Search for Z(4430) and other resonances

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B Meeting

http://www-d0.fnal.gov/~rakitin/d0_private/tex/2008.Jan.17.Z4430/tr.pdf

Motivation

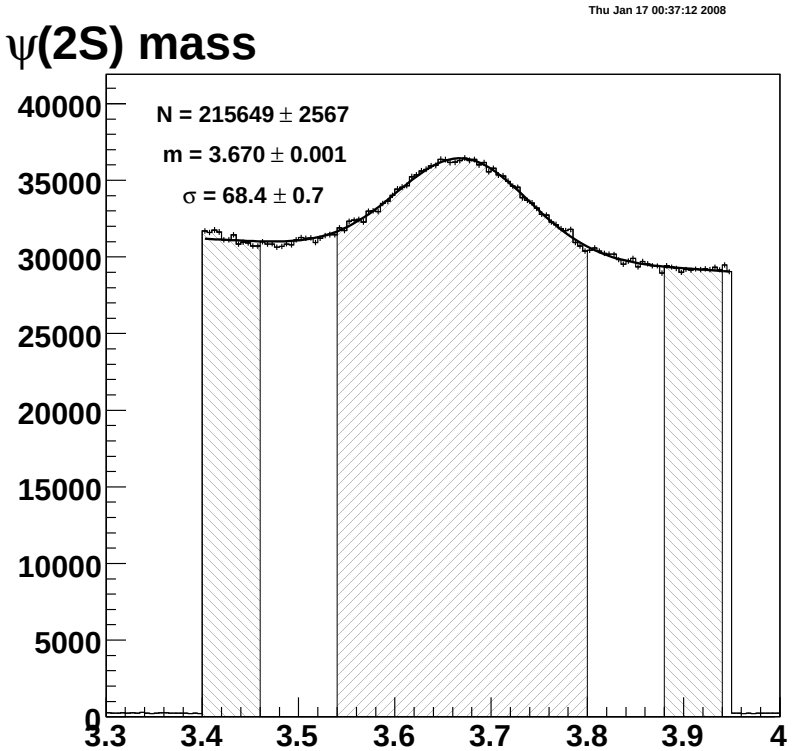
- About a month ago Belle discovered a new particle $Z(4430)$ in decay $B^0 \to Z(4430)K, Z(4430) \to \Psi(2S)\pi, \Psi(2S) \to e^+e^-$
- It is charged so it cannot be regular charmonium $c\bar{c}$
- Candidates:
  - Diquark-antidiquark: $[qq'][\bar{q}\bar{q}']$
  - Deuterium-like molecule: $[q\bar{q}][q'\bar{q}']$
  - Or other exotic stuff...
- We looked for both prompt and non-prompt production of $Z(4430)$ in the channels
  - $Z(4430) \to \Psi(2S)\pi, \Psi(2S) \to \mu^+\mu^-$ (3 tracks)
  - $Z(4430) \to \Psi(2S)\pi, \Psi(2S) \to J/\psi\pi^+\pi^-, J/\psi \to \mu^+\mu^-$ (5 tracks)
- The reprocessed di-muon event lists provided by D. Strom include all the pre-shutdown data
- The cuts are optimized by maximizing $S/\sqrt{B}$:
  - Signal from $Z(4430)$ Monte Carlo
  - Background from data sidebands

Monte Carlo

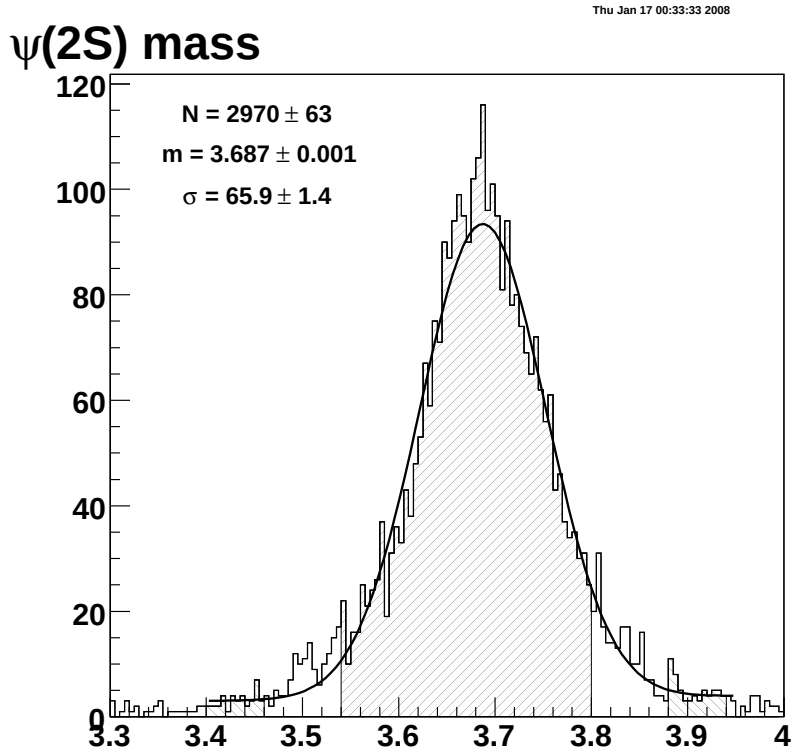
- Belle reported $m(Z) = 4.433 \pm 0.004(\text{stat.}) \pm 0.002(\text{syst.})$ GeV$/c^2$ and $\Gamma(Z) = 45^{+18}_{-13}(\text{stat.})^{+30}_{-13}(\text{syst.})$
- We changed mass and width of $B^{\pm}$ to these values in Pythia and EvtGen control files
- Changed EvtGen decay file as follows:
  - Force $B^{\pm} \to \psi(2S)\pi^{\pm}$ (prompt production of $B^{\pm}$)
  - Force 50% $\psi(2S) \to \mu^+\mu^-$
  - Force the other 50% $\psi(2S) \to J/\psi\pi^+\pi^-, J/\psi \to \mu^+\mu^-$
  - Force $B^0 \to B^{\pm}K$ (non-prompt production of $B^{\pm}$)
  - RCP file requires presence of $B^{\pm}$ and two muons
- This way we can use the same MC sample for all searches provided that each search selects only its own events
- Generated 54K events (on clued0)
- Drawback: forgot to change mass/width in d0sim control file, only noticed two days ago, hope it doesn't matter

$\psi(2S) \to \mu^+\mu^-$

Data



Monte Carlo



$\psi(2S) + \pi$

- We add 3rd track (with π mass) to $\psi(2S)$
- Mass distributions are fitted with single Gaussian plus exponential background using binned likelihood
- The significance of the peak is determined as $\sqrt{-2\log(L_0/L_{max})}$, where L_0 is likelihood from fit with exponent only, and L_{max} - from exponent with Gaussian
- $S/\sqrt{B}$ value is also quoted

List of cuts for 3-track signature

$$Z(4430) \to \Psi(2S)\pi, \Psi(2S) \to \mu^+\mu^-$$

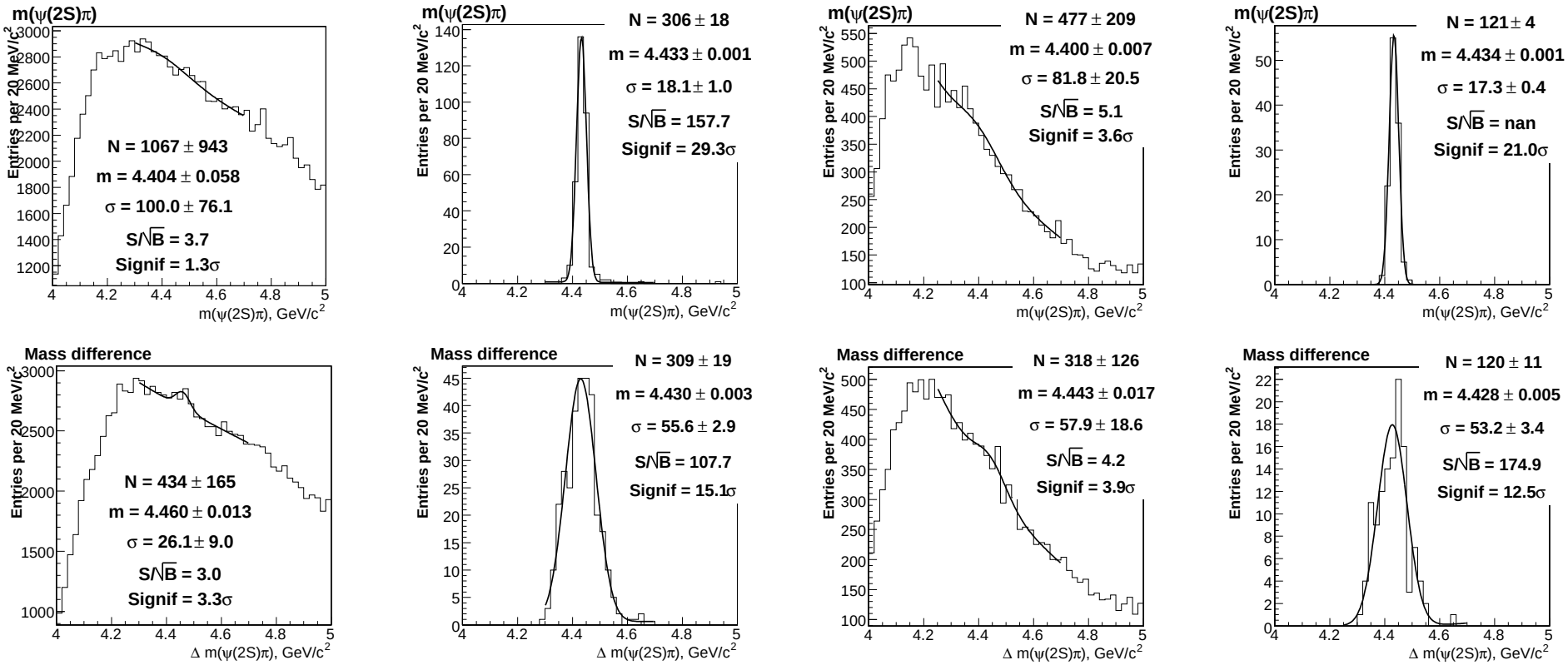
- $p_t(J/\psi) > 6$ GeV$/c$
- $p_t(Z) > 7$ GeV$/c$
- $\Delta R(\pi) < 0.7$
- $p_t(\pi) > 1.5$ GeV$/c$
- $iso(Z) > 0.7$

- $\chi^2(Z_{\text{vertex}}) < 9$
- $p_t(\mu_1) > 2$ GeV$/c$
- $p_t(\mu_2) > 2$ GeV$/c$
- $N_{SMT}(\pi) >= 2$

- To look at non-prompt separately: $L_{xy} > 0 \;\; \&\& \;\; L_{xy}/\sigma(L_{xy}) > 5$

$\psi(2S) + \pi$

Data | Monte Carlo | Data (non-prompt) | MC (non-prompt)

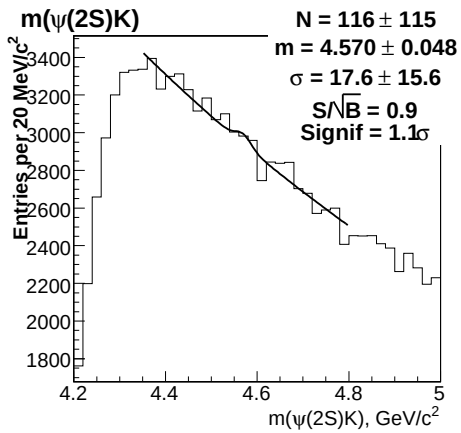


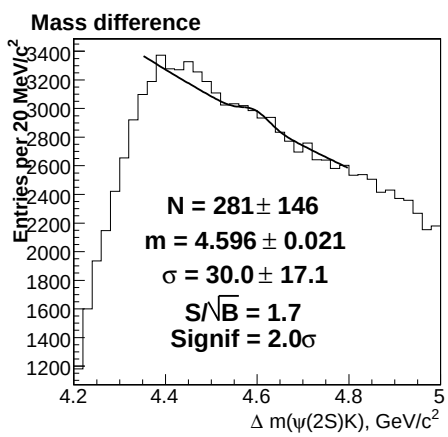
- Cross-check by looking at both mass $m(\psi(2S)\pi)$ and mass difference $m(\psi(2S)\pi) - m(J/\psi\pi^+\pi^-) + m_{PDG}(\psi(2S))$ (helps diminish vertex errors in data)
- Not clear why MC mass peak is so narrow
- Not clear why MC mass difference peak is wider
- Main conclusion: $Z(4430)$ is not seen

$\psi(2S) + K$

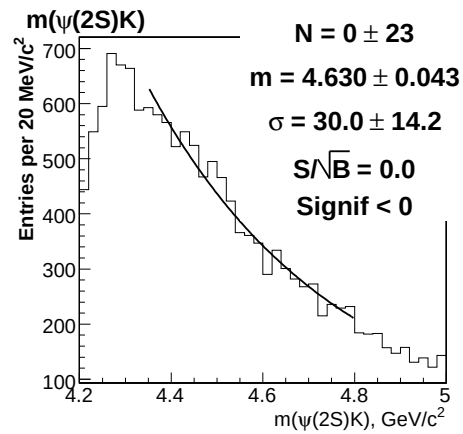
- Assign 3rd track with K mass
- Keep the same cuts
- One would expect to see reflection of $\psi(2S) + \pi$ system at around 4.6 GeV$/c^2$

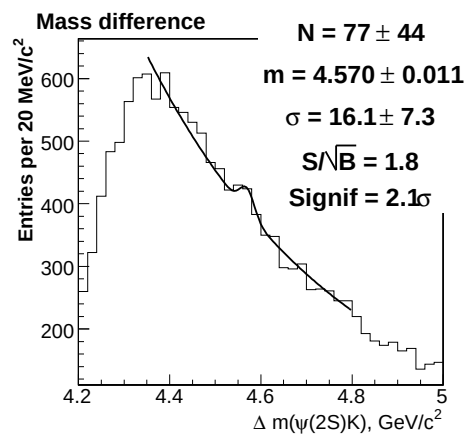
Data





Data (non-prompt)

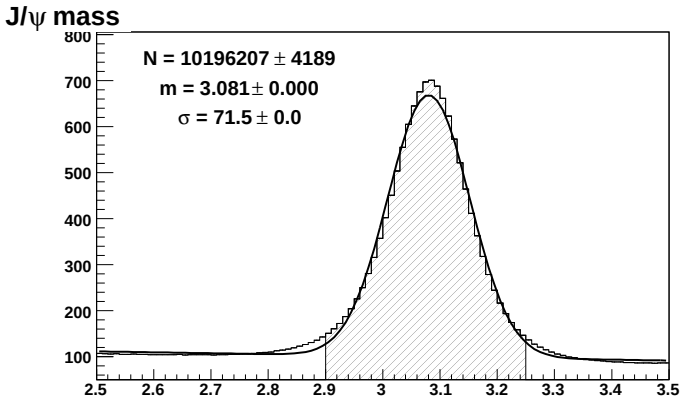


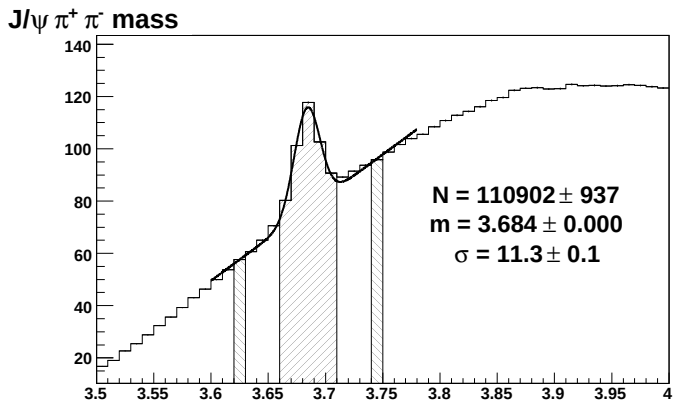


No reflection seen

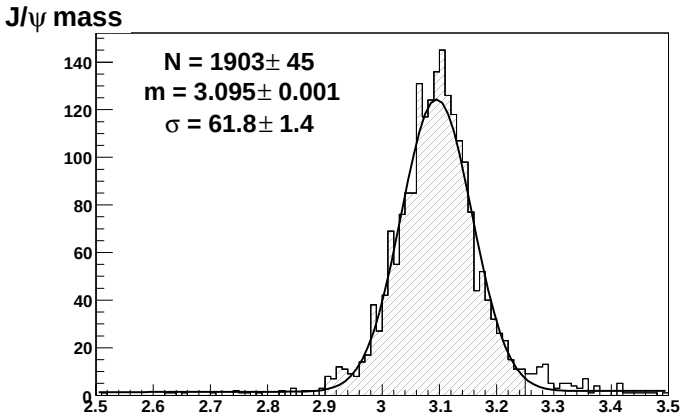
$\psi(2S) \to J/\psi\pi^+\pi^-$

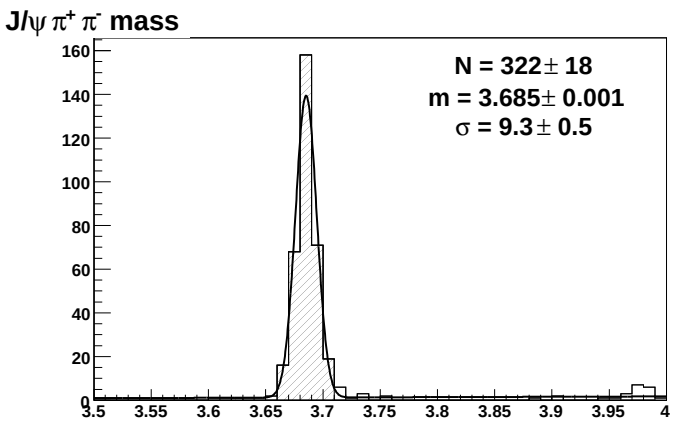
Data





Monte Carlo





Rec. eff. is smaller than for 3-track signature $\Longrightarrow$

- Cannot really optimize cuts on low-statistics MC
- Need to generate much more MC
- Use un-optimized cuts for the time being

List of cuts for 5-track signature

$$Z(4430) \to \Psi(2S)\pi, \Psi(2S) \to J/\psi\pi^+\pi^-, J/\psi \to \mu^+\mu^-$$

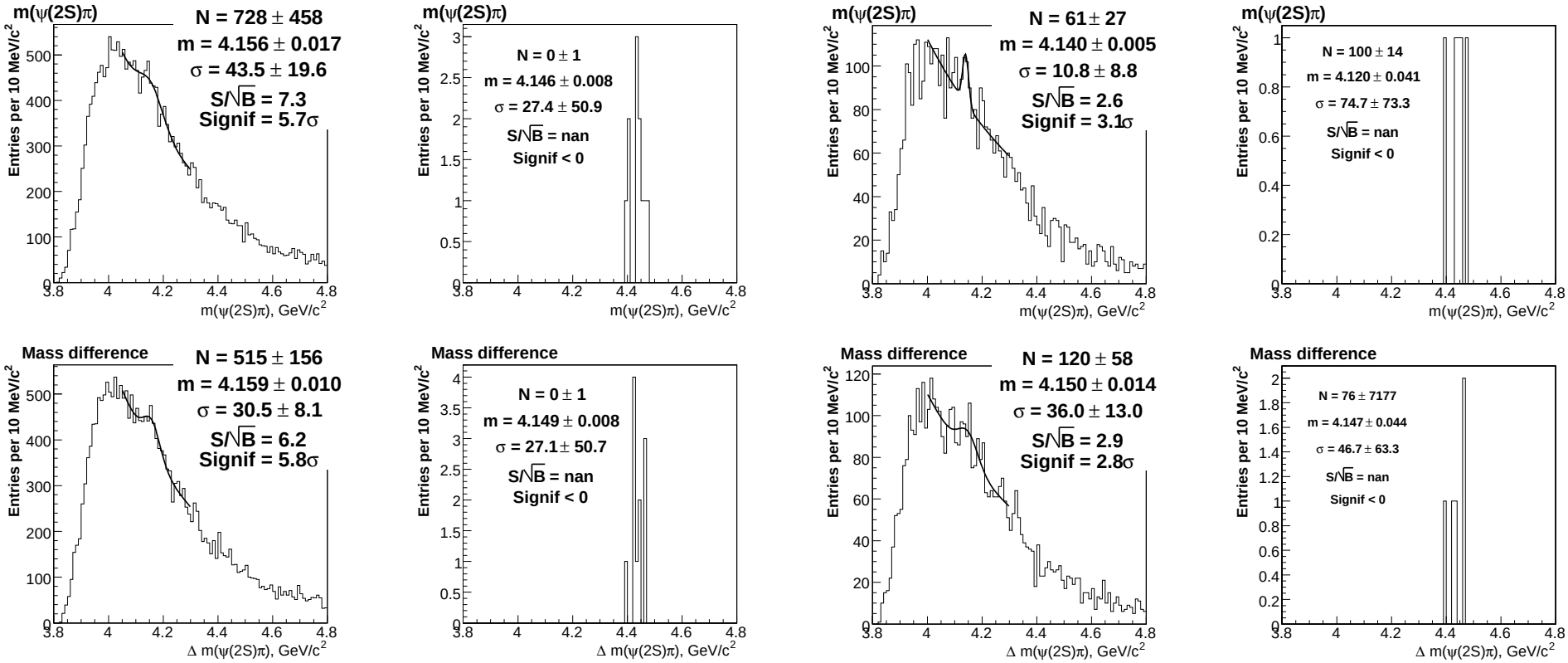
- $p_t(J/\psi) > 5$ GeV$/c$
- $p_t(\pi^+) > 0.7$ GeV$/c$
- $p_t(\pi^-) > 0.7$ GeV$/c$
- $p_t(\pi_3) > 1$ GeV$/c$
- $\Delta R(\pi^+) < 0.5$
- $\Delta R(\pi^-) < 0.5$
- $\Delta R(\pi_3) < 0.4$

- $\cos\theta^* < 0.7$
- $m(\pi^+\pi^-) < 0.52$ GeV$/c^2$
- $\chi^2(Z_{\text{vertex}}) < 16$
- $N_{SMT}(\pi^+) >= 2$
- $N_{SMT}(\pi^-) >= 2$
- $N_{SMT}(\pi_3) >= 2$

- To look at non-prompt separately: $L_{xy} > 0 \;\; \&\& \;\; L_{xy}/\sigma(L_{xy}) > 5$

$\psi(2S) + \pi$

Data | Monte Carlo | Data (non-prompt) | MC (non-prompt)

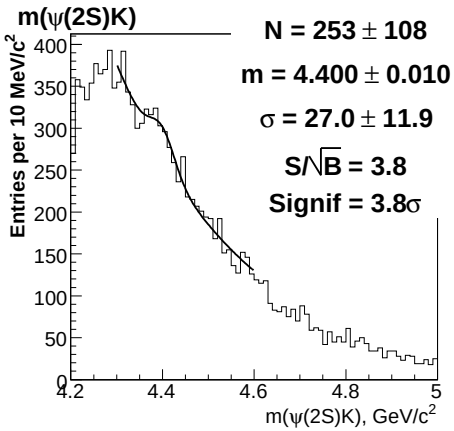


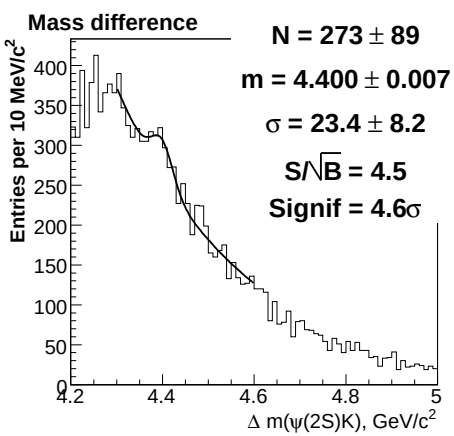
- No $Z(4430)$ is seen
- Something else is seen around 4.160 GeV$/c^2$
- Corresponding bumps for non-prompt histograms have low significance

$\psi(2S) + K$

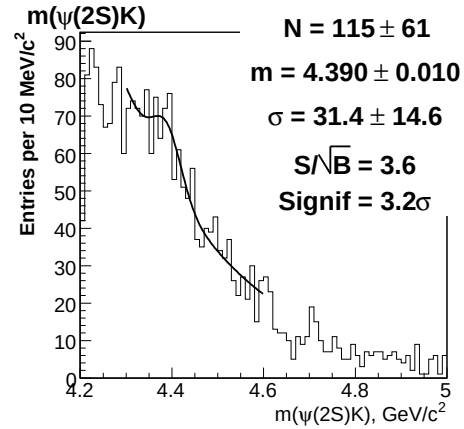
Check for kaon reflection (with almost the same cuts):

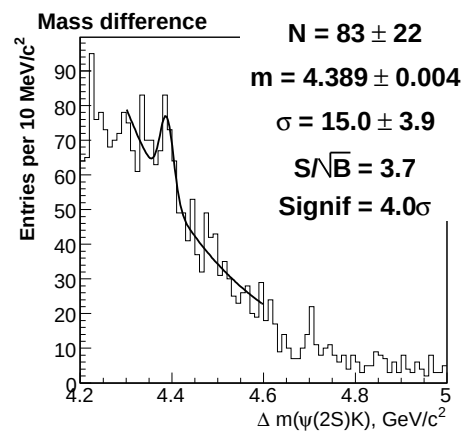
Data





Data (non-prompt)





- The width in kaons is smaller than in pions (compatible with detector resolution)
  $\Longrightarrow$ looks like $\psi(2S)K$ decay with $\psi(2S)\pi$ reflection
- Non-prompt histograms show something...
- There is also a spike at around 4.7 GeV$/c^2$ in non-prompt histograms, but it is too narrow

$\psi(2S) + K$ MC

To optimize cuts for this strange bump on we generated two more Monte Carlo samples:

- First: Set mass and width of $B^{\pm}$ to be 4.400 GeV$/c^2$ and 100 keV$/c^2$ (114K events)
- Second: Set mass and width of $B^{\pm}$ to be 4.400 GeV$/c^2$ and 27 MeV$/c^2$ (87K events)
- In both: Forced $B^{\pm} \to \psi(2S)K^{\pm}$

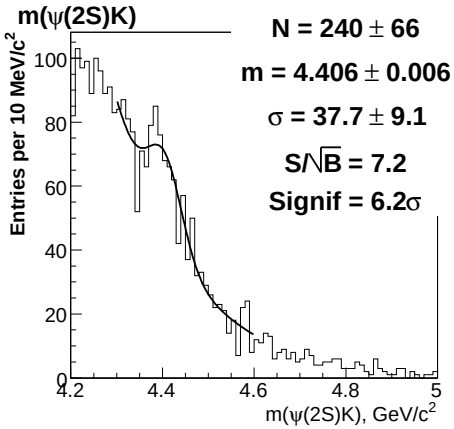
But, unfortunately, the samples are too small to optimize the cuts,

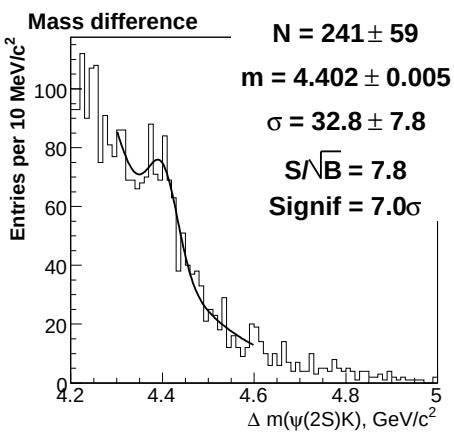
we need factor of 10 more...

Bump vs $p_t(Z)$

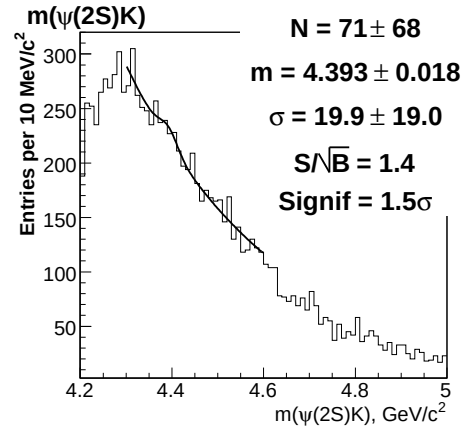
Another cross-check for this bump is to plot it in different $p_t(Z)$ bins:

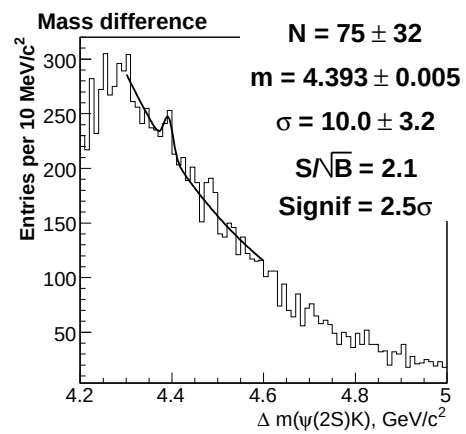
$p_t(Z) < 12$ GeV$/c$





$p_t(Z) > 12$ GeV$/c$





Strange effect with no explanation...

Conclusions

- We looked enhancement around mass 4.430 GeV$/c^2$ in both decay signatures:
  - ☞ $Z(4430) \to \psi(2S)\pi$, $\psi(2S) \to \mu^+\mu^-$
  - ☞ $Z(4430) \to \psi(2S)\pi$, $\psi(2S) \to J/\psi\pi^+\pi^-$, $J/\psi \to \mu^+\mu^-$
- Generated corresponding Monte Carlo and optimized the cuts on it
- In the latter decay signature we observe an enhancement around mass 4.150 GeV$/c^2$ for $\psi(2S)\pi$ and 4.400 GeV$/c^2$ for $\psi(2S)K$. Probably, this is a decay into $\psi(2S)K$ with pion reflection.
- Need much more Monte Carlo to properly optimize the cuts
- We would be grateful for any information on how to successfully generate MC on CAB