Recent Results from the KEDR Detector

Simon Eidelman

Budker Institute of Nuclear Physics,
Novosibirsk, Russia

Outline
1. $J/\psi$ and $\psi'$ masses
2. Parameters of $\psi'$
3. Parameters of $\psi(3770)$
4. Search for narrow resonances
5. Conclusions
Circumference: 366 m
Beam energy: 1÷6 GeV
Number of bunches: 2 × 2
Luminosity, $E = 1.5$ GeV: $2 \times 10^{30} \text{ cm}^{-2}\text{s}^{-1}$
Luminosity, $E = 5.0$ GeV: $2 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$

- Resonant depolarization technique:
  Instantaneous measurement accuracy $\approx 1 \times 10^{-6}$
  Energy interpolation accuracy $(5 \div 15) \times 10^{-6}$ (10 ÷ 30 keV)

- Infrared light Compton backscattering:
  Statistical accuracy $\approx 5 \times 10^{-5}$ / 30 minutes
  Systematic uncertainty $\approx 3 \times 10^{-5}$ (50 ÷ 70 keV)
Compton Backscattering Monitor

Realized at BESSY-I in 1987
During the run, $E$ measured by CBS and from interpolation
KEDR detector

1. Vacuum chamber
2. Vertex detector
3. Drift chamber
4. Threshold aerogel counters
5. ToF counters
6. Liquid krypton calorimeter
7. Superconducting coil
8. Magnet yoke
9. Muon tubes
10. CsI calorimeter
11. Compensating s/c solenoid
\[ M_{J/\psi} = (3096.913 \pm 0.006 \pm 0.009) \text{ MeV} \]

\[ M_{\psi'} = (3686.126 \pm 0.007 \pm 0.011) \text{ MeV} \]
Systematic errors in mass measurements are the main issue.

More than 20 different effects considered.

Energy spread, energy assignment, energy difference of $e^+$ and $e^-$, beam misalignment, luminosity etc.

No significant improvement for the $J/\psi$ because the additional scan had bigger systematics.
$J/\psi$ and $\psi'$ Mass Measurement – III

S.Eidelman, BINP
Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi' \rightarrow \text{hadrons})$ for $\psi' - I$

$\sigma \ [\text{nb}]$

Scan 1, $\sigma_W = 1.08 \text{ MeV}$
Scan 2, $\sigma_W = 1.05 \text{ MeV}$
Scan 3, $\sigma_W = 0.98 \text{ MeV}$
**Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi' \rightarrow \text{hadrons})$ for $\psi' - \Pi$**

<table>
<thead>
<tr>
<th>Source</th>
<th>Scan 1</th>
<th>Scan 2</th>
<th>Scan 3</th>
<th>Common 1-2</th>
<th>Common</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumin.</td>
<td>1.6</td>
<td>1.7</td>
<td>1.2</td>
<td>1.6</td>
<td>0.4</td>
</tr>
<tr>
<td>MC gener.</td>
<td>0.9</td>
<td>0.9</td>
<td>1.1</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Trigger</td>
<td>0.6</td>
<td>0.6</td>
<td>0.3</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Selection</td>
<td>0.5</td>
<td>0.3</td>
<td>0.6</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>MC nucl.</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Energy</td>
<td>0.15</td>
<td>0.18</td>
<td>0.60</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>MC vert. det.</td>
<td>0.10</td>
<td>0.17</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Fit</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td>2.0</td>
<td>2.1</td>
<td>1.9</td>
<td>2.0</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Measurement of $\Gamma_{ee} \cdot B(\psi' \rightarrow \text{hadrons})$ for $\psi' - \text{III}$

- $\Gamma_{e^+e^-} \cdot B(\psi' \rightarrow h) = (2.245 \pm 0.015 \pm 0.036) \text{ keV}$, much more precise than the only previous direct measurement.

- Using the world-average value of $B_h$
  $\Gamma_{e^+e^-} = (2.294 \pm 0.015 \pm 0.037) \text{ keV}$, about 3 times better than the best previous one.

- Using the world-average values of $\Gamma_{e^+e^-}$ and $B_h$
  $\Gamma = (297 \pm 2 \pm 8) \text{ keV}$, again about 3 times better than the best previous one.
Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi' \rightarrow \text{hadrons})$ for $\psi'$ – IV

$\Gamma_{ee} \times \mathcal{B}_{\text{hadrons}} \psi(2S)$

KEDR

MRK I 1975

1.8 2 2.2 2.4 2.6 keV

KEDR 2011
BES2 2008
BES2 2006
BES2 2002
$\Upsilon$ rev. 1989
DASP 1979
MRK1 1975

1.8 2 2.2 2.4 2.6 keV

$\Gamma_{ee}(\psi(2S))$, keV
Measurement of $\Gamma_{ee} \cdot B(\psi' \rightarrow \text{hadrons})$ for $\psi' - V$
Determination of $\psi(3770)$ Parameters – I

$\sigma, \text{ [nb]}$

$\sigma_{D\bar{D}} \propto |A_{\psi(3770)} + A_{\psi'} e^{i\phi} + B e^{i\phi}|^2$

$\sigma_{D\bar{D}} \propto |A_{\psi(3770)} + B_{\text{n.r.}} F e^{i\phi}|^2$
## Determination of $\psi(3770)$ Parameters – III

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VDM($\psi'$)</td>
<td>$3779.7 \pm 1.7$</td>
<td>$24.9 \pm 4.3$</td>
<td>18.5</td>
</tr>
<tr>
<td>No Interf.</td>
<td>$3773.2 \pm 0.5$</td>
<td>$23.9 \pm 2.3$</td>
<td>2.5</td>
</tr>
<tr>
<td>$e^{-\frac{q^2}{a^2}}$</td>
<td>$3780.5 \pm 2.3$</td>
<td>$28.2 \pm 4.5$</td>
<td>15.3</td>
</tr>
<tr>
<td>constant</td>
<td>$3778.1 \pm 1.5$</td>
<td>$30.4 \pm 3.9$</td>
<td>13.7</td>
</tr>
<tr>
<td>$\frac{1}{1+aq^2+bq^4}$</td>
<td>$3779.3 \pm 1.7$</td>
<td>$25.1 \pm 4.4$</td>
<td>17.2</td>
</tr>
<tr>
<td>$\frac{1}{1+aq^b}$</td>
<td>$3779.0 \pm 1.7$</td>
<td>$24.4 \pm 3.7$</td>
<td>17.7</td>
</tr>
<tr>
<td>$\frac{1}{(W-M_{\psi'})^a}$</td>
<td>$3780.0 \pm 1.9$</td>
<td>$25.3 \pm 4.7$</td>
<td>17.6</td>
</tr>
<tr>
<td>VDM ($\psi(4039))$</td>
<td>$3778.2 \pm 1.6$</td>
<td>$30.6 \pm 3.9$</td>
<td>12.2</td>
</tr>
</tbody>
</table>
### Determination of $\psi(3770)$ Parameters – IV

<table>
<thead>
<tr>
<th>Source</th>
<th>Mass, MeV</th>
<th>Width, MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_{NR}$ shape</td>
<td>$+0.3$ (-1.6)</td>
<td>$+5.7$ (-0.5)</td>
</tr>
<tr>
<td>$R_0$ variation</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Event selection</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Luminosity</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Detection efficiency</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Energy assignment</td>
<td>0.03</td>
<td>$-$</td>
</tr>
<tr>
<td>Total</td>
<td>$\approx +0.5$ (-1.7)</td>
<td>$\approx +5.7$ (-0.7)</td>
</tr>
</tbody>
</table>

KEDR: $M_{\psi(3770)} = (3779.3 \pm 1.7^{+0.5}_{-1.7})$ MeV, $\Gamma_{\psi(3770)} = (24.9 \pm 4.3^{+5.7}_{-0.7})$ MeV

PDG: $M_{\psi(3770)} = (3772.92 \pm 0.35)$ MeV, $\Gamma_{\psi(3770)} = (27.3 \pm 1.0)$ MeV
Determination of $\psi(3770)$ Parameters – V

A few general conclusions:

- Mass is higher than in previous measurements, but agrees with BaBar that also took into account interference.
- Width is in reasonable agreement with previous measurements.
- With our data sample we do not observe any shape anomaly.
- Absolutely mandatory to take into account interference:
  - There are usually two solutions with the same mass, width and likelihood, but strongly differing (a factor of up to 3) leptonic width.
  - While the current world-average value is $\Gamma_{e^+e^-} = 259 \pm 16$ eV, with interference effects included it is higher and might be (400-500) eV.
Search for Narrow Resonances – I

KEDR scanned the c.m. energy range from 1.85 to 3.1 GeV searching for narrow resonances.
\[ \int L dt \approx 300 \text{ nb}^{-1} \text{ was collected} \]
in a scan with a step \( \approx 2\sigma_W \) (1.4-1.9 MeV)
Search for Narrow Resonances – III

- The model: a resonance with $M_R$, $\Gamma_{ee}^R$ on top of a flat BG
- The fits use the range $M_R \pm 13$ MeV
- $M_R$ is varied in 0.1 MeV steps
- A systematic error of $\sim 50\%$ conservatively
- $\Gamma_{ee}^R \cdot \mathcal{B}(R \rightarrow \text{hadrons}) < 120$ eV,
  4-5 times more stringent than at ADONE in 1975-1978:
  $\gamma\gamma^2$, $B\bar{B}$ and BOSON groups scanned 1.42-3.1 GeV
- KEDR hopes to measure $R$ in this $W$ range to 5%
Conclusions

- Masses of $J/\psi$ and $\psi(2S)$ measured. The accuracy reaches $(3 - 5) \times 10^{-6}$

- New precise value of $\Gamma_{e^+e^-} \cdot B(\psi')$ significantly improves the values of both leptonic and total width for $\psi'$

- Interference effects are important for $M$ and $\Gamma$ of $\psi(3770)$

- Multiple solutions make difficult $\Gamma_{e^+e^-}$ determination for $\psi(3770)$

- No narrow states found between 1.85 GeV and $J/\psi$

- New $R$ measurements are planned between 2 and 11 GeV