

The 7th International Workshop on Charm Physics (CHARM 2015)

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Wayne State University

Book of Abstracts

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Mixing and CP-violation I / 1**Implications of SU(3)_F on Charm CP Violation****Authors:** Sarah Müller¹; Stefan Schacht¹; Ulrich Nierste¹¹ *Karlsruhe Institute of Technology***Corresponding Author:** stefan.schacht@kit.edu

We present recent results on improved predictions for charm CP violation in nonleptonic decays. These are obtained from a fit of a diagrammatic parametrization to branching ratios including linear SU(3)_F breaking. The predictions make possible future tests of the Standard Model once improved data is available.

Quark masses, leptonic and semileptonic and rare decays / 2**D Leptonic and semi-leptonic decays from BESIII****Author:** Xiao-Rui Lyu¹¹ *UCAS***Corresponding Authors:** xiaorui@ucas.ac.cn, mahl@ihep.ac.cn

The BESIII experiment has taken 2.92/fb of data at $\sqrt{s} = 3.773$ GeV which contains the largest sample of $e^+e^- \rightarrow \psi(3770) \rightarrow D\bar{D}$ in the world to date. We report the result of our branching fraction measurement of $D^+ \rightarrow \mu^+ \nu$ based on this sample from which we extract its weak decay constant, f_{D^+} , with the $|V_{cd}|$ determined from a global Standard Model fit as an input. We also obtain $|V_{cd}|$ from the measured branching fraction together with a Lattice QCD prediction for f_{D^+} . In addition, we present measurements of $D^0 \rightarrow (K^-/\pi^-) e^+ \nu$, $D^+ \rightarrow KL e^+ \nu$, and $D^+ \rightarrow (\omega/\phi/K\pi) e^+ \nu$ decays. Based on analysis of $D^0 \rightarrow (K^-/\pi^-) e^+ \nu$ and $D^+ \rightarrow K_L e^+ \nu$, we extract different parameterizations of the form factors together with the CKM matrix elements $|V_{cs}(d)|$. These will give a precision test on the LQCD calculation on these form factors and the unitarity of the CKM matrix. Based on analysis of $D^+ \rightarrow K^- \pi^+ e^+ \nu$, we perform a partial wave analysis and in return, we determine the S-wave contribution and its phase, the helicity basis form factors of $D^+ \rightarrow K^*(892) e^+ \nu$ based on the SPD model, and we also measure them in a model-independent way. We also report searches for some rare semi-leptonic decays.

Parallel Session 3 / 7**D⁰ to K_sKK and D to omega pi****Author:** Xiao-Rui Lyu¹¹ *UCAS***Corresponding Author:** xiaorui@ucas.ac.cn

Based on 2.92 fb^{-1} of e^+e^- collision data taken at $\sqrt{s} = 3.773$ GeV with the BESIII detector at BEPCII, we present preliminary results from the analysis of the decay $D^0 \rightarrow K_S^0 K^+ K^-$. We measure the branching fraction and investigate the rich substructure in the final state by performing a Dalitz plot analysis.

Parallel Session 3 / 8**D rare/fobidden decays****Author:** Xiao-Rui Lyu¹¹ UCAS**Corresponding Authors:** xiaorui@ucas.ac.cn, zhaomg@ihep.ac.cn

Based on the sample taken at $\sqrt{s} = 3.773$ GeV with 2.92/pb, which corresponds to the largest sample of $e^+e^- \rightarrow \psi(3770)$ in the world to date, we present our results of searches for flavor changing neutral current and lepton number violation decays of the charged D meson in the final states of; $D^+ \rightarrow K^+ e^+ \nu$, $K^- e^+ e^+$, $\pi^+ e^+ e^-$, $\pi^+ e^+ e^+$, as well as other searches such as for $D^0 \rightarrow \gamma$ gamma.

Parallel Session 3 / 11**Mixing/coherence in D mesons****Author:** Xiao-Rui Lyu¹¹ UCAS**Corresponding Authors:** xiaorui@ucas.ac.cn, albayrak@phys.cmu.edu

We report the measurement of the D^0 - D^0 bar mixing parameter, y_{CP} based on the sample taken at the $D\bar{D}$ bar mass threshold. Based on the events where we reconstruct one D decays to CP eigenstates while the other D decays semi-leptonially, we obtain $y_{\text{CP}} = (-2.0 \pm 1.3 \pm 0.7)\%$. We also present results for model independent measurement of the strong phase difference between D^0 and D^0 bar $\rightarrow K^0 \pi^+ \pi^-$, through a binned dalitz analysis. These results represent a significant improvement in a previously statistically limited measurement, which will then allow for increased precision in the measurement of unitarity triangle angle γ/ϕ_3 using the decay $B^{+-} \rightarrow D \rightarrow K_s \pi^+ \pi^-$ K^+ through the GGSZ method.

Parallel Session 4 / 12**DD-bar shape****Author:** Xiao-Rui Lyu¹¹ UCAS**Corresponding Authors:** xiaorui@ucas.ac.cn, fangy@ihep.ac.cn

BESIII collected about 70 pb⁻¹ e^+e^- annihilation data around the nominal mass of $\psi(3770)$, based on which we present preliminary results of study on the production line-shape of $e^+e^- \rightarrow D\bar{D}$ bar. In this study, we take into account the effect of interference due to the non-reconant $D\bar{D}$ bar production to describe the observed anomalous line-shape.

Parallel Session 2 / 13**Studies of Charmonium at BESIII**

Authors: Rong-Gang Ping¹; Xiao-Rui Lyu²

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The BESIII Experiment at the Beijing Electron Positron Collider (BEPC2) has accumulated the world's largest samples of e^+e^- collisions in the tau-charm region. From these samples – which include J/ψ , $\psi(2S)$, and $\psi(3770)$ decays, among others – BESIII has produced many new results in the spectroscopy, transitions, and decays of charmonium. This talk will review the current status of these analyses, which cover a wide range of topics from rare decays to radiative transitions to new precision measurements.

Parallel Session 2 / 15

Hadronic Transitions above 4 GeV at BESIII

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The BESIII Experiment at the Beijing Electron Positron Collider (BEPC2) collected large data samples for electron-positron collisions with center-of-mass above 4 GeV during 2013 and 2014. A number of hadronic transitions have been measured in these data samples, leading to a rather complex picture of the physics of charmonium above 4 GeV. In this talk we will present results for $e^+e^- \rightarrow \pi^0\pi^0 J/\psi$ (where the $Y(4260)$ is seen in the cross section), as well as results for apparently more complex cross sections, such as $e^+e^- \rightarrow \omega \chi_{c0}$ and $\eta J/\psi$, where structures are less apparent.

Parallel Session 2 / 16

XYZ radiative transitions

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The BESIII Experiment at the Beijing Electron Positron Collider (BEPC2) collected large data samples for electron-positron collisions with center-of-mass above 4 GeV during 2013 and 2014. In this mass region, there are several states that are yet to be understood. In this talk we will discuss BESIII analyses of radiative transitions among these states, which may improve our understanding of this important mass region. One example is the observation of the process $e^+e^- \rightarrow \gamma X(3872)$.

Mixing and CP-violation I / 17

Recent results on violation of discrete symmetries in charm decays at BaBar and Belle

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The status of CP violations in charm sector is still unsettled.

According to SM, the predicted asymmetries are small, but often affected by large uncertainties due to long-distance effects. However, it is possible to build observables which SM predicts to be CP conserving, so that any measured asymmetry is, with no doubts, a sign of New Physics.

We present recent results on charm CP violation at Belle and BaBar. We show the measurement of CP asymmetries in $D^+ \rightarrow K^+ K^- \pi^+$, $D^+ \rightarrow KS K^+$, $Ds^+ \rightarrow KS K^+$, $Ds^+ \rightarrow KS \pi^+$ at BABAR. Moreover, we show the Belle measurements of indirect CP violation parameters from $D^0 \rightarrow KS \pi^0$ decay.

Spectroscopy I / 18

Dalitz plot analysis of three-body charmonium decays in BaBar.

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We study the reaction $e^+ e^- \rightarrow \gamma_{ISR} J/\psi$, where $J/\psi \rightarrow \pi^+ \pi^- \pi^0$ and $J/\psi \rightarrow K^+ K^- \pi^0$, using events obtained from the Initial State Radiation process. We measure the relative J/ψ branching fraction and perform a Dalitz plot analysis of both J/ψ decay modes using the isobar and Veneziano model.

We study the process $\gamma \gamma \rightarrow K \text{ anti-K } \pi$. We observe the decays $\eta_c \rightarrow Ks K^+ \pi^-$ and $\eta_c \rightarrow K^+ K^- \pi^0$ and perform a Dalitz analysis of both η_c decay modes. We also extract the mass dependent $K\pi$ amplitude and phase using the model-independent partial wave analysis approach.

Production / 19

Study of inclusive charmonium production in e^+e^- annihilation and B decays at BaBar

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In a e^+e^- B factory charmonium states can be produced through different mechanisms, as in e^+e^- annihilation, with double charmonium production, and in B-meson decays.

Prompt production of J/ψ or $\psi(2S)$ in association with a second charmonium state has been observed by both the BaBar and Belle experiments in e^+e^- annihilation at a center-of-mass energy of 10.58 GeV. These processes provide an opportunity to study both perturbative and non-perturbative effects in QCD and to search for new charmonium states recoiling against the reconstructed J/ψ or $\psi(2S)$. We present a study of such events using the full BaBar dataset.

We also present measurements of absolute branching fractions of the two-body decays of B mesons $B(B \rightarrow K X_{cc})$, where X_{cc} is a charmonium state. In fact, in events where one B is fully reconstructed, the charmonium spectrum can be observed in an unbiased way, looking at the distribution of the K momentum in the recoiling B rest frame.

Parallel Session 2 / 20**Search for exotic charmonium at BaBar****Author:** fabio anulli¹¹ *INFN Sezione di Roma***Corresponding Author:** anulli@slac.stanford.edu

One of the most intriguing puzzles in hadron spectroscopy are the numerous charmonium-like states observed in the last decade, including charged states that are manifestly exotic.

Over the years BaBar has extensively studied these states in B meson decays, initial state radiation processes and two photon reactions. We report on recent studies on some of these states performed using the entire data sample collected by BaBar in e^+e^- collisions at center of mass energies near $10.58 \text{ GeV}/c^2$. Among these, the study of the process $B \rightarrow J/\psi \phi K$ with a search for the $X(4140)$ and $X(4270)$ in their decays to $J/\psi \phi$, and a search for charged charmonium-like state $Z_c(3900)^+$ in the decay $Y(4260) \rightarrow J/\psi \pi^+\pi^-$.

Parallel Session 3 / 22**Measurement of the $D \rightarrow \pi^- e^+ \nu$ partial branching fraction, form factor and implications for V_{ub} .****Author:** fabio anulli¹¹ *INFN Sezione di Roma***Corresponding Authors:** anulli@slac.stanford.edu, arantza.oyanguren@ific.uv.es

Precision measurements of the $D \rightarrow \pi e^+ \nu$ form factor could shed new light on the persistent difference between inclusive and exclusive measurements of V_{ub} . We report the measurement of the partial branching fraction of $D \rightarrow \pi e^+ \nu$ in bins of the four-momentum transfer squared of the D to pi system using 347.2 /fb of integrated luminosity of the BaBar data. The $D \rightarrow \pi$ form factor is extracted with fits to the unfolded partial branching fraction using pole or generalized expansions and the value at zero recoil is determined. These form factors are compared to the current world average, the available lattice predictions, and interpreted with the expectation of a single dominant pole term. The measured form factor is then combined with previous BaBar $B \rightarrow \pi l \nu$ information to determine a value of V_{ub} .

Parallel Session 4 / 23**Open charm spectroscopy****Author:** Olivier Leroy¹¹ *CPPM, Aix-Marseille Université CNRS/IN2P3, Marseille, France***Corresponding Authors:** olivier.leroy@in2p3.fr, mwhitehe@cern.ch

Excited charm states are studied at LHCb both in the pp collision and in decays of B hadrons. The latter method has the advantage of starting from a clean and well defined initial state with known quantum numbers. LHCb presents the observation of new spin-3 mesons decaying to $D^{(*)}K$ and $D\pi$, as well as many measurements of mass, width and spin of already known mesons.

Parallel Session 3 / 24**Measurements of mixing and indirect CP violation****Author:** Olivier Leroy¹¹ CPPM, Aix-Marseille Université CNRS/IN2P3, Marseille, France**Corresponding Authors:** olivier.leroy@in2p3.fr, stefanie.reichert@cern.ch

LHCb has collected the world's largest sample of charmed hadrons. This sample is used to search for indirect CP violation in charm, and to measure D0 mixing parameters. New measurements from several decay modes are presented.

Parallel Session 2 / 25**Measurements of time-integrated CP and other asymmetries****Author:** Olivier Leroy¹¹ CPPM, Aix-Marseille Université CNRS/IN2P3, Marseille, France**Corresponding Authors:** olivier.leroy@in2p3.fr, marco.gersabeck@manchester.ac.uk

LHCb has collected the world's largest sample of charmed hadrons. This sample is used to search for direct CP violation in charm. New updated measurements from several decay modes, including DeltaACP from D0->hh decays, are presented. The talk also focuses on measurements of production and detection asymmetries.

Parallel Session 3 / 26**Measurements of T-odd observables****Author:** Olivier Leroy¹¹ CPPM, Aix-Marseille Université CNRS/IN2P3, Marseille, France**Corresponding Authors:** olivier.leroy@in2p3.fr, maurizio.martinelli@cern.ch

The study of T-odd observables using four-body hadronic final states of charm meson decays provides complementary insight to measuring CP asymmetries via decay rate asymmetries. New results based on the full LHCb dataset are presented.

Parallel Session 4 / 30 **τ physics at LHCb****Author:** Olivier Leroy¹¹ CPPM, Aix-Marseille Université CNRS/IN2P3, Marseille, France

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The observation of neutrino oscillations has re-opened the case for searches of lepton-flavour violating decays. We report on recent results and prospects on lepton-flavour violating τ decays.

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TBD

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TBD

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TBD

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TBD

Spectroscopy I / 35

Charmonium and exotics on the continuum

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Spectroscopy I / 36

Lattice studies of charmonia and exotics

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Spectroscopy I / 38

Charmonia and exotics from BES III

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Parallel Session 2 / 40**J/psi Upsilon production****Author:** Alexey Luchinsky¹**Co-authors:** Anatoly Likhoded¹; Stanislav Poslavsky²¹ *IHEP, Protvino*² *IHEP, Prtovino***Corresponding Author:** alexey.luchinsky@gmail.com

The talk is devoted to theoretical description of J/psi Upsilon production at LHC. This process is interesting since at LO color-singlet approximation it is forbidden, so investigation of this reaction allows one to probe alternative mechanisms, such as color-octet production, double parton scattering, etc.

Spectroscopy II / 41**A New Dynamical Picture for Production and Decay of the XYZ Mesons****Author:** Richard Lebed¹¹ *Arizona State University***Corresponding Author:** richard.lebed@asu.edu

I introduce an entirely new dynamical description for tetraquark mesons, based upon the competing effects of the strong attraction between quarks in a diquark, and the inability of the diquark to hadronize on its own due to being a color nonsinglet. This mechanism naturally explains, for example, the strong preference of the Z(4475) to decay to psi(2S) rather than the J/psi, the existence of a state Y(4630) that decays to Lambda_c baryon pairs, and why some but not all exotics lie near hadronic thresholds. Owing to high-energy constituent counting rules, the four-quark nature of the states produces major changes to both the high-s scaling of cross sections for producing such states and to the potency of the cusp effect of attracting resonances to pair-production thresholds.

High energy charm / 42**Studies of associated charmonium production at ATLAS****Author:** d ATLAS Collaboration¹¹ *CERN***Corresponding Authors:** judith.katzy@cern.ch, b.yabsley@physics.usyd.edu.au

We present new measurements of the production of a charmonium state in association with a W boson, Z boson, or another charmonium state (covering diJpsi, Z+J/psi, W+J/psi).

These rare production modes provide novel insight into the mechanisms of charmonium production and the impact of proton structure on these observables.

Parallel Session 4 / 43

D \pm production asymmetry at the LHC from heavy quark recombination mechanism

Authors: Adam Leibovich¹; Alexey Petrov²; Wai Kin Lai¹

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The asymmetry in the forward region production cross section of D \pm is calculated using the heavy quark recombination mechanism for pp collisions at 7 TeV. By suitable choices of four nonperturbative parameters, our calculated results can reproduce those obtained at LHCb. We find $A_p \sim -1\%$ when integrated over $2.0 \text{ GeV} < p_T < 18 \text{ GeV}$ and $2.2 < \eta < 4.75$, which agrees with $A_p = -0.96 \pm 0.26 \pm 0.18\%$ as measured by LHCb. Furthermore, the calculated distributions in η and p_T agree reasonably well with those obtained at LHCb. Predictions on production asymmetry of heavy baryons are also made in the same formalism.

Parallel Session 4 / 44

Search for B decays to final states with the eta_c meson

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We report a search for B decays to selected final states with the eta_c meson: $B \rightarrow K \eta_c \pi^+ \pi^-$, $B \rightarrow K \eta_c \omega$, $B \rightarrow K \eta_c \eta$ and $B \rightarrow K \eta_c \pi^0$. The analysis is based on 772 millions of BB pairs collected at the Upsilon (4S) resonance with the Belle detector at the KEKB asymmetric-energy e+e- collider. We set 90% confidence level upper limits on the branching fractions of the studied B decay modes, independent of intermediate resonances, in the range $(0.6 - 5.3) \cdot 10^{-4}$. We also search for molecular-state candidates for the D(0) combinations, neutral partners of the Z(3900) $^{+-}$ and Z(4020) $^{+-}$, and a poorly understood state X(3915) as possible intermediate states in the decay chain, and set 90% confidence level upper limits on the product of branching fractions to X and decay branching fractions of X in the range $(0.6 - 0.9) \cdot 10^{-5}$.

Production / 45

Conventional and exotic charmonium production at the ATLAS experiment

Author: Judith Katzy¹

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We present detailed precision measurements of the prompt and non-prompt differential production cross sections for the J/psi, psi2s, chi_c and X(3872) charmonium states at $\sqrt{s}=8 \text{ TeV}$, covering J/psi and psi2s \rightarrow muu, psi2s \rightarrow J/psi pipi and chi_c. The results are compared with leading theoretical models.

Parallel Session 3 / 46

Rare Semileptonic Charm Decays

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We present a study of $c \rightarrow u\ell\ell$ transitions.

In the Standard Model these semileptonic charm decays are induced via Flavor Changing Neutral Currents and, thus are rare.

This opens possibilities for potential Beyond Standard Model physics searches.

We estimate phenomenological observables within the SM and effects due to BSM physics.

Charm in media / 48

Experimental aspects of quarkonia production and suppression in cold and hot nuclear matter

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Charm in media / 49

Theory aspects of quarkonia production and suppression in cold and hot nuclear matter

Charm in media / 50

Experimental aspects of open heavy flavor production and suppression in cold and hot nuclear matter

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Theory aspects of open heavy flavor production and suppression in cold and hot nuclear matter

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Production / 52

Theoretical aspects of quarkonia production in vacuum

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TBA**High energy charm / 54****Higgs and EW decays to charm****Corresponding Author:** frankjp@physics.wisc.edu**Summary / 56****Theory summary****Corresponding Author:** luca.silvestrini@roma1.infn.it**Summary / 57****Experimental summary****Corresponding Author:** alan.j.schwartz@uc.edu**Parallel Session 2 / 58****Measuring the CP content of D decays to multibody self-conjugate final states****Author:** Jim Libby¹¹ *Indian Institute of Technology Madras***Corresponding Author:** libby@iitm.ac.in

Quantum-correlated $\psi(3770)$ to $D\bar{D}$ decays collected by the CLEO-c experiment are used to perform first measurements of F_+ , the fractional CP-even content of the self-conjugate decays $D \rightarrow \pi^+\pi^-\pi^0$ and $D \rightarrow K^+K^-\pi^0$. Values of $0.968 \pm 0.017 \pm 0.006$ and $0.731 \pm 0.058 \pm 0.021$ are obtained for $\pi^+\pi^-\pi^0$ and $K^+K^-\pi^0$, respectively. It is demonstrated how modes of this sort can be cleanly included in measurements of the unitarity triangle angle γ/ϕ_3 using $B^+ \rightarrow DK^+$ decays. The high CP-even content of $D \rightarrow \pi^+\pi^-\pi^0$, in particular, makes this a promising mode for improving the precision on γ/ϕ_3 . Prospects with other modes are also discussed.

Summary:

This abstract is based on Phys. Lett. B740 (2015) 1.

Parallel Session 2 / 59

A new method for measuring CPV in charm decays and the first measurement of F_+ in $D \rightarrow \pi^+\pi^+\pi^-\pi^-$ decaysAuthor: Sneha Malde¹¹ University of Oxford

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A first measurement of F_+ , the CP-even content of the decay $D \rightarrow 4\pi$ using quantum correlated $\psi(3770)$ to $D\bar{D}$ decays collected by the CLEO-c experiment is presented. A high value is obtained, which makes the decay mode particularly suitable for both measurements of the CKM angle γ and charm CP violation in a model independent way.

This novel approach to studying indirect CP violation in charm decays is based on the time-dependent inclusive analysis of multibody self-conjugate states. These final states can be used to determine the indirect CP-violating observable A_Γ and the mixing observable y_{CP} , provided that F_+ is known. This approach can yield significantly improved sensitivity compared with the conventional method that relies on decays to CP eigenstates. Extensions including direct CP violation are also presented.

Summary:

This abstract is based on the work in arXiv:1502.04560 and the upcoming measurement of F_+ in $D \rightarrow 4\pi$.

Parallel Session 3 / 60

Search for CP violation in $D^0 \rightarrow \pi^0\pi^0$ and $\pi\pi/KK$ decays at BelleAuthor: Nisar Nellikunnummel¹¹ Tata Institute of Fundamental Research, Mumbai

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Open charm + exotics (expt)

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Open charm + exotics (theory)

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TBA

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TBA

Spectroscopy II / 65

Open-charm and exotics states from LHC

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Spectroscopy II / 66

Open charm and exotics on the lattice

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TBA

Mixing and CP-violation I / 69

Charm mixing and CP-violation

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C, P, and CP asymmetry observables based on triple product asymmetries

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LHCb results/serches for CP-violation in charm

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TBA**Quark masses, leptonic and semileptonic and rare decays / 74****Charm and bottom quark masses on the lattice****Corresponding Author:** andrew.lytle@glasgow.ac.uk**Quark masses, leptonic and semileptonic and rare decays / 75****Charm and bottom quark masses off the lattice****Corresponding Author:** vicent.mateu@univie.ac.at**Quark masses, leptonic and semileptonic and rare decays / 76****Lattice perspective on leptonic and semileptonic decays****Corresponding Author:** egamiz@fnal.gov**Quark masses, leptonic and semileptonic and rare decays / 77****Leptonic and semileptonic charm decays at Belle****Corresponding Author:** s.i.eidelman@inp.nsk.su

We describe recent developments in experimental studies of D and Ds meson leptonic decays at the BaBar, Belle, BESIII and CLEO-c detectors and their implications for the determination of charm meson decay constants as well as searches for charged Higgs. Also discussed are semileptonic decays of D and Ds mesons and their relevance to hadronic form factors.

Rare and radiative decays and CP-violation / 78**Theoretical perspective on rare and radiative charm decays****Corresponding Author:** svjetlana.fajfer@ijs.si**Rare and radiative decays and CP-violation / 79**

Searches for rare and radiative charm decays

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Future experimental facilities / 80

Future prospects at LHCb

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Future prospects at Belle II

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Future prospects for charm physics at BES III and beyond

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Novosibirsk project

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We present the concept design of Novosibirsk tau-charm factory: physics case, detector and machine. Status of its construction is discussed. Also briefly described is a similar project currently discussed at the University of Science and Technology of China (USTC) in Hefei.

Parallel Session 1 / 84

New Physics Models Facing Lepton Flavor Violating Higgs Decays

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We speculate about the possible interpretations of the recently observed excess in the h to τ μ decay. We derive a robust lower bound on the Higgs boson coupling strength to a tau and a muon, even

in presence of the most general new physics affecting other Higgs properties. Then we reevaluate complementary indirect constraints coming from low energy observables as well as from theoretical considerations. In particular, the tentative signal should lead to tau to mu gamma at rates which could be observed at Belle II. In turn we show that, barring fine-tuned cancellations, the effect can only be accommodated within models with an extended scalar sector. These general conclusions are demonstrated using a number of explicit new physics models. Finally we show how, given the h to tau mu signal, the current and future searches for mu to e gamma and mu to e nuclear conversions unambiguously constrain the allowed rates for h to tau e.

Parallel Session 3 / 86

Measurements of rare charm decays at LHCb

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Following the intriguing hints of deviations from the Standard Model in rare B meson decays, searches for rare and forbidden decays of charm hadrons become a hot topic again. We present recent results on penguin $D \rightarrow \mu\mu h'$ and lepton-flavour violating $D \rightarrow e\mu$ decays. These results are presented on behalf of the LHCb collaboration.

Parallel Session 2 / 88

Probing the nature of Z_c states via the η_c rho decay

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The nature of the so-called XYZ states is a long-standing problem. It has been suggested that such particles may be described as compact four-quark states or loosely bound meson molecules. In the present work we analyze the $Z_c^{(\prime)} \rightarrow \eta_c \rho$ decay using both approaches. Such channel might provide useful insights on the nature of the $Z_c^{(\prime)}$, helping discriminating between the two different models.

Summary:

This work is based on arXiv:1409.3551 [hep-ph] plus some further developments.

We study the branching ratios for the decays of the $Z_c(3900)$ and $Z_c'(4020)$ into $\eta_c \rho$ under both the assumptions of a compact 4-quark (tetraquark) and of a loosely bound meson molecule.

In the tetraquark picture we adopt the both the so-called type-I and type-II pictures (see Maiani et al. hep-ph/0412098 and 1412.2049[hep-ph]) and also with and without a model for the internal dynamics recently developed by Brodsky et al. (see 1406.7281).

For the molecular picture, instead, we employ the well-known Non-Relativistic Effective Field Theory (see e.g. 1301.6461 [hep-ph]).

Including proper theoretical errors, we compute the branching ratios for the decays into $\eta_c \rho$ and show that, in almost all cases, the predictions of the tetraquark model and of the molecular one are

different with a 2 sigma C.L. Therefore, this channel might provide a valuable insight to determine the nature of these resonances.

We also show that the molecular interpretation might be in contrast with the current data on the decays of Z_c and Z_c' into $J/\psi \pi$.

Parallel Session 4 / 89

Study of $B \rightarrow \chi_{cJ} X$ at Belle

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In spite of the fact that the two-body B decays into χ_{c2} such as $B \rightarrow \chi_{c2} K^{(*)}$ are suppressed by the QCD factorization effect, the inclusive $B \rightarrow \chi_{c2} X$ branching fraction amounts to one third of the non-suppressed $B \rightarrow \chi_{c1} X$ decays because of the decay modes to the multi-body final states. Using a large statistics $\Upsilon(4S)$ data sample corresponding to 772 million B meson pairs accumulated by the Belle detector at the KEKB e^+e^- collider, precise measurements of inclusive $B \rightarrow \chi_{c1}$ and χ_{c2} branching fractions are carried out. The multi-body final states such as $\chi_{cJ} K\pi$, $\chi_{cJ} K\pi\pi$ and so on are also investigated to look for new charmonium-like resonance.

Parallel Session 4 / 90

Dalitz plot analysis of $B \rightarrow D D K$ decays

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We present Dalitz plot analyses for the decays of B mesons to $D^- D^0 K^+$ and $D^0 \bar{D}^0 K^+$. We report the observation of the $D_{s1}^{(2700)^+}$ resonance in these two channels and obtain measurements of the mass

$M(D_{s1}^{(2700)^+}) = 2699^{+14}_{-1}$ MeV/ c^2 and of the width

$\Gamma(D_{s1}^{(2700)^+}) = 127^{+24}_{-1}$ MeV, including statistical and

systematic uncertainties. In addition, we observe an enhancement in the

$D^0 K^+$ invariant mass around 2350–2500 MeV/ c^2 in both decays

B^0 to $D^- D^0 K^+$ and B^+ to $D^0 \bar{D}^0 K^+$, which we are not able to interpret. The results are based on 429 fb⁻¹ of data containing 471×10^6 $B\bar{B}$ pairs collected at the $\Upsilon(4S)$ resonance with the BaBar detector at the SLAC National Accelerator Laboratory.

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Search for $H \rightarrow \gamma^* \gamma$ and $H \rightarrow J/\psi/\gamma$ decays at CMS

Author: CMS experiment CMS experiment¹

¹ *CMS experiment*

A search for a Higgs boson decaying into two photons, one of which has an internal conversion to a muon or an electron pair will be described. Events are required have an opposite-sign muon or electron pair and a high transverse momentum photon. Additionally, upper limits on the branching fraction of a Higgs boson decays to a Jpsi and a photon will be reported.

Parallel Session 1 / 92

Search for stop decays to charm + LSP at CMS

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The supersymmetric partner of the top quark, the stop, is among the best candidates for stabilizing the Higgs mass against large radiative corrections. In the scenario where the dark matter candidate is close in mass to the stop, the decay stop \rightarrow charm, LSP is an important search channel. This talk describes the application of a monojet search topology to hunt for this decay with the CMS detector at the LHC.

Spectroscopy I / 94

Charmonium and exotics from Belle

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Studies of many charmonium(-like) states including exotic candidates performed at Belle experiment are presented. Besides the candidates of conventional charmonium states, more and more charged charmonium-like states are found. The charged charmonium-like states look like forming a new spectroscopy.

Parallel Session 3 / 96

Semileptonic D-decays at BESIII

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Parallel Session 1 / 99

LHCb High Level Trigger design issues for post Long Stop 1 running

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The LHCb High Level Trigger uses two stages of software running on an Event Filter Farm (EFF) to select events for offline reconstruction and analysis. In LHC runs 1 & 2 the first stage (Hlt1) processes approximately 1 MHz of events accepted by a hardware trigger. In 2012, the second stage (Hlt2) wrote 5 kHz to permanent storage for later processing. Following the LHC's Long Stop 1, the machine energy will increase from 8 TeV in the center-of-mass to 13 TeV. The cross sections for beauty and charm are expected to grow proportionately. We plan to increase the Hlt2 output to 12.5 kHz, ~10 kHz for offline processing and ~ 2.5 kHz ready for immediate analysis. By increasing the absolute computing power of the EFF, buffering data for processing between machine fills, and improving algorithms, we should be able to significantly increase the efficiency for signal while improving signal-to-background ratios. Hlt1 will use a boosted decision tree to increase efficiency at that stage. We will determine calibration and alignment constants between Hlt1 and Hlt2, allowing Hlt2 to use reconstruction very close to that used offline, including RICH and calorimetric information. Post Long Stop 2 we will read out the front-end electronics at 40 MHz and move to a full software trigger while operating at higher luminosity. The implications for increasing charm yields are emphasized.

Parallel Session 3 / 100

An exclusive approach on D \bar{D} bar mixing

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I will show an exclusive approach on calculating the D \bar{D} bar mixing parameters y and x . We will sum up the contributions from the hadronic decays, based on the factorization-assisted topological-amplitude approach in which most SU(3) breaking effects are involved.

Parallel Session 4 / 101

Study of $B \rightarrow X(3872) K \pi$ at Belle

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We report the first observation of $B^0 \rightarrow X(3872)(K^+\pi^-)$ and evidence for $B^+ \rightarrow X(3872)(K^0\pi^+)$. We measure the product of branching fractions for the former to be $\text{cal}B(B^0 \rightarrow X(3872)(K^+\pi^-)) \times \text{cal}B(X(3872) \rightarrow J/\psi\pi^+\pi^-) = (7.9 \pm 1.3(\text{stat.}) \pm 0.4(\text{syst.})) \times 10^{-6}$ and find that $B^0 \rightarrow X(3872)K^*(892)^0$ does not dominate the $B^0 \rightarrow X(3872)K^+\pi^-$ decay mode in contrast to other charmonium states like ψ' . We also measure $\text{cal}B(B^+ \rightarrow X(3872)(K^0\pi^+)) \times \text{cal}B(X(3872) \rightarrow J/\psi\pi^+\pi^-) = (10.6 \pm 3.0(\text{stat.}) \pm 0.9(\text{syst.})) \times 10^{-6}$. This study is based on the full data sample of 711-fb^{-1} ($772 \times 10^6 B\bar{B}$ pairs) collected at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB collider.

Parallel Session 4 / 102**B_c spectroscopy at ATLAS****Author:** Rui Wang¹¹ *Argonne national laboratory***Corresponding Author:** rui.wang@cern.ch

We present latest results from the ATLAS experiment on B_c spectroscopy, including branching fraction measurements of B_c → J/ψππ and B_c → J/ψDs(*) and observation of the B_c(2S) state.

Parallel Session 2 / 103**Strategies for an accurate determination of the X(3872) energy from QCD lattice simulations****Authors:** Eugenio Javier Garzon¹; Eulogio Oset¹; Raquel Molina²¹ *IFIC, University of Valencia*² *The George Washington University***Corresponding Author:** ramope71@email.gwu.edu

We develop a method to determine accurately the binding energy of the X(3872) from lattice data for the $D\bar{D}^*$ interaction. We show that, because of the small difference between the neutral and charged components of the X(3872), it is necessary to differentiate them in the energy levels of the lattice spectrum if one wishes to have a precise determination of the the binding energy of the X(3872). The analysis of the data requires the use of coupled channels. Depending on the number of levels available and the size of the box, we determine the precision needed in the lattice energies to finally obtain a desired accuracy in the binding energy.

Mixing and CP-violation II / 104**Hadronic decays of charmed mesons from BES****Corresponding Author:** muramatsu@physics.umn.edu

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Hadronic decays of Charmed mesons from Belle**Charmed baryons / 106****Charmed baryons on the lattice**

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Charmed baryons / 107

Charmed baryons from LHCb

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Charmed baryons / 108

Lambda_c decays

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Parallel Session 1 / 109

Open heavy-flavour measurements in Pb-Pb collisions with ALICE at the LHC

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The ALICE experiment at the LHC studies Pb-Pb, p-Pb, and pp collisions to investigate the properties of the high energy-density state of strongly-interacting matter, produced in Pb-Pb collisions, the so-called quark-gluon plasma (QGP).

Heavy quarks (charm and beauty) are unique probes, since they are produced in the initial hard scattering processes in the earliest phase of the collisions and interact strongly with the medium carrying trace of its properties to the final state. In particular, heavy quarks lose less energy than light quarks and gluons and exhibit a harder fragmentation.

The main results from LHC-Run 1 data related to open heavy-flavour production in Pb-Pb collisions will be discussed. Open heavy flavours are measured in ALICE via the full reconstruction of the charged decay particles of D mesons at mid-rapidity or via semi-electronic and semi-muonic decays of charm and beauty hadrons at mid-rapidity and forward rapidity, respectively. The measurements of the suppression of heavy-flavour particles with respect to pp collisions (nuclear modification factor) and of the elliptic flow bring insights into the energy loss mechanisms in the medium and the possible thermalization of charm quark.

The perspectives on open heavy-flavour measurements will be also presented.

Parallel Session 1 / 110

Resolving charm and bottom quark masses in precision Higgs boson analyses

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Masses of the charm and bottom quarks are important inputs to precision calculations of Higgs boson observables, such as its partial widths and branching fractions. They constitute a major source of theory uncertainties that needs to be better understood and reduced in light of future high-precision measurements. Conventionally, Higgs boson observables are calculated in terms of m_c and m_b , whose values are obtained by averaging over many extractions from low-energy data. This approach may ultimately be unsatisfactory, since m_c and m_b as single numbers hide various sources of uncertainties involved in their extractions some of which call for more careful estimations, and also hide correlations with additional inputs such as α_s . Aiming at a more detailed understanding of the uncertainties from m_c and m_b in precision Higgs boson analyses, we present a calculation of Higgs boson observables in terms of low-energy observables, which reveals concrete sources of uncertainties that challenge sub-percent-level calculations of Higgs boson partial widths.

Parallel Session 1 / 111

Open heavy-flavour measurements in pp and p-Pb collisions with ALICE

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The ALICE detector is dedicated to the study of the high energy-density QCD matter produced in heavy-ion collisions. Important probes of this matter are heavy quarks (charm and beauty), as they are produced in the early stage of the collision via initial hard scatterings. Thus measurements of their production offer important information on the early stage of the collision and the parton-medium interaction. To quantify the measurements performed in Pb-Pb collisions it is necessary that the production in pp and p-Pb collisions is studied. In pp collisions, the measurement of heavy-flavour production cross sections not only provides the reference for heavy-ion studies, but also delivers critical tests of perturbative QCD. In p-Pb collisions, initial-state effects, due to the presence of a nucleus, can be accessed. Such effects include the modification of parton densities and k_T broadening, which can result from multiple soft scatterings of partons. In addition, the existence of possible final-state effects can also be investigated.

In this contribution we present the results of open heavy-flavour production measurements in pp and p-Pb collisions with ALICE. These results will include the measurement of D-meson production as a function of charged-particle multiplicity. The D mesons are reconstructed via hadronic decay channels at mid-rapidity, and the yields are measured in specific transverse-momentum intervals for various multiplicity ranges. We compare the transverse-momentum dependent evolution of the per-event yield of D mesons in different multiplicity intervals in the two collision systems to gain an understanding of the interplay between hard and soft contributions to particle production and to possibly obtain insight into the role of multiple hard partonic interaction. In addition, we present the D-meson nuclear modification factor in different multiplicity ranges, which is defined as the ratio of the D-meson yield in p-Pb and pp collisions scaled by the number of binary nucleon-nucleon collisions. Finally, the azimuthal correlation of D mesons and charged hadrons, and electrons from heavy-flavor hadron decays and charged hadrons at mid-rapidity will be discussed as a function of transverse momentum.

Parallel Session 1 / 112

Search for di-muon decays of a low-mass Higgs boson in the radiative decay of J/ψ

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We search for di-muon decays a light Higgs boson (A^0) in the radiative decay of J/ψ : $J/\psi \rightarrow \gamma A^0$, $A^0 \rightarrow \mu^+ \mu^-$. Here A^0 is the hypothetical CP-odd light Higgs boson predicted by many extensions of the Standard Model (SM), including Next-to-Minimal Supersymmetric Standard Model (NMSSM). This study is based on 225 million J/ψ events collected in 2009 by the BESIII experiment at the Institute of High Energy Physics, Beijing, China. We are studying the process and we will report the preliminary results of the work in this talk.

Parallel Session 1 / 113

J/ψ longitudinal double spin asymmetry measurement at forward rapidity in $p + p$ collisions at $\sqrt{s} = 510$ GeV

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The polarized gluon distribution, as described by the polarized parton distribution function $\Delta g(x)$, is an important part of the spin structure of the nucleon; however the current data have very limited constraints on $\Delta g(x)$ for $x < 0.01$. During the 2013 RHIC run, the PHENIX experiment collected 146 pb^{-1} of longitudinally polarized $p + p$ data at $\sqrt{s} = 510$ GeV with an average beam polarization of 52%. At this energy, J/ψ particles are predominantly produced through gluon-gluon interactions and thus the longitudinal double spin asymmetry, $A_{LL}^{J/\psi}$, is sensitive to the gluon polarization inside the proton. We measure the J/ψ A_{LL} in the rapidity range $1.2 < |\eta| < 2.4$ by detecting the decay $\mu^+ \mu^-$ pairs using the PHENIX muon detector arms. In this kinematic range, A_{LL} is sensitive to the polarized gluon distribution at small $x \sim 2 \times 10^{-3}$ as well as at moderate $x \sim 0.05$ where recent RHIC data on jet and π^0 production show possible evidence for significant gluon polarization. Compared to previous measurements in 2005 and 2006, the Run 2013 data set has roughly twenty times more statistics and will allow us to measure $A_{LL}^{J/\psi}$ with a statistical uncertainty at $\sim 1\%$ level. The preliminary result of this analysis will be presented.

Parallel Session 1 / 114

Charmonium Production in Asymmetric Nuclear Collisions by the PHENIX Experiment at RHIC

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The measurement of quarkonia production in relativistic heavy ion collisions provides a powerful tool for studying the properties of the hot and dense matter created in these collisions.

To be really useful, however, such measurements must cover a wide range of quarkonia states and colliding species.

The PHENIX experiment at RHIC has successfully measured J/ψ , ψ -prime, χ_{c0} and χ_{c1} states in p+p, d+Au and Au+Au collisions.

In this talk I will present recent results from the PHENIX collaboration on charmonium production in Cu+Au and U+U collisions at 200 GeV/c.

Rare and radiative decays and CP-violation / 115

Comments on CP-violation in charm

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Mixing and CP-violation I / 116

CDF results on CP-violation in charm

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Parallel Session 4 / 117

Charm contributions in $B \rightarrow K^* l^+ l^-$

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The rare semileptonic $B_d \rightarrow K^* l^+ l^-$ decay has been extensively studied within the Standard Model and beyond. Significant efforts from Lattice QCD groups have reduced theoretical errors in the form-factors to tractable limits in the high q^2 regime while arguments from LCSR can be used for the same in the low q^2 regime. However, hadronic contributions coming primarily from charm loops still plague the predictions of many observables in this channel. While the intricacies of QCD prevent exact estimation of these hadronic contributions, experimental analysis will be reaching a point where these can be determined from data.

We present in this work a Bayesian analysis of the decay in the full range of q^2 , in which we extract these charm loop hadronic contributions from available data. We also make well-motivated arguments about the size of the hadronic contributions and ultimately show the compatibility of the currently available experimental data with the Standard Model predictions.

Parallel Session 2 / 118

A case for $SU(3)$ in $D \rightarrow P P$ decays

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The question of the validity of analyzing charmed meson decays to pairs of hadrons within the SU(3) framework has been long and often debated. While there are convincing arguments that small breaking of this symmetry can accommodate for the current experimental results, the inability to compute QCD effects in these modes render it quite impossible to justify with complete authority the physical interpretations of the parameters extracted from experimental data. In our work we explore the SU(3) framework for its strengths and weaknesses and cross-examine it with arguments derived from a diagrammatic approach. We show that isospin non-universality of QCD should be considered within this framework. We also consider $\eta - \eta'$ mixing in our attempt to build a complete analysis of these modes.

Parallel Session 1 / 120

Exotic meson studies at CMS

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CMS has accumulated large amount of dimuon events at 7 and 8 TeV center-mass-energy. Fruitful results have been produced using these datasets. This talk will cover the observation of two structures in $J/\psi + \phi$ mass spectrum via exclusive $B \rightarrow J/\psi \phi K^+$ decays, while the first one confirms a previous observation from CDF experiment, and the second one has been observed for the first time. A related decay channel $B \rightarrow \psi(2S) \phi K^+$ has been observed by CMS for the first time and will be reported.

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Charmonia and exotics from BaBar

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Parallel Session 1 / 122

J/ψ azimuthal anisotropy in Au+Au collisions at 200 GeV

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In relativistic heavy-ion collisions, J/ψ can be produced via different mechanisms and the large mass of the charm quark makes it a valuable probe to the thermalization of the medium. The study of J/ψ azimuthal anisotropy can allow for the disentangling of a few interesting dynamic processes, e.g., J/ψ produced from direct pQCD processes, and J/ψ produced from recombination of charm quarks within the medium. J/ψ produced from direct pQCD processes have little azimuthal anisotropy due to the lack of collectivity and initial emitting azimuthal preference, while J/ψ produced from recombination of charm quarks are expected to inherit considerable azimuthal anisotropy if charm quarks have

finite elliptic flow.

In this talk, we will present J/ψ azimuthal anisotropy in Au+Au collisions at 200 GeV, from data taken by STAR during RHIC operation in year 2010 and 2011. The result will be presented as a function of centrality of Au+Au collisions and J/ψ transverse momentum.

Production / 123

Studies of P-wave and S-wave quarkonium production with the CMS detector

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Precise measurement of S-wave quarkonium cross-sections and polarizations performed at LHC helped clarifying the experimental scenario in the field of quarkonium production. From the theoretical point of view, the most promising framework to explain such phenomena has been, for almost 20 years, NRQCD. However, the interpretation of the latest results in this framework is not straightforward, and might require the revision of some of the assumptions that were so far made. The scientific community has come to realize that a thorough understanding must encompass a broader view, and that the study of P-wave states plays a fundamental role. The CMS collaboration has provided some of the most precise P-wave charmonium and bottomonium measurements to date. In this contribution, such results will be presented and discussed. The studies of heavy quarkonium prompt-production and polarization at the LHC are becoming crucial to solve the puzzle of hadron formation. A dedicated dimuon trigger strategy combined with the energy and luminosity provided by the LHC allowed the CMS experiment to collect large samples of quarkonium states decaying in the dimuon channel. This contribution presents the most recent CMS quarkonium production results including rapidity-integrated production cross sections extended up to $\sim 120\text{GeV}$ for J/ψ and $\sim 100\text{GeV}$ for $\psi(2S)$ and $Y(nS)$ with $n=1,2,3$.

Parallel Session 2 / 124

Factorized power expansion for high pT heavy quarkonium production

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From the Tevatron and the LHC data, it is clear that current models for the heavy quarkonium production are not able to explain the polarization of heavy quarkonia produced at large transverse momentum p_T in p-p collision. A new approach to evaluate the heavy quarkonium production, by expanding the cross section in powers of $1/p_T$ before the expansion in powers of α_s , was proposed recently. In terms of the QCD factorization, it is proved that both the leading-power (LP) and next-to-leading power (NLP) terms in $1/p_T$ for the cross sections can be systematically factorized to all orders of α_s . The predictive power of this new QCD factorization formalism depends on several unknown but universal fragmentation functions (FFs) at an input scale of the order of heavy quarkonium mass m_Q . Inspired by the fact that $m_Q \gg \Lambda_{\text{QCD}}$, we apply the NRQCD factorization formalism to further separate the perturbative and non-perturbative interactions. With our

calculations, all the input polarization-summed FFs are expressed as complicated functions with a few unknown NRQCD long-distance matrix elements (LDMEs). In addition, by general symmetry arguments, we successfully generalize the polarized NRQCD four-fermion operators to d dimensions and calculate the polarized FFs with conventional dimensional regularization. In the first application, we find those non-relativistic QCD channels, which are expected to be important in the J/ψ polarization, are actually dominated by the NLP term in the p_T expansion at current collider energies. Therefore the QCD factorization is very promising to solve the long standing heavy quarkonium polarization puzzle.

Parallel Session 1 / 125

Shadowing Effects on Open and Hidden Heavy Flavor Production at the LHC

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Welcome / 126

Welcome to Wayne State!

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Summary / 127

Welcome to CHARM 2016

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