

Search for the decays

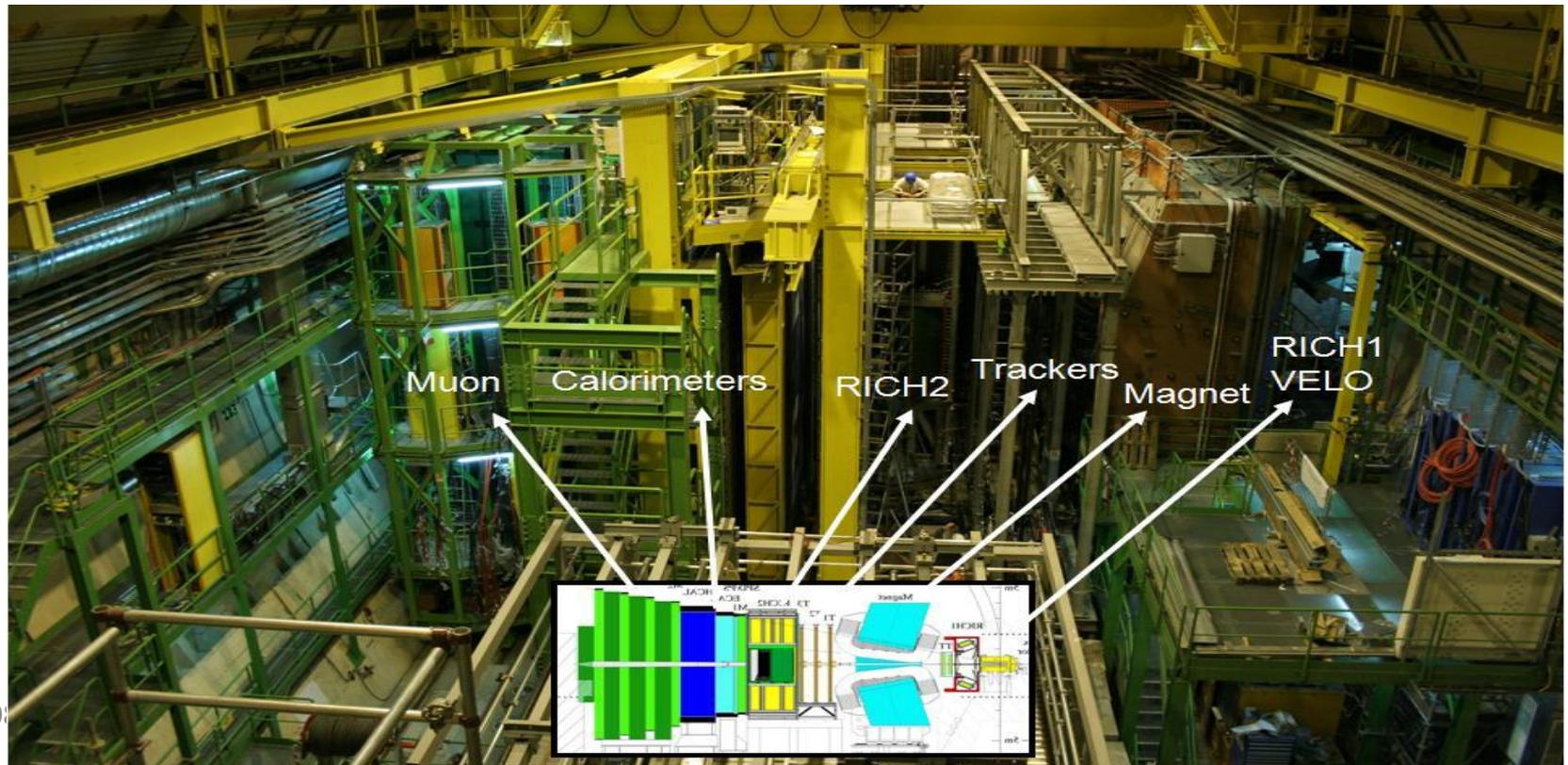
$$B_x^0 \rightarrow J/\psi K_S^0 h^\pm h'^{\mp}$$

LHCb
LHCb

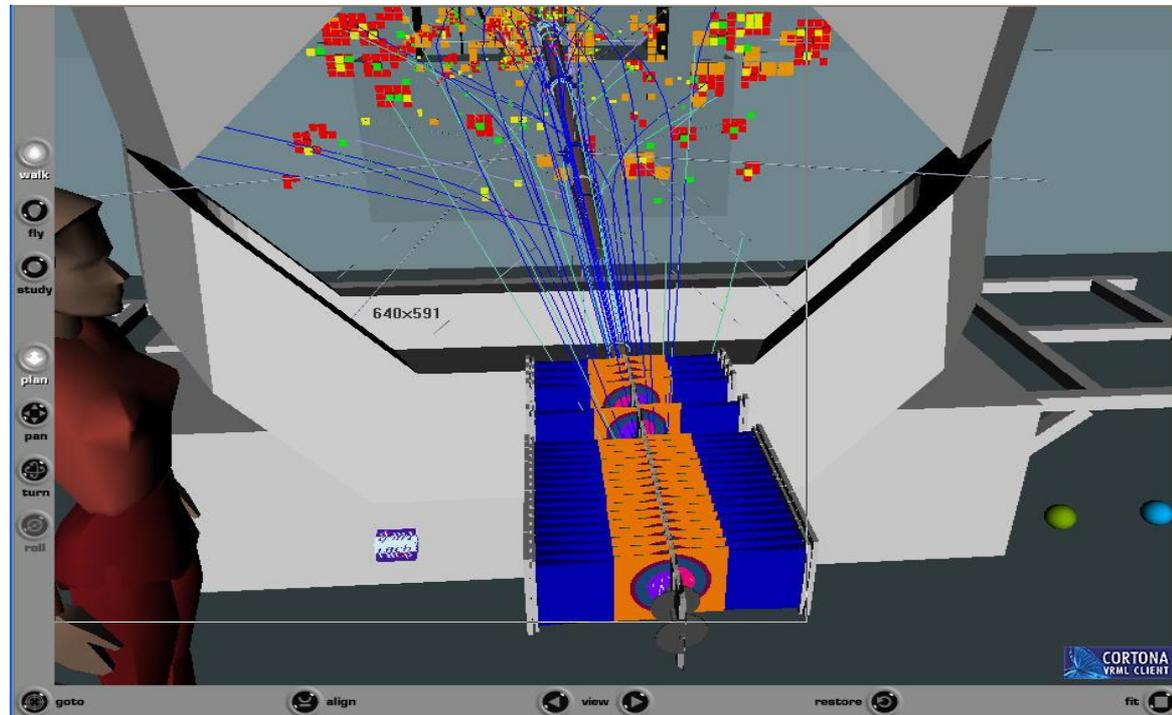
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Matthew M Reid

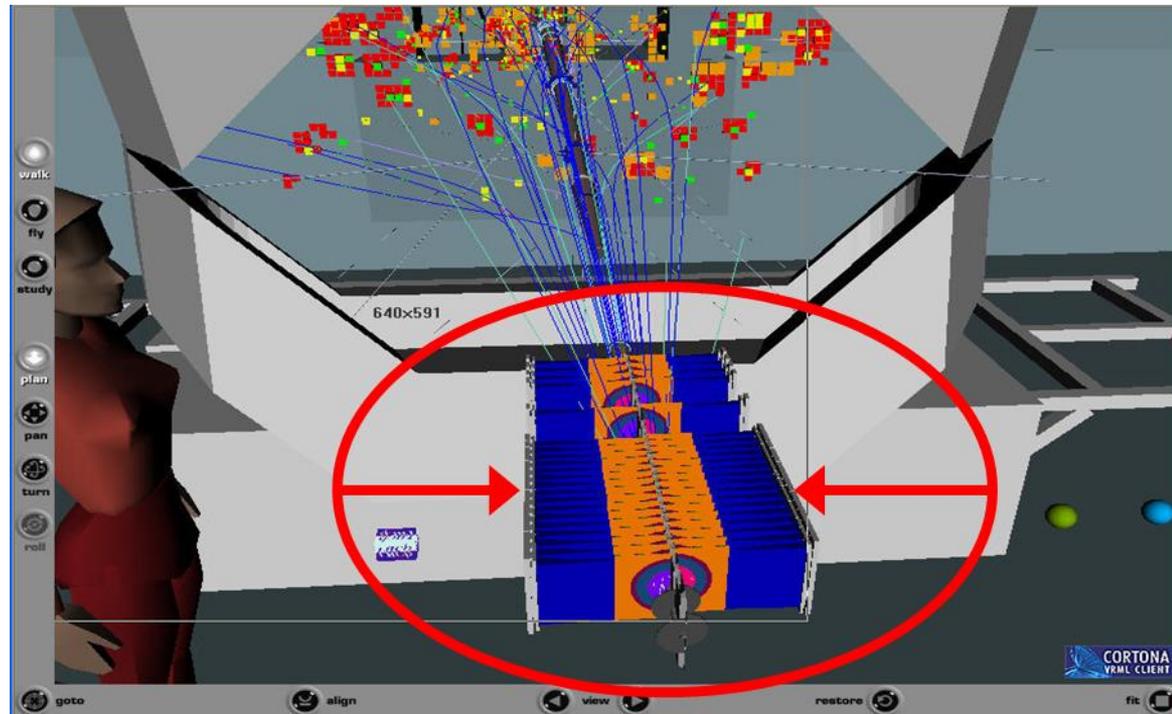
- Multipurpose detector in the forward region $2 < \eta < 5$.
- Built for study of rare decays and precision flavour physics measurements (new physics). LHCb can also do electroweak (W. Barter), top (H. Brown) jets and Higgs.



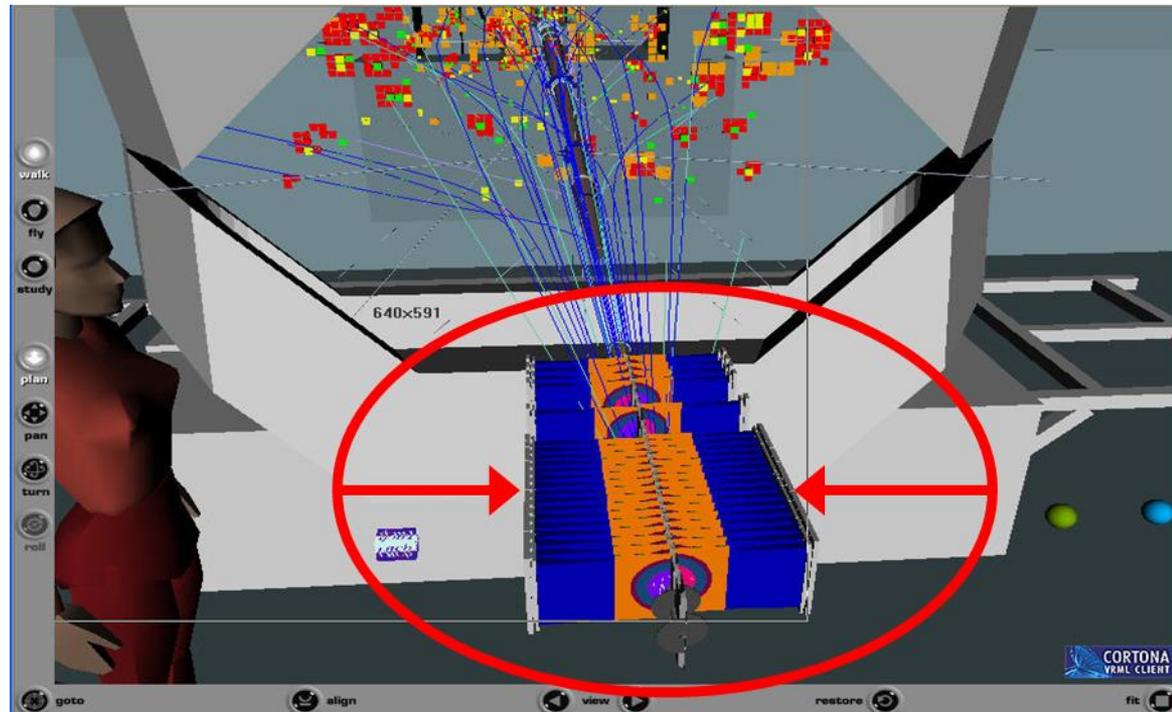
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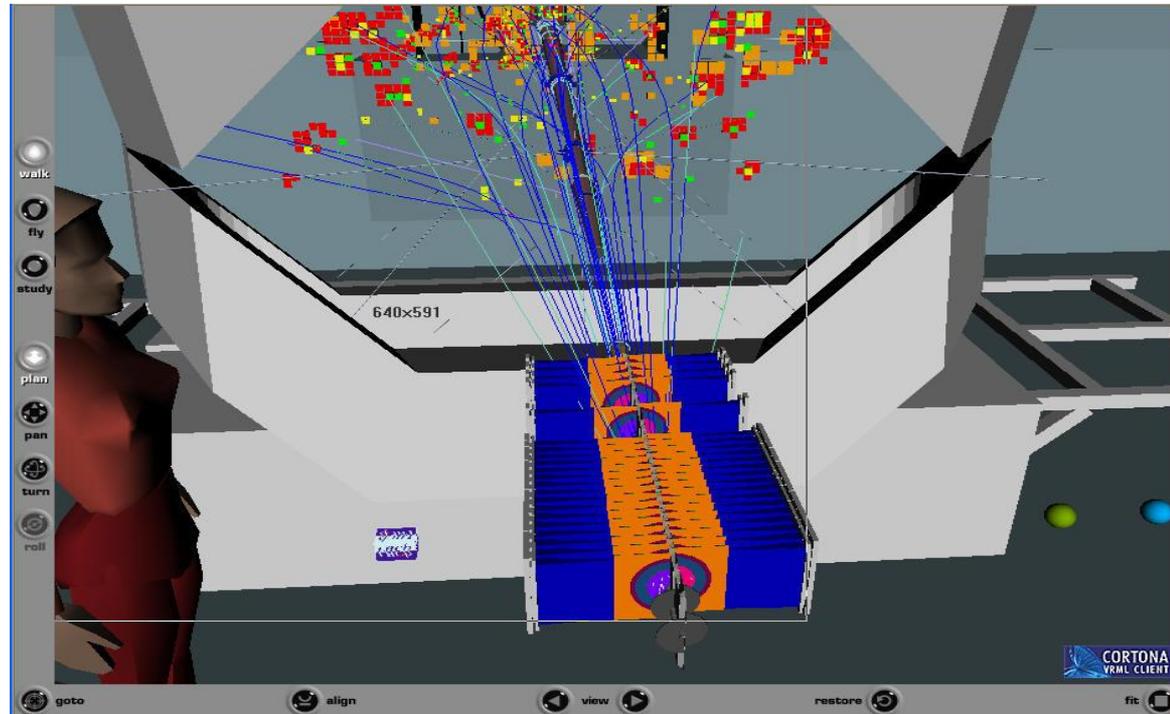
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Primary Vertex (xy) resolution:

$$\sigma_{xy} = 13\mu\text{m}$$



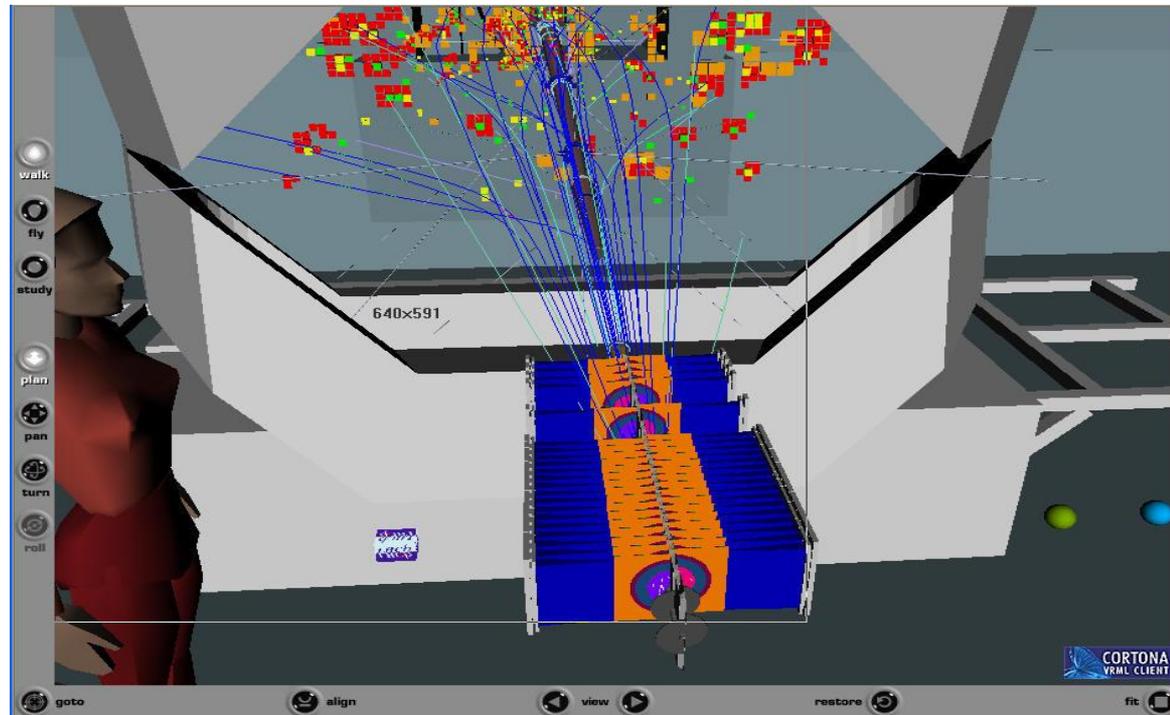
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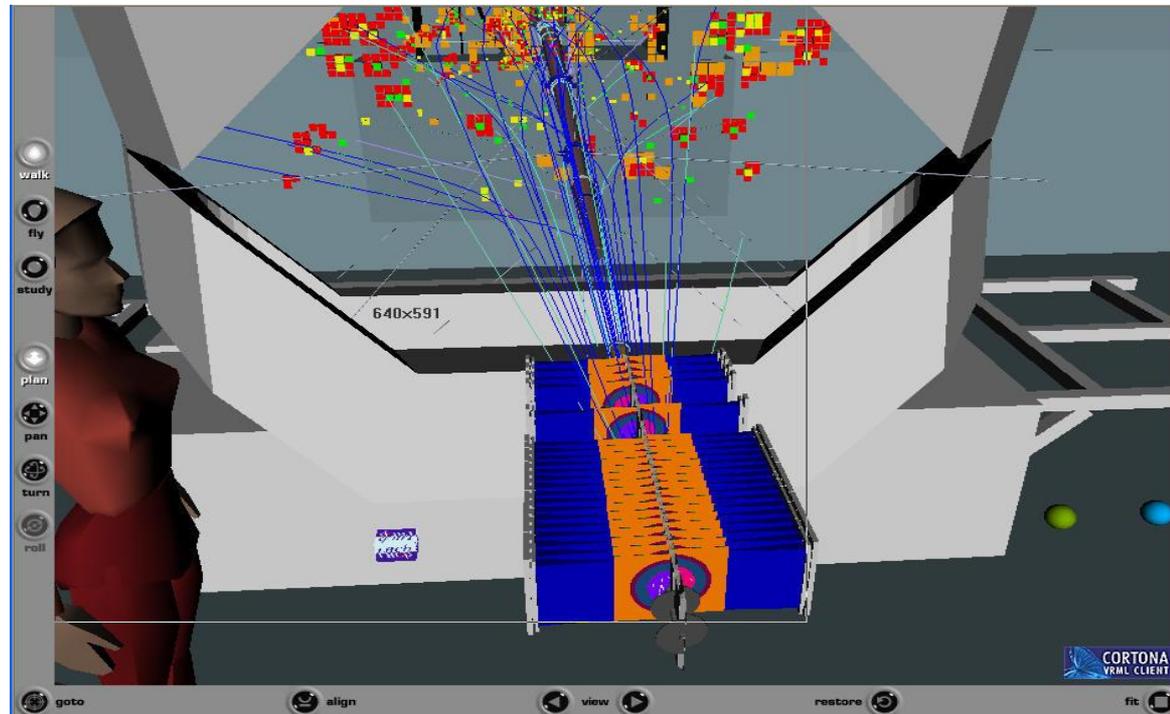
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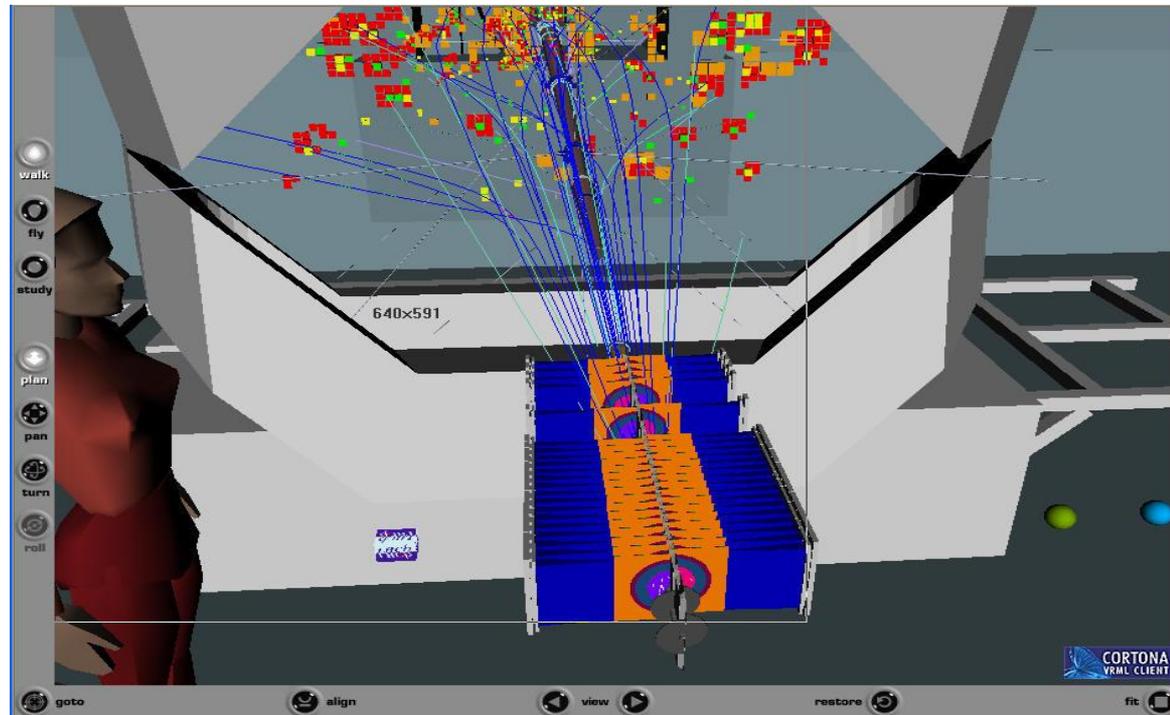
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Particle ID with Ring Imaging
CHerenkov detectors:

$$\sim 96\% \epsilon(K) (< 100\text{GeV})$$

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- **Vertex Locator** determination of displaced secondary vertices away from the proton-proton collision region.
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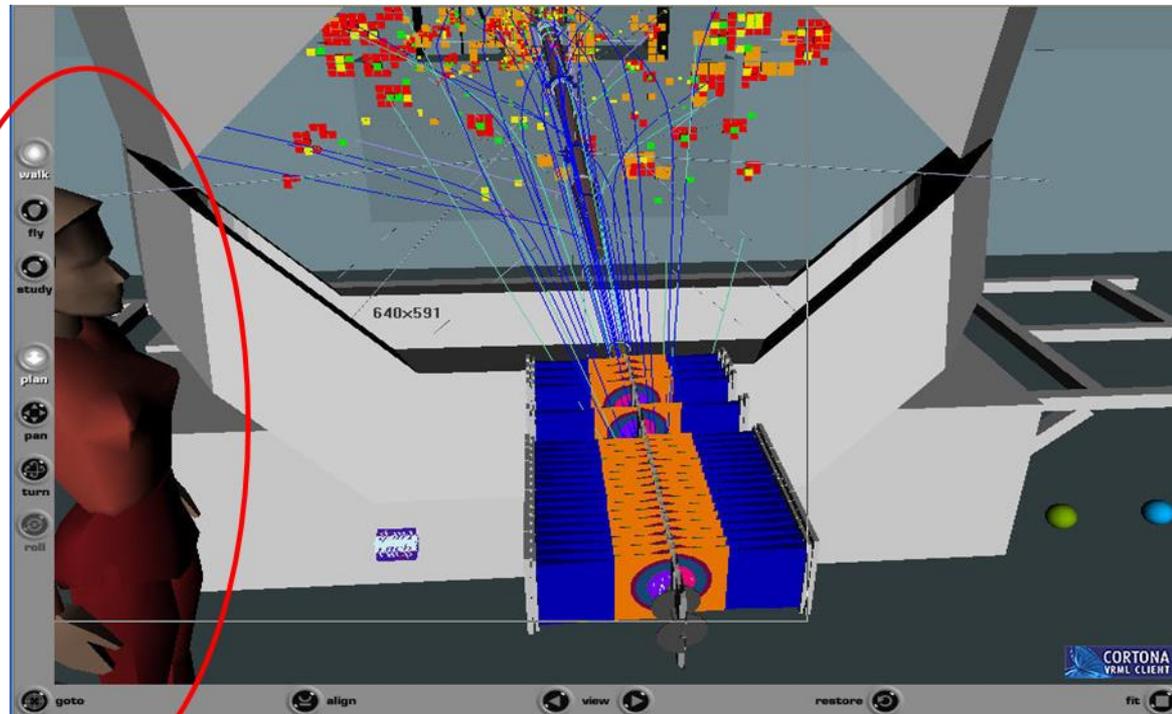
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Motivations



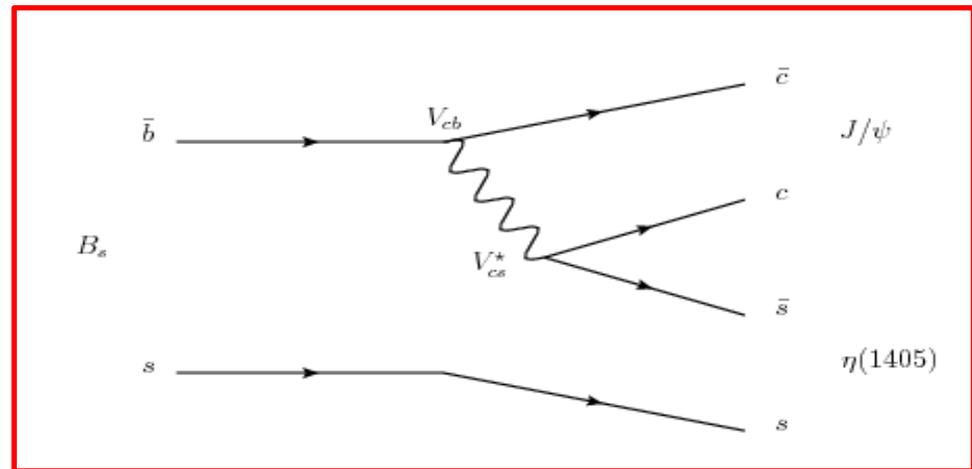
$$B_x^0 \rightarrow J/\psi K_S^0 h^\pm h'^{\mp}$$

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- We are investigating **6 possible modes**.
 - $B_{d,s}^0 \rightarrow J/\psi K_S^0 h' h$ where $h, h' = K, \pi$ (3 B_s and 3 B_d).
- **Very least add to #of B_s decays**, ~ 7 times more decays known for B_d than B_s in PDG.
- **Branching fraction measurements. Modes already observed are:-**
 - $B^0 \rightarrow J/\psi K_S^0 \pi \pi \approx (1.1 \pm 0.4 \pm 0.2) \times 10^{-3}$ (CDF, Belle).
 - $B^0 \rightarrow J/\psi K_S^0 \phi \approx (9.4 \pm 2.6) \times 10^{-5}$ (CLEO, BaBar).
- **Statistically dominated**, latter good for precise B^0 mass measurement, small Q value.
- **Measurement of CP-Violation β_s “could” be possible.**

- Rich underlying resonance structure to $B_s \rightarrow J/\psi K_S K \pi$ mode, help understand pseudo-scalar and pseudo(axial)-vector resonances.

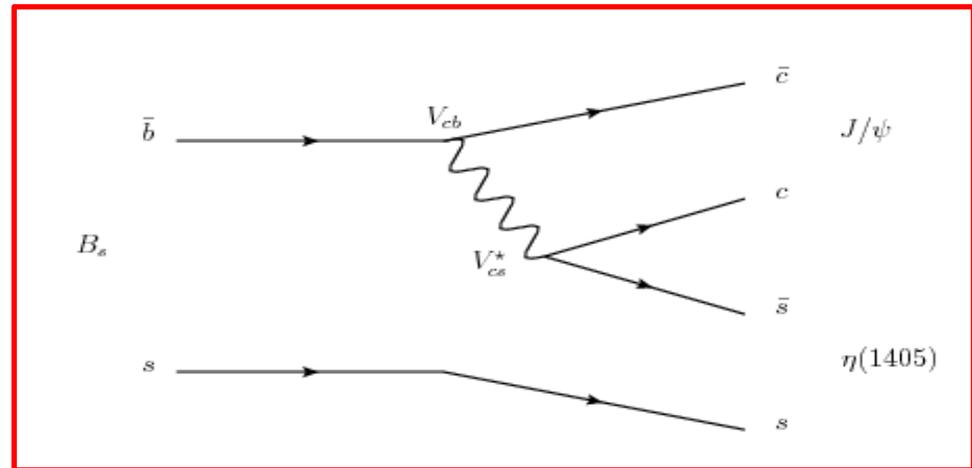
State	$I^G J^{PC}$	Mass (MeV)	Width (MeV)
$a_1(1260)$	$1^- 1^{++}$	1230 ± 40	250 to 600
$f_1(1285)$	$0^+ 1^{++}$	1281.8 ± 0.6	24.3 ± 1.1
$\eta(1405)$	$0^+ 0^{-+}$	1409.8 ± 2.5	51.1 ± 3.4
$f_1(1420)$	$0^+ 1^{++}$	1426.4 ± 0.9	54.9 ± 2.6
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Tree level Feynman diagram: $B_s^0 \rightarrow J/\psi K_S^0 K \pi$

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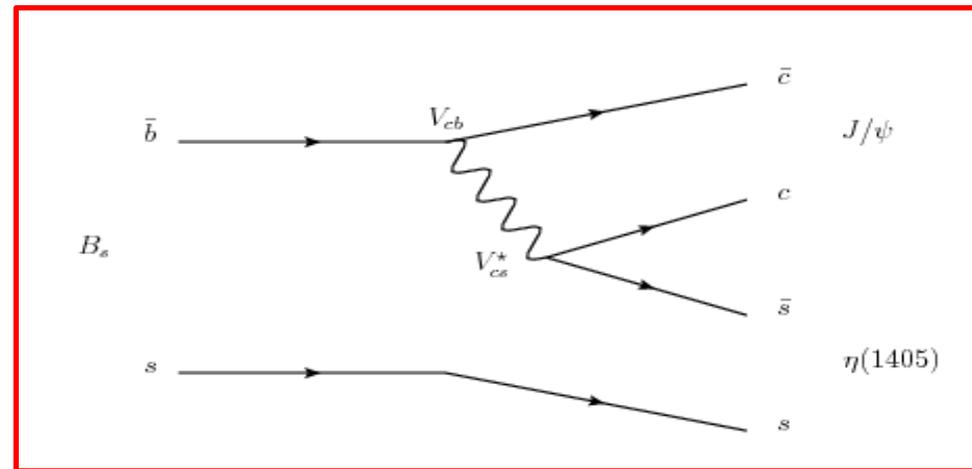


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- Requires time dependent study (**oscillation**). Limited by stats and $B - \bar{B}$ tagging power ($\sim \mathcal{O}(5\%)$).

Branching Fraction Ratio



$$\frac{B(B_d \rightarrow J/\psi K_S \pi\pi)}{B(B_d \rightarrow J/\psi K_S)}$$

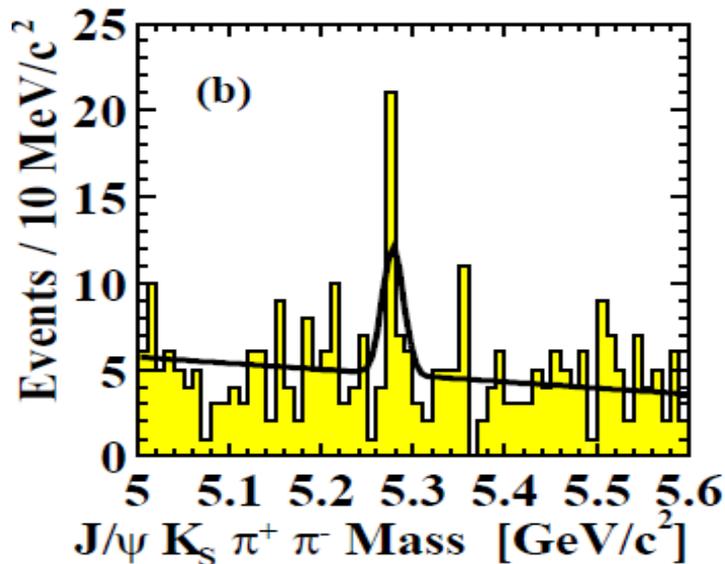
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- We use data collected during 2011 period with an integrated luminosity of $\mathcal{L} = 1.0 \text{ fb}^{-1}$.
- **A rectangular cut based selection is optimised on simulated events for $B^0 \rightarrow J/\psi K_S^0 \pi\pi$. The same selection is applied to $B^0 \rightarrow J/\psi K_S^0$ events (excluding any pion cuts).**
- 12 variables used in our optimisation. E.g. B^0 : p_T , *Vertex χ^2* , K_S^0 : *Impact Parameter χ^2* , π^\pm : *Impact Parameter χ^2*
- We obtain $\frac{\mathcal{B}(B^0 \rightarrow J/\psi K_S^0 \pi\pi)}{\mathcal{B}(B^0 \rightarrow J/\psi K_S^0)}$ using the following formula.

$$\frac{\mathcal{B}(B^0 \rightarrow J/\psi K_S^0 \pi^\pm \pi^\mp)}{\mathcal{B}(B^0 \rightarrow J/\psi K_S^0)} = \frac{\epsilon_{B^0 \rightarrow J/\psi K_S^0}^{\text{Sel.}}}{\epsilon_{B^0 \rightarrow J/\psi K_S^0 \pi^\pm \pi^\mp}^{\text{Sel.}}} \times \boxed{\frac{1}{\epsilon_{B^0 \rightarrow J/\psi K_S^0 \pi^\pm \pi^\mp}^{\text{PID}}} \times \frac{1}{\epsilon_{B^0 \rightarrow J/\psi K_S^0 \pi^\pm \pi^\mp}^{\text{Track}}}} \times \frac{N_{B^0 \rightarrow J/\psi K_S^0 \pi^\pm \pi^\mp}}{N_{B^0 \rightarrow J/\psi K_S^0}}$$

- **CDF:** $B^0 \rightarrow J/\psi K_S^0 \pi^+ \pi^-$

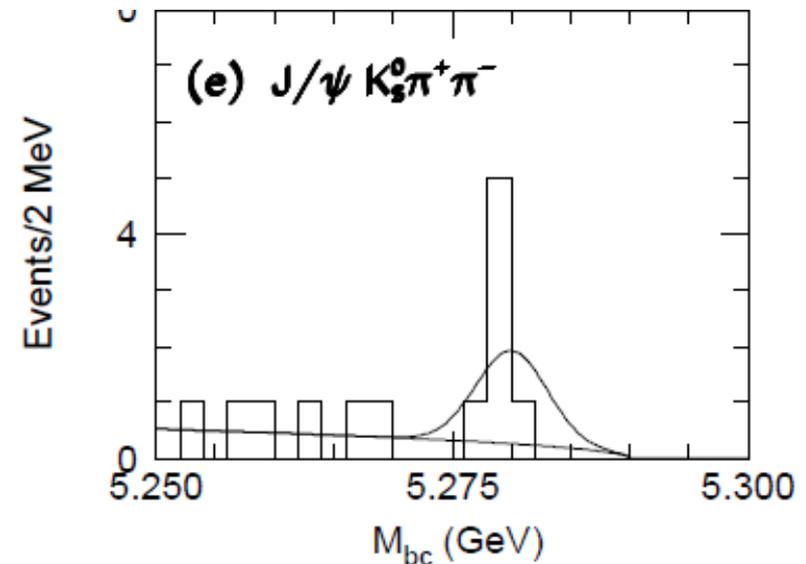
<http://xxx.lanl.gov/pdf/hep-ex/0108022v1.pdf>



- **3.3 σ evidence** observing **39 evts.**

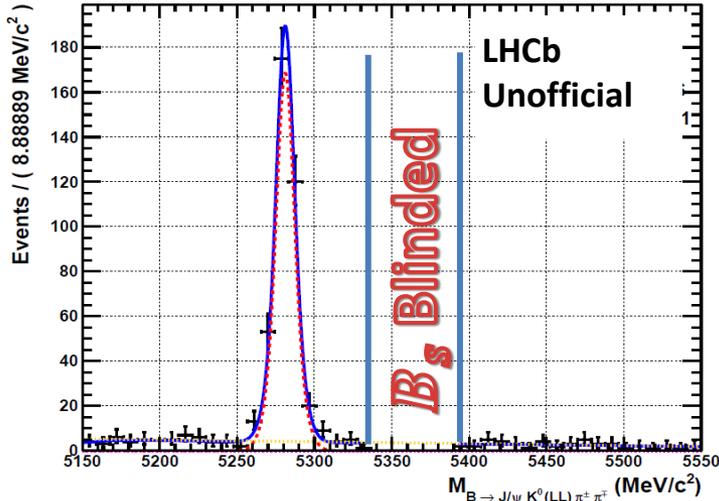
- **Belle:** $B^0 \rightarrow J/\psi K_1(1270)^0$

<http://arxiv.org/pdf/hep-ex/0105014.pdf>

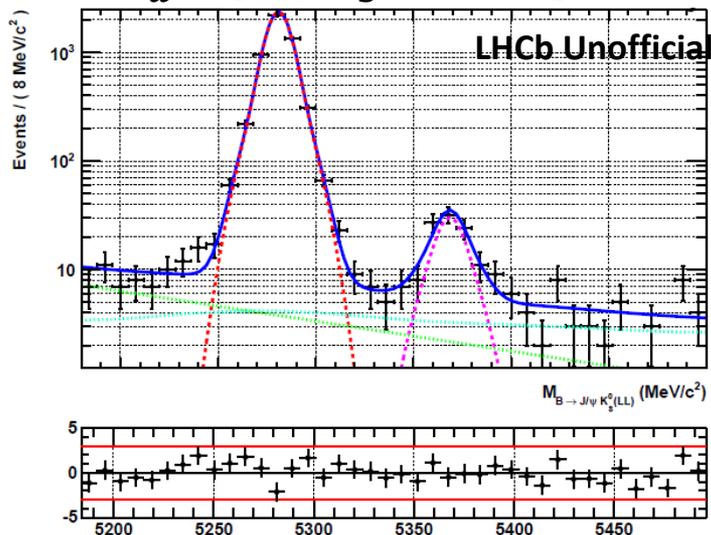


- **Observed 6.2 evts** to our mode $B^0 \rightarrow J/\psi K_S^0 \pi^+ \pi^-$.

$B_d^0 \rightarrow J/\psi K_S^0(LL)\pi\pi$



$B_d^0 \rightarrow J/\psi K_S^0(LL)$ (Log scale)



- We have two data samples, one where K_S^0 's are reconstructed in the VELO, $K_S^0(LL)$ and the other they are reconstructed downstream of magnet, $K_S^0(DD)$.

	$B_d^0 \rightarrow J/\psi K_S^0$		$B_d^0 \rightarrow J/\psi K_S^0 \pi \pi$	
Parameter	$K_S^0(LL)$	$K_S^0(DD)$	$K_S^0(LL)$	$K_S^0(DD)$
$M_{B^0}(\text{MeV}/c^2)$	5281.0 ± 0.11	5281.6 ± 0.09	5281.2 ± 0.38	5281.5 ± 0.31
$\sigma_1(\text{MeV}/c^2)$	5.80 ± 0.22	7.53 ± 0.16	5.17 ± 0.38	6.07 ± 0.40
$\sigma_2(\text{MeV}/c^2)$	11.17	18.14	8.56	15.42
B^0 Yield	5116.6 ± 72.3	10091 ± 106	363.3 ± 19.8	720.18 ± 29.4

- **23 σ statistical confirmation** of $B_d^0 \rightarrow J/\psi K_S^0 \pi \pi$ decay mode.

Decay	Event Yield
$B_d^0 \rightarrow J/\psi K_S^0 \pi \pi$	1083
$B_d^0 \rightarrow J/\psi K_S^0$	15207

- **We have a factor 10 statistics from the $K_S^0(LL)$ alone.** Not finalised, but no large deviation dominated by the fit to data.

$$B(B_d^0 \rightarrow J/\psi K_S^0 \pi \pi) = (XX \pm 2.9(stat) \pm 2.7(sys)) \times 10^{-5}$$

$$\text{PDG: } B(B_d^0 \rightarrow J/\psi K_S^0 \pi \pi) = (52 \pm 33 \pm 15) \times 10^{-5}$$

- **Systematics to be revised and will come down. New larger MC sample. Dominant was systematic PID 5%.**

- First milestone measurement of $B \left(\frac{B_{d \rightarrow J/\psi K_S^0 \pi \pi}}{B_{d \rightarrow J/\psi K_S^0}} \right)$ done. **Better statistical precision.**
- Work on going to measure other 5 decay modes. Results coming soon.
- We can use $B_d \rightarrow J/\psi K_S^0 \pi \pi$ mode as a control channel to optimise a selection from data for other modes as **similar topology.**
- Lots of physics to be investigated within these modes.



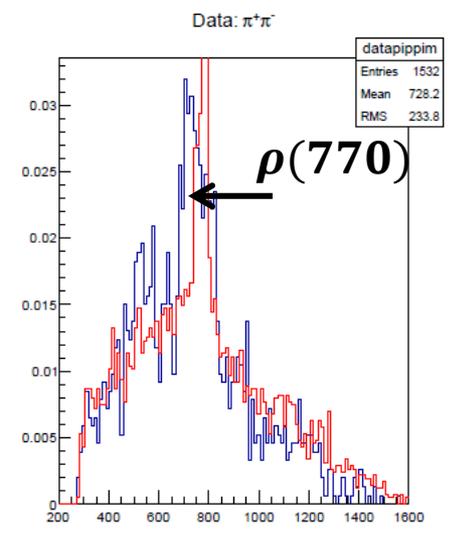
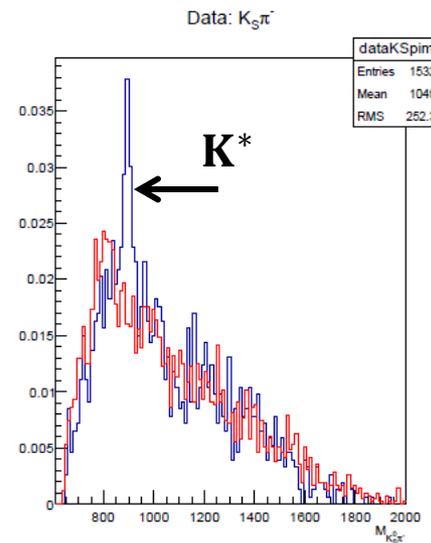
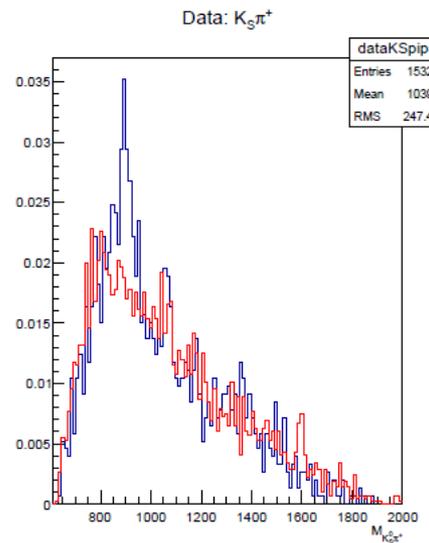
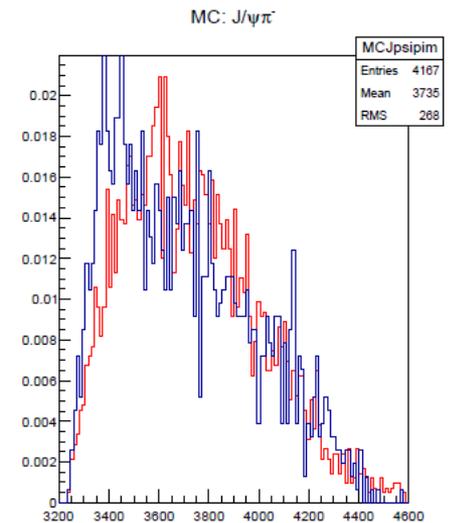
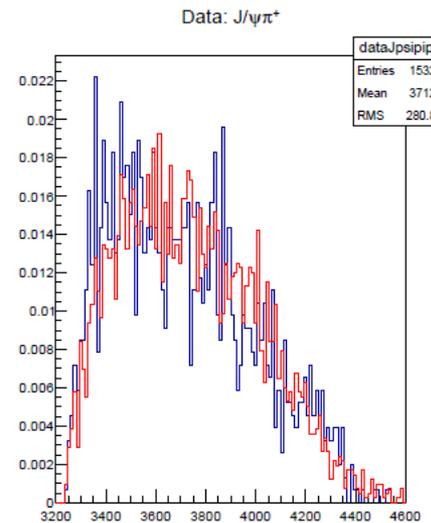
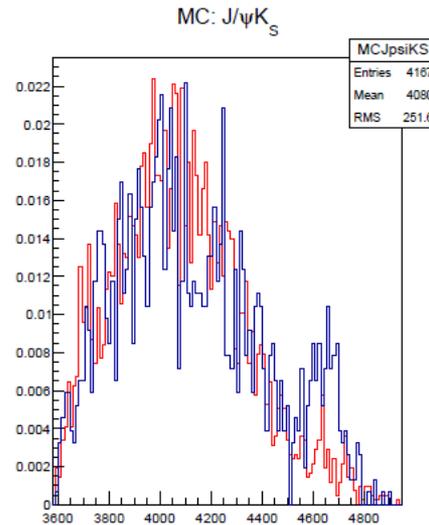
Backup

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$$B_d^0 \rightarrow J/\psi K_S^0 \pi \pi$$

- Two body invariant mass combination

- MC, Data

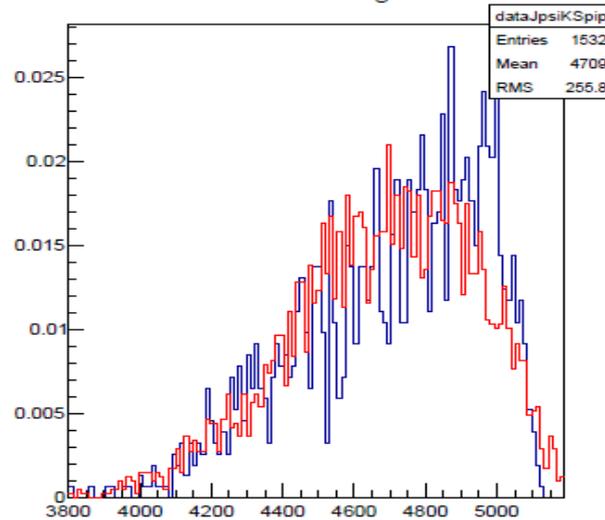


Meson	Current	J^P
Scalar	$\bar{\psi}\psi$	0^+
Pseudoscalar	$\bar{\psi}\gamma^5\psi$	0^-
Vector	$\bar{\psi}\gamma^\mu\psi$	1^-
Pseudovector	$\bar{\psi}\gamma^\mu\gamma^5\psi$	1^+

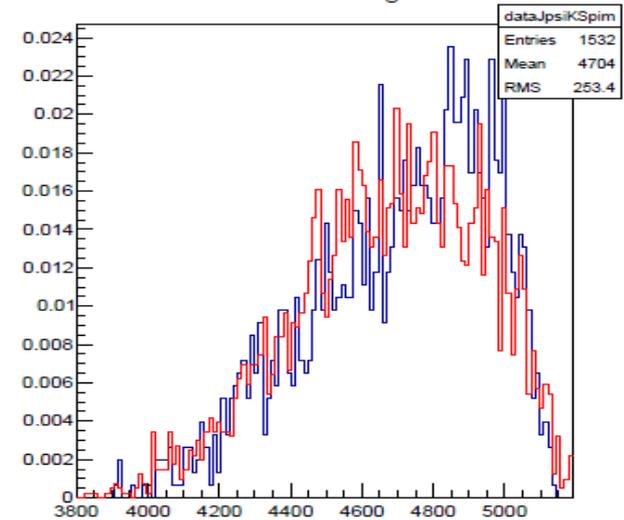
$$B_d^0 \rightarrow J/\psi K_S^0 \pi^+ \pi^-$$

- Three body invariant mass combinations
- MC, Data

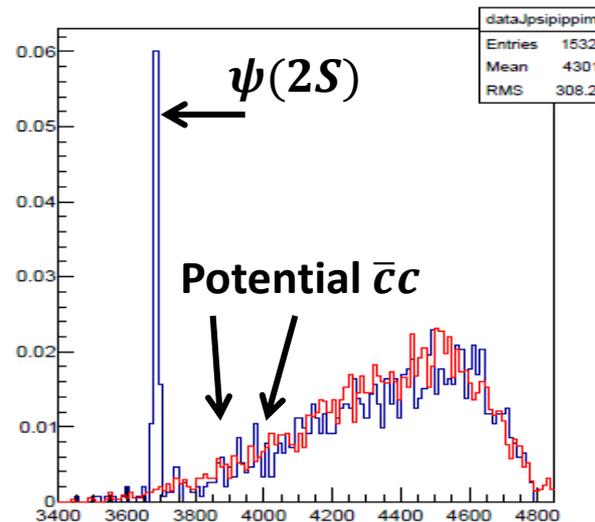
Data: $J/\psi K_S^+ \pi^-$



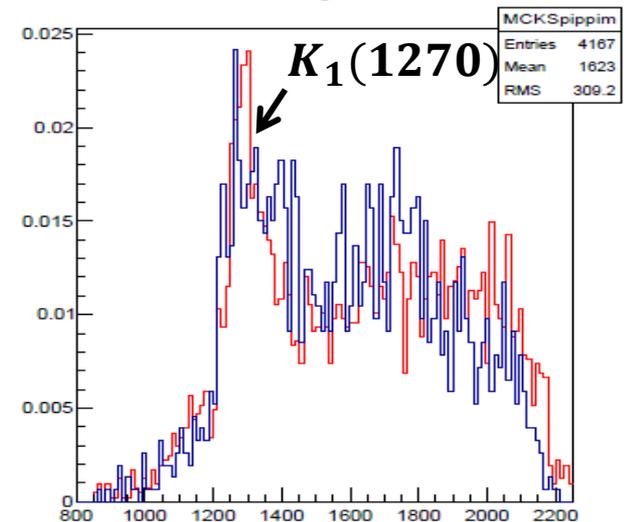
Data: $J/\psi K_S^- \pi^+$



Data: $J/\psi \pi^+ \pi^-$

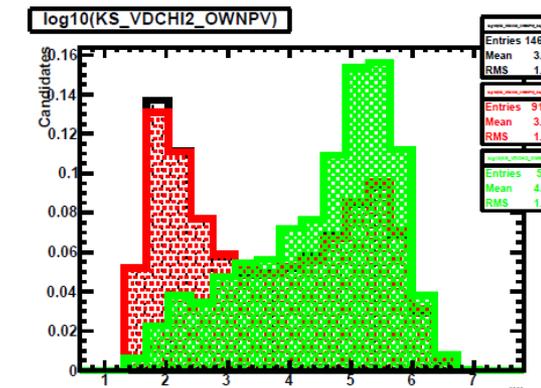
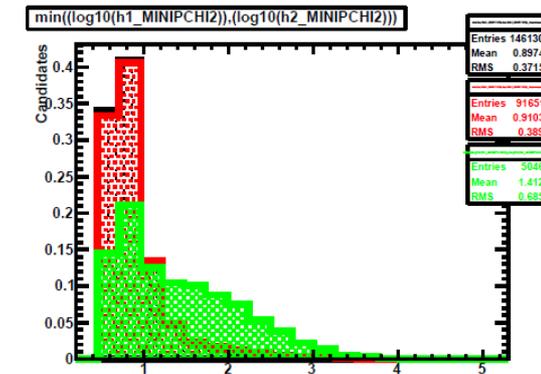
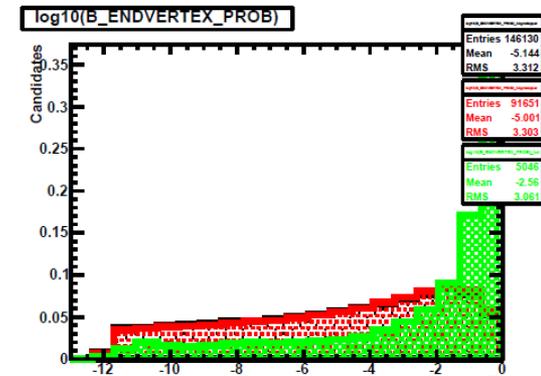
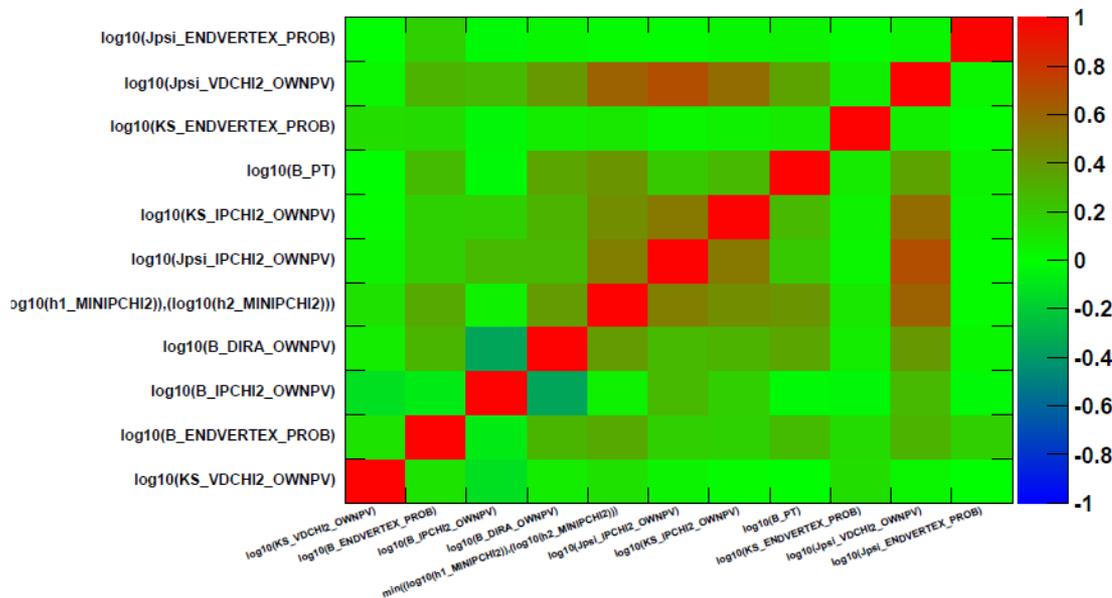


MC: $K_S \pi^+ \pi^-$



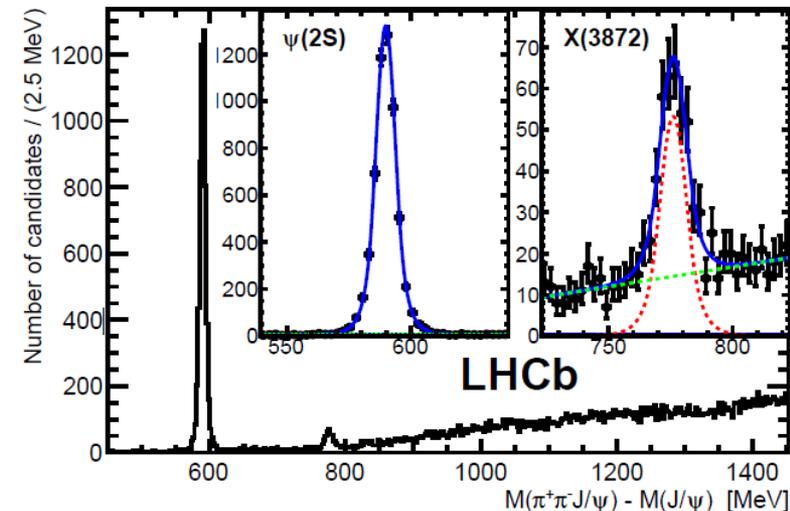
$$B_d^0 \rightarrow J/\psi K_S^0 \pi \pi$$

correlations



- There is also a chance to study various **exotic $c\bar{c}$ states**, such as $B^0 \rightarrow X(3872)K_S^0$.
- There are also a variety of other potential states we could observe through a decay, $X(3915)$, $X(3940)$, $\psi(4040)$...
- Could also look at the **hadronic form factors via angular analysis**.
- Probing HQEF theories through $B_d^0 \rightarrow J/\psi (K^*, K_1(1270))$ for example.

Determination of the $X(3872)$ meson quantum numbers <http://arxiv.org/abs/arXiv:1302.6269>



<http://arxiv.org/pdf/hep-ph/9308210.pdf>

- There is still much to learn from Heavy to light quark form factors through factorisation approximation.
- Excluding QCD penguin contributions ($O_{3..6}^q$ since Wilson Coefficients numerically small.)

$$H_{Eff} = \frac{G_F}{\sqrt{2}} \sum_{q=u,c} V_{qb} V_{qd}^* [C_1(\mu) O_1^q + C_2(\mu) O_2^q]$$

- Probing HQEF theories. Such as those done at Belle and CLEOc