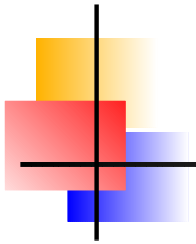
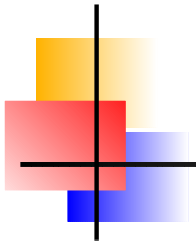


Charmonium States

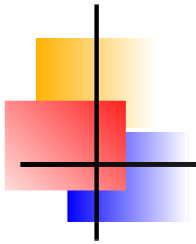
M. L. Lekala

UNISA



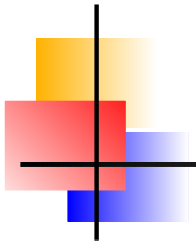
Outline

- Motive & Challenges



Outline

- Motive & Challenges
- Approach



Outline

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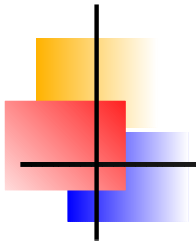
- Conclusions



Motive & Challenges

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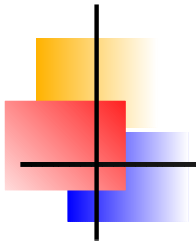

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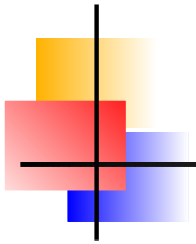

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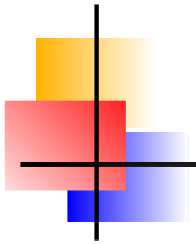

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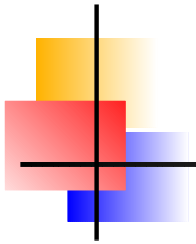

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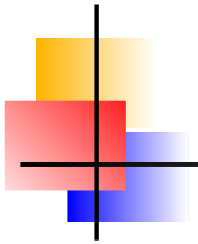
- Look for possible interpretations.
- States of charmonium are close to one another.
- We are concerned with obtaining the spectrum of the $c\bar{c}$ system using few-body methods.



X(3872) state & interpretation/challenges

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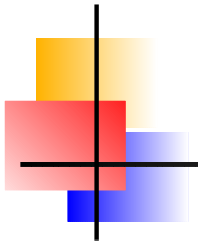

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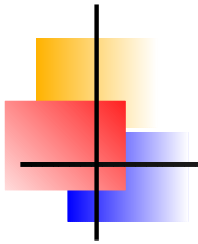

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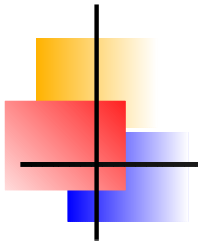

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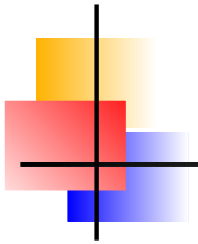

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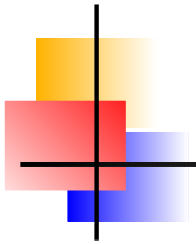
- Experimental focus: Determination of mass, width, and decay properties: i.e. quantum numbers & (possible) position in $c\bar{c}$ system of states.



X(3872) state & interpretation/challenges · · · · · ·

- Experimental knowledge:

X(3872) state & interpretation/challenges · · · · · ·

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Decays	$\rightarrow \pi^+\pi^- J/\psi$ $\rightarrow \gamma J/psi$ $\rightarrow D^0\bar{D}^0\pi^0$
Mass	3872.2 $\pm$ 0.8 MeV/c^2
Γ	$<$ 2.3 MeV ($J/\psi\pi^+\pi^-$) $3.0^{1.9}_{1.4} \pm$ 0.9 MeV ($D^0\bar{D}^0$)

X(3872) state & interpretation/challenges · · · · · ·

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X(3872) state & interpretation/challenges · · · · · ·

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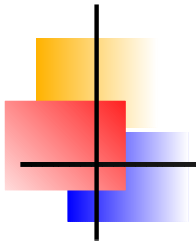
  $\Longrightarrow J^P = 0^-, 1^+, 2^-$ are favoured (which are unnatural).



X(3872) state & interpretation/challenges · · · · · ·

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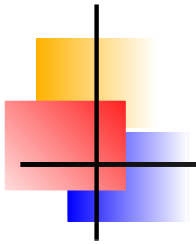

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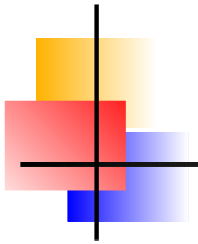

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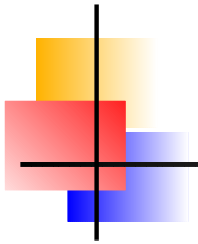

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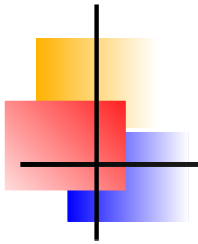
- Also, $J^{PC} = 2^{-+}$ is disfavoured by $D^0 \bar{D}^0 \pi$ decay mode
- On the other hand, $J^{PC} = 2^{-+}$, it is argued, could naturally explain the observed mass shift between the $\pi^+ \pi^- J\psi$ and $D^0 \bar{D}^0$ modes



Other $c\bar{c}$ states

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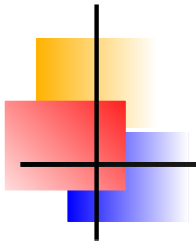

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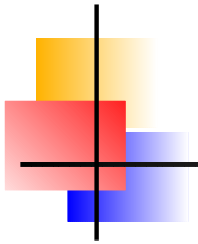

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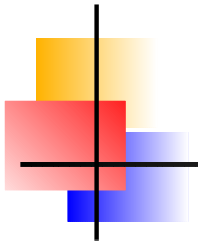

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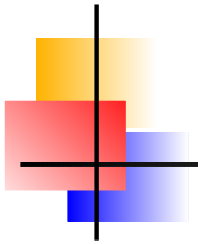

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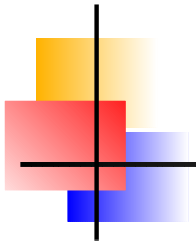
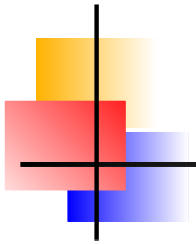
  - CDF collaboration



X(3872) state & interpretation/challenges · · · · · ·

- Conventional $c\bar{c}$ states



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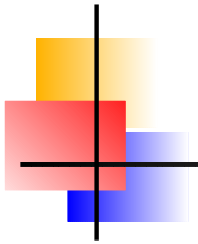

X(3872) state & interpretation/challenges · · · · · ·

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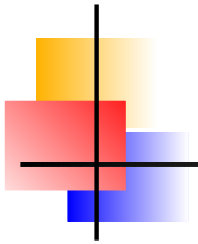

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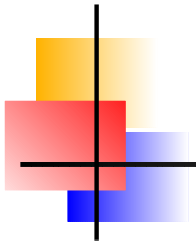
Need for robust methods



Approach

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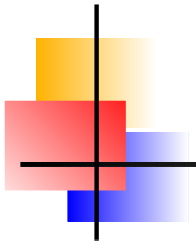

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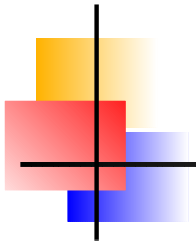

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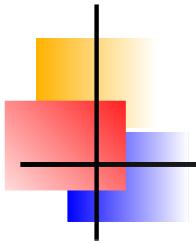

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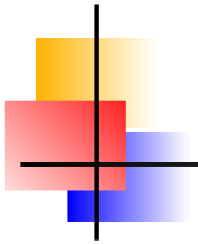
  # $D^0\bar{D}^{*0}$ "molecule"



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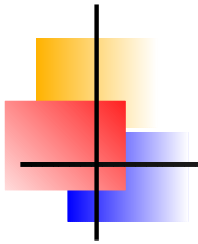

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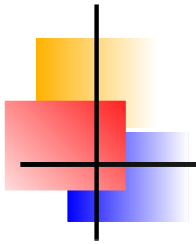
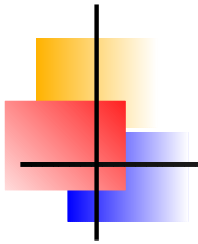
  - NRQCD
- starting point, Faddeev-like equations ($J = 1, 2$)



Approach · · ·

- Case 1=2

$$\left(H_0 + V_\alpha + V_3 + \sum_{\alpha \neq \beta} V_\beta^l - E \right) \psi_\alpha = -V_\alpha \sum_{\beta \neq \alpha} \psi_\beta \,, \quad \alpha, \beta = 1, 2$$



Approach · · ·

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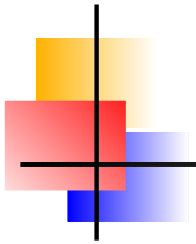
- Capable for studying, e.g.

$$X \to J/\psi + \pi + \pi$$

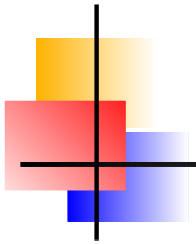


Approach · · ·

- Expansions leads to linear inhomogeneous equations

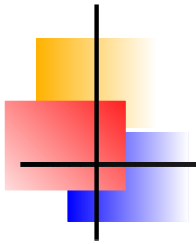
$$\sum_{ijk}(A_{ijk}+EB_{ijk})a_{ijk} \quad = \quad \sum_{ijk}\mathrm{P}_{ijk}a_{ijk}$$

$$\sum_{ijk}(1+EB_{ijk}A^{-1}_{ijk})\tilde{a}_{ijk} \quad = \quad \sum_{ijk}\mathrm{P}_{ijk}A^{-1}_{ijk}\tilde{a}_{ijk}$$



Example

- Potential: $V(r) = \frac{a}{r} + br$



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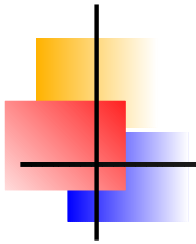
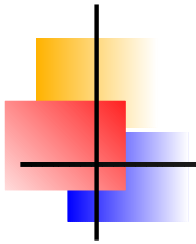
- $\ell = 1$: $X \sim 3600 \pm 23$



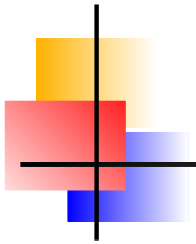
Example

- Potential: $V(r) = \frac{a}{r} + br$
- $\ell = 1$: $X \sim 3600 \pm 23$
- $\ell = 2$: $X \sim 3518 \pm 50$



Conclusions

- Systematic searches for states such as X(3972), which lies close to threshold are needed. Independent confirmation required.



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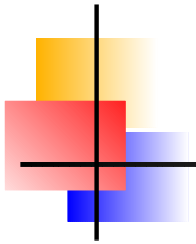

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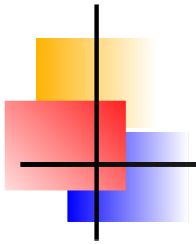

Conclusions

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- Other methods/approaches that are more sensitive may be employed. E.g. global minimization search.
- Faddeev approach holds promise.
- Further work necessary and underway.
  - $X(3872) \to \pi^+ + \pi^- + J/\psi?$ or
  - $X(3872) \to \pi^+ + \pi^- + \pi^0 + J/\psi?$