Probing the molecular interpretation of X(3872)

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work in collaboration with

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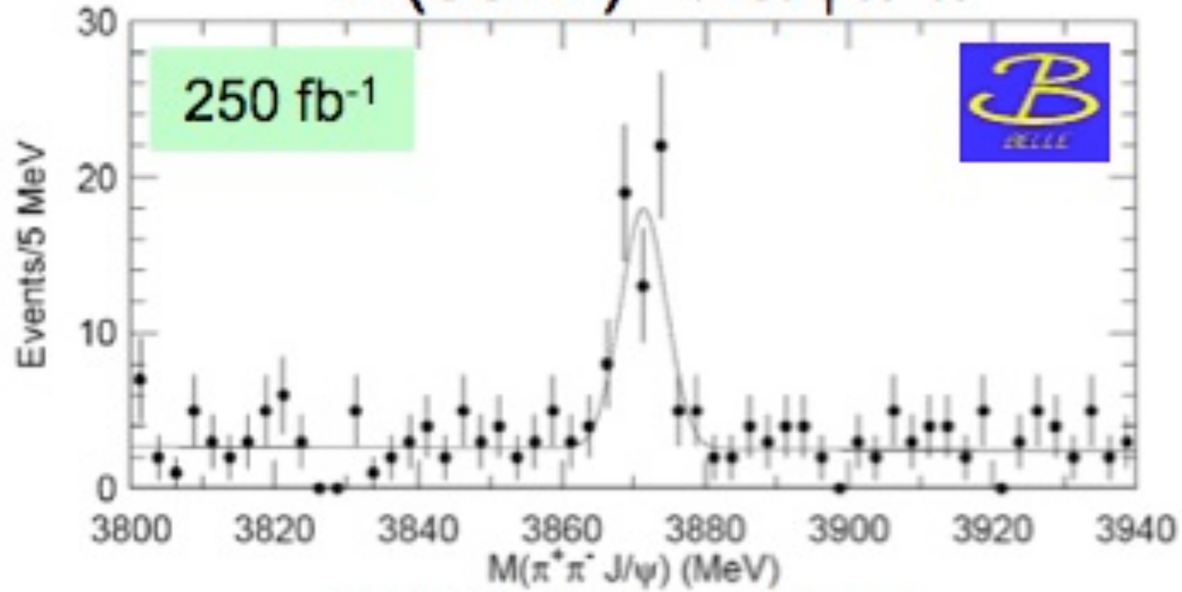
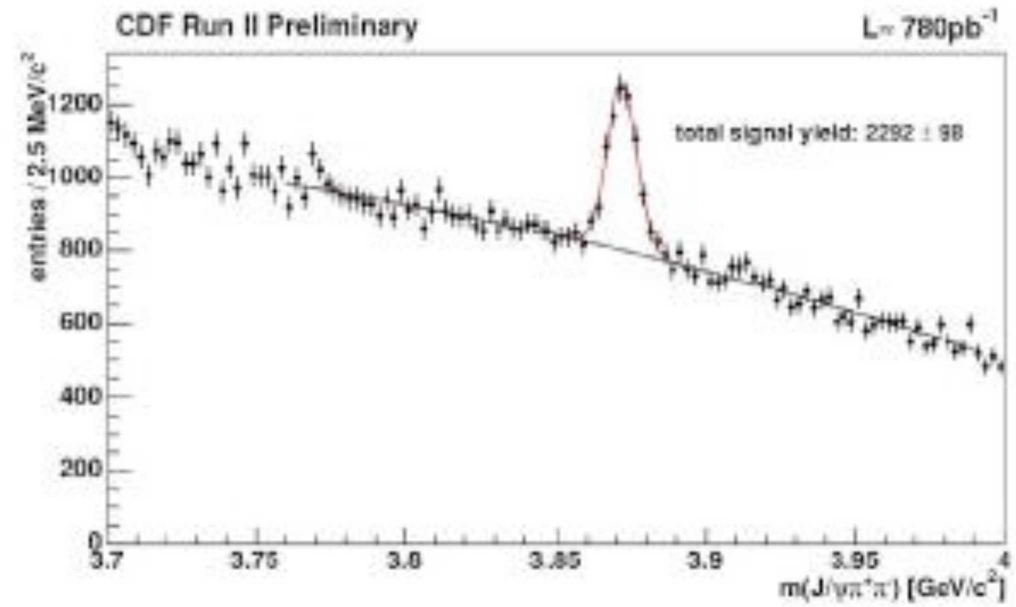
Experimental Facts

$$B^\pm \to K^\pm \underbrace{\pi^+\pi^- J/\psi}_{X\to\rho J/\psi}$$

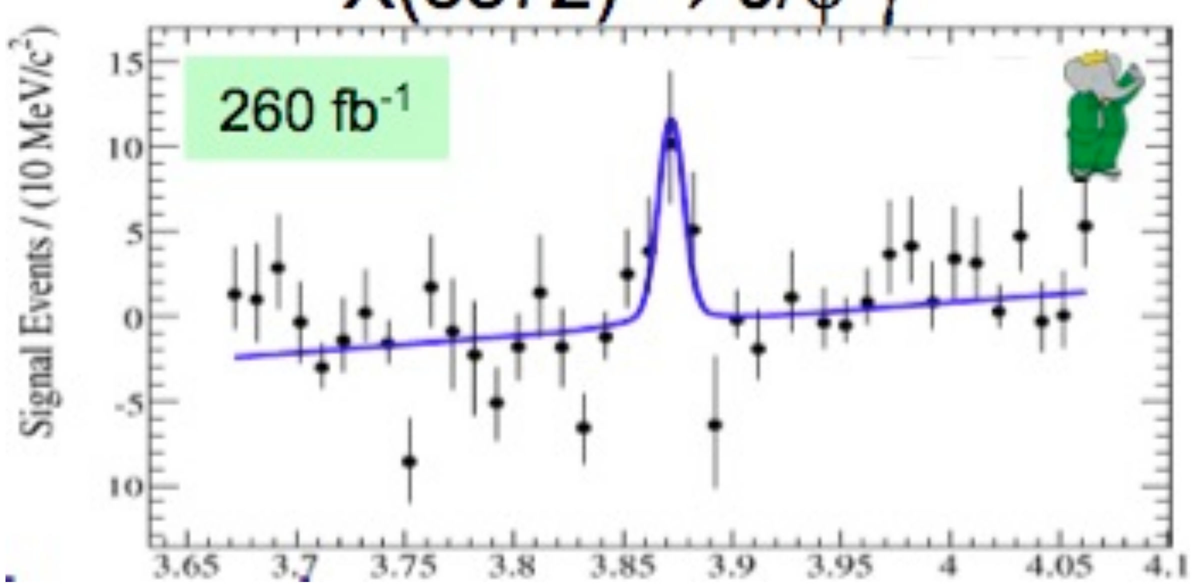
$$pp \to X \to \underbrace{\pi^+\pi^- J/\psi}_{X\to\rho J/\psi}$$

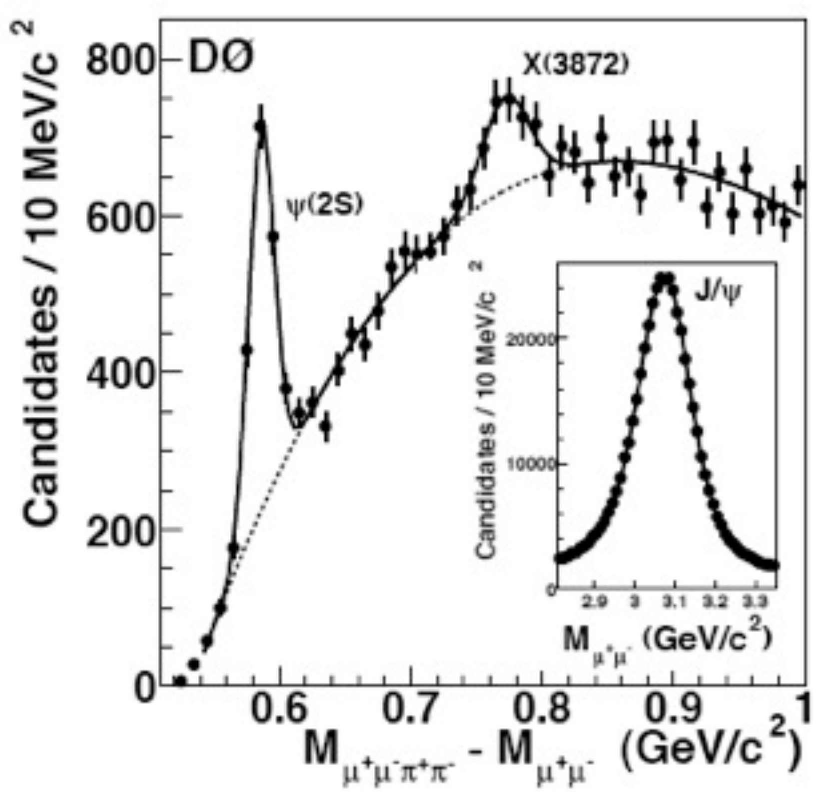
X(3872) → J/ψπ⁺π⁻





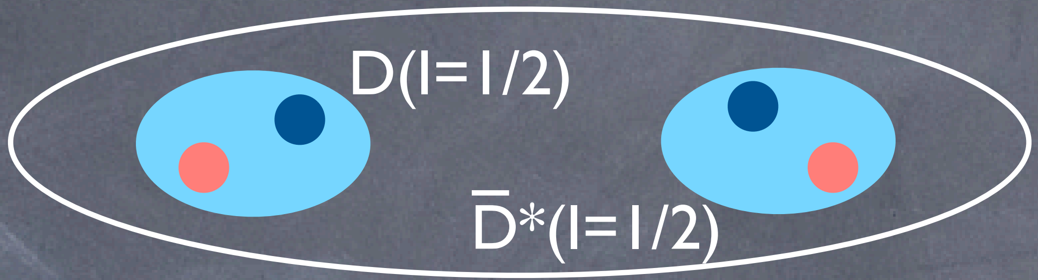
X(3872) → J/ψ γ





$$X \to \gamma J/\psi \mapsto C = +1 \quad \text{and} \quad X \to \rho^0 J/\psi \to (\pi^+\pi^-)_S J/\psi \mapsto P = 1$$

The molecule interpretation



$$\mathcal{E}_0 \sim -0.25 \pm 0.40 \text{ MeV}$$

$$\frac{\hbar^2}{\mu r_0^2} - \frac{g^2}{4\pi} \frac{e^{-\frac{m_\pi c}{\hbar} r_0}}{r_0} = \mathcal{E}_0$$

$$\boxed{r_0 \sim 8 \text{ fm}}$$

This is a large (with respect to strong interaction characteristic range) loosely bound state: can it be formed prompt in pp collisions at high energy? The COM momentum of one of the D's is

$$k = \sqrt{\lambda(m_X^2, m_D^2, m_D^{*2})}/2m_X^2 \lesssim 10 \text{ MeV}$$

The expected width of X(3872)

BaBar for example finds

$$\Gamma(X \to J/\psi\rho) < 2.3 \text{ MeV @ } 90\% \text{ C.L.}$$

A reasonable estimate could be

$$\Gamma(X) \sim \Gamma(D^*) \sim 65 \text{ keV}$$

Can such a sharp resonance be formed in S-wave scattering of two D's?

Attractive potentials do not generate sharp resonances in S-wave (they do it in higher partial waves thanks to the centrifugal barrier). But here

$$\ell \lesssim k/m_\pi \sim 10/135 \ !$$

se we have to consider S-waves...

Estimating the prompt production cross section ...

... we attempt the following estimate of its upper bound

$$
\begin{aligned}
\sigma(p\bar{p} \to X(3872)) &\sim \left| \int_{\mathcal{R}} d^3\mathbf{k} \langle X | D\bar{D}^*(\mathbf{k})\rangle \langle D\bar{D}^*(\mathbf{k}) | p\bar{p}\rangle \right|^2 \\
&\leq \int_{\mathcal{R}} d^3\mathbf{k} |\psi(\mathbf{k})|^2 \int_{\mathcal{R}} d^3\mathbf{k} |\langle D\bar{D}^*(\mathbf{k}) | p\bar{p}\rangle|^2 \\
&= \int_{\mathcal{R}} d^3\mathbf{k} |\langle D\bar{D}^*(\mathbf{k}) | p\bar{p}\rangle|^2 \equiv \sigma(p\bar{p} \to X(3872))^{\max}
\end{aligned}
$$

where k is the relative momentum and R is the k region where ψ is significantly different from zero (r~8 fm ⇒ Δk~12 MeV)

The latter matrix element can be evaluated using Pythia & Herwig by selecting D mesons in the final state which are in the conditions of forming our molecule (the integration region R~[0,30] MeV). The molecule formed must in turn pass the kinematical cuts described below.

CDF data

We extract from available data a lower bound on the prompt cross section production

$$\frac{\sigma(p\bar{p} \to X(3872) + \text{All})_{\text{prompt}} \times \mathcal{B}(X(3872) \to J/\psi\pi^+\pi^-))}{\sigma(p\bar{p} \to \psi(2S) + \text{All})} \simeq 4.6\%$$

$$\sigma(p\bar{p} \to X(3872) + \text{All})_{\text{prompt}} \geq 0.046 \times \sigma(p\bar{p} \to \psi(2S) + \text{All})$$

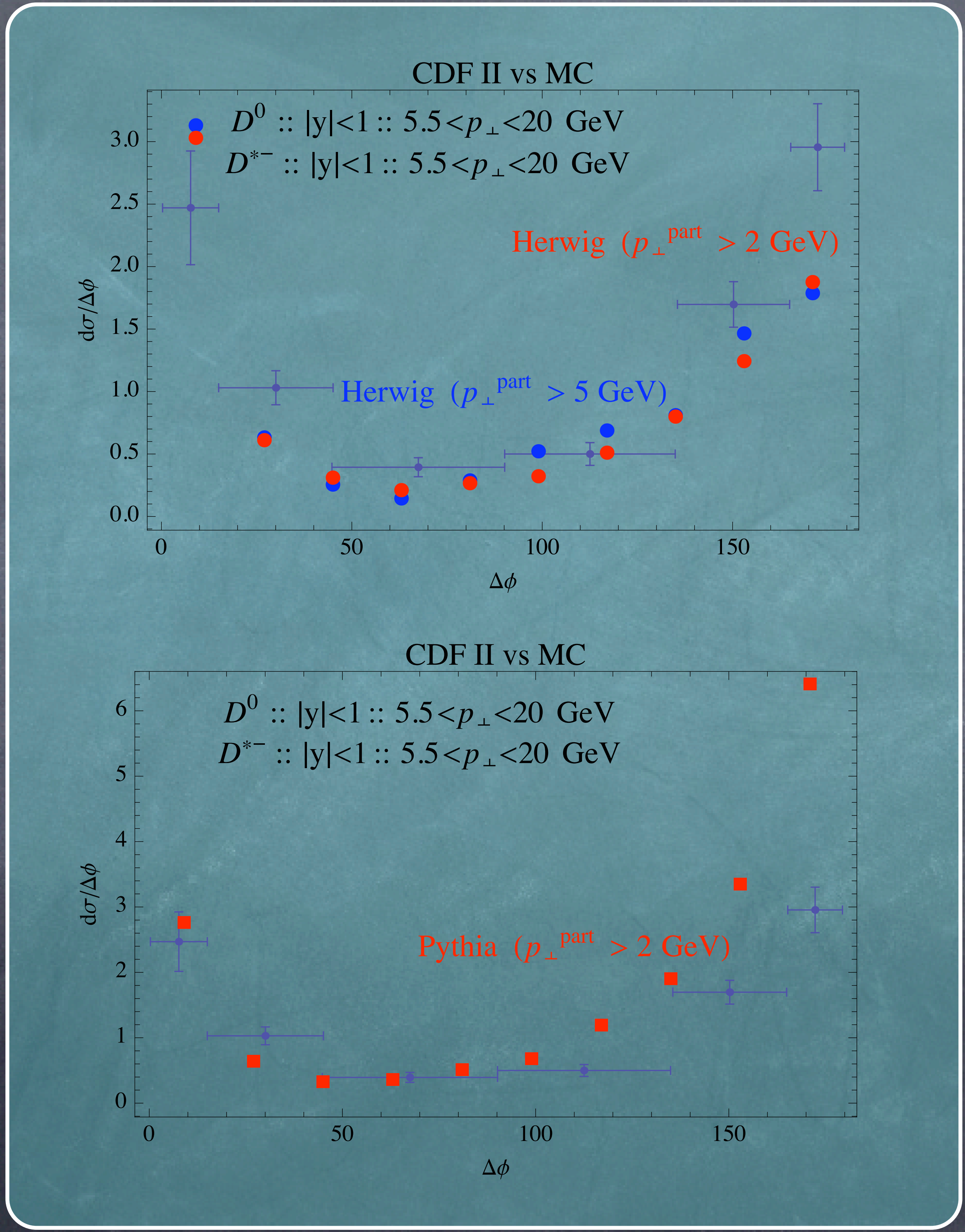
$$\sigma(p\bar{p} \to \psi(2S) + \text{All}) = 0.507 \pm 0.046 \text{ nb} \times (7.5 \times 10^{-3})^{-1} = 68 \pm 9 \text{ nb}$$

$$\sigma(p\bar{p} \to X(3872) + \text{All})^{\text{min}} \simeq 3.2 \pm 0.7 \text{ nb}$$

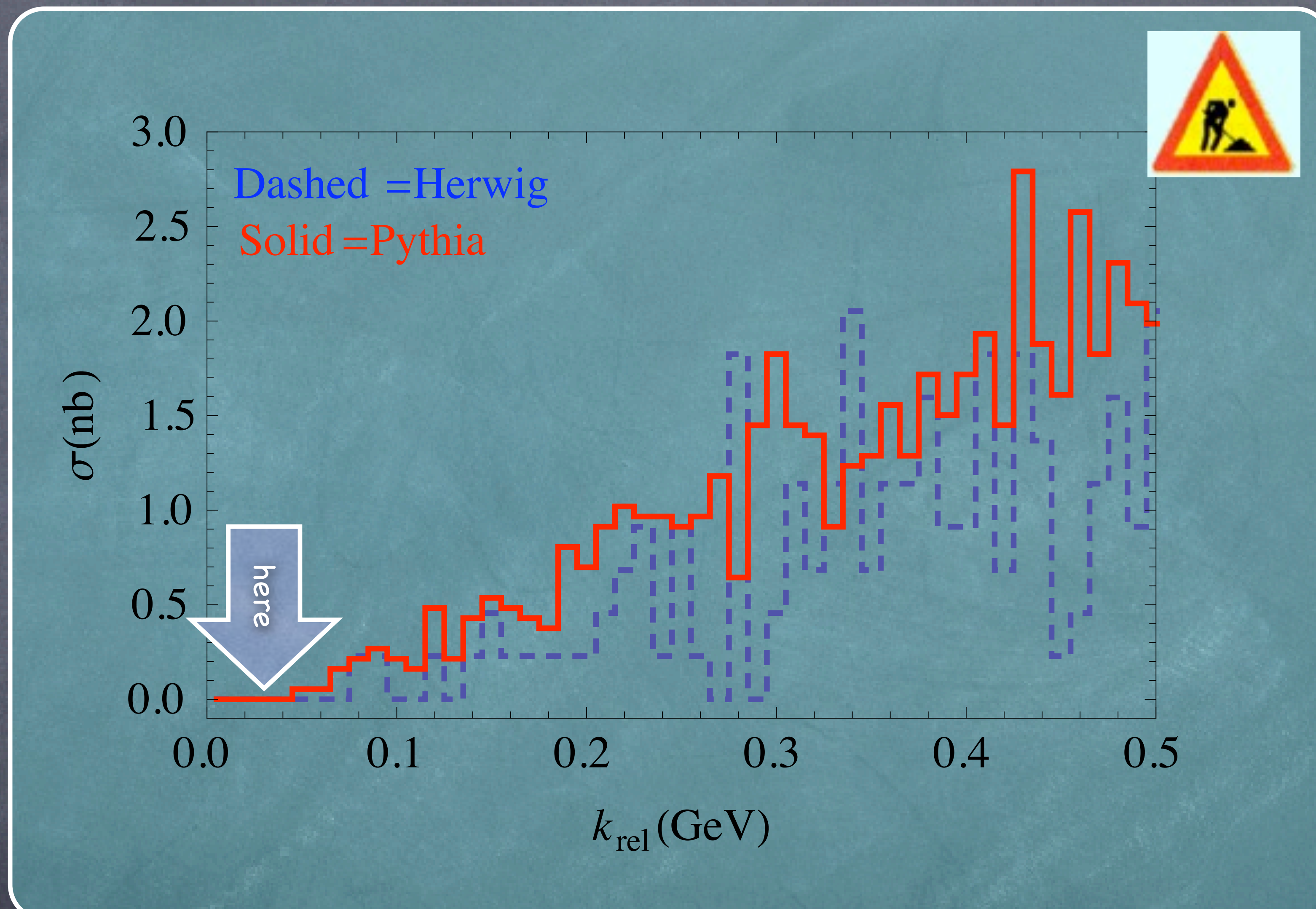
This number is to be compared with the upper bound found in the previous slide.
The kinematical cuts used in the analysis are

$$p_\perp > 5 \text{ GeV} \quad |y| < 0.6$$

Tuning the MC's on open charm @ CDF



Preliminary Results (low luminosity)



... as for the moment we are dealing with

$$\sigma_{th}^{max} \simeq 0.03 \text{ nb} \quad \text{vs} \quad \sigma_{exp}^{min} \simeq 3.2 \text{ nb}$$

Conclusions

One of the most widely accepted interpretation of the X(3872) is that of a molecule of open charm mesons (instead of a tetraquark).
We are trying to probe this hypothesis with CDF data on <u>prompt</u> X(3872) production in proton collisions.

To do so, we make use of the hadronization models in Pythia and Herwig to estimate an upper bound on this cross section. We aim to reach an MC luminosity* similar to that of CDF ($\sim$1 fb^{-1}) to compare more sharply our theory xsect against data.

Results coming soon.

*now 100 nb^{-1} :: soon x 100