

Signal extraction for exclusive $\psi(2S)/J/\psi(1S)$ in PHP

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- Extraction of (uncorrected) number of events in W bins, 2-prongs, three methods:
 - fit of Gaussian shapes
 - counting of events in mass windows centered around resonances
 - MC templates fractional fit (`root TFracFitter`)
- 4-prongs
- Conclusions/Plans

2PR: Signal extraction: fit parametrisation

- Gaussian shape: $G(x)$ or $g(x) = N \cdot \Delta \cdot \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(x-m)^2}{2\sigma^2}\right)$
where: N – number of events, Δ – mass bin width,
 m – mean value, σ – RMS

- for J/ψ : $N_1 \cdot G_1(x) + N_2 \cdot G_2(x)$

- for ψ' : $N'_1 \cdot g_1(x) + N'_2 \cdot g_2(x)$

- introducing: $N = N_1 + N_2$, $N' = N'_1 + N'_2$, $R = \frac{N'}{N}$

- with additional constrains: $m_1 = m_2$, $m'_1 = m'_2$,

$$\frac{\sigma'_1}{\sigma_1} = \frac{\sigma'_2}{\sigma_2} = \alpha, \quad \xi = \frac{N_1}{N} = \frac{N'_1}{N'}$$

- final formulae:

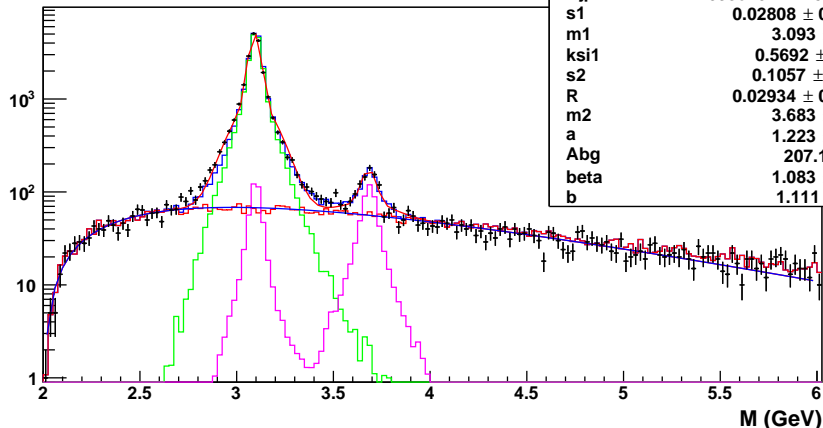
$$F(x) = N \cdot ((\xi \cdot G_1(x) + (1 - \xi) \cdot G_2(x))) + R \cdot (\xi \cdot g_1(x) + (1 - \xi) \cdot g_2(x))) + BG(x)$$

- background function: $BG(x) = A \cdot (x - B)^C \cdot \exp(-D(x - B))$
where A, B, C, D are fit parameters

2PR: Signal fit: ALL W bins (30-180) GeV

mass01_JPSI_PSI2S_ext2: W ALL (30,180)

events

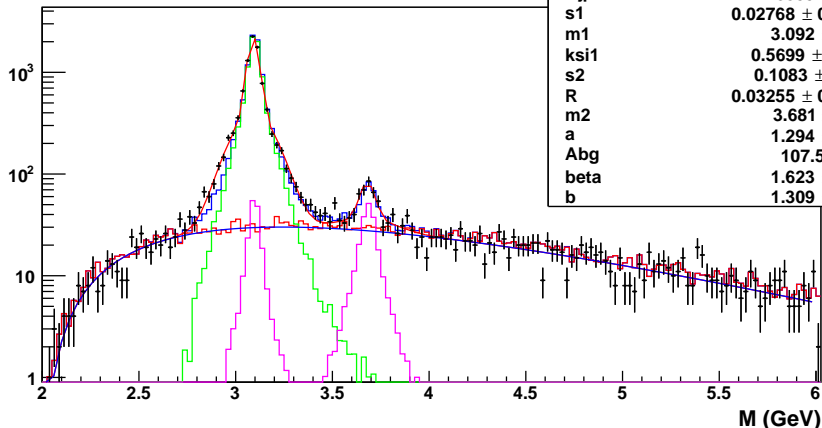


- histograms are DIFFVM and GRAPE (BH) MC
- good description of data by fits and MC

2PR: Signal fit: W1 bin (30-80) GeV

mass01_JPSI_PSI2S_ext2_W1: W(30,80)

events



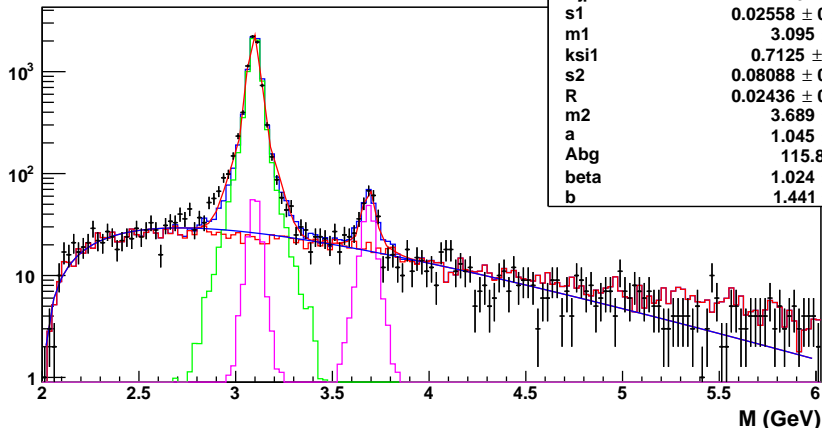
χ^2 / ndf	176.7 / 148
Njpsi	8859 \pm 103.3
s1	0.02768 \pm 0.00066
m1	3.092 \pm 0.000
ksi1	0.5699 \pm 0.0135
s2	0.1083 \pm 0.0031
R	0.03255 \pm 0.00360
m2	3.681 \pm 0.005
a	1.294 \pm 0.158
Abg	107.5 \pm 12.5
beta	1.623 \pm 0.106
b	1.309 \pm 0.079

- histograms are DIFFVM and GRAPE (BH) MC
- good description of data by fits and MC

2PR: Signal fit: W2 bin (80-130) GeV

mass01_JPSI_PSI2S_ext2_W2: W(80,130)

events



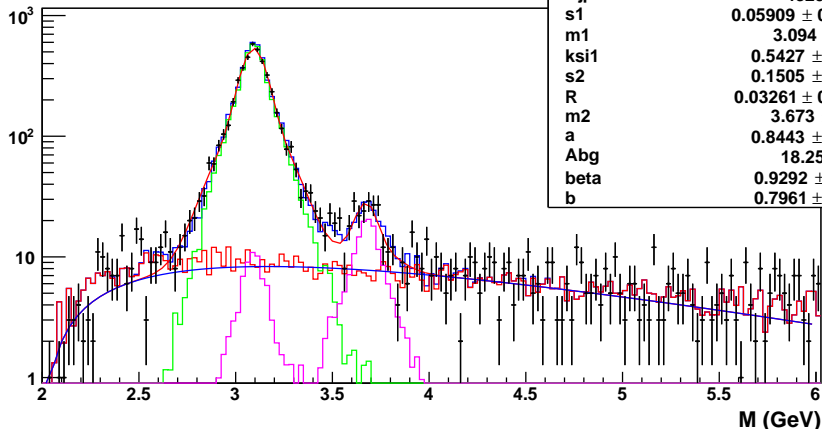
χ^2 / ndf	221.9 / 149
Njpsi	7314 \pm 89.2
s1	0.02558 \pm 0.00060
m1	3.095 \pm 0.000
ksi1	0.7125 \pm 0.0193
s2	0.08088 \pm 0.00420
R	0.02436 \pm 0.00264
m2	3.689 \pm 0.004
a	1.045 \pm 0.127
Abg	115.8 \pm 11.3
beta	1.024 \pm 0.067
b	1.441 \pm 0.068

- histograms are DIFFVM and GRAPE (BH) MC
- good description of data by fits and MC
- BH MC differs from BG fit for high mass

2PR: Signal fit: W3 bin (130-180) GeV

mass01_JPSI_PSI2S_ext2_W3: W(130,180)

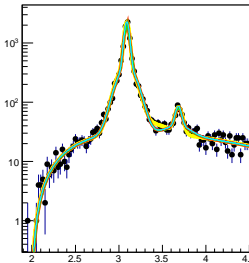
events



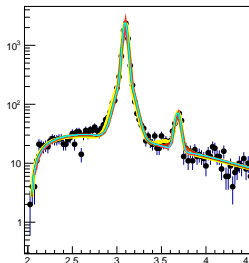
- histograms are DIFFVM and GRAPE (BH) MC
- good description of data by fits and MC
- BH MC differs from BG fit for low mass

Double Gaussian mass fits: systematics checks

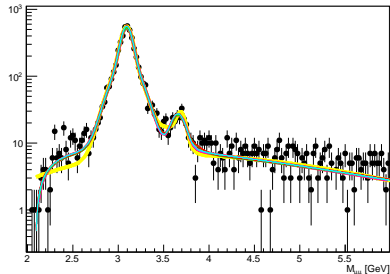
$\mu+\mu^-$ inv mass. $30 < W < 80$



$\mu+\mu^-$ inv mass. $80 < W < 130$



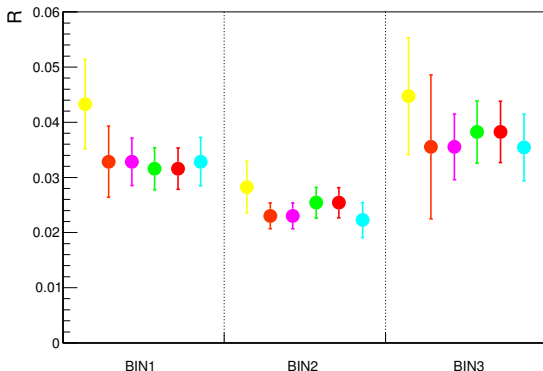
$\mu+\mu^-$ inv mass. $130 < W < 180$



- various fit schemes were compared:
 - relaxing mass constrains: $m_1 \neq m_2$, $m'_1 \neq m'_2$, (yellow curve)
 - no constrains on $\alpha = \frac{\sigma'_1}{\sigma_1} = \frac{\sigma'_2}{\sigma_2}$, or $\xi = \frac{N_1}{N} = \frac{N'_1}{N'}$, etc.

(PLOTS BY MA)

Mass fits: systematics checks: summary



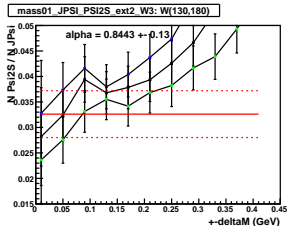
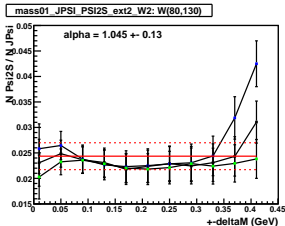
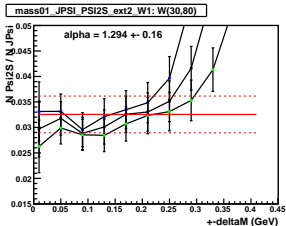
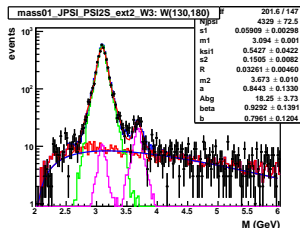
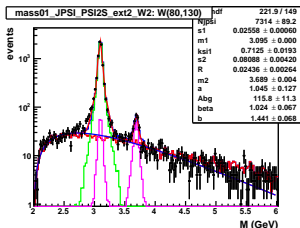
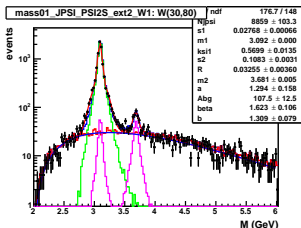
- $R = \frac{N'}{N}$ values in W bins, various fit schemes were compared:
relaxing mass constrains: $m_1 \neq m_2$, $m'_1 \neq m'_2$, (yellow point)
no constrains on $\alpha = \frac{\sigma'_1}{\sigma_1} = \frac{\sigma'_2}{\sigma_2}$, or $\xi = \frac{N_1}{N} = \frac{N'_1}{N'}$, etc.

(PLOTS BY MA)

Independent cross-check of signal extraction in W bins

- event counting w/o Gaussian fits, (only BG fit used for BG subtraction)
- Ratio $R = \frac{N'}{N}$ obtained counting events in mass windows centered around J/ψ and ψ' peaks is plotted as a function of the half window width $\pm\Delta M_{J/\psi}$
- ratio of the windows width $\Delta M_{\psi'}/\Delta M_{J/\psi}$ fixed according to detector resolution obtained from Gaussian fits: $\alpha = \frac{\sigma'_1}{\sigma_1} = \frac{\sigma'_2}{\sigma_2}$
- for comparison red lines are $R \pm err$ values from the Gaussian fits

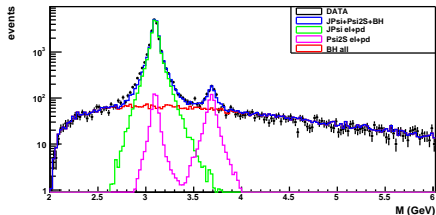
Independent cross-check of signal extraction in W bins



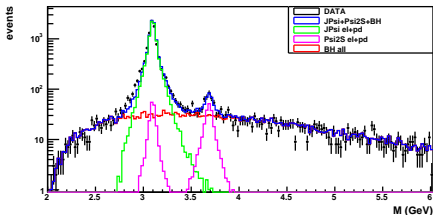
- for comparison **red lines** are $R \pm err$ values from the Gaussian fits
- consistent ratio ($R = \frac{N'}{N}$) and its errors
- ratio R is plotted as a function of the half window width $\Delta M_{\psi'} = \alpha \Delta M_{J/\psi}$

Number of events from MC template fits do DATA

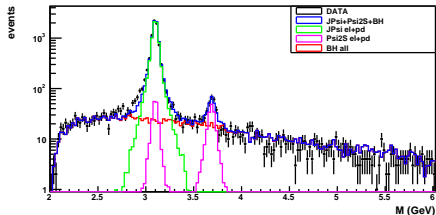
mass01_JPSi_PSi2S_ext2: W ALL (30,180)



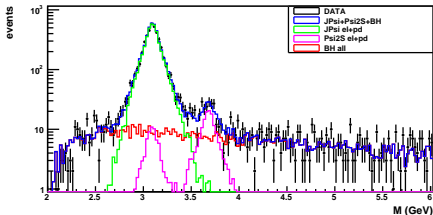
mass01_JPSi_PSi2S_ext2_W1: W (30,80)



mass01_JPSi_PSi2S_ext2_W2: W (80,130)



mass01_JPSi_PSi2S_ext2_W3: W (130,180)



- using `root TFracFitter`
- delivers only number of events (bug in errors calculation for weighted MC)
- (second pink peak from cascade decays of ψ' events)

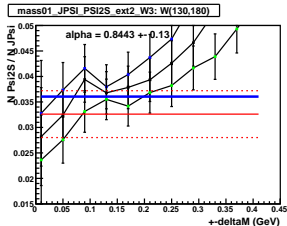
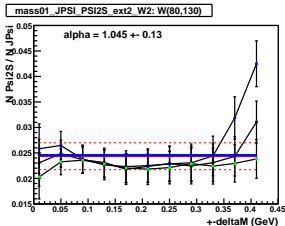
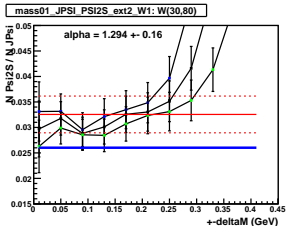
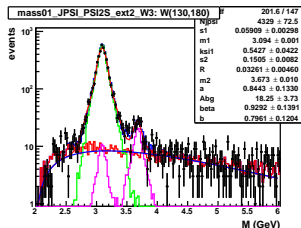
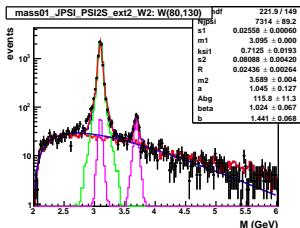
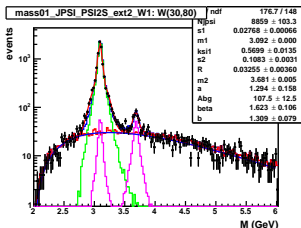
2PR: Number of events: templates fit vs. Gaussian fit

Sheet1

	N_JPSI_temp	N_JPSI_bg	N_JPSI_fit	_err	N_PSI2S_temp	N_PSI2S_fit	_err
ALL	20125.2	440.139	20380	151.2	545.708	598	45.4
W1	8711.88	185.526	8859	103.3	226.704	288.4	33.7
W2	7276.63	182.829	7314	89.2	178.514	186.7	14.4
W3	4327.45	74.3153	4329	72.5	156.017	141.2	20

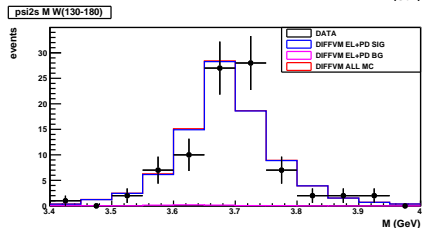
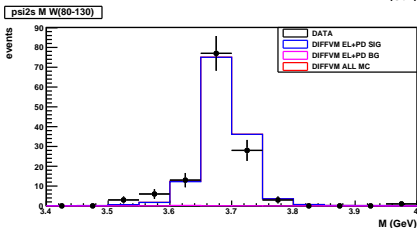
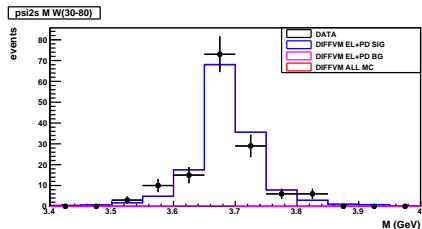
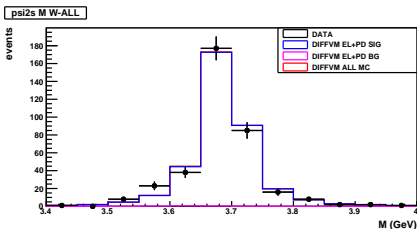
- fractional fitter allows to subtract BG to the J/ψ peak from cascade decays of $\psi' \rightarrow J/\psi + \dots$, $J/\psi \rightarrow \mu^+ + \mu^-$
- all numbers in W1-W3 bins consistent within < 1 sigma
- with exception of $N_{\psi'}$ in W1 bin (~ 1.8 sigma agreement)
 \rightarrow different BG shape from fit and MC template and a bit asymmetric template for main $N_{J/\psi}$ peak (see page no. 5)

R in 2PR: summary of 3 methods



- red lines are $R \pm err$ values from the Gaussian fits
- blue lines are R from MC templates fit ($T_{FracFitter}$)
- points are R from event counting in mass window $\Delta M_{\psi'} = \alpha \Delta M_{J/\psi}$, $\alpha \pm err$

4PR: Number of events



- $M(\mu^+, \mu^-, \pi^+, \pi^-)$
- (almost) background free (see next table): ALL, W1, W2, W3 bins
- good description by DIFFVM MC

Sheet1

	N_psi2s	N_bg	N_bg_err
ALL	361	1.7	0.22
W1	142	0.6	0.16
W2	131	0.4	0.11
W3	88	0.8	0.14

- BG estimated from ALL non $(\mu^+, \mu^-, \pi^+, \pi^-)$ final states of DIFFVM MC like photon conversion from $\psi' \rightarrow (\mu^+, \mu^-, \pi^0, \pi^0)$ final states etc...
- running on inelastic ψ' MC for HERA II (HERWIG generated by Alessandro) delivered exactly 0 events after all selection cuts

Conclusions/Plans:

- 2PR: consistent number of events for J/ψ and ψ' resonances in W bins using 3 different methods
- apply corrections for BR and acceptance for each channel and each data taking period
- compare corrected number of ψ' events for 2PR and 4PR channels
- calculate the final / corrected ratio R in W bins
- systematics
- paper draft (started already)