NINPHA
Hadron and particle physics
Exotic spectroscopy
Nuclear matrix elements
Transport Equations

Responsabile nazionale: Boglione
Nodi
Cagliari: Murgia
Genova: Santopinto
Pavia: Radici
Perugia:Scopetta
Torino: Boglione

NINPHA

FTE=1,3

Nodo di Genova

Responsabile: E. Santopinto

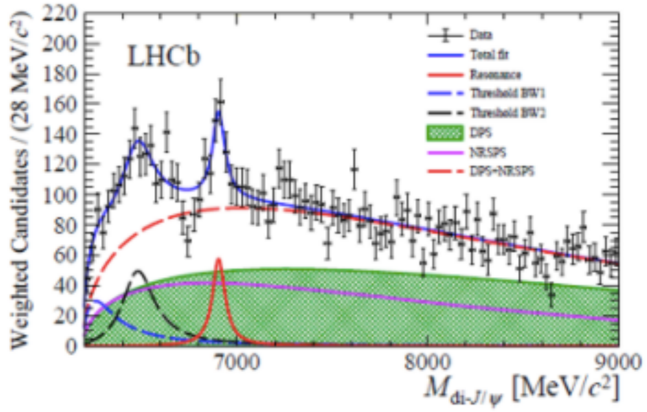
Componenti:

Ruslan Magana Vsevoldovna (post doc infn) 20%.

A. Pilloni (Ric. tempo det. Roma1) 20%,

E. Santopinto(Primo Ric.) 50% ,

P. Saracco(Ric.) 40%



1 JULY, 2020

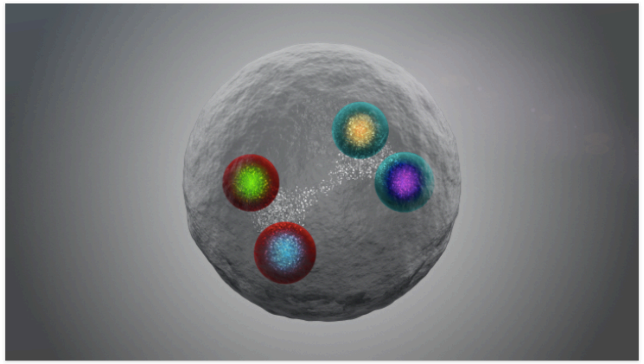


Illustration of a tetraquark composed of two charm quarks and two charm antiquarks, detected for the first time by the LHCb collaboration at CERN (Image: CERN)

arXiv.org > hep-ex > arXiv:2006.16957

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High Energy Physics – Experiment

[Submitted on 30 Jun 2020]

Observation of structure in the J/ψ-pair mass spectrum

LHCb collaboration: R. Aaij, C. Abellán Beteta, T. Ackernley, B. Adeva, M. Adinolfi, H. Afsharnia, C.A. Aidala, S. Aiola, Z. Ajaltouni, S. Akar, J. Albrecht, F. Alessio, M. Alexander, A. Alfonso Albero, Z. Aliouche, G. Alkhazov, P. Alvarez Cartelle, A.A. Alves Jr, S. Amato, Y. Amhis, L. An, L. Anderlini, G. Andreassi, A. Andreianov, M. Andreotti, F. Archilli, A. Artamonov, M. Artuso, K. Arzymatov, E. Aslanides, M. Atzeni, B. Audurier, S. Bachmann, M. Bachmayer, J.J. Back, S. Baker, P. Baladron Rodriguez, V. Balagura, W. Baldini, J. Baptista Leite, R.J. Barlow, S. Barsuk, W. Barter, M. Bartolini, F. Baryshnikov, J.M. Basels, G. Bassi, V. Batozskaya, B. Batsukh, A. Battig, A. Bay, M. Becker, F. Bedeschi, I. Bediaga, A. Beiter, V. Belavin, S. Belin, V. Bellee, K. Belous, I. Belyaev, G. Bencivenni, E. Ben-Haim, A. Berezhnoy, R. Bernet, D. Berninghoff, H.C. Bernstein, C. Bertella, E. Bertholet, A. Bertolin, C. Betancourt, F. Betti, M.O. Bettler, Ia. Bezshyiko, S. Bhasin, J. Bhom, L. Bian, M.S. Bieker, S. Bifani, P. Billoir, M. Birch, F.C.R. Bishop, A. Bizzeti, M. Bjørn, M.P. Blago, T. Blake, F. Blanc, S. Blusk, D. Bobulska, V. Bocci, J.A. Boelhauve, O. Boente Garcia, T. Boettcher, A. Boldyrev, A. Bondar, N. Bondar, S. Borghi, M. Borisyak, M. Borsato, J.T. Borsuk et al. (873 additional authors not shown)

Using proton-proton collision data at centre-of-mass energies of $\sqrt{s} = 7, 8$ and $13\,\text{TeV}$ recorded by the LHCb experiment at the Large Hadron Collider, corresponding to an integrated luminosity of $9\,\text{fb}^{-1}$, the invariant mass spectrum of J/ψ pairs is studied. A narrow structure around $6.9\,\text{GeV}/c^2$ matching the lineshape of a resonance and a broad structure just above twice the J/ψ mass are observed. The deviation of the data from nonresonant J/ψ-pair production is above five standard deviations in the mass region between 6.2 and $7.4\,\text{GeV}/c^2$, covering predicted masses of states composed of four charm quarks. The mass and natural width of the narrow $X(6900)$ structure are measured assuming a Breit--Wigner lineshape.

It has cited 3 articles of the Genoa group!

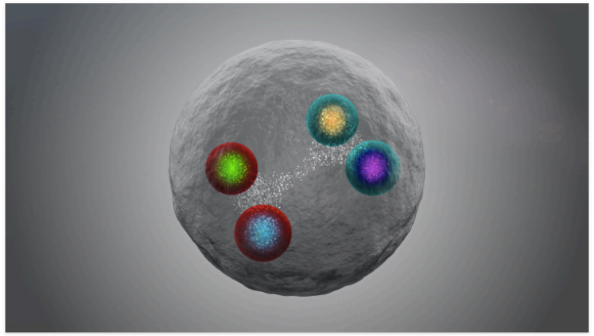


Illustration of a tetraquark composed of two charm quarks and two charm antiquarks, detected for the first time by the LHCb collaboration at CERN (Image: CERN)

1 July 2020: Observation of a four-charm-quark tetraquark.

A “smoking gun” for tightly bound tetraquarks.

Today, the LHCb collaboration submitted a paper reporting the discovery of a possible tetraquark candidate, $T_{cc\bar{c}\bar{c}}$, composed of two charm quarks and two charm antiquarks, referred to as the X(6900) in the paper. These results have been already presented at a CERN seminar on June 16th. The full Run 1 and Run 2 data sets are used in this analysis. The invariant-mass spectrum of prompt-J/ψ pairs is investigated, where the J/ψ mesons are reconstructed through the decay $J/\psi \rightarrow \mu^+\mu^-$. The three images below show the data (black points with error bars) analysed under different assumptions as explained in the seminar and paper. A narrow peaking structure at 6900 MeV/c^2, matching the expected signature of the production of a new particle, and a broader structure around 6400-6600 MeV/c^2, close to the threshold, are observed. The top plot shows the null hypothesis of only continuum J/ψ pair production, which is found to be inconsistent with the data by more than 5σ in the mass range 6200-7400 MeV/c^2 in which particles composed of four charm quarks have been predicted. The decay of the new particle into the J/ψ pair suggests a minimum quark content of $cc\bar{c}\bar{c}$, consistent with a $T_{cc\bar{c}\bar{c}}$ tetraquark interpretation.

Search for $T_{cc\bar{c}\bar{c}}$

- $T_{cc\bar{c}\bar{c}}$ states predicted to have $M \in [5.8, 7.4]$ GeV$/c$, isolated from both quarkonia and quarkonium-like exotic states
- A $T_{cc\bar{c}\bar{c}}$ state can decay into a pair of charmonia ⇒ search in J/ψ-pair mass spectrum

	$cc\bar{c}\bar{c}$	
J^{PC}	$N[(S_D, S_D)S, L]J$	E^{th} [MeV]
0^{++}	$1[(1,1)0,0]0$	5883
0^{++}	$2[(1,1)0,0]0$	6573
0^{++}	$1[(1,1)2,2]0$	6835
0^{++}	$3[(1,1)0,0]0$	6948
0^{++}	$2[(1,1)2,2]0$	7133
0^{++}	$3[(1,1)2,2]0$	7387
1^{+-}	$1[(1,1)1,0]1$	6120
1^{+-}	$2[(1,1)1,0]1$	6669
1^{+-}	$1[(1,1)1,2]1$	6829
1^{+-}	$3[(1,1)1,0]1$	7016
1^{+-}	$2[(1,1)1,2]1$	7128
1^{+-}	$3[(1,1)1,2]1$	7382
1^{--}	$1[(1,1)0,1]1$	6580
1^{--}	$1[(1,1)2,1]1$	6584
1^{--}	$2[(1,1)0,1]1$	6940
1^{--}	$2[(1,1)2,1]1$	6943
1^{--}	$3[(1,1)0,1]1$	7226
1^{--}	$3[(1,1)2,1]1$	7229
0^{-+}	$1[(1,1)1,1]0$	6596
0^{-+}	$2[(1,1)1,1]0$	6953
0^{-+}	$3[(1,1)1,1]0$	7236
1^{++}	$1[(1,1)2,2]1$	6832
1^{++}	$2[(1,1)2,2]1$	7130
1^{++}	$3[(1,1)2,2]1$	7384
2^{++}	$1[(1,1)2,0]2$	6246
2^{++}	$1[(1,1)2,2]2$	6827
2^{++}	$1[(1,1)0,2]2$	6827
2^{++}	$2[(1,1)2,0]2$	6739
2^{++}	$3[(1,1)2,0]2$	7071
2^{++}	$2[(1,1)2,2]2$	7125
2^{++}	$2[(1,1)0,2]2$	7126
2^{++}	$3[(1,1)2,2]2$	7380
2^{++}	$3[(1,1)0,2]2$	7380

[arXiv: 1911.00960]

J^{PC}	m_{X_c}(GeV)
0^{++}	6.44 ± 0.15
	6.59 ± 0.17
	6.47 ± 0.16
	6.46 ± 0.16
	6.82 ± 0.18
0^{-+}	6.84 ± 0.18
	6.85 ± 0.18
0^{--}	6.84 ± 0.18
1^{++}	6.40 ± 0.19
	6.34 ± 0.19
1^{+-}	6.37 ± 0.18
	6.51 ± 0.15
1^{-+}	6.84 ± 0.18
	6.88 ± 0.18
1^{--}	6.84 ± 0.18
	6.83 ± 0.18
2^{++}	6.51 ± 0.15
	6.37 ± 0.19

J^{PC}	S-wave	P-wave
0^{++}	$\eta_c(1S)\eta_c(1S)$, $J/\psi J/\psi$	$\eta_c(1S)\chi_{c1}(1P)$, $J/\psi h_c(1P)$
0^{-+}	$\eta_c(1S)\chi_{c0}(1P)$, $J/\psi h_c(1P)$	$J/\psi J/\psi$
0^{--}	$J/\psi\chi_{c1}(1P)$	$J/\psi\eta_c(1S)$
1^{++}	–	$J/\psi h_c(1P)$, $\eta_c(1S)\chi_{c1}(1P)$, $\eta_c(1S)\chi_{c0}(1P)$
1^{+-}	$J/\psi\eta_c(1S)$	$J/\psi\chi_{c0}(1P)$, $J/\psi\chi_{c1}(1P)$ $\eta_c(1S)h_c(1P)$
1^{-+}	$J/\psi h_c(1P)$, $\eta_c(1S)\chi_{c1}(1P)$	–
1^{--}	$J/\psi\chi_{c0}(1P)$, $J/\psi\chi_{c1}(1P)$ $\eta_c(1S)h_c(1P)$	$J/\psi\eta_c(1S)$

[arXiv: 1803.02522]

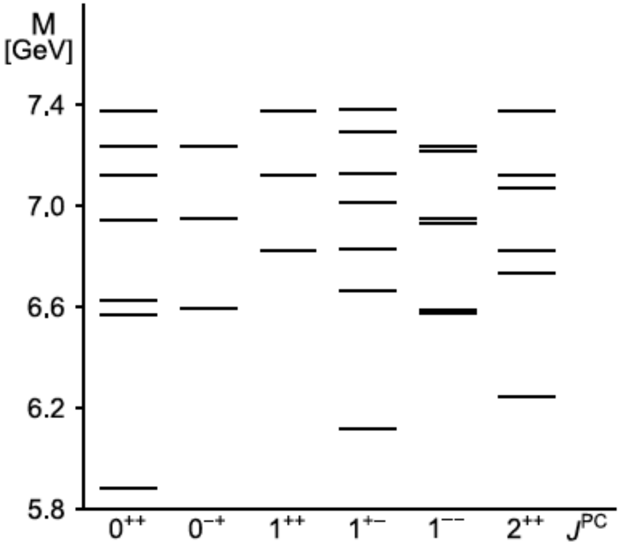


FIG. 1: Pictorial representation of the $(cc)_{\bar{3}_c}(\bar{c}\bar{c})_{3_c}$ (left panel)

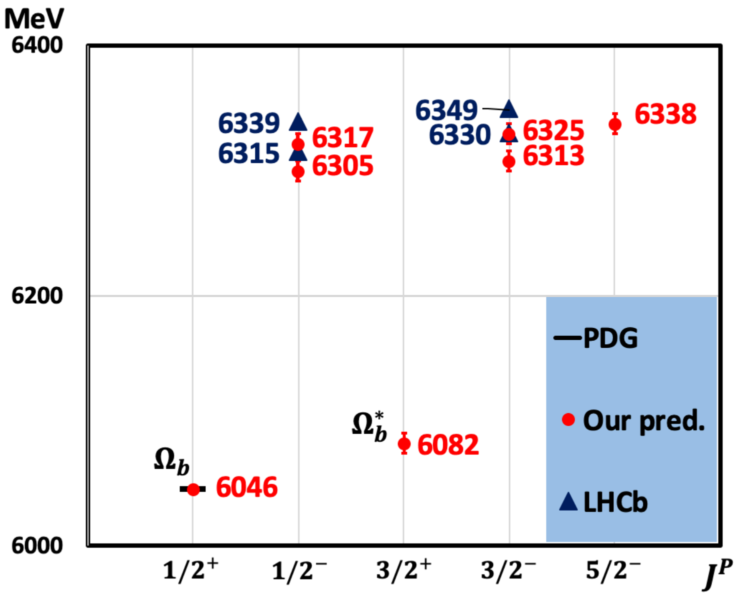
arXiv:1911.00960

Genoa Group (Bedolla, Ferretti, Santopinto)

Liupan An, https://indico.cern.ch/event/900972/attachments/2051939/3451258/ExoticStates_20200616.pdf

- **GE-Roma1 collaboration has already produced two papers:**
- **On searc at LHC of the fully bottom tetraquark**:
- [1] C. Becchi, A Giachino, L. Maiani, E. Santopinto, Search for bb¯b ¯b tetraquark decays in 4 muons, B+B−, B0B¯0 and B0 sB¯0 s channels at LHC, **PLB 805** (2020) 135495
- **On the searc at LHC of the fully charm tetraquark**:
- [2] C. Becchi, J. Ferretti, A Giachino, L. Maiani, E. Santopinto, a study of cc bar{c}bar{c} tetraquarks in $D(*)\bar{D}(*)$D(∗)D¯(∗) **at LHC**, Jun 25, 2020, e-Print: **arXiv:2006.14388**

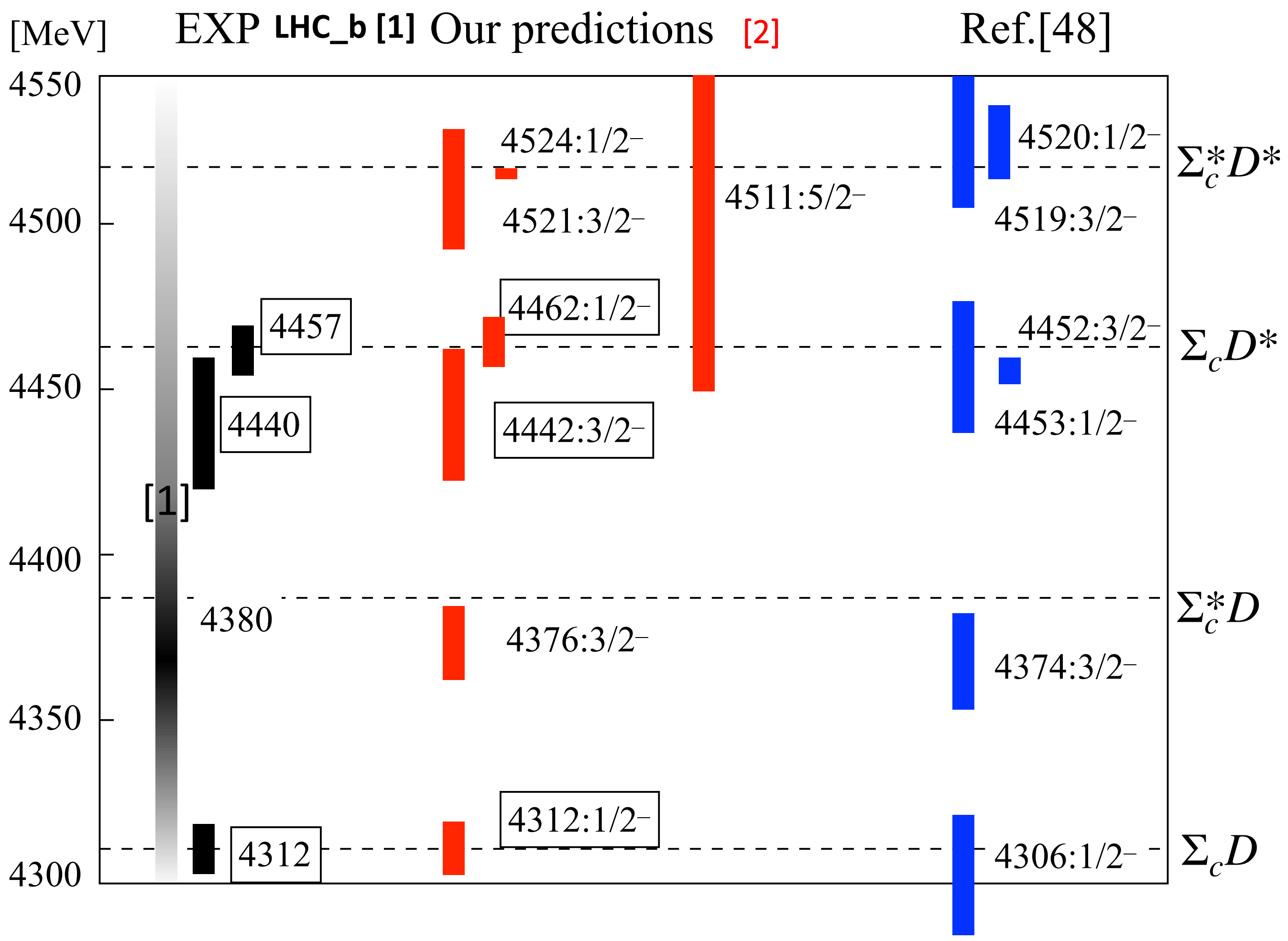
During this year, important results in the field have been obtained, in particular regarding heavy hadron spectroscopy (the new Omega_ b states [3] predicted by us before their detections by LHC_b and also the new LHC_b pentaquark states predicted by us before detection in 2020 and one of those new states interpreted as a virtual state [4-5], and for tetraquark and exotic states [1,8]) and also their decays. Our results are of interest for LHC, in particular for LHC_b, and also for Belle, BES and JLab and in a future for an EIC. The transport equation formalism has been developed [16-17] with important results and also theoretical formalism useful for three-body scattering and decays [18-20].



[1] Santopinto et al., EPJC 2019

The new Omega_b states have been Predicted by us [1]before their discovery in 2020

The new LHCb states have been predicted by us, before their discovery in 2019 !



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ARTICOLI NINPHA GE :

[1] C. Becchi, A Giachino, L. Maiani, E. Santopinto, Search for bb¯b ¯b tetraquark decays in 4 muons, B+B−, B0B¯0 and B0 sB¯0 s channels at LHC, **PLB 805** (2020) 135495

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[6] D. Winney, at al., Double Polarization Observables in Pentaquark Photoproduction, **Phys. Rev. D100 (2019), 034019**

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[17] N.Chentre, P. Saracco, S.Dulla, P.Ravetto, On Fick's law in asymptotic transport theory**, EPJ Plus 134 (2019)m516**

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[21] L.X. Gutiérrez-Guerrero et al., Masses of Light and Heavy Mesons and Baryons: A Unified Picture, **Phys. Rev. D 100 (2019) no.11, 114032**

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Topics 2021:

- Tetraquark pesanti e loro decadimenti; Spettroscopia di adroni pesanti; Studio di decadimenti; Studio di spettroscopia anche per EIC (Santopinto)
- Analisi fenomenologica di ampiezze di scattering per decadimenti a tre corpi di mesoni pesanti come D0 -> pi+ pi- pi0 per ricerca di nuova fisica. Analisi di ampiezze di scattering per la spettroscopia. Calcolo e stima di sezioni d'urto per l'ÉIC (Pilloni)
- Equazioni di trasporto per esperimenti di cinetica neutroni in sistemi moltiplicativi sottocritici (Saracco)
- Elementi di matrice nucleari di interesse astrofisico, **implementando anche tecniche di Machine Learning** (Magana Vsevolodovna, Santopinto)

- **Responsabilita':**
- **I progetti di spettroscopia sono di interesse per Jlab12, LHC ed EIC**, anzi il nodo di Genova fornisce supporto teorico non ad uno ma a diversi esperimenti che stanno rannando o futuri. Il progetto sulle equazioni di trasporto e' di interesse per **INFN-E (GE). Il** progetto di astrofisica nucleare e' di interesse per esperimenti INFN presenti anche a GE.

Richieste ai servizi per NINPHA/NUMEN per il 2021:

1 mese uomo del Calcolo

- installazione del software di cui abbiamo bisogno per eseguire job
- sulla farm (come ad esempio varie versioni di compilatori fortran,

Software Python per il Machine Learning e software Python per parallelizzazione).

Principali collaborazioni straniere :

- Osaka University (Japan) – A. Hosaka, S. Takeuchi
- RIKEN – Nishina Center for Accelerator-Based Science (Japan) – M. Takizawa,Y. Yamaguchi
- Pitsburgh University (USA) –E. Swanson
- Nanjing University (China) – C.D. Roberts
- Indiana University (USA) – E. Passemar, A. Szczepaniak
- IHEP, Beijing (China) – Yubing Dong
- Pitsburg University , (USA), E. Swanson
- UNAM, Mexico City (Messico) – R. Bijker, C. Fernandez-Ramirez,, E. Ortiz-Pacheco
- J Dubna, (Russia)   M. Barabanov
- ITA-CTA, S. Jose dos Campos (Brazil) – T. Frederico, W. De Paula
- Universidad Complutense Madrid (Spain) – V. Mathie
- Universidad Nacional de Colombia, Bogotà (Colombia) – M. De Sanctisi
- Concepción University (Chile) – J. Barea
- EPFL, Lausanne, LPTP (Swizerland) – A . Esposito
- University of Jyvaskyla (Finland) -J. Kotila, **J. Ferretti**
- IFM-UMSNH, Michoacan (Mexico) - Adnan Bashir
- JCHP, Jülich Center for Hadron Physics (Germany) – M. N. Anwar
- Bonn University, HISKP (Germany) – Y. Lu
- La Plata University (Chile) – **H. Garcia Tecocoazti**
- Chiapas Autonoma University.(Mexico) - L.X. Gutierrez-Guerrero, M. A. Bedolla