Charm-strange mesons and *D K* scattering

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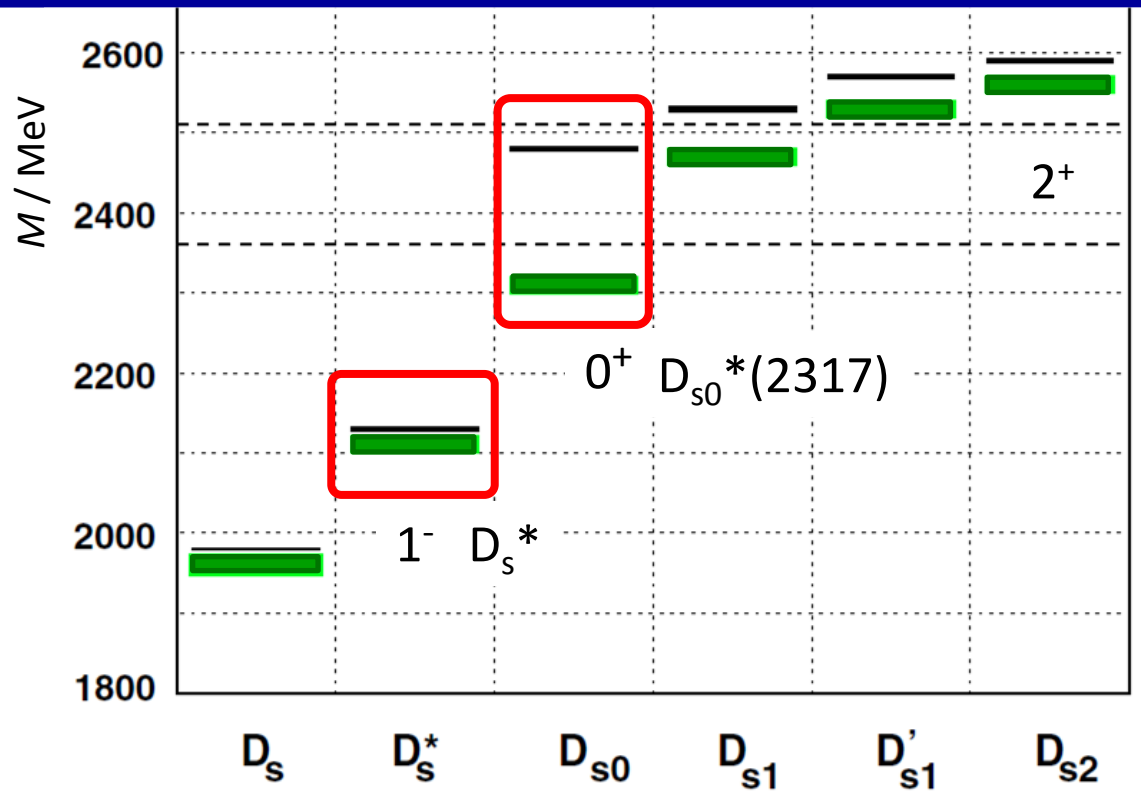
Hadron Spectrum Collaboration

DK (I=0) scattering and charm-strange mesons

D K (I=0): $J^P = 0^+, 1^-, 2^+, \ldots$

Isospin = 0
Strangeness = 1
Charm = 1

$c\bar{s}$, $c\bar{\ell}\ell\bar{s}$



D K* thresh.

D K thresh.

Close & Swanson
[PR D72, 094004 (2005)]

DK (I=0) scattering and charm-strange mesons

Same setup and techniques as previous talk

m_π = 391 MeV, m_K = 549 MeV, m_D = 1890 MeV
2 volumes: 20^3 x 128 and 24^3 x 128 ($L \approx 2 - 3$ fm)

$$C_{ij}(t) = < 0 | \mathcal{O}_i(t) \mathcal{O}_j^\dagger(0) | 0 >$$

'single-meson ' $\sim \bar{\psi} \Gamma D \ldots \psi$

+ '*D K* ' operators $\mathcal{O}(\vec{P}) = \sum_{\hat{p}_1,\ \hat{p}_2} \mathcal{C}_\Lambda(\vec{P}, \vec{p}_1, \vec{p}_2)\ \mathcal{O}_D(\vec{p}_1)\ \mathcal{O}_K(\vec{p}_2)$

CT *et al* (HadSpec Collaboration) in preparation (these are preliminary results)
[methods in PR D86, 034031; PR D87 034505; PRL 113, 182001; PR D91 054008]

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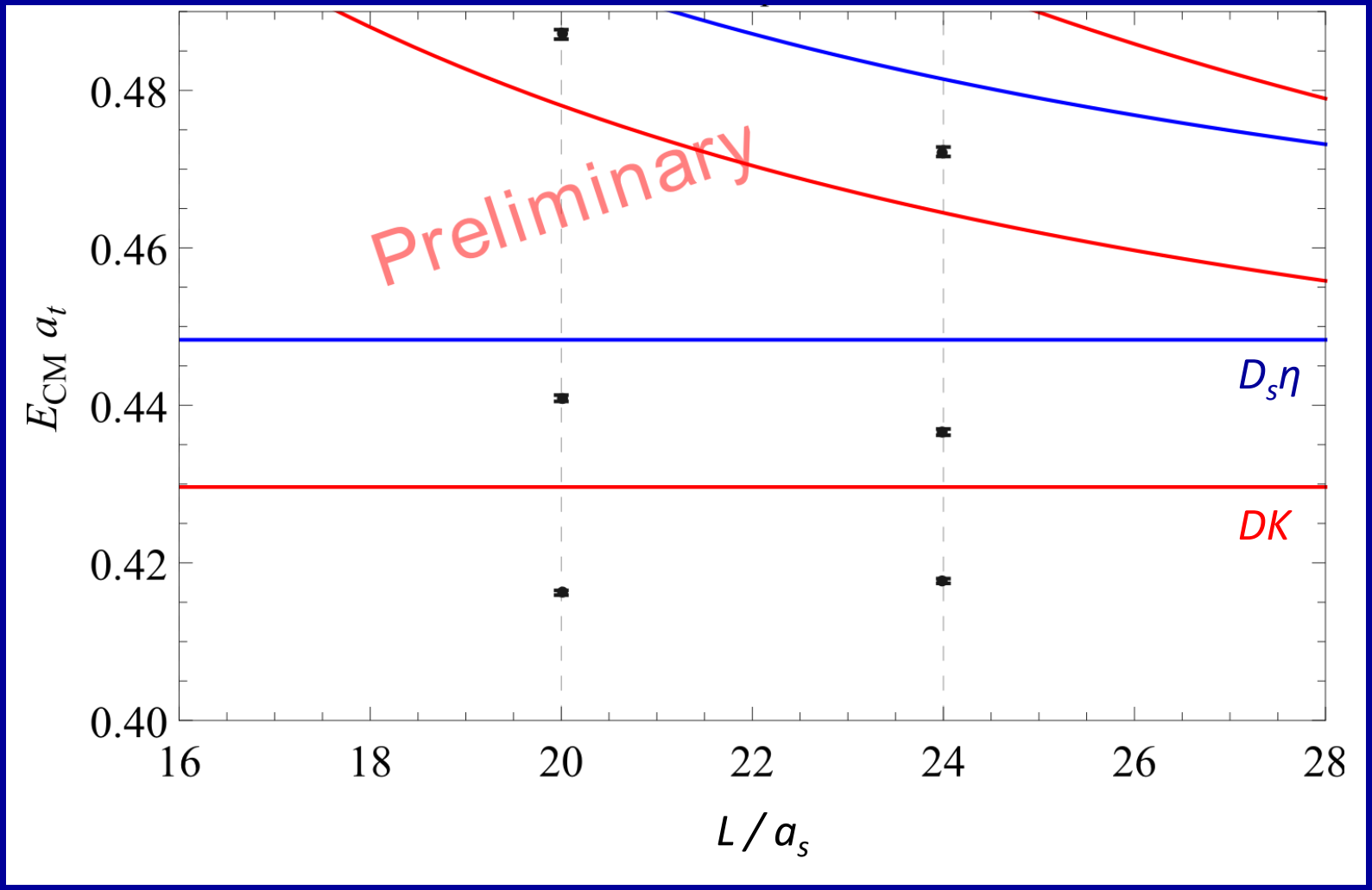
Some previous lattice QCD studies:

- Mohler et al [PRL 111, 222001 (2013)] – 0^+ $D_s(2317)$ below *D K* threshold
- Lang et al [PRD 90, 034510 (2014)] – 0^+ $D_s(2317)$ and 1^+ $D_{s1}(2460)$, $D_{s1}(2536)$

DK (I=0) spectra

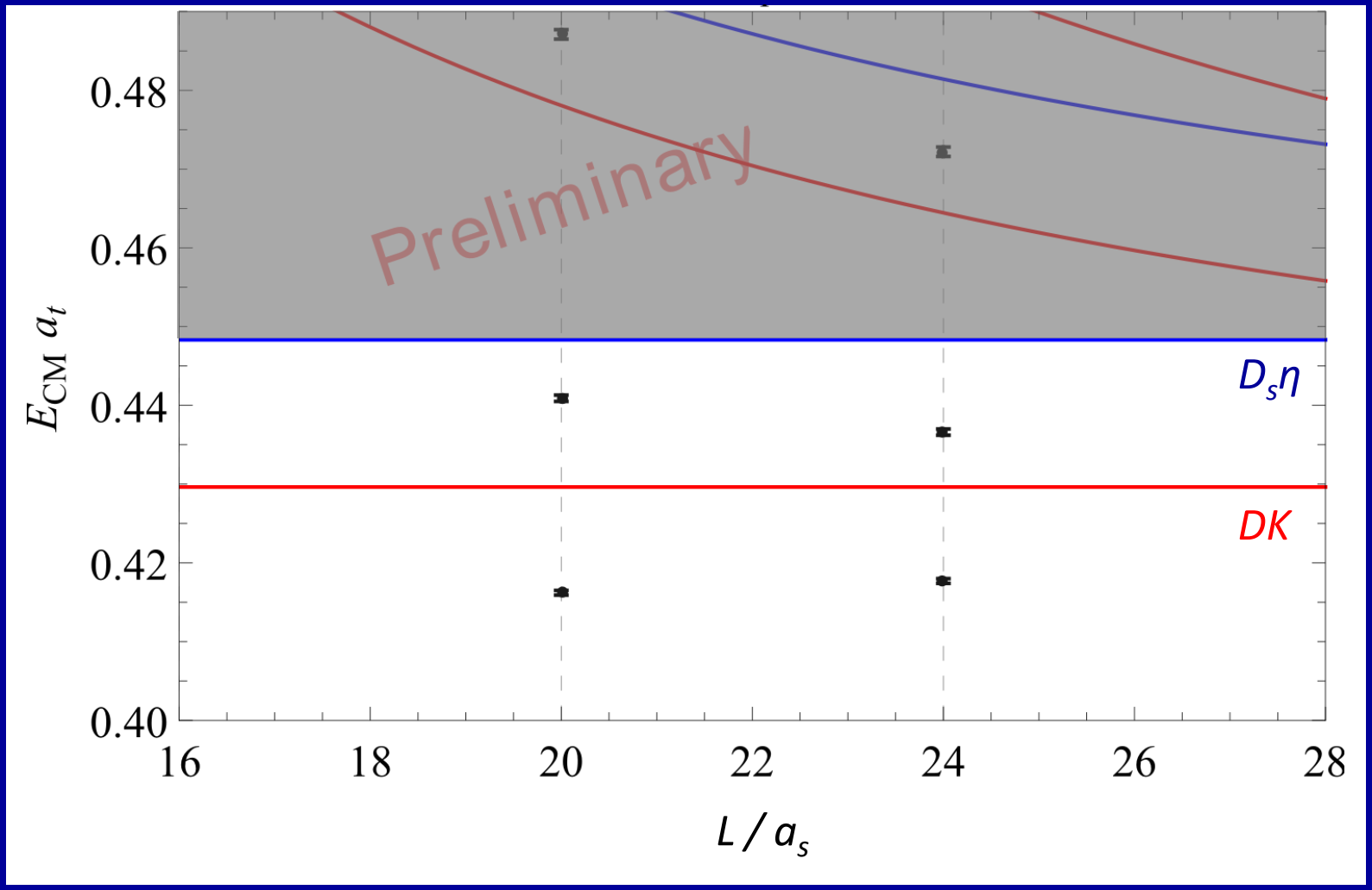
P = [0,0,0] A_1^+



$J^P = 0^+, 4^+, \ldots [\ell = 0, 4, \ldots]$

DK (I=0) spectra

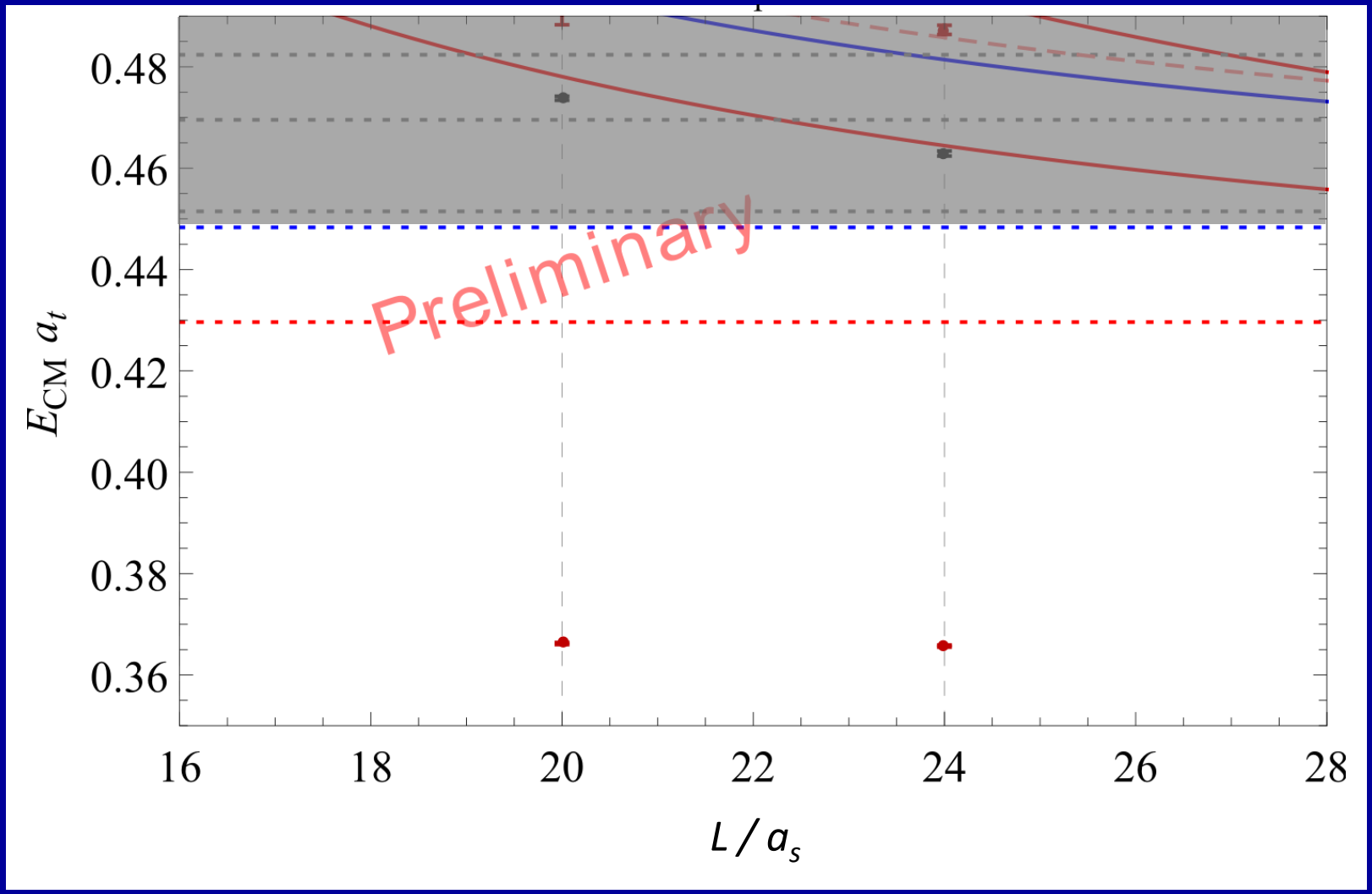
P = [0,0,0] A_1^+



$J^P = 0^+, 4^+, \ldots [\ell = 0, 4, \ldots]$

DK (I=0) spectra

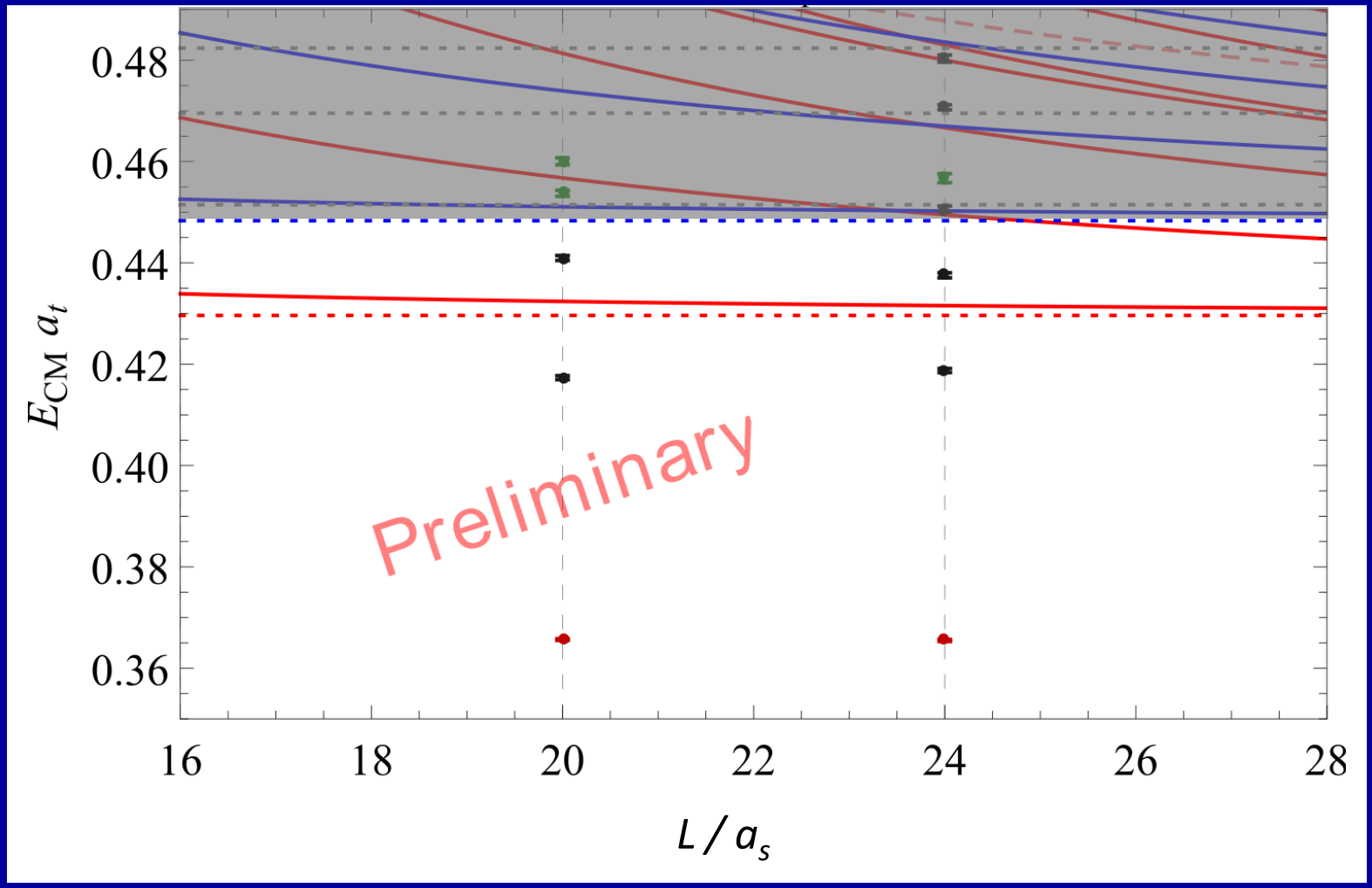
$P = [0,0,0]\ T_1^-$



$J^P = 1^-, 3^-, (4^-), \ldots [\ell = 1, 3, \ldots]$

DK (I=0) spectra

P = [0,0,1] A_1



$|\lambda| = 0^+, 4, \ldots \quad [\ell = 0, 1, 2, 3, 4^2, \ldots]$

DK (I=0) scattering

Lüscher method → scattering phase shifts δ (elastic *DK* scattering)

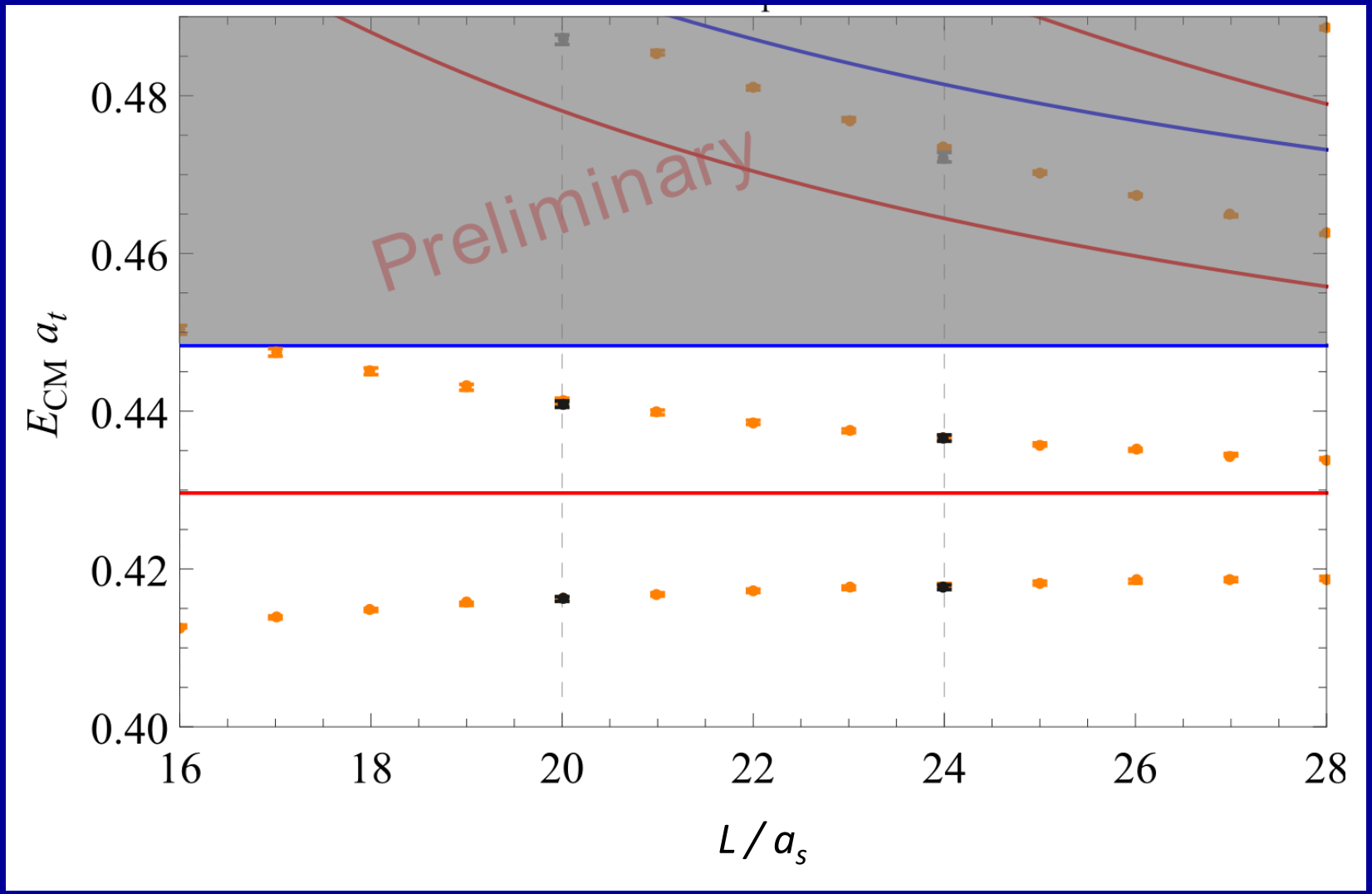
Various different:

- parameterizations of the scattering *t*-matrix
  (effective range, Breit-Wigner, various *K*-matrix params.)
- sets of energy levels across relevant irreps on two vols.
  (up to 34 levels)

Consider only $\ell = 0, 1$ (can also look at $\ell = 2$)

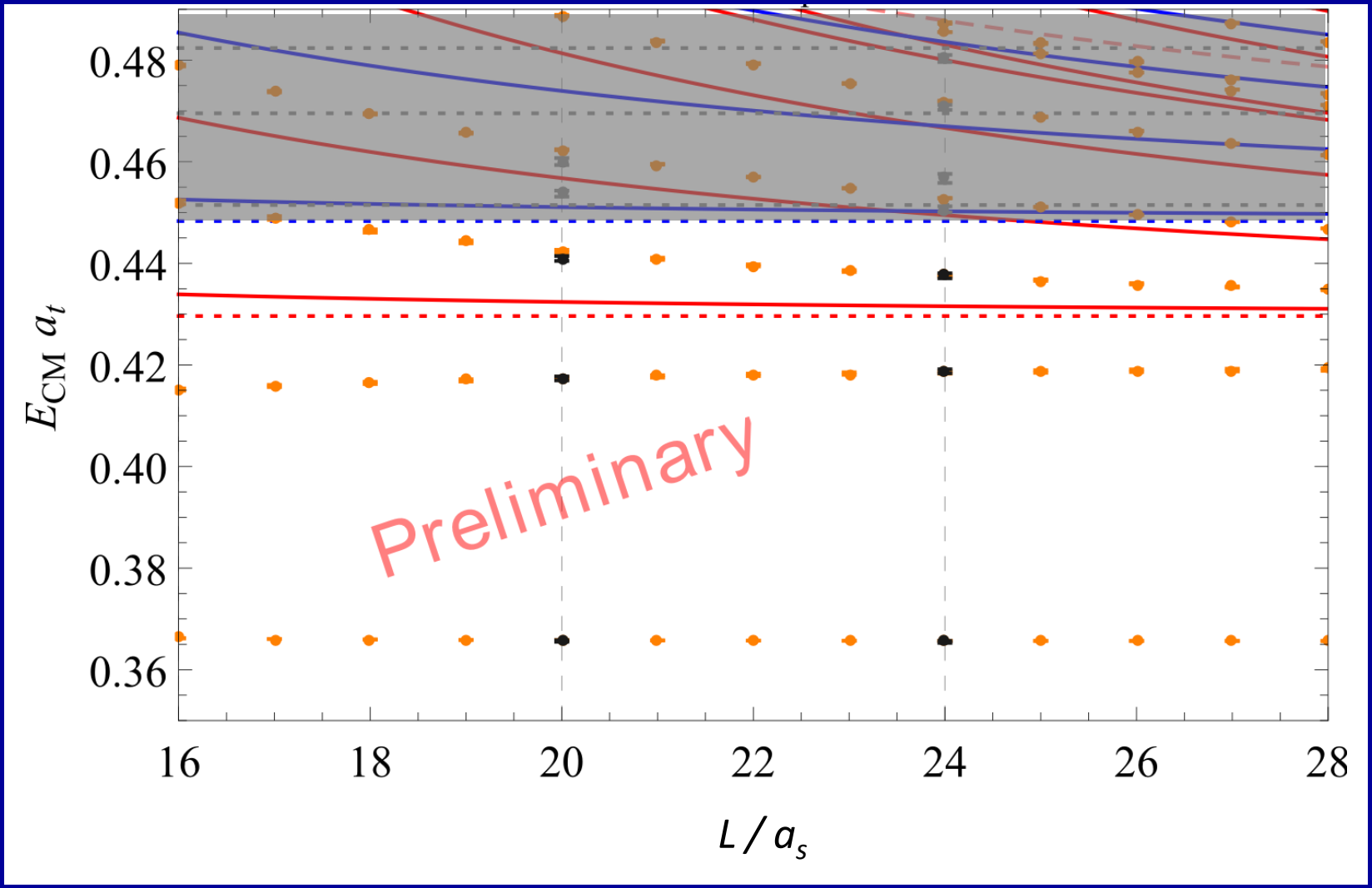
DK (I=0): S-wave

P = [0,0,0] A_1^+

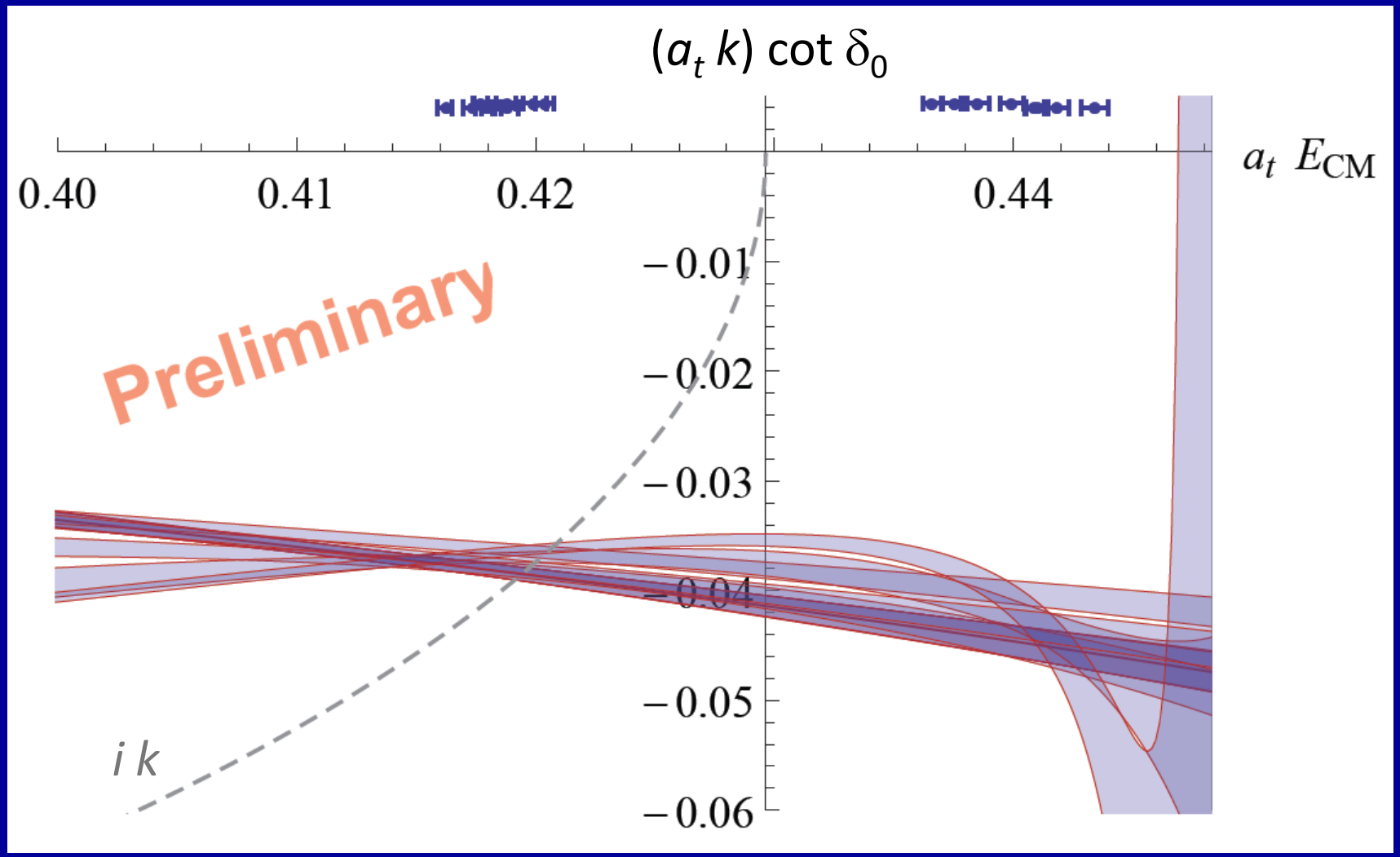


DK (I=0): S and P-waves

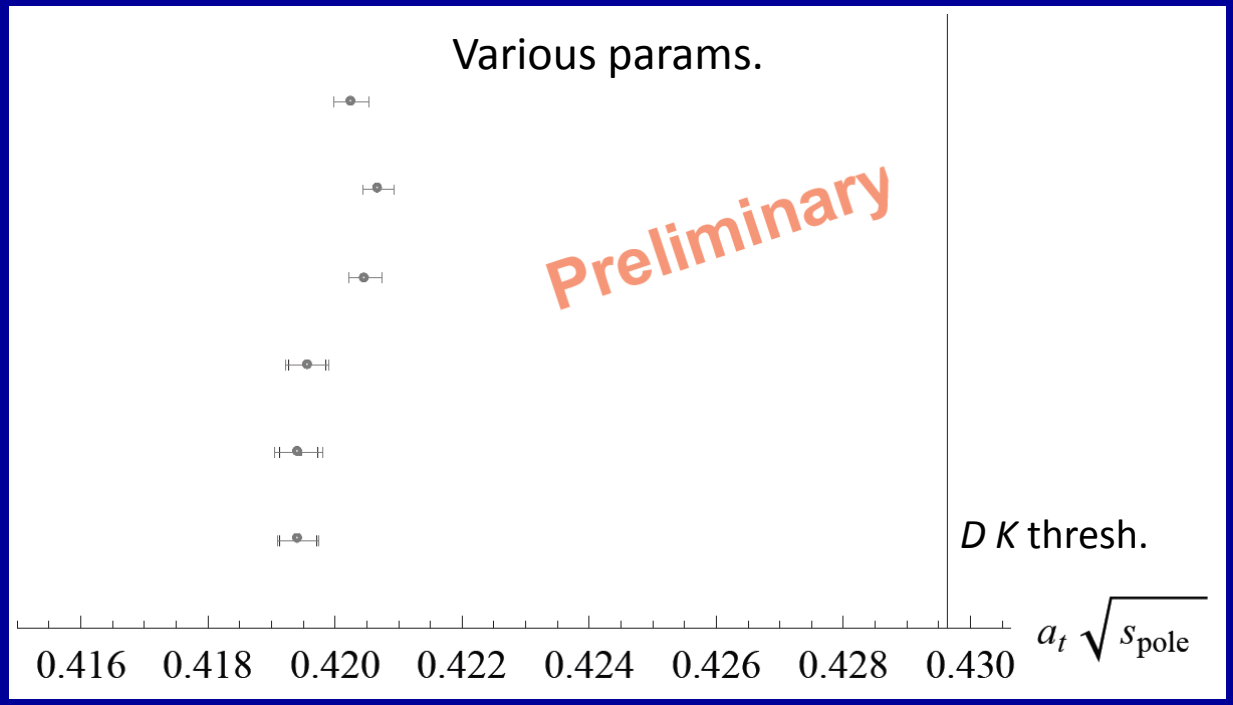
P = [0,0,1] A_1



DK (I=0): S-wave amp.



DK (I=0): S-wave pole



Pole in *t*-matrix on real axis (physical sheet):

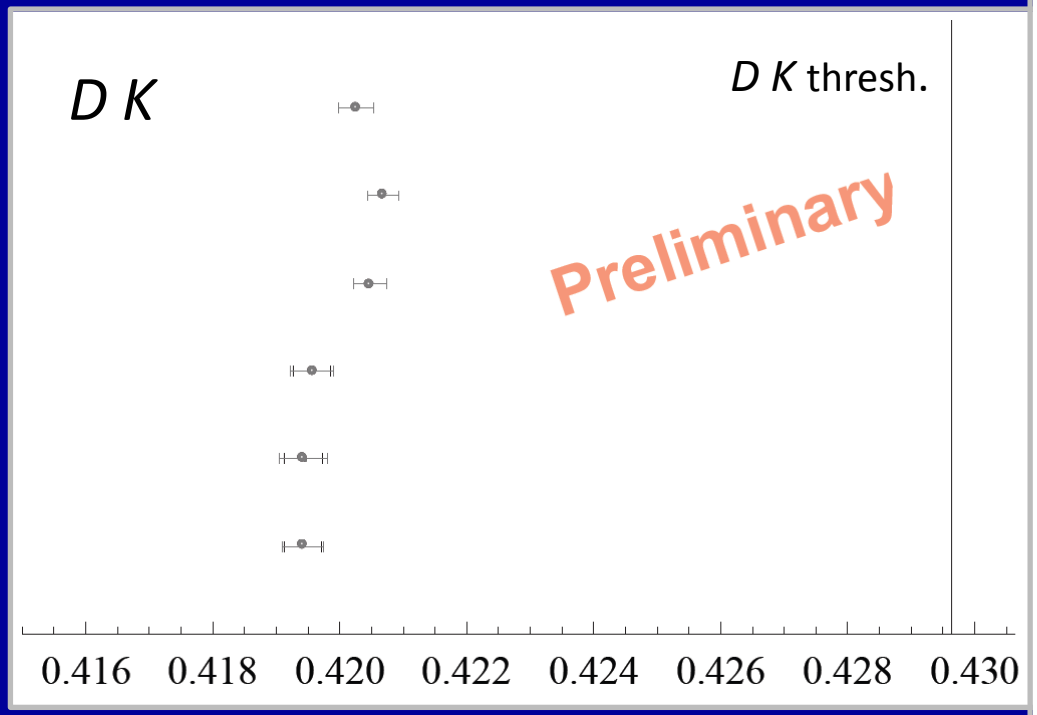
$a_t\, m \approx 0.420 \rightarrow m \approx 2380$ MeV

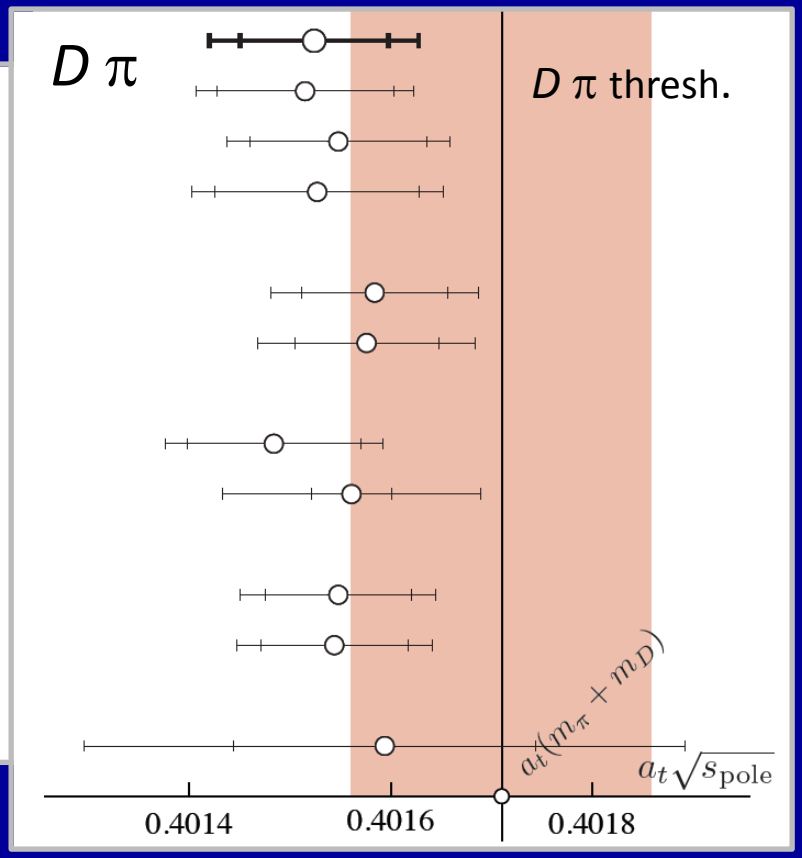
Bound state, below *DK* threshold:

$a_t\, \Delta m \approx 0.010 \rightarrow \Delta m \approx 55$ MeV

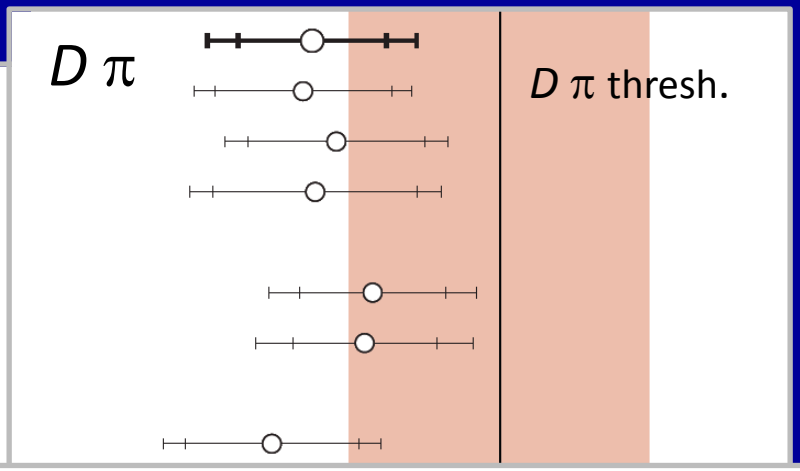
C.f. experimentally for $D_s(2317)$: $\Delta m \approx 40$-50 MeV

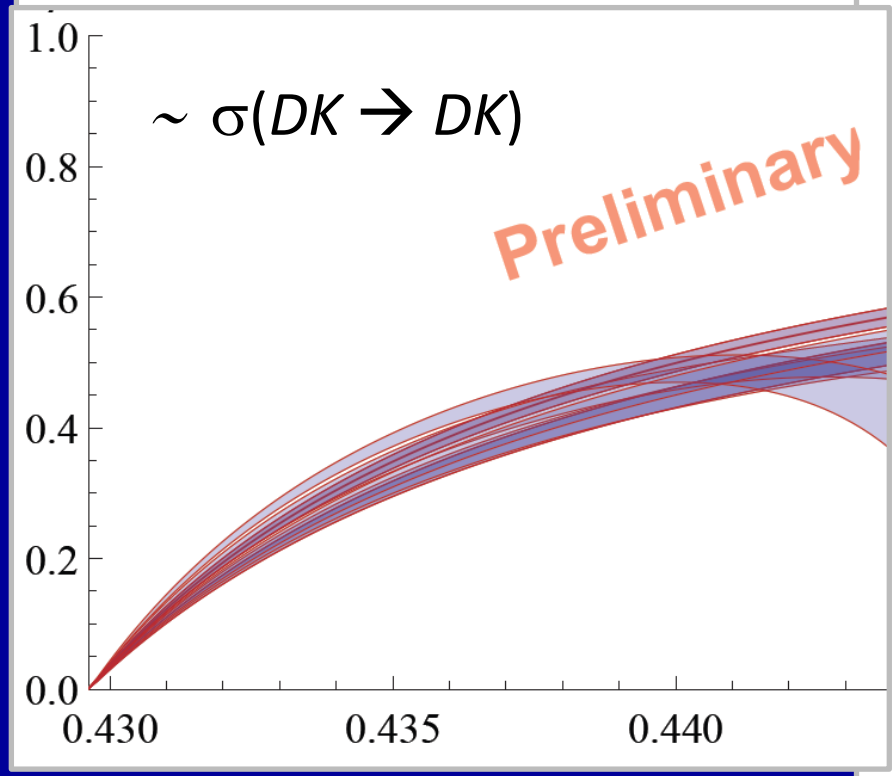
DK (I=0) c.f. Dπ (I=½) S-wave

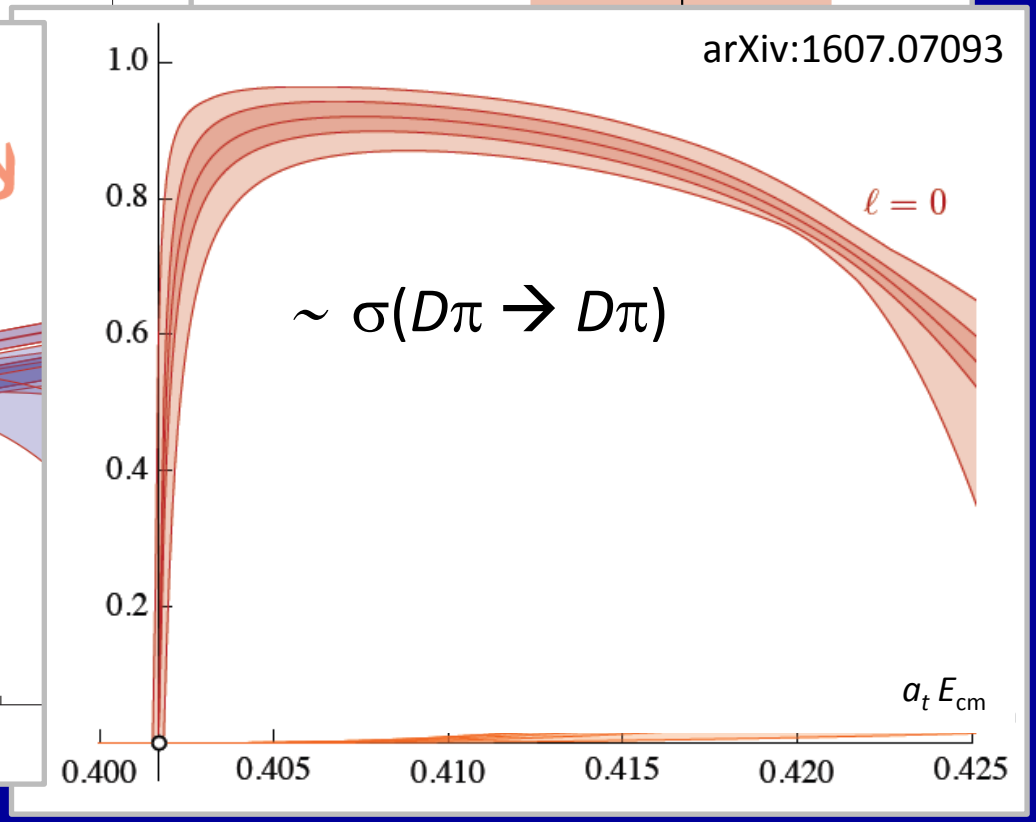




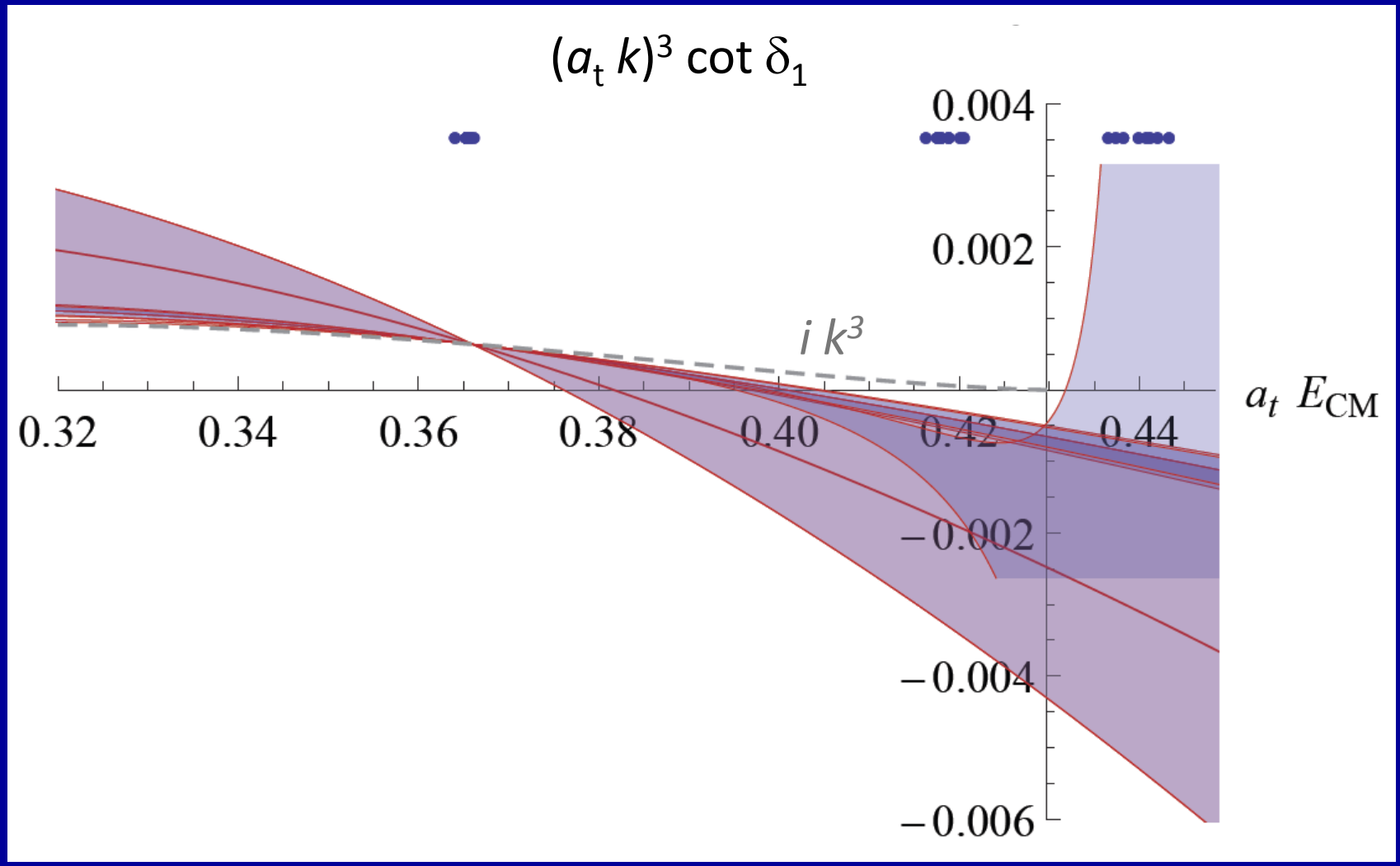
DK (I=0) c.f. Dπ (I=½) S-wave







DK (I=0): P-wave amp.



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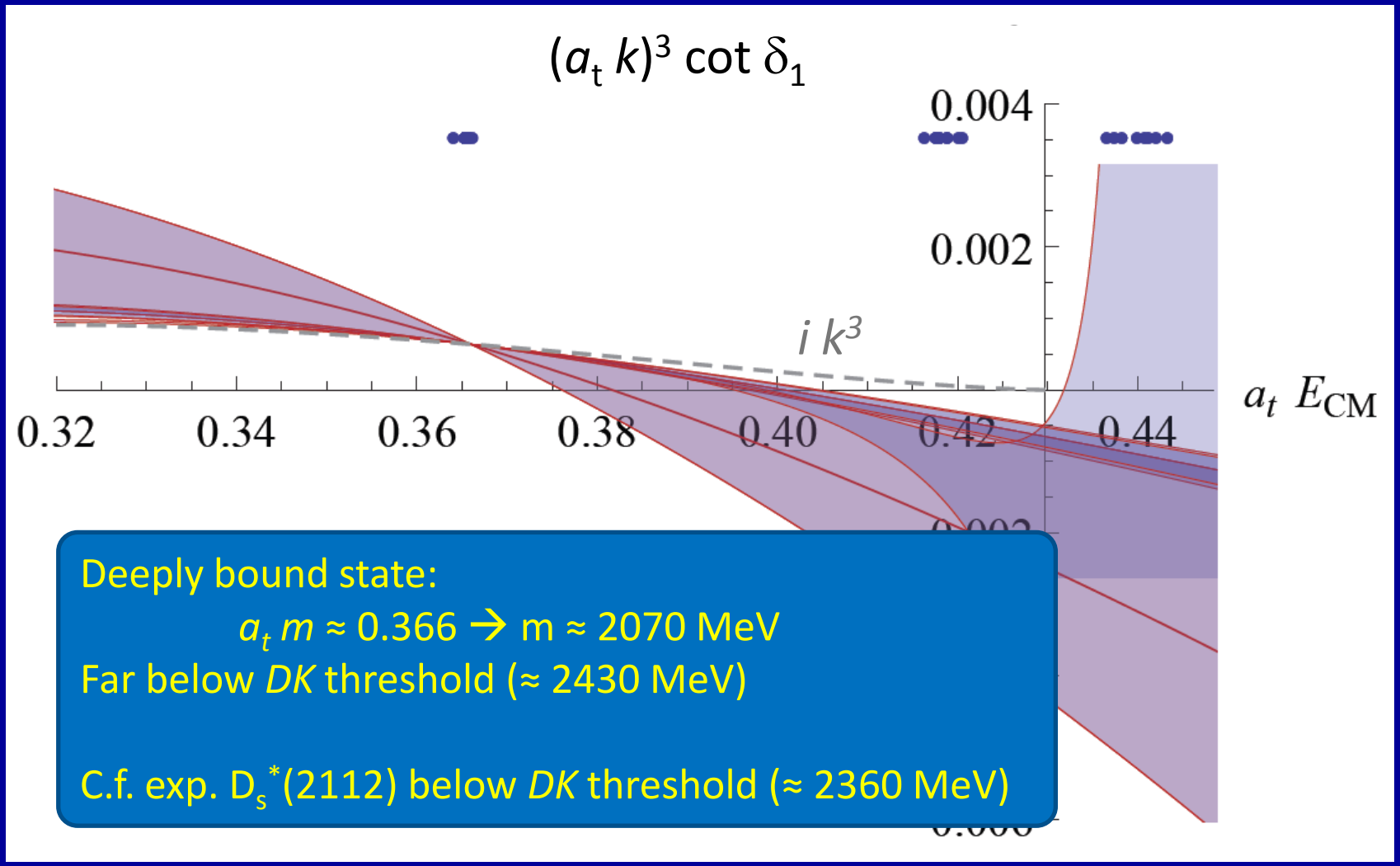


Deeply bound state:

$a_t\, m \approx 0.366$ → m ≈ 2070 MeV

Far below *DK* threshold (≈ 2430 MeV)

C.f. exp. $D_s^*(2112)$ below *DK* threshold (≈ 2360 MeV)

$D\bar{K}$ (I=1) scattering

$D\bar{K}$ (I=1): $J^P = 0^+, 1^-, 2^+, \ldots$

Isospin = **1**
Strangeness = **-1**
Charm = **1**

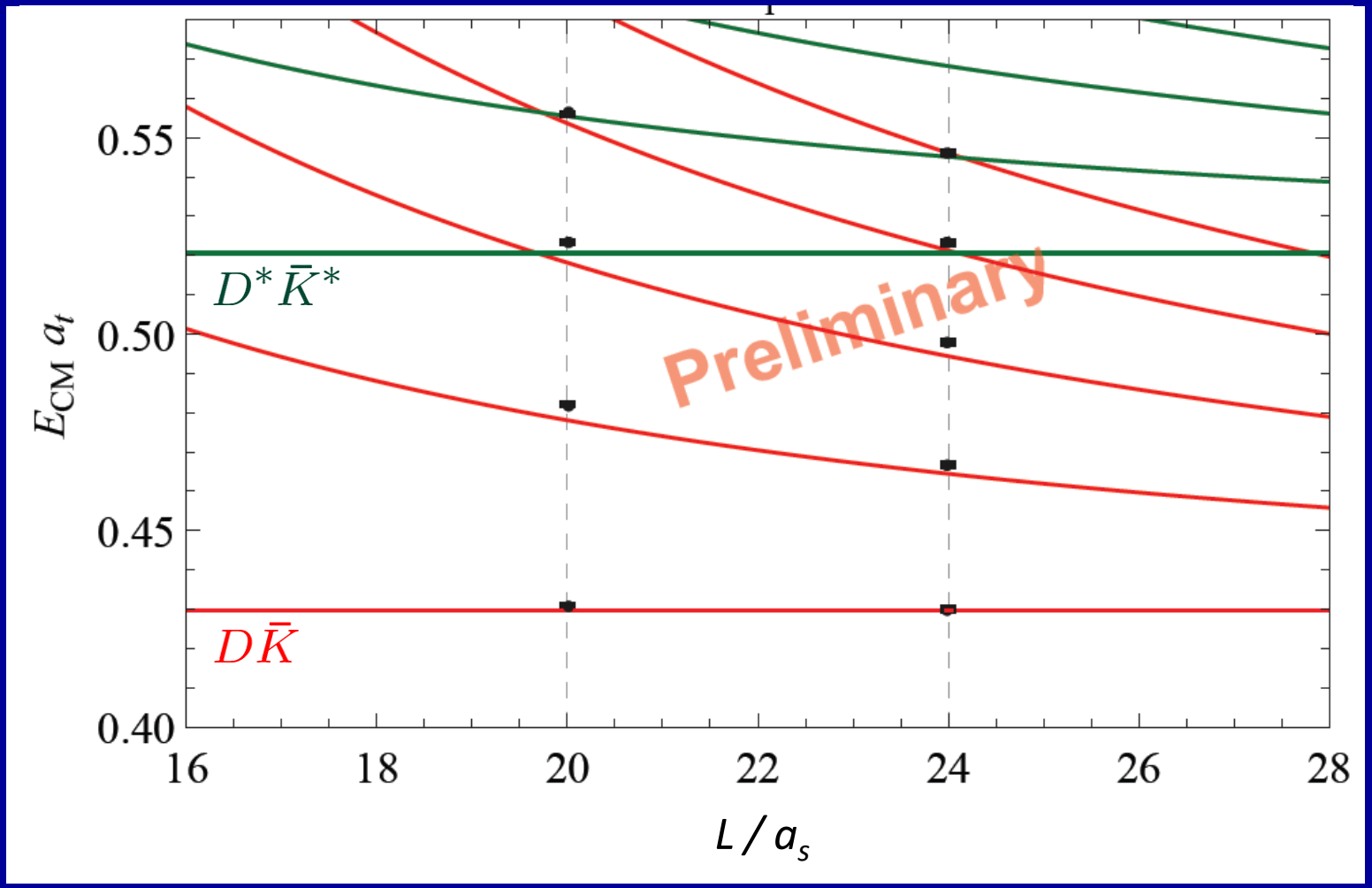
Flavour exotic
$c\bar{\ell}s\bar{\ell}$

$$C_{ij}(t) = < 0 | \mathcal{O}_i(t) \mathcal{O}_j^\dagger(0) | 0 >$$

'$D\bar{K}$' operators

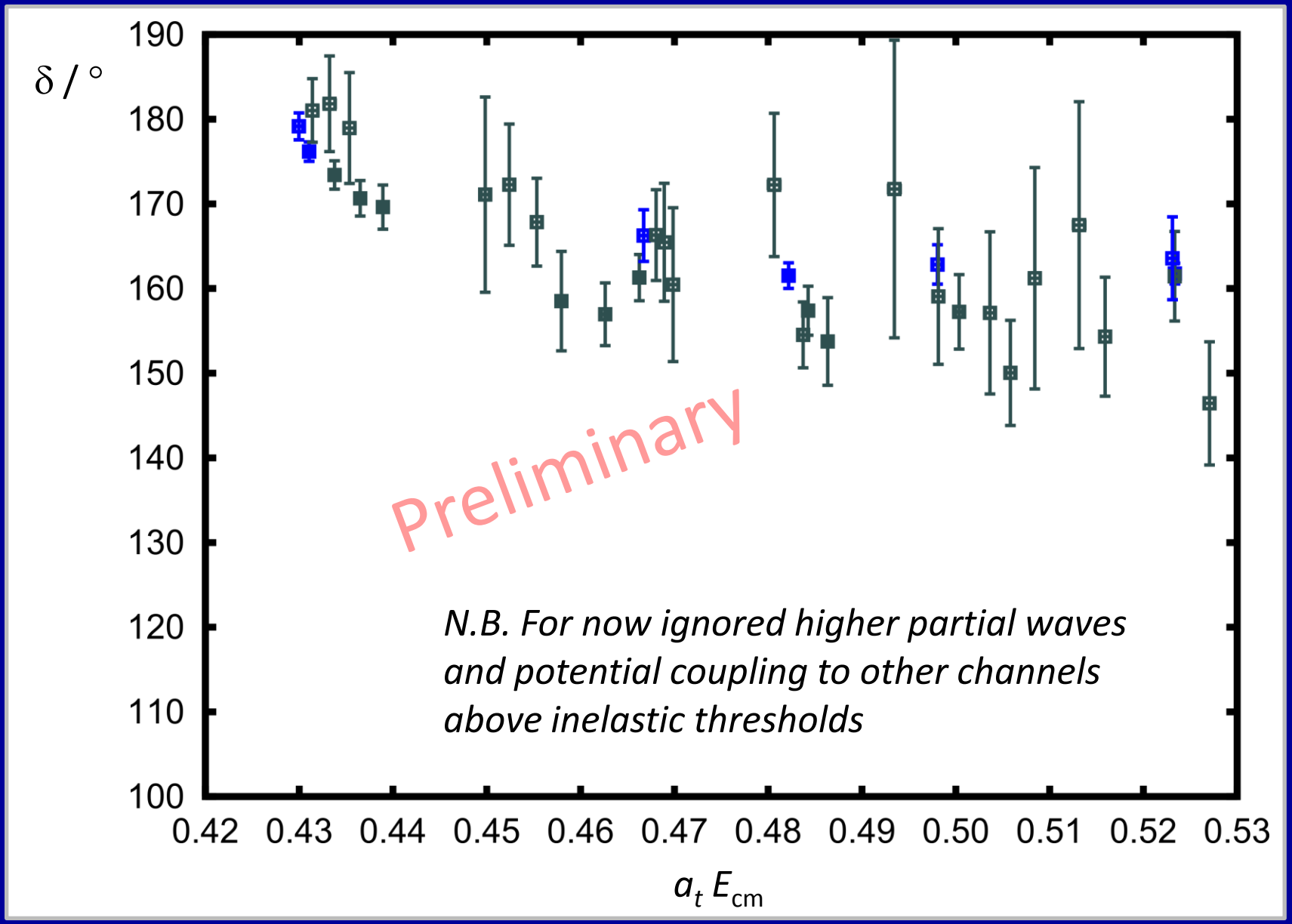
$D\bar{K}$ (I=1) spectra

P = [0,0,0] A_1^+



$J^P = 0^+, 4^+, \ldots$ [ℓ = 0, 4, ...]

$D\bar{K}$ (I=1): S-wave only



Summary and outlook

Summary

- Many energy levels → map out phase shifts
- Charm-strange mesons near $D\,K$ threshold:

  0^+ bound state [c.f. $D_{s0}(2317)$], 1^- very bound,

  also narrow 2^+ resonance ≈ 2580 MeV [c.f. $D_{s2}(2573)$]
- C.f. D π – talk by Graham Moir
- HadSpec Collab. work in light sector – talks by David Wilson, Antoni Woss, Raul Briceno, Jo Dudek

Outlook

- Many other interesting (coupled-) channels
- Evolution of phenomena as vary pion mass?
- Transitions