Search for the weak decay $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^- + c.c.$[*]

M. Ablikim(麦迪娜)[1]   M. N. Achasov[11,b]   P. Adlarson[70]   M. Albrecht[4]   R. Aliberti[31]   A. Amoroso[69A,69C]

M. R. An(安美儒)[35]   Q. An(安琪)[53,66]   X. H. Bai(白旭红)[61]   Y. Bai(白羽)[52]   O. Bakina[32]   R. Baldini Ferroli[26A]

I. Balossino[27A,1]   Y. Ban(班勇)[42,g]   V. Batozskaya[1,40]   D. Becker[31]   K. Begzsuren[29]   N. Berger[31]   M. Bertani[26A]

D. Bettoni[27A]   F. Bianchi[69A,69C]   J. Bloms[63]   A. Bortone[69A,69C]   I. Boyko[32]   R. A. Briere[5]   A. Brueggemann[63]

H. Cai(蔡浩)[71]   X. Cai(蔡啸)[1,53]   A. Calcaterra[26A]   G. F. Cao(曹国富)[1,58]   N. Cao(曹宁)[1,58]   S. A. Cetin[57A]

J. F. Chang(常劲帆)[1,53]   W. L. Chang(常万玲)[1,58]   G. Chelkov[32,a]   C. Chen(陈琛)[39]   Chao Chen(陈超)[50]

G. Chen(陈刚)[1]   H. S. Chen(陈和生)[1,58]   M. L. Chen(陈玛丽)[1,53]   S. J. Chen(陈申见)[38]   S. M. Chen(陈少敏)[56]

T. Chen[1]   X. R. Chen(陈旭荣)[28,58]   X. T. Chen[1]   Y. B. Chen(陈元柏)[1,53]   Z. J. Chen(陈卓俊)[23,h]

W. S. Cheng(成伟帅)[69C]   X. Chu(初晓)[39]   G. Cibinetto[27A]   F. Cossio[69C]   J. J. Cui(崔佳佳)[45]   H. L. Dai(代洪亮)[1,53]

J. P. Dai(代建平)[73]   A. Dbeyssi[17]   R. E. de Boer[4]   D. Dedovich[32]   Z. Y. Deng(邓子艳)[1]   A. Denig[31]

I. Denysenko[32]   M. Destefanis[69A,69C]   F. De Mori[69A,69C]   Y. Ding(丁勇)[36]   J. Dong(董静)[1,53]   L. Y. Dong(董燎原)[1,58]

M. Y. Dong(董明义)[1]   X. Dong(董翔)[71]   S. X. Du(杜书先)[75]   P. Egorov[32,a]   Y. L. Fan(范玉兰)[71]   J. Fang(方建)[1,53]

S. S. Fang(房双世)[1,58]   W. X. Fang(方文兴)[1]   Y. Fang(方易)[1]   R. Farinelli[27A]   L. Fava[69B,69C]   F. Feldbauer[4]

G. Felici[26A]   C. Q. Feng(封常青)[53,66]   J. H. Feng(冯俊华)[54]   K Fischer[64]   M. Fritsch[4]   C. Fritzsch[63]

C. D. Fu(傅成栋)[1]   H. Gao(高涵)[58]   Y. N. Gao(高原宁)[42,g]   Yang Gao(高扬)[53,66]   S. Garbolino[69C]   I. Garzia[27A,27B]

P. T. Ge(葛潘婷)[71]   Z. W. Ge(葛振武)[38]   C. Geng(耿聪)[54]   E. M. Gersabeck[62]   A Gilman[64]   K. Goetzen[12]

L. Gong(龚丽)[36]   W. X. Gong(龚文煊)[1,53]   W. Gradl[31]   M. Greco[69A,69C]   L. M. Gu(谷立民)[38]   M. H. Gu(顾旻皓)[1,53]

Y. T. Gu(顾运厅)[14]   C. Y Guan(关春懿)[1,58]   A. Q. Guo(郭爱强)[28,58]   L. B. Guo(郭立波)[37]   R. P. Guo(郭如盼)[44]

Y. P. Guo(郭玉萍)[10,f]   A. Guskov[32,a]   T. T. Han(韩婷婷)[45]   W. Y. Han(韩文颖)[35]   X. Q. Hao(郝喜庆)[18]

F. A. Harris[60]   K. K. He(何凯凯)[50]   K. L. He(何康林)[1,58]   F. H. Heinsius[4]   C. H. Heinz[31]   Y. K. Heng(衡月昆)[1]

C. Herold[55]   M. Himmelreich[12,d]   G. Y. Hou(侯国一)[1,58]   Y. R. Hou(侯颖锐)[58]   Z. L. Hou(侯治龙)[1]

H. M. Hu(胡海明)[1,58]   J. F. Hu[51,i]   T. Hu(胡涛)[1]   Y. Hu(胡誉)[1]   G. S. Huang(黄光顺)[53,66]   K. X. Huang(黄凯旋)[54]

L. Q. Huang(黄麟钦)[67]   L. Q. Huang(黄麟钦)[28,58]   X. T. Huang(黄性涛)[45]   Y. P. Huang(黄燕萍)[1]   Z. Huang(黄震)[42,g]

T. Hussain[68]   N Hüsken[25,31]   W. Imoehl[25]   M. Irshad[53,66]   J. Jackson[25]   S. Jaeger[4]   S. Janchiv[29]   Q. Ji(纪全)[1]

Q. P. Ji(姬清平)[18]   X. B. Ji(季晓斌)[1,58]   X. L. Ji(季筱璐)[1,53]   Y. Y. Ji(吉钰瑶)[45]   Z. K. Jia(贾泽坤)[53,66]

H. B. Jiang(姜侯兵)[45]   S. S. Jiang(姜赛赛)[35]   X. S. Jiang(江晓山)[1]   Y. Jiang[58]   J. B. Jiao(焦健斌)[45]   Z. Jiao(焦铮)[21]

S. Jin(金山)[38]   Y. Jin(金毅)[61]   M. Q. Jing(荆茂强)[1,58]   T. Johansson[70]   N. Kalantar-Nayestanaki[59]

X. S. Kang(康晓珅)[36]   R. Kappert[59]   B. C. Ke(柯百谦)[75]   I. K. Keshk[4]   A. Khoukaz[63]   P. Kiese[31]   R. Kiuchi[1]

R. Kliemt[12]   L. Koch[33]   O. B. Kolcu[57A]   B. Kopf[4]   M. Kuemmel[4]   M. Kuessner[4]   A. Kupsc[40,70]   W. Kühn[33]

J. J. Lane[62]   J. S. Lange[33]   P. Larin[17]   A. Lavania[24]   L. Lavezzi[69A,69C]   Z. H. Lei(雷祚弘)[53,66]   H. Leithoff[31]

M. Lellmann[31]   T. Lenz[31]   C. Li(李翠)[43]   C. Li(李聪)[39]   C. H. Li(李春花)[35]   Cheng Li(李澄)[53,66]

D. M. Li(李德民)[75]   F. Li(李飞)[1,53]   G. Li(李刚)[1]   H. Li(李慧)[47]   H. Li(李贺)[53,66]   H. B. Li(李海波)[1,58]

H. J. Li(李惠静)[18]   H. N. Li[51,i]   J. Q. Li[4]   J. S. Li(李静舒)[54]   J. W. Li(李井文)[45]   Ke Li(李科)[1]   L. J. Li[1]

L. K. Li(李龙科)[1]   Lei Li(李蕾)[3]   M. H. Li(李明浩)[39]   P. R. Li(李培荣)[34,j,k]   S. X. Li(李素娴)[10]   S. Y. Li(栗帅迎)[56]

T. Li(李腾)[45]   W. D. Li(李卫东)[1,58]   W. G. Li(李卫国)[1]   X. H. Li(李旭红)[53,66]   X. L. Li(李晓玲)[45]

Xiaoyu Li(李晓宇)[1,58]   H. Liang(梁昊)[53,66]   H. Liang(梁浩)[1,58]   H. Liang(梁浩)[30]   Y. F. Liang(梁勇飞)[49]

Y. T. Liang(梁羽铁)[28,58]   G. R. Liao(廖广睿)[13]   L. Z. Liao(廖龙洲)[45]   J. Libby[24]   A. Limphirat[55]

C. X. Lin(林创新)[54]   D. X. Lin(林德旭)[28,58]   T. Lin[1]   B. J. Liu(刘北江)[1]   C. X. Liu(刘春秀)[1]   D. Liu[17,66]

F. H. Liu(刘福虎)[48]   Fang Liu(刘芳)[1]   Feng Liu(刘峰)[6]   G. M. Liu(刘国明)[51,i]   H. Liu[34,j,k]   H. B. Liu(刘宏邦)[14]

H. M. Liu(刘怀民)[1,58]   Huanhuan Liu(刘欢欢)[1]   Huihui Liu(刘汇慧)[19]   J. B. Liu(刘建北)[53,66]   J. L. Liu(刘佳俊)[67]

J. Y. Liu(刘晶译)[1,58]   K. Liu(刘凯)[1]   K. Y. Liu(刘魁勇)[36]   Ke Liu(刘珂)[20]   L. Liu(刘亮)[53,66]   Lu Liu(刘露)[39]

M. H. Liu(刘美宏)[10,f]   P. L. Liu(刘佩莲)[1]   Q. Liu(刘倩)[58]   S. B. Liu(刘树彬)[53,66]   T. Liu(刘桐)[10,f]

W. K. Liu(刘维克)[39]   W. M. Liu(刘卫民)[53,66]   X. Liu(刘翔)[34,j,k]   Y. Liu(刘英)[34,j,k]   Y. B. Liu(刘玉斌)[39]

Z. A. Liu(刘振安)[1]   Z. Q. Liu(刘智青)[45]   X. C. Lou(娄辛丑)[1]   F. X. Lu(卢飞翔)[54]   H. J. Lu(吕海江)[21]

J. G. Lu(吕军光)[1,53]   X. L. Lu(陆小玲)[1]   Y. Lu(卢宇)[7]   Y. P. Lu(卢云鹏)[1,53]   Z. H. Lu[1]   C. L. Luo(罗成林)[37]

M. X. Luo(罗民兴)[74]   T. Luo(罗涛)[10,f]   X. L. Luo(罗小兰)[1,53]   X. R. Lyu(吕晓睿)[58]   Y. F. Lyu(吕翌丰)[39]

F. C. Ma(马凤才)[36]   H. L. Ma(马海龙)[1]   L. L. Ma(马连良)[45]   M. M. Ma(马明明)[1,58]   Q. M. Ma(马秋梅)[1]

R. Q. Ma(马润秋)[1,58]   R. T. Ma(马瑞廷)[58]   X. Y. Ma(马骁妍)[1,53]   Y. Ma(马尧)[42,g]   F. E. Maas[17]   M. Maggiora[69A,69C]

S. Maldaner[4]   S. Malde[64]   Q. A. Malik[68]   A. Mangoni[26B]   Y. J. Mao(冒亚军)[42,g]   Z. P. Mao(毛泽普)[1]

S. Marcello[69A,69C]   Z. X. Meng(孟召霞)[61]   J. G. Messchendorp[59]   G. Mezzadri[27A,1]   H. Miao[1]   T. J. Min(闵天觉)[38]

R. E. Mitchell[25]   X. H. Mo(莫晓虎)[1]   N. Yu. Muchnoi[11,b]   Y. Nefedov[32]   F. Nerling[17,d]   I. B. Nikolaev[11,b]

Z. Ning(宁哲)[1,53]   S. Nisar[9,l]   Y. Niu(牛艳)[45]   S. L. Olsen[58]   Q. Ouyang(欧阳群)[1]   S. Pacetti[26B,26C]   X. Pan(潘祥)[10,f]

Y. Pan(潘越)[52]   A. Pathak[30]   M. Pelizaeus[4]   H. P. Peng(彭海平)[53,66]   K. Peters[12,d]   J. L. Ping(平加伦)[37]

R. G. Ping(平荣刚)[1,58]   S. Plura[31]   S. Pogodin[32]   V. Prasad[53,66]   F. Z. Qi(齐法制)[1]   H. Qi(齐航)[53,66]

H. R. Qi(漆红荣)[56]   M. Qi(祁鸣)[38]   T. Y. Qi(齐天钰)[10,f]   S. Qian(钱森)[1,53]   W. B. Qian(钱文斌)[58]   Z. Qian(钱圳)[54]

C. F. Qiao(乔从丰)[58]   J. J. Qin(秦佳佳)[67]   L. Q. Qin(秦丽清)[13]   X. P. Qin(覃满平)[10,f]   X. S. Qin(秦小帅)[45]

Z. H. Qin(秦中华)[1,53]   J. F. Qiu(邱进发)[1]   S. Q. Qu(屈三强)[56]   K. H. Rashid[68]   C. F. Redmer[31]   K. J. Ren(任旷洁)[35]

A. Rivetti[69C]   V. Rodin[59]   M. Rolo[69C]   G. Rong(荣刚)[1,58]   Ch. Rosner[17]   S. N. Ruan(阮氏宁)[39]

H. S. Sang(桑昊榆)[66]   A. Sarantsev[32,c]   Y. Schelhaas[31]   C. Schnier[4]   K. Schoenning[70]   M. Scodeggio[27A,27B]

K. Y. Shan(尚科羽)[10,f]   W. Shan(单葳)[22]   X. Y. Shan(单心钰)[53,66]   J. F. Shangguan(上官剑锋)[50]

L. G. Shao(邵立港)[1,58]   M. Shao(邵明)[53,66]   C. P. Shen(沈成平)[10,f]   H. F. Shen(沈宏飞)[1,58]   X. Y. Shen(沈肖雁)[1,58]

B. A. Shi(施伯安)[58]   H. C. Shi(石煌超)[53,66]   J. Y. Shi(石京燕)[1]   q. q. Shi(石勤强)[50]   R. S. Shi(师荣盛)[1,58]

X. Shi(史欣)[1,53]   X. D Shi(师晓东)[53,66]   J. J. Song(宋娇娇)[18]   W. M. Song(宋维民)[1,30]   Y. X. Song(宋昀轩)[42,g]

S. Sosio[69A,69C]   S. Spataro[69A,69C]   F. Stieler[31]   K. X. Su(苏可馨)[71]   P. P. Su(苏彭彭)[50]   Y. J. Su(粟杨捷)[58]

G. X. Sun(孙功星)[1]   H. Sun[58]   H. K. Sun(孙浩凯)[1]   J. F. Sun(孙俊峰)[18]   L. Sun(孙亮)[71]   S. S. Sun(孙胜森)[1,58]

T. Sun(孙童)[1,58]   W. Y. Sun(孙文玉)[30]   X Sun(孙翔)[23,h]   Y. J. Sun(孙勇杰)[53,66]   Y. Z. Sun(孙永昭)[1]

Z. T. Sun(孙振田)[45]   Y. H. Tan(谭英华)[71]   Y. X. Tan(谭雅星)[53,66]   C. J. Tang(唐昌建)[49]   G. Y. Tang(唐光毅)[1]

J. Tang(唐健)[54]   L. Y Tao(陶璐燕)[67]   Q. T. Tao(陶秋田)[23,h]   M. Tat[64]   J. X. Teng(滕佳秀)[53,66]   V. Thoren[70]

W. H. Tian(田文辉)[47]   Y. Tian(田野)[28,58]   I. Uman[57B]   B. Wang(王斌)[1]   B. L. Wang(王滨龙)[58]

C. W. Wang(王成伟)[38]   D. Y. Wang(王大勇)[42,g]   F. Wang(王菲)[67]   H. J. Wang(王泓鉴)[34,j,k]   H. P. Wang(王宏鹏)[1,58]

K. Wang(王科)[1,53]   L. L. Wang(王亮亮)[1]   M. Wang(王萌)[45]   M. Z. Wang(王梦真)[42,g]   Meng Wang(王蒙)[1,58]

S. Wang[13]   S. Wang(王顺)[10,f]   T. Wang(王婷)[10,f]   T. J. Wang(王腾蛟)[39]   W. Wang(王为)[54]   W. H. Wang(王文欢)[71]

W. P. Wang(王维平)[53,66]   X. Wang(王轩)[42,g]   X. F. Wang(王雄飞)[34,j,k]   X. L. Wang(王小龙)[10,f]   Y. Wang(王亦)[56]

Y. D. Wang(王雅迪)[41]   Y. F. Wang(王贻芳)[1]   Y. H. Wang(王英豪)[43]   Y. Q. Wang(王雨晴)[1]

Yaqian Wang(王亚乾)[1,16]   Z. Wang(王铮)[1,53]   Z. Y. Wang(王至勇)[1,58]   Ziyi Wang(王子一)[58]   D. H. Wei(魏代会)[13]

F. Weidner[63]   S. P. Wen(文硕频)[1]   D. J. White[62]   U. Wiedner[4]   G. Wilkinson[64]   M. Wolke[70]   L. Wollenberg[4]

J. F. Wu(吴金飞)[1,58]   L. H. Wu(伍灵慧)[1]   L. J. Wu(吴连近)[1,58]   X. Wu(吴潇)[10,f]   X. H. Wu(伍雄浩)[30]   Y. Wu[66]

Z. Wu(吴智)[1,53]   L. Xia(夏磊)[53,66]   T. Xiang(相腾)[42,g]   D. Xiao(肖栋)[34,j,k]   G. Y. Xiao(肖光延)[38]   H. Xiao(肖浩)[10,f]

S. Y. Xiao(肖素玉)[1]   Y. L. Xiao(肖云龙)[10,f]   Z. J. Xiao(肖振军)[37]   C. Xie(谢陈)[38]   X. H. Xie(谢昕海)[42,g]

Y. Xie(谢勇)[45]   Y. G. Xie(谢宇广)[1,53]   Y. H. Xie(谢跃红)[6]   Z. P. Xie(谢智鹏)[53,66]   T. Y. Xing(邢天宇)[1,58]

C. F. Xu[1]   C. J. Xu(许创杰)[54]   G. F. Xu(许国发)[1]   H. Y. Xu(许皓月)[61]   Q. J. Xu(徐庆君)[15]   X. P. Xu(徐新平)[50]

Y. C. Xu(胥英超)[58]   Z. P. Xu(许泽鹏)[38]   F. Yan(严芳)[10,f]   L. Yan(严亮)[10,f]   W. B. Yan(鄢文标)[53,66]

W. C. Yan(闫文成)[75]   H. J. Yang(杨海军)[46,e]   H. L. Yang(杨昊霖)[30]   H. X. Yang(杨洪勋)[1]   L. Yang(杨玲)[47]

S. L. Yang(杨双莉)[58]   Tao Yang(杨涛)[1]   Y. F. Yang(杨艳芳)[39]   Y. X. Yang(杨逸翔)[1,58]   Yifan Yang(杨翊凡)[1,58]

M. Ye(叶梅)[1,53]   M. H. Ye(叶铭汉)[8]   J. H. Yin(殷俊昊)[1]   Z. Y. You(尤郑昀)[54]   B. X. Yu(俞伯祥)[1]

C. X. Yu(喻纯旭)[39]   G. Yu(余刚)[1,58]   T. Yu(于涛)[67]   C. Z. Yuan(苑长征)[1,58]   L. Yuan(袁丽)[2]   S. C. Yuan[1]

X. Q. Yuan(袁晓庆)[1]   Y. Yuan(袁野)[1,58]   Z. Y. Yuan(袁朝阳)[54]   C. X. Yue(岳崇兴)[35]   A. A. Zafar[68]

F. R. Zeng(曾凡蕊)[45]   X. Zeng(曾鑫)[6]   Y. Zeng(曾云)[23,h]   Y. H. Zhan(詹永华)[54]   A. Q. Zhang(张安庆)[1]

B. L. Zhang[1]   B. X. Zhang(张丙新)[1]   D. H. Zhang(张丹昊)[39]   G. Y. Zhang(张广义)[18]   H. Zhang[66]

H. H. Zhang(张宏浩)[54]   H. H. Zhang(张宏宏)[30]   H. Y. Zhang(章红宇)[1,53]   J. L. Zhang(张杰磊)[72]

J. Q. Zhang(张敬庆)[37]   J. W. Zhang(张家文)[1]   J. X. Zhang(张学尧)[34,j,k]   J. Y. Zhang(张建勇)[1]   J. Z. Zhang(张景芝)[1,58]

Jianyu Zhang(张剑宇)[1,58]   Jiawei Zhang(张嘉伟)[1,58]   L. M. Zhang(张黎明)[56]   L. Q. Zhang(张丽青)[54]

Lei Zhang(张雷)[38]   P. Zhang[1]   Q. Y. Zhang(张秋岩)[35,75]   Shuihan Zhang(张水涵)[1,58]   Shulei Zhang(张书磊)[23,h]

X. D. Zhang(张小东)[41]   X. M. Zhang[1]   X. Y. Zhang(张学尧)[45]   X. Y. Zhang(张旭颜)[50]   Y. Zhang[64]

Y. T. Zhang(张亚腾)[75]   Y. H. Zhang(张银鸿)[1,53]   Yan Zhang(张言)[53,66]   Yao Zhang(张瑶)[1]   Z. H. Zhang[1]

Z. Y. Zhang(张振宇)[71]   Z. Y. Zhang(张子羽)[39]   G. Zhao(赵光)[1]   J. Zhao(赵静)[35]   J. Y. Zhao(赵静宜)[1,58]

J. Z. Zhao(赵京周)[1,53]   Lei Zhao(赵雷)[53,66]   Ling Zhao(赵玲)[1]   M. G. Zhao(赵明刚)[39]   Q. Zhao(赵强)[1]   S.

J. Zhao(赵书俊)[75]   Y. B. Zhao(赵豫斌)[1,53]   Y. X. Zhao(赵宇翔)[28,58]   Z. G. Zhao(赵政国)[53,66]   A. Zhemchugov[32,a]

B. Zheng(郑波)[67]   J. P. Zheng(郑建平)[1,53]   Y. H. Zheng(郑阳恒)[58]   B. Zhong(钟彬)[37]   C. Zhong(钟翠)[67]

X. Zhong(钟鑫)[54]   H. Zhou(周航)[45]   L. P. Zhou(周利鹏)[1,58]   X. Zhou(周详)[71]   X. K. Zhou(周晓康)[58]

X. R. Zhou(周小蓉)[53,66]   X. Y. Zhou(周兴玉)[35]   Y. Z. Zhou(周祎卓)[10,f]   J. Zhu(朱江)[39]   K. Zhu(朱凯)[1]

K. J. Zhu(朱科军)[1]   L. X. Zhu(朱琳萱)[58]   S. H. Zhu(朱世海)[65]   S. Q. Zhu(朱仕强)[38]   T. J. Zhu(朱腾蛟)[72]

W. J. Zhu(朱文静)[10,f]   Y. C. Zhu(朱莹春)[53,66]   Z. A. Zhu(朱自安)[1,58]   B. S. Zou(邹冰松)[1]   J. H. Zou(邹佳恒)[1]

(BESIII Collaboration)

[1]Institute of High Energy Physics, Beijing 100049, China
[2]Beihang University, Beijing 100191, China
[3]Beijing Institute of Petrochemical Technology, Beijing 102617, China
[4]Bochum Ruhr-University, D-44780 Bochum, Germany
[5]Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA
[6]Central China Normal University, Wuhan 430079, China
[7]Central South University, Changsha 410083, China
[8]China Center of Advanced Science and Technology, Beijing 100190, China
[9]COMSATS University Islamabad, Lahore Campus, Defence Road, Off Raiwind Road, 54000 Lahore, Pakistan
[10]Fudan University, Shanghai 200433, China
[11]G.I. Budker Institute of Nuclear Physics SB RAS (BINP), Novosibirsk 630090, Russia
[12]GSI Helmholtzcentre for Heavy Ion Research GmbH, D-64291 Darmstadt, Germany
[13]Guangxi Normal University, Guilin 541004, China
[14]Guangxi University, Nanning 530004, China
[15]Hangzhou Normal University, Hangzhou 310036, China
[16]Hebei University, Baoding 071002, China
[17]Helmholtz Institute Mainz, Staudinger Weg 18, D-55099 Mainz, Germany
[18]Henan Normal University, Xinxiang 453007, China
[19]Henan University of Science and Technology, Luoyang 471003, China
[20]Henan University of Technology, Zhengzhou 450001, China
[21]Huangshan College, Huangshan 245000, China
[22]Hunan Normal University, Changsha 410081, China
[23]Hunan University, Changsha 410082, China
[24]Indian Institute of Technology Madras, Chennai 600036, India
[25]Indiana University, Bloomington, Indiana 47405, USA
[26A]INFN Laboratori Nazionali di Frascati, I-00044, Frascati, Italy
[26B]INFN Sezione di Perugia, I-06100, Perugia, Italy

[26C]University of Perugia, I-06100, Perugia, Italy

[27A]INFN Sezione di Ferrara, I-44122, Ferrara, Italy

[27B]University of Ferrara, I-44122, Ferrara, Italy

[28]Institute of Modern Physics, Lanzhou 730000, China

[29]Institute of Physics and Technology, Peace Avenue 54B, Ulaanbaatar 13330, Mongolia

[30]Jilin University, Changchun 130012, China

[31]Johannes Gutenberg University of Mainz, Johann-Joachim-Becher-Weg 45, D-55099 Mainz, Germany

[32]Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia

[33]Justus-Liebig-Universitaet Giessen, II. Physikalisches Institut, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

[34]Lanzhou University, Lanzhou 730000, China

[35]Liaoning Normal University, Dalian 116029, China

[36]Liaoning University, Shenyang 110036, China

[37]Nanjing Normal University, Nanjing 210023, China

[38]Nanjing University, Nanjing 210093, China

[39]Nankai University, Tianjin 300071, China

[40]National Centre for Nuclear Research, Warsaw 02-093, Poland

[41]North China Electric Power University, Beijing 102206, China

[42]Peking University, Beijing 100871, China

[43]Qufu Normal University, Qufu 273165, China

[44]Shandong Normal University, Jinan 250014, China

[45]Shandong University, Jinan 250100, China

[46]Shanghai Jiao Tong University, Shanghai 200240, China

[47]Shanxi Normal University, Linfen 041004, China

[48]Shanxi University, Taiyuan 030006, China

[49]Sichuan University, Chengdu 610064, China

[50]Soochow University, Suzhou 215006, China

[51]South China Normal University, Guangzhou 510006, China

[52]Southeast University, Nanjing 211100, China

[53]State Key Laboratory of Particle Detection and Electronics, Beijing 100049, Hefei 230026, China

[54]Sun Yat-Sen University, Guangzhou 510275, China

[55]Suranaree University of Technology, University Avenue 111, Nakhon Ratchasima 30000, Thailand

[56]Tsinghua University, Beijing 100084, China

[57A]Istinye University, 34010, Istanbul, Turkey

[57B]Near East University, Nicosia, North Cyprus, Mersin 10, Turkey

[58]University of Chinese Academy of Sciences, Beijing 100049, China

[59]University of Groningen, NL-9747 AA Groningen, The Netherlands

[60]University of Hawaii, Honolulu, Hawaii 96822, USA

[61]University of Jinan, Jinan 250022, China

[62]University of Manchester, Oxford Road, Manchester, M13 9PL, United Kingdom

[63]University of Muenster, Wilhelm-Klemm-Strasse 9, 48149 Muenster, Germany

[64]University of Oxford, Keble Road, Oxford OX13RH, United Kingdom

[65]University of Science and Technology Liaoning, Anshan 114051, China

[66]University of Science and Technology of China, Hefei 230026, China

[67]University of South China, Hengyang 421001, China

[68]University of the Punjab, Lahore-54590, Pakistan

[69A]University of Turin, I-10125, Turin, Italy

[69B]University of Eastern Piedmont, I-15121, Alessandria, Italy

[69C]INFN, I-10125, Turin, Italy

[70]Uppsala University, Box 516, SE-75120 Uppsala, Sweden

[71]Wuhan University, Wuhan 430072, China

[72]Xinyang Normal University, Xinyang 464000, China

[73]Yunnan University, Kunming 650500, China

[74]Zhejiang University, Hangzhou 310027, China

[75]Zhengzhou University, Zhengzhou 450001, China

[a]Also at the Moscow Institute of Physics and Technology, Moscow 141700, Russia

[b]Also at the Novosibirsk State University, Novosibirsk, 630090, Russia

[c]Also at the NRC "Kurchatov Institute", PNPI, 188300, Gatchina, Russia

[d]Also at Goethe University Frankfurt, 60323 Frankfurt am Main, Germany

[e]Also at Key Laboratory for Particle Physics, Astrophysics and Cosmology, Ministry of Education; Shanghai Key Laboratory for Particle Physics and Cosmology; Institute of Nuclear and Particle Physics, Shanghai 200240, China

[f]Also at Key Laboratory of Nuclear Physics and Ion-beam Application (MOE) and Institute of Modern Physics, Fudan University, Shanghai 200443, China

[g]Also at State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China

[h]Also at School of Physics and Electronics, Hunan University, Changsha 410082, China

[i]Also at Guangdong Provincial Key Laboratory of Nuclear Science, Institute of Quantum Matter, South China Normal University, Guangzhou 510006, China

[j]Also at Frontiers Science Center for Rare Isotopes, Lanzhou University, Lanzhou 730000, China

[k]Also at Lanzhou Center for Theoretical Physics, Lanzhou University, Lanzhou 730000, China

[1]Also at the Department of Mathematical Sciences, IBA, Karachi, Pakistan

Abstract: Using $(448.1 \pm 2.9) \times 10^6$ $\psi(3686)$ events collected with the BESIII detector, we perform the first search for the weak baryonic decay $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^- + c.c.$. The analysis procedure is optimized using a blinded method. No significant signal is observed, and the upper limit on the branching fraction ($\mathcal{B}$) of $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^- + c.c.$ is set as 1.4×10^{-5} at the 90% confidence level.

Keywords: weak decay, upper limit, BESIII detector

DOI: 10.1088/1674-1137/ac9895

I. INTRODUCTION

The weak decays of J/ψ and $\psi(3686)$ are extremely rare compared to their dominant strong and electromagnetic decays. For example, the branching fractions of the semi-leptonic and hadronic weak decays of J/ψ are predicted to be less than 10^{-9} in the framework of the standard model (SM) [1, 2]. Over the past few years, the BESIII collaboration has searched for the baryon and lepton number violating decay $J/\psi \to \Lambda_c^+ e^-$ [3] and flavor changing neutral current decay $\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$ [4] as well as the weak decays $J/\psi \to D^- e^+ \nu_e$ [5] and $J/\psi \to D_s^{(*)-} e^+ \nu_e$ [6]. Throughout this paper, charge conjugated channels are always implied. To date, however, no signal has been observed in these channels.

Searches for purely baryonic weak $\psi(3686)$ decays involving a charmed baryon Λ_c^+ in the final state have not been previously performed. Figure 1 shows the lowest order Feynman diagram for the rare baryonic decay $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$ in the SM. Here, the c quark acts as a spectator, $\bar{c}$ quark transforms into an $\bar{s}$, $d\bar{u}$ pair is produced via W-boson exchange, and $u\bar{u}$ pair is then produced from the vacuum. These quarks and anti-quarks hadronize into Λ_c^+ and $\bar{\Sigma}^-$. In Ref. [7], the branching fraction of $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$ was predicted to be of the order of 10^{-9} to 10^{-11} in the SM, which is comparable to those of the decays of $\psi(3686) \to$ charmed meson + anything. New physics mechanisms beyond the SM, such as the top-color model [8] and Randall-Sundrum model [9], may enhance this decay branching fraction significantly. The experimental study of $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$ may therefore offer important information for a comprehensive un-

derstanding of the weak decay mechanisms of charmonium states.

A sample of $(448.1 \pm 2.9) \times 10^6$ $\psi(3686)$ events [10] is collected using electron and positron collisions, thereby offering an ideal opportunity to search for the $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$ decay. By analyzing this data sample, we report the first search for $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$.

II. BESIII DETECTOR AND MONTE CARLO SIMULATION

The BESIII detector [11] records symmetric $e^+ e^-$ collisions provided by the BEPCII storage ring [12], which operates with a peak luminosity of 1×10^{33} cm^{-2}s^{-1} in the center-of-mass energy range from 2.0 to 4.95 GeV. BESIII has collected more than 32 fb^{-1} of data samples in this energy region [13]. The cylindrical core of the BESIII detector consists of a helium-based multilayer drift chamber (MDC), plastic scintillator time-of-flight system (TOF), and CsI(Tl) electromagnetic calorimeter (EMC), which are all enclosed in a superconducting solenoidal magnet providing a 1.0 T magnetic field. The solenoid is supported by an octagonal flux-return yoke with resistive plate counter muon identification modules interleaved with steel. The charged-particle momentum resolution at 1 GeV/c is 0.5%, and the dE/dx resolution is 6% for electrons from Bhabha scattering. The EMC measures photon energies with a resolution of 2.5% (5%) at 1 GeV in the barrel (end cap) region. The time resolution in the TOF barrel region is 68 ps, whereas that in the end cap region is 110 ps.

Simulated event samples produced with the GEANT4-based [14] Monte Carlo (MC) package, which includes a geometric description of the BESIII detector and the detector responses, are used to determine the detection efficiency and estimate the backgrounds. The simulation includes the beam energy spread and initial state radiation in the $e^+ e^-$ annihilations, modeled with the generator KKMC [15, 16]. The inclusive MC sample consists of the production of charmonium resonances and continuum processes incorporated in KKMC. The known decay modes are modeled with EVTGEN [17] using branching fractions taken from the Particle Data Group [18], and the remaining unknown decays are taken from
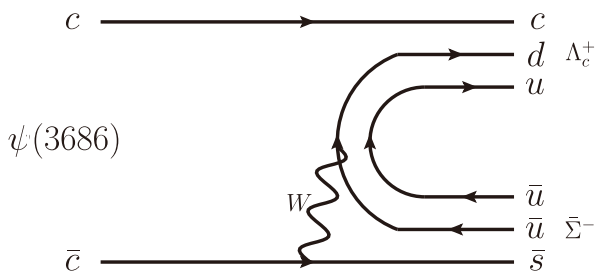

Fig. 1. Feynman diagram for the process $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$ in the SM [7].

the charmonium states with LUNDCHARM [19, 20]. Final state radiation from charged final-state particles is incorporated with the PHOTOS package [21]. In this analysis, the $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$ and $\bar{\Sigma}^- \to \bar{p}\pi^0$ decays are generated according to phase space, and the $\Lambda_c^+ \to pK^-\pi^+$ decay is generated using an amplitude analysis model [22]. As in previous BESIII published papers [3, 4], Λ_c^+ is only reconstructed via $\Lambda_c^+ \to pK^-\pi^+$, which provides the best sensitivity among all decay modes.

III. EVENT SELECTION AND DATA ANALYSIS

The procedure for selecting candidate events from the process $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$, where the Λ_c^+ baryon decays to $pK^-\pi^+$ and the $\bar{\Sigma}^-$ baryon decays to $\bar{p}\pi^0$, is outlined below.

It is required that there are at least four charged tracks and two photons in the candidate events. The polar angle of each charged track is required to be in the range $|\cos\theta| < 0.93$, coinciding with the coverage of the MDC. The charged tracks from $\Lambda_c^+ \to pK^-\pi^+$ decays must originate from the interaction point with a distance of closest approach less than 1 cm on the transverse plane ($|V_{xy}|$) and less than 10 cm along the z axis ($|V_z|$). For the charged tracks from $\bar{\Sigma}^-$ decays, the requirements of $|V_{xy}|$ and $|V_z|$ are loosened to be less than 10 cm and 20 cm, respectively, owing to the relatively long lifetime of $\bar{\Sigma}^-$. No secondary vertex is considered because there is only one charged track from $\bar{\Sigma}^-$. Particle identification (PID) for the charged pion, kaon, and proton is performed using dE/dx and the TOF information. The particle type with the highest probability is assigned to each track.

The π^0 candidates are identified as photon pairs reconstructed from the EMC showers. Each EMC shower is required to be within a 700 ns time window, which is applied to suppress electronic noise and energy depositions unrelated to the event. The energy deposited in nearby TOF counters is included in the energy of the EMC showers to improve the photon reconstruction efficiency and energy resolution. At least two photon candidates are required, with a minimum energy of 25 MeV in the barrel region ($|\cos\theta| < 0.80$) or 50 MeV in the end cap region ($0.86 < |\cos\theta| < 0.92$). The opening angle between the photon candidate and the nearest charged track must be greater than 10°.

A five-constraint (5C) kinematic fit is performed on the hypothesis of $e^+e^- \to pK^-\pi^+\bar{p}\gamma\gamma$, with the invariant mass of the $\gamma\gamma$ combination constrained to the π^0 nominal mass. The helix parameters of the charged tracks of the MC events are corrected to improve consistency with the data, following Ref. [23]. Events satisfying $\chi^2_{5C} < 60$, which has been optimized based on the Punzi method [24], are kept for further analysis. If there are multiple candidates in an event, the one with the smallest χ^2_{5C} is retained.

After applying all the above requirements, there are two main background sources [25], $\psi(3686) \to K^*(892)^- p\bar{\Lambda}$ ($K^*(892)^- \to \pi^0 K^-$, $\bar{\Lambda} \to \pi^+\bar{p}$) and $\psi(3686) \to \bar{K}^{*0}(892)p\bar{\Sigma}^-$ ($\bar{K}^{*0}(892) \to \pi^+ K^-$, $\bar{\Sigma}^- \to \bar{p}\pi^0$). The former and latter are suppressed by requiring the invariant mass of $\pi^+\bar{p}$ ($M(\pi^+\bar{p})$) $\notin [1.090, 1.130]$ GeV/c^2 and the invariant mass of $K^-\pi^+$ ($M(K^-\pi^+)$) $\notin [0.756, 1.036]$ GeV/c^2, respectively. These requirements have also been optimized with the Punzi method [24]. The requirements of $M(\pi^+\bar{p})$ and $M(K^-\pi^+)$ reject 94.2% of background events with an efficiency loss of 45.5%. At present, the branching fraction of $\psi(3686) \to \bar{K}^{*0}(892)p\bar{\Sigma}^-$ is absent. With the same $\psi(3686)$ data sample, we estimate the branching fraction of $\psi(3686) \to \bar{K}^{*0}(892)p\bar{\Sigma}^- + c.c.$ to be $(3.2 \pm 0.2_{\text{stat.}}) \times 10^{-3}$ by examining the $M(K^-\pi^+)$ distribution of the accepted candidate events. Based on this, we estimate that the $\psi(3686) \to \bar{K}^{*0}(892)p\bar{\Sigma}^-$ background channel contributes to approximately 91 background events; however, they do not form a peak in the $M(pK^-\pi^+)$ distribution.

Figure 2(a) and 2(b) show the distributions of the invariant mass of $\bar{p}\pi^0$ ($M(\bar{p}\pi^0)$) versus the invariant mass of $pK^-\pi^+$ ($M(pK^-\pi^+)$) surviving the event selection for the signal MC sample and data, respectively. The $\bar{\Sigma}^-$ can-
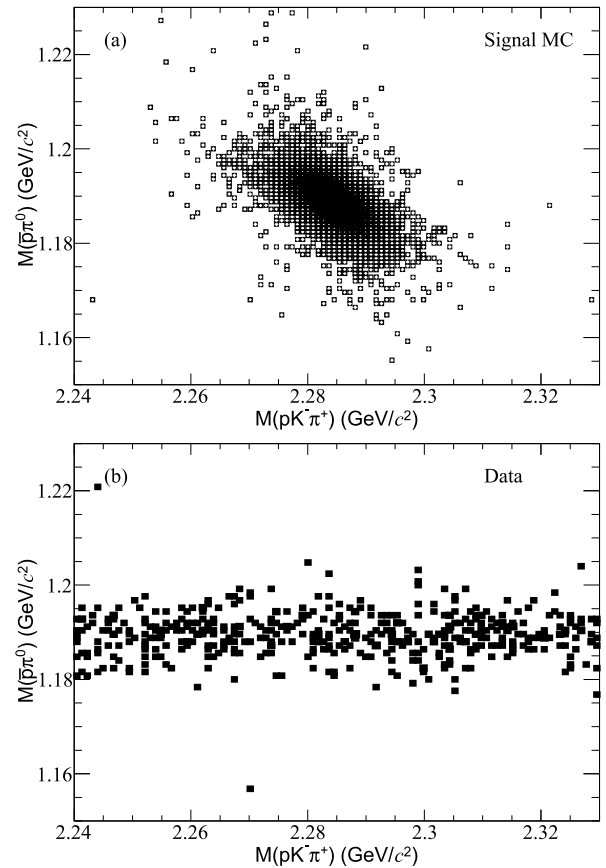

Fig. 2. Distribution of $M(\bar{p}\pi^0)$ versus $M(pK^-\pi^+)$ for the accepted candidate events in the signal MC sample and data.

didates are required to be within the interval $M(\bar{p}\pi^0) \in (1.150, 1.230)$ GeV/c^2, which corresponds to three times the resolution around the $\bar{\Sigma}^-$ peak. The signal yield of $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$ is extracted from an unbinned maximum likelihood fit to the $M(pK^-\pi^+)$ distribution, as shown in Fig. 3. In the fit, the lineshapes of the signal and background are modeled by the signal MC simulation and a first-order Chebyshev polynomial, respectively. In addition, the yields of the signal and background are free to float. In Fig. 3, the background level is significantly higher than that expected by the inclusive $\psi(3686)$ MC sample, which may be due to some unknown decay, for example, $\psi(3686) \to \pi^+K^-p\bar{\Sigma}^- + c.c.|_{\text{non}-K^*}$. With the same $\psi(3686)$ data sample, we estimate the branching fraction of $\psi(3686) \to \pi^+K^-p\bar{\Sigma}^-|_{\text{non}-K^*}$ to be $(1.49 \pm 0.03_{\text{stat.}}) \times 10^{-4}$ by examining the $M(p\pi^+)$ distribution of the accepted candidate events. Based on this, we estimate that the $\psi(3686) \to \pi^+K^-p\bar{\Sigma}^-|_{\text{non}-K^*}$ background channel contributes to approximately five background events; however, they do not form a peak in the $M(pK^-\pi^+)$ distribution. Although there is still room for various background channels, they do not all form a peak in the $M(pK^-\pi^+)$ distribution. Because no significant signal is observed from the $\psi(3686)$ data, conservative upper limits will assume that all the fitted signals are from $\bar{\Sigma}^-$ after the following two checks: First, the events in the $\bar{\Sigma}^-$ sideband region show that the non-$\bar{\Sigma}^-$ contribution in the selected candidates is negligible. Second, an analysis of 2.93 fb^{-1} of data taken at $\sqrt{s} = 3.773$ GeV shows that no peaking background of the continuum production of $e^+e^- \to \Lambda_c^+ \bar{\Sigma}^-$ is estimated.

To estimate the upper limit on the branching fraction of $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$, we use a likelihood scan method after incorporating systematic uncertainties, as discussed

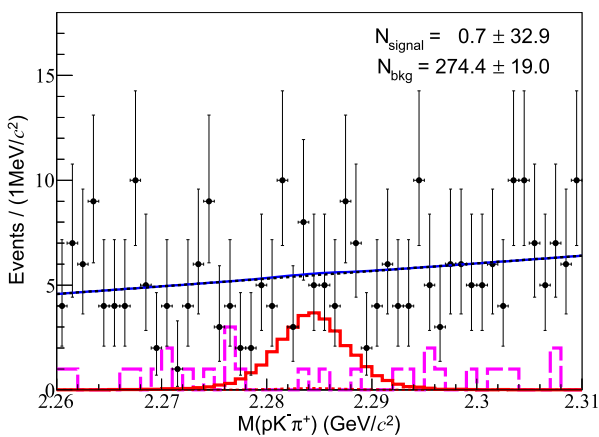**Fig. 3.** (color online) Fit to the $M(pK^-\pi^+)$ distribution for the candidate events from $\psi(3686) \to \Lambda_c^+ \bar{\Sigma}^-$. Points with error bars are data. The red (black) dashed line is the signal (background), and the blue solid curve is the total fit. The pink dashed line is the inclusive MC sample. The red solid curve is the signal shape enlarged by a factor of 100.

in next section.

IV. SYSTEMATIC UNCERTAINTY

Systematic uncertainties for the upper limit on the branching fraction can be classified into two categories: additive terms and multiplicative terms.

Additive terms contain uncertainties caused by the chosen signal shape, background shape, and fit range. The effect due to the signal shape is estimated by replacing the signal MC shape with the signal MC shape convolved with a Gaussian resolution function with a mean of 1.0 MeV/c^2 and a resolution of 1.3 MeV/c^2. These parameters are obtained from a fit to the $M(pK^-\pi^+)$ spectrum using a data sample taken above the $\Lambda_c^+ \bar{\Lambda}_c^-$ production threshold. The effect from the background shape is evaluated using first-order and second-order Chebyshev polynomials. The effect from the fit range is estimated with fit ranges of [2.26, 2, 31] GeV/c^2, [2.26, 2, 32] GeV/c^2, and [2.25, 2, 31] GeV/c^2. Among all of these terms, the case yielding the largest upper limit is chosen for further analysis.

The sources of multiplicative systematic uncertainties include the number of $\psi(3686)$ events, tracking efficiency, PID efficiency, π^0 reconstruction, the $\bar{\Sigma}^-$ mass window, kinematic fit, the quoted branching fractions of intermediate states, and the signal MC model. The systematic uncertainties on the requirements of $M(\pi^+\bar{p})$ and $M(\pi^+K^-)$ are estimated by changing individual veto regions by 10 MeV/c^2. The associated effects on the upper limits are less than 0.1%, which are negligible. The other systematic uncertainties are discussed below.

(a) Number of $\psi(3686)$ events: The total number of $\psi(3686)$ events in the data sample was determined as $(448.1 \pm 2.9) \times 10^6$ with inclusive hadronic events in Ref. [10]. The uncertainty on the total number of $\psi(3686)$ events, 0.6%, is assigned as a systematic uncertainty.

(b) Tracking and PID efficiencies: The uncertainties from the tracking and PID efficiencies have been studied with the high purity control samples $\psi(3686) \to \pi^+\pi^- J/\psi$ [26]. The systematic uncertainty due to the tracking or PID efficiency is assigned to be 1.0% for each track.

(c) π^0 reconstruction: The systematic uncertainty on the π^0 reconstruction efficiency has been studied with the control sample of $J/\psi \to \rho\pi$ in Ref. [26]. The associated systematic uncertainty is assigned to be 1.0% for each π^0.

(d) $\bar{\Sigma}^-$ mass window: To estimate the systematic uncertainty from the $\bar{\Sigma}^-$ mass window, we use the control sample of $\psi(3686) \to \Sigma^+\bar{\Sigma}^-$ with $\Sigma^+ \to p\pi^0$ and $\bar{\Sigma}^- \to \bar{p}\pi^0$. The difference between the acceptance efficiencies of data and MC simulation, 0.1%, is taken as the corres-

ponding systematic uncertainty.

(**e**) 5C kinematic fit: To examine the systematic uncertainty due to the 5C kinematic fit, we examine the signal efficiencies with and without correcting the MDC helix parameters for the signal MC events. The change in the signal efficiency, 0.2%, is assigned as the systematic uncertainty.

(**f**) Quoted branching fraction: The branching fractions of $\Lambda_c^+ \to pK^-\pi^+$, $\bar{\Sigma}^- \to \bar{p}\pi^0$, and $\pi^0 \to \gamma\gamma$ are quoted from the Particle Data Group [18], which are $(6.28 \pm 0.32)\%$, $(51.57 \pm 0.30)\%$, and $(98.823 \pm 0.034)\%$, respectively. They contribute to a total uncertainty of 5.2%, which is regarded as a systematic uncertainty.

(**g**) MC model: The signal MC sample of $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$ is generated according to phase space. To estimate the systematic uncertainty on the MC model, we generate alternative signal MC samples using the J2BB1 model [27] with an angular distribution of $1 + \alpha\cos^2\theta$. To be conservative, two extreme scenarios corresponding to $\alpha = -1$ and $\alpha = 1$ are considered. The difference in the efficiencies between the phase space model and the J2BB1 model, 11.0%, is taken as the corresponding systematic uncertainty.

Assuming that all sources are independent, the total multiplicative systematic uncertainty is determined to be

Table 1. Multiplicative systematic uncertainties in the branching fraction measurement.

Source	Uncertainty (%)
Number of $\psi(3686)$ events	0.6
Tracking efficiencies	4.0
PID efficiencies	4.0
π^0 reconstruction	1.0
$\bar{\Sigma}^-$ mass window	0.1
5C kinematic fit	0.2
Quoted branching fractions	5.2
MC model	11.0
Total	13.5

13.5% by adding all uncertainties quadratically. The systematic uncertainties are summarized in Table 1.

V. RESULT

The branching fraction of $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$ is calculated using

$$\mathcal{B}(\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-) = \frac{N_{\text{sig}}}{N_{\psi(3686)} \cdot \Pi\mathcal{B}_i \cdot \epsilon}, \qquad (1)$$

where $N_{\psi(3686)}$ is the total number of $\psi(3686)$ events in the data sample, $\Pi\mathcal{B}_i$ is the product of the branching fractions of the intermediate decays $\Lambda_c^+ \to pK^-\pi^+$, $\bar{\Sigma}^- \to \bar{p}\pi^0$, and $\pi^0 \to \gamma\gamma$, and ϵ is the detection efficiency, which is determined as $(11.03 \pm 0.08)\%$ based on MC simulation.

No significant signal is observed, and the upper limit on the signal yield is set to be 21.1 at the 90% confidence level by assuming that the fitted signal yield is entirely from the process $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$. The raw likelihood distribution versus $\mathcal{B}(\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-)$ is represented by the blue dashed curve in Fig. 4. This curve is then smeared by a Gaussian function with a mean of 0 and a width equal to the multiplicative systematic uncertainty of 13.5% according to Refs. [28, 29]. The updated likelihood distribution is shown as the red solid curve in Fig. 4. By integrating the red dashed curve from zero to 90% of the physical region, the upper limit on the branching fraction of $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$ at the 90% confidence level is set to be

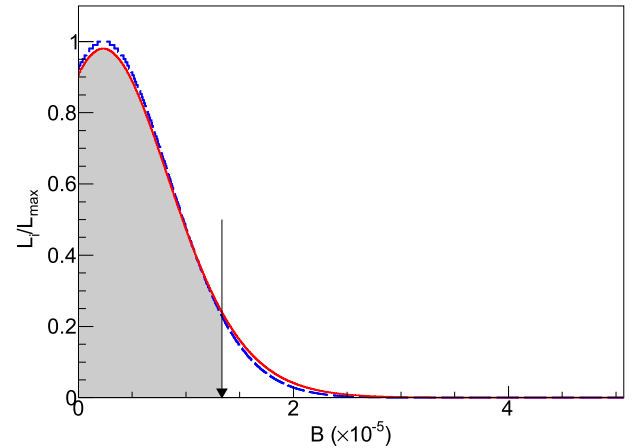**Fig. 4.** (color online) Distributions of the likelihoods versus the branching fraction of $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$. The results obtained with and without incorporating the systematic uncertainties are represented by the red solid and blue dashed curves, respectively. The black arrow shows the result corresponding to the 90% confidence level.

$$\mathcal{B}(\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-) < 1.4 \times 10^{-5}.$$

VI. SUMMARY

By analyzing $(448.1 \pm 2.9) \times 10^6$ $\psi(3686)$ events collected with the BESIII detector, we present the first search for $\psi(3686) \to \Lambda_c^+\bar{\Sigma}^-$. No significant signal is observed in the data sample. Therefore, we set an upper lim-

it on the branching fraction of 1.4×10^{-5} at the 90% confidence level. This is far above the prediction in the SM. An additional 2.3 billion $\psi(3686)$ events at BESIII will be available soon. This larger $\psi(3686)$ data sample offers an opportunity to further improve the sensitivity of the search for this decay [13].

References

[1] Y. M. Wang, H. Zou, Z. T. Wei *et al*., Eur. Phys. J. C **55**, 607 (2008)

[2] Y. M. Wang, H. Zou, Z. T. Wei *et al*., Eur. Phys. J. C **54**, 107 (2008)

[3] M. Ablikim *et al*. (BESIII Collaboration), Phys. Rev. D **99**, 072006 (2019)

[4] M. Ablikim *et al*. (BESIII Collaboration), Phys. Rev. D **97**, 091102 (2018)

[5] M. Ablikim *et al*. (BESIII Collaboration), JHEP **2021**, 157 (2021)

[6] M. Ablikim *et al*. (BESIII Collaboration), Phys. Rev. D **90**, 112014 (2014)

[7] H. W. Ke, Y. Z. Chen and X. Q. Li, Chin. Phys. Lett. **28**, 071301 (2011)

[8] J. Z. Han, Commun. Theor. Phys. **54**, 1091-1096 (2010)

[9] B. Lillie, L. Randall and L. T. Wang, JHEP **09**, 074 (2007)

[10] M. Ablikim *et al* (BESIII Collaboration), Chin. Phys. C **42**, 023001 (2018)

[11] M. Ablikim *et al*. (BESIII Collaboration), Nucl. Instrum. Meth. A **614**, 345 (2010)

[12] C. H. Yu *et al.*, *Proceedings of IPAC2016*, Busan, Korea, 2016.

[13] M. Ablikim *et al*. (BESIII Collaboration), Chin. Phys. C **44**, 040001 (2020)

[14] S. Agostinelli *et al* (GEANT4 Collaboration), Nucl. Instrum. Meth. Phys. Res., Sect. A **506**, 250 (2003)

[15] S. Jadach, B. F. L. Ward, and Z. Was, Phys. Rev. D **63**, 113009 (2001)

[16] S. Jadach, B.F.L. Ward, and Z. Waṣ, Comput. Phys. Commun. **130**, 260 (2000)

[17] D. J. Lange, Nucl. Instrum. Meth. Phys. Res., Sect. A **462**, 152 (2001)

[18] R.L. Workman *et al*. (Particle Data Group), Prog. Theor. Exp. Phys. **2022**, 083C (2022)

[19] J. C. Chen, G. S. Huang, X. R. Qi *et al*., Phys. Rev. D **62**, 034003 (2000)

[20] R. L. Yang, R. G. Ping, and H. Chen, Chin. Phys. Lett. **31**, 061301 (2014)

[21] E. Richter-Was, Phys. Lett. B **303**, 163 (1993)

[22] M. Ablikim *et al*. (BESIII Collaboration), Phys. Rev. Lett. **116**, 052001 (2016)

[23] M. Ablikim *et al*. (BESIII Collaboration), Phys. Rev. D **88**, 112001 (2013)

[24] G. Punzi, *Sensitivity optimization of multichannel searches for new signals*, arXiv: 2011.11770

[25] X. Y. Zhou, S. X. Du, G. Li *et al*., Comput. Phys. Commun. **258**, 107540 (2021)

[26] M. Ablikim *et al*. (BESIII Collaboration), Phys. Rev. D **81**, 052005 (2010)

[27] R. G. Ping, Chin. Phys. C **32**, 599 (2008)

[28] K. Stenson, *A more exact solution for incorporating multiplicative systematic uncertainties in branching ratio limits*, arXiv: physics/0605236

[29] X. X. Liu, X. R. Lyu and Y. S. Zhu, Chin. Phys. C **39**, 113001 (2015)