分类号________ 密级________

UDC________ 编号________

中国科学院
博士学位研究生学位论文

$\psi(2S)$共振参数的测量

莫 晓 虎

指导教师姓名 朱永生 研究员 中国科学院高能物理研究所

申请学位级别 博 士 学科专业名称 粒子物理与原子核物理

论文提交日期 2001年4月25日 论文答辩日期 2001年6月26日

学位授予单位名称 中国科学院高能物理研究所

答辩委员会主席 叶铭汉

Measurement of $\psi(2S)$ Resonance Parameters

A dissertation submitted to the graduate division of the
Institute of High Energy Physics,
the Chinese Academy of Sciences

Doctor of Philosophy

in Physics

April. 25th, 2001

By

Mo XiaoHu

Directed by

Prof. **Zhu YongSheng**

献给故乡北京

目　　录

图 目 录

表 目 录

摘　　要

自从$\psi(2S)$粒子发现以来,不同实验组给出的$\psi(2S)$粒子衰变总宽度,衰变为$\mu^+\mu^-$、$\pi^+\pi^- J/\psi$和强子末态的部分宽度及分支比的测量值一直存在很大的差异.为了改善现状,提高测量精度,北京谱仪(BES)依据细致切实的方案在北京正负电子对撞机(BEPC)上进行了为期一周的$\psi(2S)$的精细扫描,获取了24个能量点近三百万在线事例.

利用这批数据,在细致的质量检查的基础上,系统地研究了如下三个过程

$$e^+e^- \rightarrow e^+e^- \tag{0.1}$$

$$e^+e^- \rightarrow \mu^+\mu^- \tag{0.2}$$

$$e^+e^- \rightarrow hadrons \tag{0.3}$$

针对扫描实验的特点,对每一过程的事例判选进行了详尽的考察.通过比较多种方法的优劣,拣择出最优化的判选方法.采用结构函数的方法推导出截面的辐射修正公式,其拟合精度达0.1%.研究了真空极化给拟合公式带来的修正, 计算出最终的观测截面的解析近似式.本文还详细地介绍了接收度计算中涉及到的有关概念、原则和技巧.对于误差分析的一般概念和基本原则也作了条理化、简明化的说明.详细地研究了上述各过程的系统误差.

最后,结合并利用关于

$$e^+e^- \rightarrow \psi(2S) \rightarrow \pi^+\pi^- J/\psi \tag{0.4}$$

过程的数据分析结果,应用χ^2-最小化技术,对过程(1~4)的观测截面-能量的扫描曲线进行拟合,采用简单可靠的的抽样方法确定了拟合误差, 相关结果总结如下

衰变宽度	Γ_t(keV)	Γ_h(keV)	$\Gamma_{\pi\pi J/\psi}$(keV)	Γ_μ(keV)
拟合结果	248.2 ± 23.3	242.5 ± 22.8	80.56 ± 7.31	2.389 ± 0.139
分支比		$\mathcal{B}_h(\%)$	$\mathcal{B}_{\pi\pi J/\psi}(\%)$	$\mathcal{B}_\mu(\%)$
拟合结果		97.70 ± 0.13	32.46 ± 0.74	0.963 ± 0.066

从相对误差角度来看,新的测量结果为当今世界最佳值,对PDG中相应的值都有不同程度的改善.尤其是在世界上首次直接测定了$\psi(2S)\rightarrow \pi^+\pi^-J/\psi$的衰变宽度,同时对$\Gamma_h$、$\Gamma_\mu$、$\mathcal{B}_h$、$\mathcal{B}_\mu$、$\mathcal{B}_{\pi^+\pi^-J/\psi}$的测量精度提高了1.5~4.7倍.

关键词: $\psi(2S)$粒子, 衰变宽度, 分支比, 截面, 拟合

Abstract

Since the discovery of $\psi(2S)$ resonance, there have been rather different measurement values of its total width,partial widths to $\mu^+\mu^-$、 $\pi^+\pi^- J/\psi$ 、 $hadrons$ final states and corresponding branching ratios reported by different experiment groups. For ameliorating the current situation and improving the accuracy of the measurements, the finer $\psi(2S)$ scan was carried out according to the careful and practical scheme by BES(BEijing Spectrometer) at BEPC(Beijing Electron-Positron Collider) within a week. Approximate three million events online data at 24 energy points were collected.

Using these data sample, on the base of meticulous quality check, the following three processes have been studied systematically

$$e^+e^- \rightarrow e^+e^- \tag{0.1}$$

$$e^+e^- \rightarrow \mu^+\mu^- \tag{0.2}$$

$$e^+e^- \rightarrow hadrons \tag{0.3}$$

Event selection of each process is examined throughly in the light of scan experiment's feature. Many schemes have been compared to pick out the most optimal one.Structure function method is adopted to derive the radiatively corrected cross section whose accuracy is up to the level of 0.1%. The correction from vacuum polarization is also studied. The final analytical approximation formulea of the observed cross sections are worked out. In the thesis, a detailed introduction is also given to the related concept、 principle and technique involving the acceptance calculation. The general concept and primary principle about error analysis is also explained . The systematic error about the above processes is studied.

At last, using the data of the above 3 processes together with the data analysis results of process

$$e^+e^- \rightarrow \psi(2S) \rightarrow \pi^+\pi^- J/\psi \tag{0.4}$$

the observed cross section-energy scan curves are fitted by applying χ^2 minimization technique. The sampling method is used to draw out the errors of decay widths and branching ratios. The relevant results are summed up as follows

Decay Width	Γ_t(keV)	Γ_h(keV)	$\Gamma_{\pi\pi J/\psi}$(keV)	Γ_μ(keV)
Fitting Result	248.2 ± 23.3	242.5 ± 22.8	80.56 ± 7.31	2.389 ± 0.139
Branching Ratio		$\mathcal{B}_h$(%)	$\mathcal{B}_{\pi\pi J/\psi}$(%)	$\mathcal{B}_\mu$(%)
Fitting Result		97.70 ± 0.13	32.46 ± 0.74	0.963 ± 0.066

For the relative errors, the new measurement results are the best in the world nowadays and improve the accuracies of the corresponding values in PDG significantly.In particular,it is the first time that the decay width of $\psi(2S)\to\pi^+\pi^-J/\psi$ is measured directly and the accuracies of Γ_h、 Γ_μ、 $\mathcal{B}_h$、 $\mathcal{B}_\mu$ and $\mathcal{B}_{\pi^+\pi^-J/\psi}$ are greatly improved by a factor of 1.5~4.7 respectively.

Key Words: $\psi(2S)$ particle, decay width, branching ratio, cross section, fitting