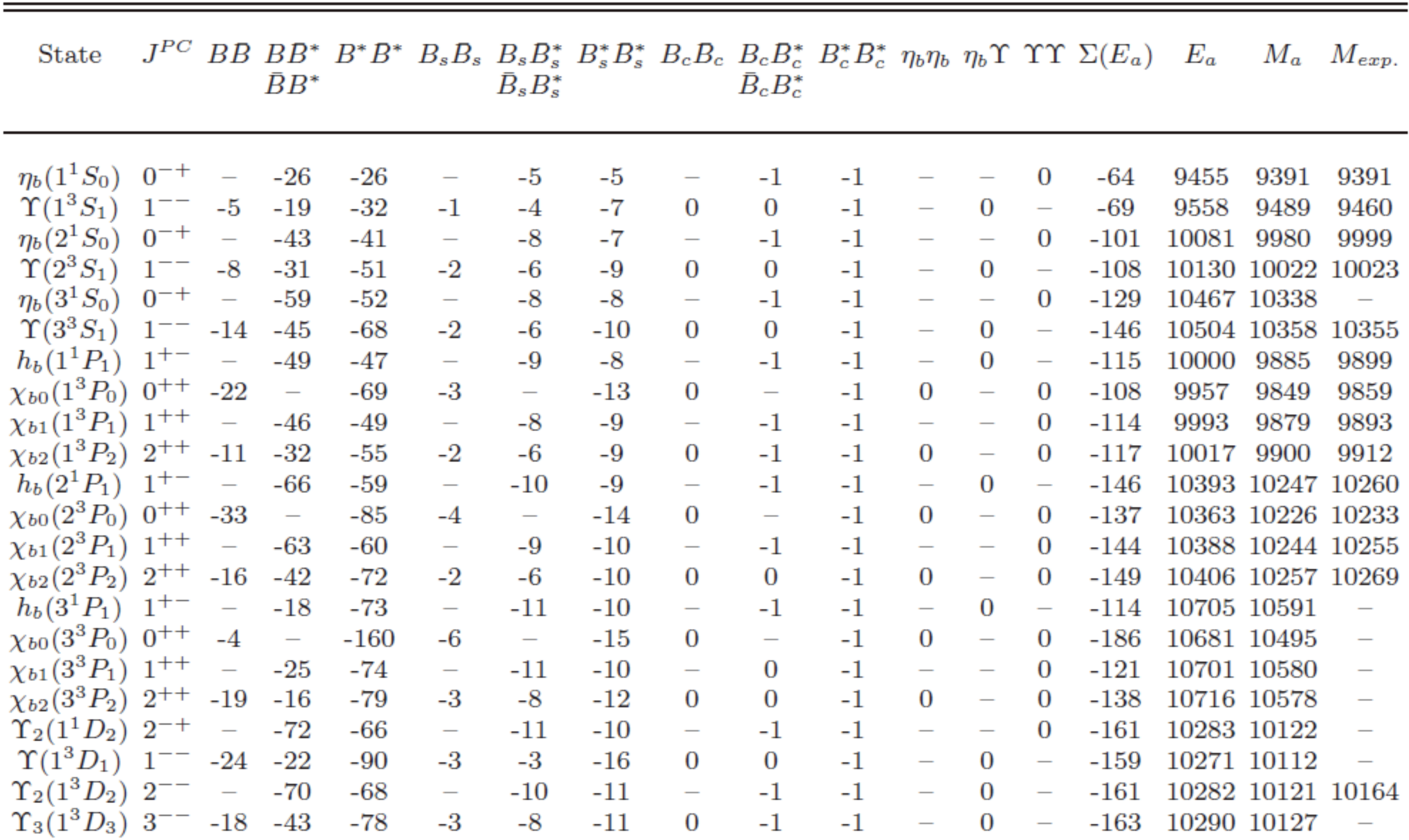
- Two-body strong decays. Results:



State	Mass [MeV]	J^{PC}	BB	BB^* $\bar{B}B^*$	B^*B^*	B_sB_s	$B_sB_s^*$ $\bar{B}_sB_s^*$	$B_s^*B_s^*$
$\Upsilon(4^3S_1)$	10.595 $10579.4 \pm 1.2^\dagger$	1^{--}	21	–	–	–	–	–
$\chi_{b2}(2^3F_2)$	10585	2^{++}	34	–	–	–	–	–
$\Upsilon(3^3D_1)$	10661	1^{--}	23	4	15	–	–	–
$\Upsilon_2(3^3D_2)$	10667	2^{--}	–	37	30	–	–	–
$\Upsilon_2(3^1D_2)$	10668	2^{-+}	–	55	57	–	–	–
$\Upsilon_3(3^3D_3)$	10673	3^{--}	15	56	113	–	–	–
$\chi_{b0}(4^3P_0)$	10726	0^{++}	26	–	24	–	–	–
$\Upsilon_3(2^3G_3)$	10727	3^{--}	3	43	39	–	–	–
$\chi_{b1}(4^3P_1)$	10740	1^{++}	–	20	1	–	–	–
$h_b(4^1P_1)$	10744	1^{+-}	–	33	5	–	–	–
$\chi_{b2}(4^3P_2)$	10751	2^{++}	10	28	5	1	–	–
$\chi_{b2}(3^3F_2)$	10800	2^{++}	5	26	53	2	2	–
$\Upsilon_3(3^1F_3)$	10803	3^{+-}	–	28	46	–	3	–
$\Upsilon(10860)$	$10876 \pm 11^\dagger$	1^{--}	1	21	45	0	3	1
$\Upsilon_2(4^3D_2)$	10876	2^{--}	–	28	36	–	4	4
$\Upsilon_2(4^1D_2)$	10877	2^{-+}	–	22	37	–	4	3
$\Upsilon_3(4^3D_3)$	10881	3^{--}	1	4	49	0	1	2
$\Upsilon_3(3^3G_3)$	10926	3^{--}	7	0	13	2	0	5
$\Upsilon(11020)$	$11019 \pm 8^\dagger$	1^{--}	0	8	26	0	0	2

Bottomonium spectrum (in couple channel calculations)

Ferretti, Santopinto, Phys.Rev. D90, 094022 (2014)

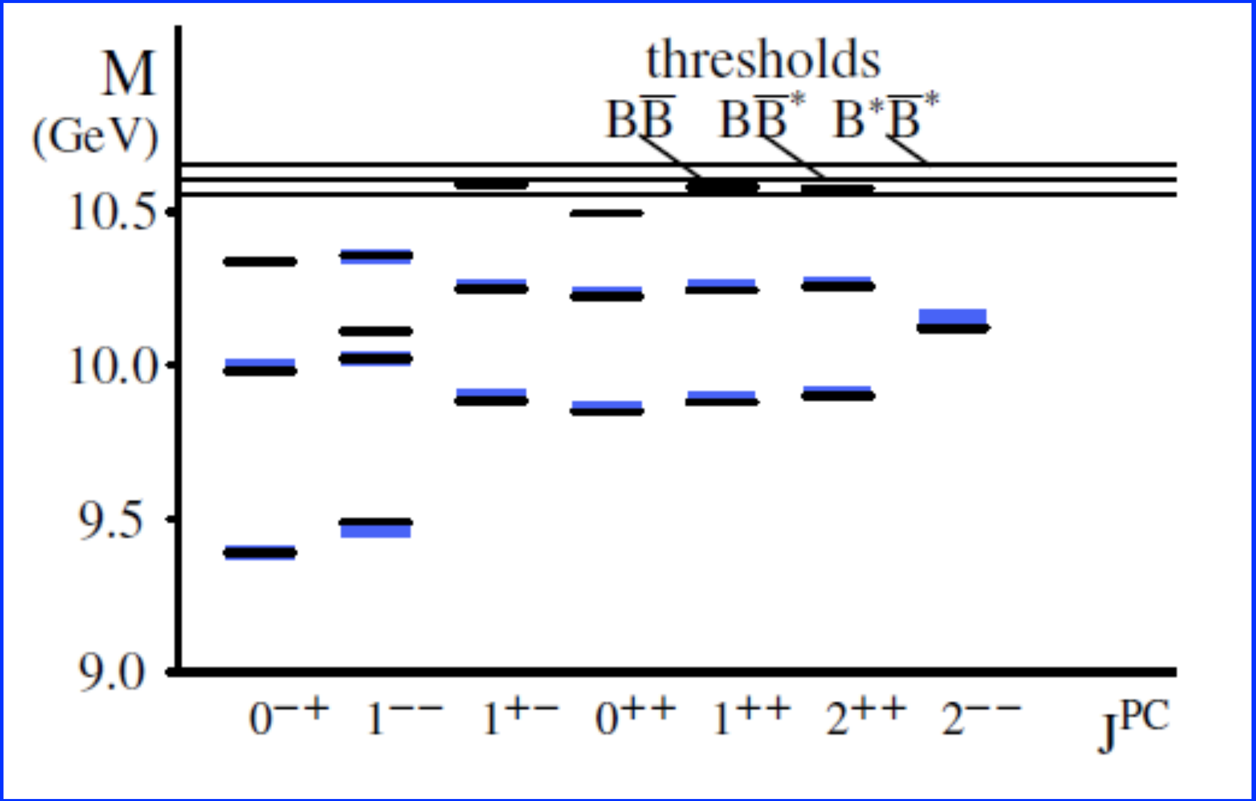


State	J^{PC}	$B\bar{B}$	$B\bar{B}^*$ $\bar{B}B^*$	$B^*\bar{B}^*$	$B_s\bar{B}_s$	$B_s\bar{B}_s^*$ $\bar{B}_sB_s^*$	$B_s^*\bar{B}_s^*$	$B_c\bar{B}_c$	$B_c\bar{B}_c^*$ $\bar{B}_cB_c^*$	$B_c^*\bar{B}_c^*$	$\eta_b\eta_b$	$\eta_b\Upsilon$	$\Upsilon\Upsilon$	$\Sigma(E_a)$	E_a	M_a	$M_{exp.}$
$\eta_b(1^1S_0)$	0^{-+}	–	-26	-26	–	-5	-5	–	-1	-1	–	–	0	-64	9455	9391	9391
$\Upsilon(1^3S_1)$	1^{--}	-5	-19	-32	-1	-4	-7	0	0	-1	–	0	–	-69	9558	9489	9460
$\eta_b(2^1S_0)$	0^{-+}	–	-43	-41	–	-8	-7	–	-1	-1	–	–	0	-101	10081	9980	9999
$\Upsilon(2^3S_1)$	1^{--}	-8	-31	-51	-2	-6	-9	0	0	-1	–	0	–	-108	10130	10022	10023
$\eta_b(3^1S_0)$	0^{-+}	–	-59	-52	–	-8	-8	–	-1	-1	–	–	0	-129	10467	10338	–
$\Upsilon(3^3S_1)$	1^{--}	-14	-45	-68	-2	-6	-10	0	0	-1	–	0	–	-146	10504	10358	10355
$h_b(1^1P_1)$	1^{+-}	–	-49	-47	–	-9	-8	–	-1	-1	–	0	–	-115	10000	9885	9899
$\chi_{b0}(1^3P_0)$	0^{++}	-22	–	-69	-3	–	-13	0	–	-1	0	–	0	-108	9957	9849	9859
$\chi_{b1}(1^3P_1)$	1^{++}	–	-46	-49	–	-8	-9	–	-1	-1	–	–	0	-114	9993	9879	9893
$\chi_{b2}(1^3P_2)$	2^{++}	-11	-32	-55	-2	-6	-9	0	-1	-1	0	–	0	-117	10017	9900	9912
$h_b(2^1P_1)$	1^{+-}	–	-66	-59	–	-10	-9	–	-1	-1	–	0	–	-146	10393	10247	10260
$\chi_{b0}(2^3P_0)$	0^{++}	-33	–	-85	-4	–	-14	0	–	-1	0	–	0	-137	10363	10226	10233
$\chi_{b1}(2^3P_1)$	1^{++}	–	-63	-60	–	-9	-10	–	-1	-1	–	–	0	-144	10388	10244	10255
$\chi_{b2}(2^3P_2)$	2^{++}	-16	-42	-72	-2	-6	-10	0	0	-1	0	–	0	-149	10406	10257	10269
$h_b(3^1P_1)$	1^{+-}	–	-18	-73	–	-11	-10	–	-1	-1	–	0	–	-114	10705	10591	–
$\chi_{b0}(3^3P_0)$	0^{++}	-4	–	-160	-6	–	-15	0	–	-1	0	–	0	-186	10681	10495	–
$\chi_{b1}(3^3P_1)$	1^{++}	–	-25	-74	–	-11	-10	–	0	-1	–	–	0	-121	10701	10580	–
$\chi_{b2}(3^3P_2)$	2^{++}	-19	-16	-79	-3	-8	-12	0	0	-1	0	–	0	-138	10716	10578	–
$\Upsilon_2(1^1D_2)$	2^{-+}	–	-72	-66	–	-11	-10	–	-1	-1	–	–	0	-161	10283	10122	–
$\Upsilon(1^3D_1)$	1^{--}	-24	-22	-90	-3	-3	-16	0	0	-1	–	0	–	-159	10271	10112	–
$\Upsilon_2(1^3D_2)$	2^{--}	–	-70	-68	–	-10	-11	–	-1	-1	–	0	–	-161	10282	10121	10164
$\Upsilon_3(1^3D_3)$	3^{--}	-18	-43	-78	-3	-8	-11	0	-1	-1	–	0	–	-163	10290	10127	–

Bottomonium

Ferretti, Santopinto, Phys.Rev. D90 (2014) 9, 094022

- Results:



Couple Channels corrections to Bottomonium , the $\chi_b(3P)$ system

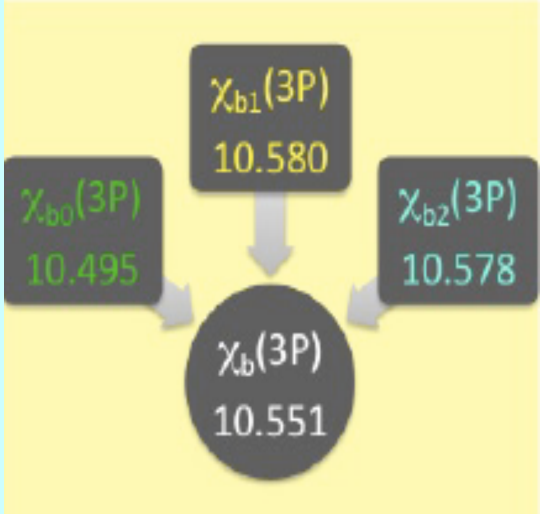
Ferretti, Santopinto, Phys.Rev. D90 (2014) 9, 094022

- Results used to study some properties of the $\chi_b(3P)$ system, meson multiplet with N=3, L=1 quantum numbers
- $\chi_b(3P)$ states close to first open bottom decay thresholds
- Possible importance of continuum coupling effects?
- Pure c bar-c and c bar-c + continuum effects interpretations
- Necessary to study decays (strong, e.m., hadronic, ...) to confirm one interpretation

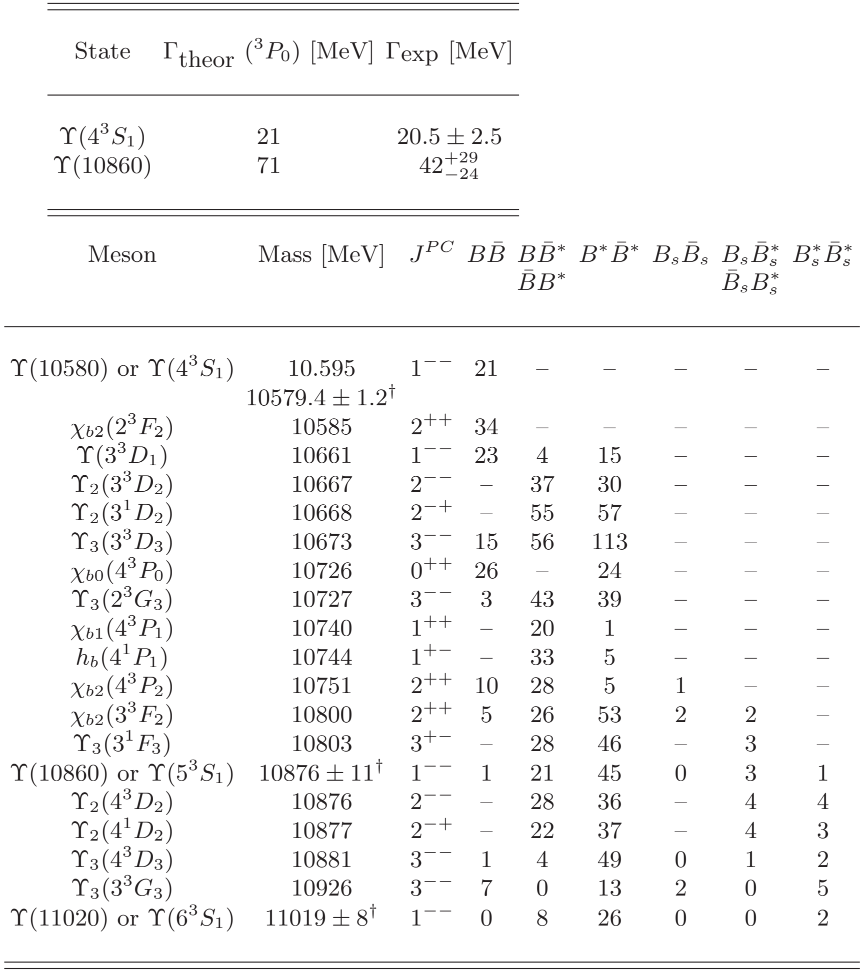
Couple Channels corrections to Bottomonium , the $\chi_b(3P)$ system

Ferretti, Santopintio, Phys.Rev. D90 (2014) 9, 094022

- Some experimental results for the mass barycenter of the system:
- $M[\chi_b(3P)] = 10.530 \pm 0.005$ (stat.) ± 0.009 (syst.) GeV
- Aad et al. [ATLAS Coll.], Phys. Rev. Lett. **108**, 152001 (2012)
- $M[\chi_b(3P)] = 10.551 \pm 0.014$ (stat.) ± 0.017 (syst.) GeV
- Abazov et al. [D0 Coll.], Phys. Rev. D 86, 031103 (2012)



J. Ferretti E. Santopinto ,**Phys.Rev. D90 (2014) 9, 094022**
arXiv:1506.04415 [hep-ph]



State	Γ_{theor} ($^3P_0$) [MeV]	Γ_{exp} [MeV]
$\Upsilon(4^3S_1)$	21	20.5 ± 2.5
$\Upsilon(10860)$	71	42^{+29}_{-24}

Meson	Mass [MeV]	J^{PC}	$B\bar{B}$	$B\bar{B}^*$ $\bar{B}B^*$	$B^*\bar{B}^*$	$B_s\bar{B}_s$	$B_s\bar{B}_s^*$ $\bar{B}_sB_s^*$	$B_s^*\bar{B}_s^*$
$\Upsilon(10580)$ or $\Upsilon(4^3S_1)$	10.595 $10579.4 \pm 1.2^\dagger$	1^{--}	21	–	–	–	–	–
$\chi_{b2}(2^3F_2)$	10585	2^{++}	34	–	–	–	–	–
$\Upsilon(3^3D_1)$	10661	1^{--}	23	4	15	–	–	–
$\Upsilon_2(3^3D_2)$	10667	2^{--}	–	37	30	–	–	–
$\Upsilon_2(3^1D_2)$	10668	2^{-+}	–	55	57	–	–	–
$\Upsilon_3(3^3D_3)$	10673	3^{--}	15	56	113	–	–	–
$\chi_{b0}(4^3P_0)$	10726	0^{++}	26	–	24	–	–	–
$\Upsilon_3(2^3G_3)$	10727	3^{--}	3	43	39	–	–	–
$\chi_{b1}(4^3P_1)$	10740	1^{++}	–	20	1	–	–	–
$h_b(4^1P_1)$	10744	1^{+-}	–	33	5	–	–	–
$\chi_{b2}(4^3P_2)$	10751	2^{++}	10	28	5	1	–	–
$\chi_{b2}(3^3F_2)$	10800	2^{++}	5	26	53	2	2	–
$\Upsilon_3(3^1F_3)$	10803	3^{+-}	–	28	46	–	3	–
$\Upsilon(10860)$ or $\Upsilon(5^3S_1)$	$10876 \pm 11^\dagger$	1^{--}	1	21	45	0	3	1
$\Upsilon_2(4^3D_2)$	10876	2^{--}	–	28	36	–	4	4
$\Upsilon_2(4^1D_2)$	10877	2^{-+}	–	22	37	–	4	3
$\Upsilon_3(4^3D_3)$	10881	3^{--}	1	4	49	0	1	2
$\Upsilon_3(3^3G_3)$	10926	3^{--}	7	0	13	2	0	5
$\Upsilon(11020)$ or $\Upsilon(6^3S_1)$	$11019 \pm 8^\dagger$	1^{--}	0	8	26	0	0	2

State	J^P	Mass [MeV]	$D\pi$	$D^*\pi$	$D\rho$	$D^*\rho$	$D\eta$	$D^*\eta$	$D\omega$	$D^*\omega$	D_sK	D_s^*K	D_sK^*	$D_s^*K^*$
$D_1(1^3S_1)$	1^-	2038 $2009^\dagger$	0	–	–	–	–	–	–	–	–	–	–	–
$D_0^*(2400)$ or $D_0(1^3P_0)$	0^+	2398 $2318 \pm 29^\dagger$	66	–	–	–	–	–	–	–	–	–	–	–
$D_2^*(2460)$ or $D(1^3P_2)$	2^+	2501 $2463^\dagger$	6	2	–	–	0	–	–	–	–	–	–	–
$D_0(2550)$ or $D(2^1S_0)$	0^-	2582 $2539.4 \pm 4.5 \pm 6.8^\dagger$	–	42	–	–	–	–	–	–	–	–	–	–
$D_1(2^3S_1)$	1^-	2645	18	36	0	–	6	5	–	–	4	1	–	–
$D_1(1^3D_1)$	1^-	2816	20	13	13	1	10	5	4	0	6	2	–	–
$D_3(1^3D_3)$	3^-	2833	11	8	1	15	2	1	0	4	1	0	–	–
$D_0(2^3P_0)$	0^+	2931	18	–	–	38	2	–	–	12	0	–	–	–
$D_2(2^3P_2)$	2^+	2957	13	23	22	45	6	7	7	16	4	4	1	–
$D_0(3^1S_0)$	0^-	3067	–	1	4	38	–	1	1	13	–	3	8	8
$D_1(3^3S_1)$	1^-	3111	3	2	1	31	0	0	0	11	0	1	5	15
$D_4(1^3F_4)$	4^+	3113	11	8	4	36	2	1	1	12	1	0	0	1
$D_2(1^3F_2)$	2^+	3132	10	9	11	12	5	3	4	4	2	2	1	0
$D_3(2^3D_3)$	3^-	3226	8	14	16	21	4	5	5	7	3	3	2	9
$D_1(2^3D_1)$	1^-	3231	7	2	0	51	1	0	0	17	0	0	1	4
$D_0(3^3P_0)$	0^+	3343	1	–	–	13	0	–	–	4	1	–	–	11
$D_2(3^3P_2)$	2^+	3352	2	1	0	13	0	0	0	5	0	1	1	6
$D_3(1^3G_3)$	3^-	3398	5	2	7	15	2	2	2	5	1	1	1	1
$D_0(4^1S_0)$	0^-	3465	–	1	4	11	–	1	1	4	–	1	1	0
$D_4(2^3F_4)$	4^+	3466	5	8	10	12	2	3	3	4	2	2	2	4
$D_2(2^3F_2)$	2^+	3490	3	1	0	38	1	0	0	12	0	0	0	5
$D_3(3^3D_3)$	3^-	3578	2	1	0	6	0	0	0	2	0	0	1	2
$D_0(4^3P_0)$	0^+	3709	0	–	–	9	0	–	–	3	0	–	–	1
$D_3(2^3G_3)$	3^-	3721	2	1	0	24	0	0	0	8	0	0	0	3
$D_4(3^3F_4)$	4^+	3788	1	1	0	3	0	0	0	1	0	0	0	1
$D_4(4^3F_4)$	4^+	4085	0	0	0	2	0	0	0	1	0	0	0	0

- Unquenching of hadron models: we have constructed the formalism in an explicit way, also thanks to group th. tecniques.

During 2016, many applications to Jlab Physics e LHC_b physics,

Dark Matter

Jlab will be involved in Dark Matter Experiments and will need Theory support.

R.Cenni,P.Saracco,E.Santopinto