White Paper → TDR (?)

Introductory Comments

B. Meadows

For the charm team

Charm Team (Elba, 2011)

Milind Purohit and Nicola Neri have agreed to join in the organization of the charm working group in its next phase → TDR.

Welcome to both – there is much to do!

Things included in the WP

- Most studies were projections from Babar and CLEO-c. A few FastSim studies had been made:
  - Mixing in $D^0 \rightarrow K_s\pi^+\pi^-$ at Y(4S)
  - At ¨(3770) preliminary feasibility study of $D^0 \rightarrow \mu^+\mu^-$
  - → More are needed
- Studies at Y(4S):
  - Mixing parameters (x, y) and |q/p|, arg {q/p} from their D^0 -$\bar{D}^0$ asymmetries
  - CPV (in time-integrated decay and Time-correlation studies)
  - Rare decays $D^0 \rightarrow \mu^+\mu^-$, $D^0 \rightarrow \gamma\gamma$ $D^0 \rightarrow h^+\ell^+\ell^-$, $D^0 \rightarrow \rho^0\ell^+\ell^-$
- Running at threshold
  - QC phase measurements - how to include them in 4S mixing measurements
  - Estimates for $\sigma(A_{SL})$
  - Rare decays such as $D^0 \rightarrow \mu^+\mu^-$, $D^0 \rightarrow \gamma\gamma$ and $D^0 \rightarrow \pi^\circ\pi^\circ$
  - Suggestion: we consider how to use time-dependent decay correlations

- Various physics items added since the WP
  - D^0 -> invisible , γ + invisible, "X^0" + invisible
  - T-correlations in D^0 -> $\ell^+ \ell^- h^+ h^-$ and D^0 -> $\ell^+ \ell^- \ell^+ \ell^-$
  - CPT Violation
  - Charm baryons
  - Run at D_s threshold too – $f(D_s)$ and semi-leptonic decays (V_{cs})
  - Time-dependent quantum correlated decay studies
    - Various dougle-tsgged combinations

Threshold Running Scenario

- The run envisaged here is a 500 fb^{-1} exposure at $\psi(3770)$
  - About 600 x CLEO-c and (50-100) x BES III
  - Just above $D\bar{D}$ threshold
  - At one-tenth nominal luminosity, Super B can complete this in a few months
  - Set up and tuning of final focus may take another few months
    - → Perhaps a year altogether – maybe less?
- Possible schedules (in order of preference)
  - Plan this in as a run after 25 ab^{-1} at $\Upsilon(4S)$
  - Run because of a discovery at $\Upsilon(4S)$
  - Start-up Super B with this run
  - Do this only at the end of 10 years at $\Upsilon(4S)$
- Since Elba 2010 and the White Paper new possibilities exist
  - Perhaps the boost can be raised from $\beta\gamma$=0.23 to 0.1 (P. Raimundo)
  - Maybe other thresholds or even larger runs can be made.

White Paper → TDR

- More FastSim verification of projections made in the WP
  - We should verify performance of T-odd correlation measurements where PID was one of the limiting systematic uncertainties
  - Charm baryons
- FastSim studies at threshold
  - $\sigma(A_{SL})$ – using
    - $\psi(3770) \rightarrow D^0\overline{D}^0$ with $D^0 \rightarrow K^{(*)}\ell\nu_\ell$ vs $\overline{D}^0 \rightarrow K^{(*)}\ell\nu_\ell$ AND
    - $\psi(3770) \rightarrow D^0\overline{D}^0$ with $D^0 \rightarrow K^{(*)}\ell\nu_\ell$ vs $\overline{D}^0 \rightarrow K^- \pi^+$ (time-dependent study)
  - $D^0 \rightarrow$ invisible , γ + invisible, "X" + invisible (with background)
  - CPT Violation
- Studies at $D_s\overline{D}_s$ threshold
  - Projections for V_{cs} from D_s semi-leptonic decays in D_s threshold run

Computation

- Running at threshold
  - Set up FastSim models to include DD and D_sD_s thresholds wrt
    - Geometry - much work by G. Kosta and R. Andreassen
    - Generic backgrounds - G. Kosta has done some work here
    - Machine backgrounds – we are depending on background simulation folks here
- Important parameter studies – at Y(4S) and "charm thresholds" (at various $\beta\gamma$ values
  - Kinematic quantities of interest – M_{D^0}, Δ M, t_{decay} (or Δ t)
  - Also efficiency and luminosity - ξ, $\mathbb{L}$

E-mail list (please subscribe):

- https://lists.infn.it/sympa/info/superb-physics-charm

Wiki (SuperB physics portal):

- http://mailman.fe.infn.it/superbwiki/index.php/Physics_xortal

Important Questions White Paper → TDR

- With over 100x the data, are there better ways to extract CPV information than the ones we have been using in Babar?
  - See Adrian's talk for an idea how to do this for $D^0 \rightarrow \pi^+\pi^-$ and $D^0 \rightarrow K^+K^-$
- What can we do with time-dependent *decay correlations*
  - See Mike's talk

Extra Slides

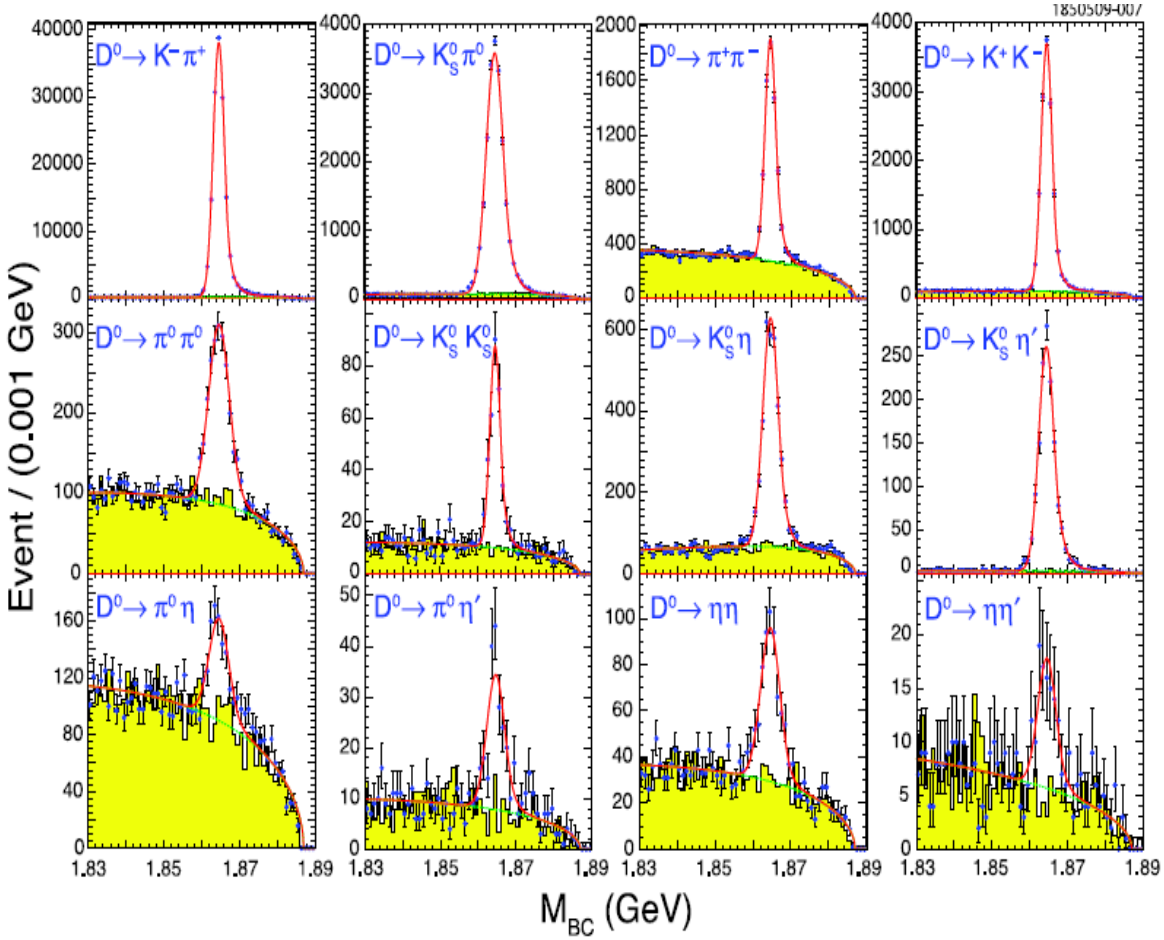
General Reasons for a $\psi(3770)$ Run

- It is possible (likely?) that an unusual effect – perhaps due to NP – will be found in the charm sector from $\Upsilon(4S)$ running
  - A true confirmation in the entirely different charm scenario at $\psi(3770)$ will trump a simple repeat performance with more luminosity at $\Upsilon(4S)$
- A 500 fb^{-1} run will improve both our own, and also LHCb's CKM γ measurement by a factor ~ 3.
- Decays of $\psi(3770) \rightarrow D^0\overline{D^0}$ produce coherent $(C=-1)$ pairs of D^0's. Quantum correlations in their subsequent decays allow measurements of strong phases
  - Required for improved measurement of CKM γ
  - Also required for D^0 mixing studies

General Reasons for a $\psi(3770)$ Run

- A record exists of several cases where CLEO-c, sometimes with just 281 pb^{-1} of their 818 pb^{-1} sample at $\psi(3770)$, has successfully competed with BaBar's ~0.5 ab^{-1} and Belle's ~1 ab^{-1} at $\Upsilon(4S)$. Examples:
  - Measurement of decay constants – f_D and f_{Ds}
  - Studies of leptonic and semi-leptonic decays,
  - Measurements of absolute hadronic branching fractions
- Other runs for CLEO-c at other CM masses have produced useful and novel results for D_s as well as D decays from $\psi(3770)$.
- → Is a program at $\Upsilon(4S)$ complete without the "service" of one at $\psi(3770)$, *etc.*?

CLEO-c Hadronic Charm Decays at $\psi(3770)$



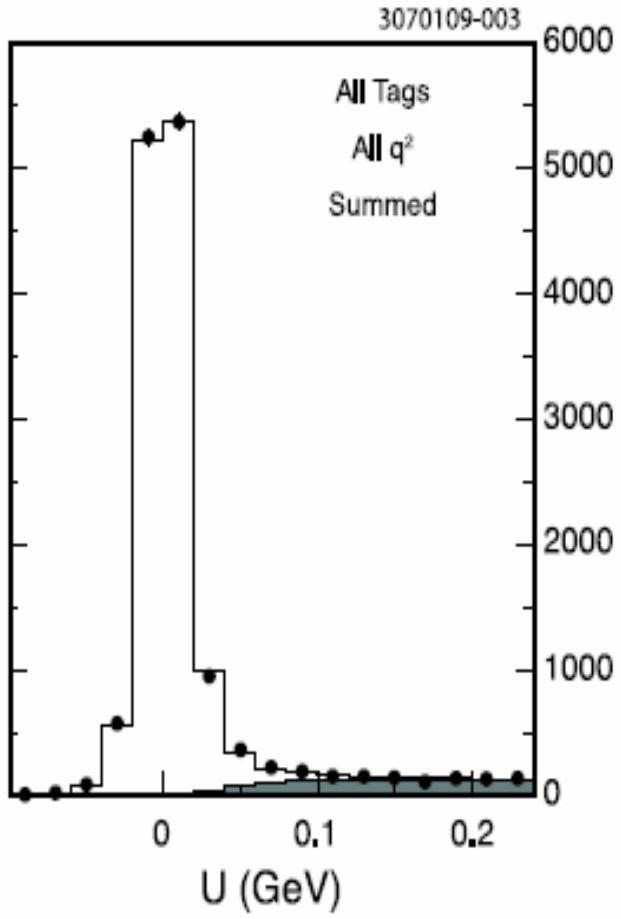
Single Tags Only

$$\Delta E = \sum_i E_i - E_{\rm beam}$$

$$M_{\rm BC} = \sqrt{E^2_{\rm beam} - (\sum_i \vec{p}_i)^2}$$

ΔE ~ 0 in signal
ΔE sidebands in yellow

Semi-Leptonic Decays



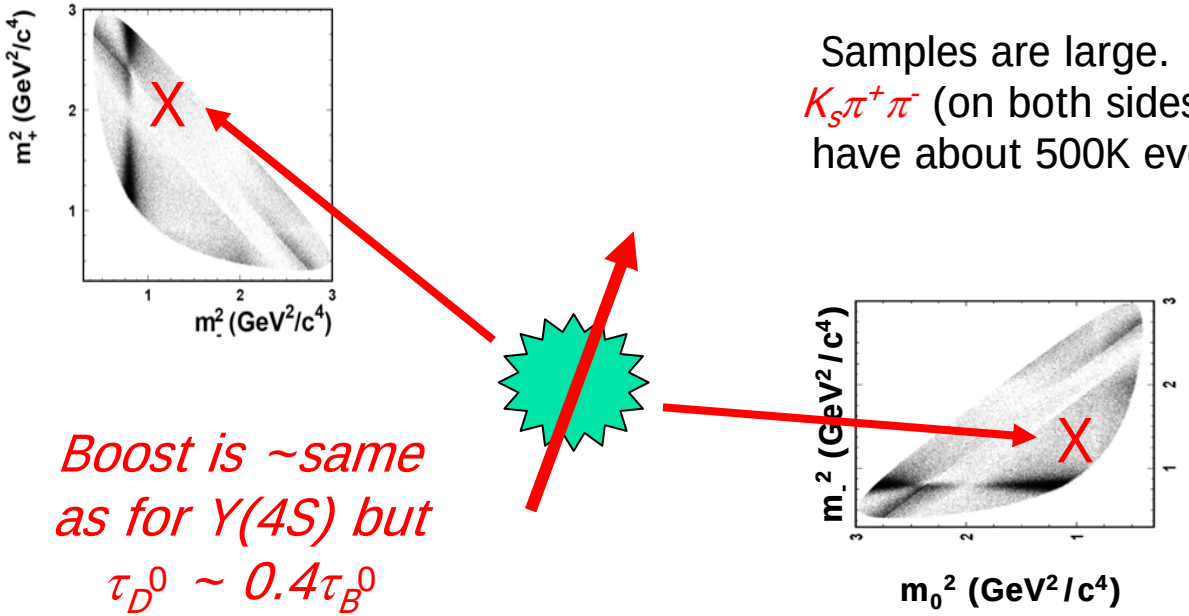
- Example of $D^0 \rightarrow K^- e^+ \nu_e$ decay from CLEO-c's *818 pb*$^{-1}$ exposure at $\psi(3770)$.
- Quantity plotted is

  $U = E_{miss} - c\,P_{miss}$

  (Note background level ~0)

Time-dependent QC Decays – "Super D" ?

- The moving CMS means we could measure time-dependent (TD) strong phases resulting from D^0 mixing.



Samples are large. E.g. $K_S\pi^+\pi^-$ (on both sides) will have about 500K events.

Boost is ~same as for Y(4S) but $\tau_{D^0} \sim 0.4\tau_{B^0}$

Re-cap from Warwick summary 2008

Is this possible or useful ?
What else can we learn from this ?

“Super D” ?

- The time-dependent “Double-Dalitz” analysis can be made on a wide variety of double-tagged events:
  - $(K_s\pi^+\pi^-)$ - $(K_s\pi^+\pi^-)$
  - $(K_s\pi^+\pi^-)$ – $(K_s\ K^+K^-)$
  - $(K_s\pi^+\pi^-)$ – $(K^-\pi^+\pi^0)$
  - $(K_s\pi^+\pi^-)$ – $(K^-\pi^+)$
  - $(K_s\pi^+\pi^-)$ – (K^-K^+)
  - … etc.

- Large samples.
- Highly constrained (model-dependent)
- Measure |q/p| and ϕ=Arg{q/p}
  direct CPV, ...

Re-cap from Warwick summary 2008

- We need a simulation to learn how well this might work in face of reduced time-resolution wrt “Super B”..

$D\bar{D}$ Threshold Measurements

- Data from $D\bar{D}$ threshold provide measurement of strong phases such as $\delta_{K\pi}$ and $<\delta_{K\pi\pi^0}>$.
- They also provide measured values of δ in Dalitz plot bins

  This can be used (with a model for the values for r) to significantly reduce uncertainties in the Dalitz plot model used in the golden channel analyses.

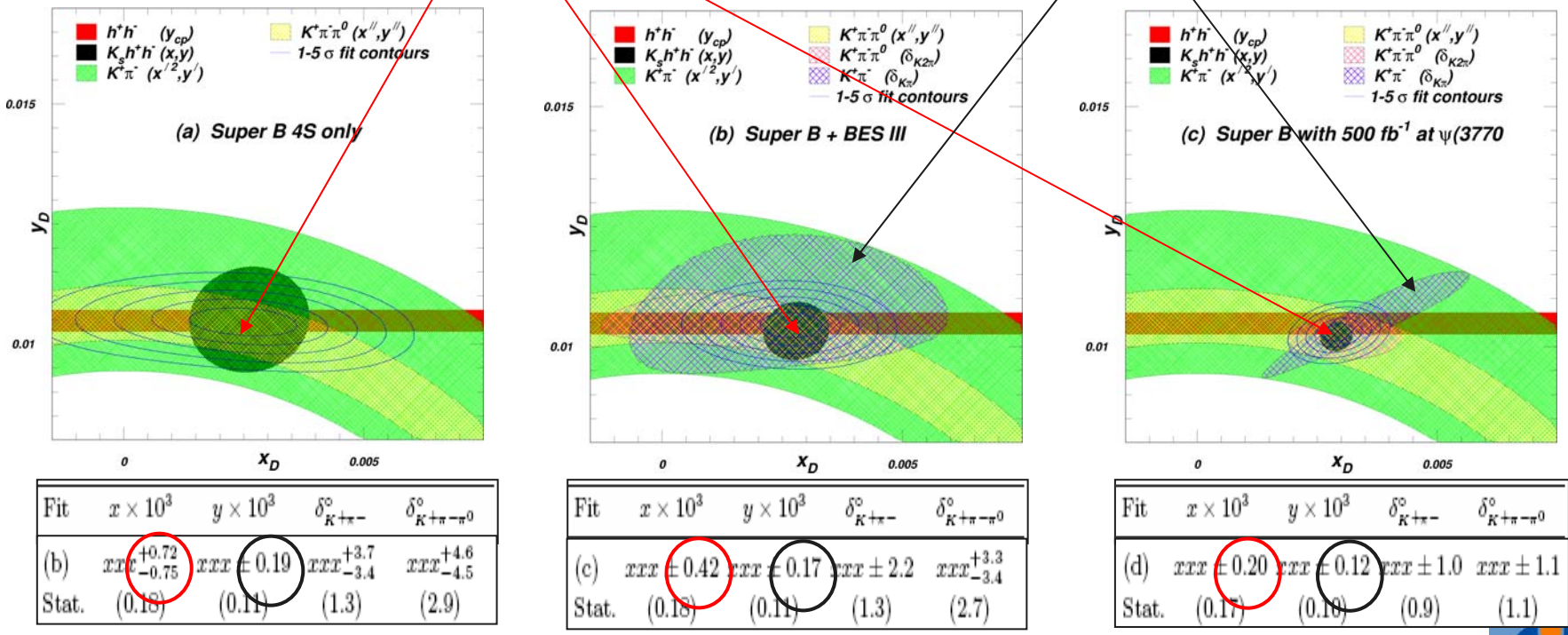
- As a basis for projection, we take results from CLEO-c:

  N. Lowrey et al, PRD80, 031105 (2009), 0903.4853

- We assume that new data from threshold will reduce the uncertainties in model uncertainty:
  - BES III – ~factor 3 improvement in model uncertainty
  - Super B 500 fb^{-1} $D\bar{D}$ threshold run – ~factor 10 improvement.

Value of Strong Phase Measurements

- Two improvements in mixing precision come from threshold data:
  - Dalitz plot model uncertainty shrinks
  - Information on overall strong phase is added



Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K^+\pi^-}$	$\delta^\circ_{K^+\pi^-\pi^0}$
(b)	$xxx^{+0.72}_{-0.75}$	$xxx \pm 0.19$	$xxx^{+3.7}_{-3.4}$	$xxx^{+4.6}_{-4.5}$
Stat.	(0.18)	(0.11)	(1.3)	(2.9)

Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K^+\pi^-}$	$\delta^\circ_{K^+\pi^-\pi^0}$
(c)	$xxx \pm 0.42$	$xxx \pm 0.17$	$xxx \pm 2.2$	$xxx^{+3.3}_{-3.4}$
Stat.	(0.18)	(0.11)	(1.3)	(2.7)

Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K^+\pi^-}$	$\delta^\circ_{K^+\pi^-\pi^0}$
(d)	$xxx \pm 0.20$	$xxx \pm 0.12$	$xxx \pm 1.0$	$xxx \pm 1.1$
Stat.	(0.17)	(0.10)	(0.9)	(1.1)

Uncertainty in x_D improves more than that of y_D

Summary of CPV Sensitivity from Mixing

Strategy	Decay	$\sigma(\lvert q/p\rvert) \times 10^2$	$\sigma(\phi_M)^\circ$
Asymmetries a_z:			
x_D	<All modes>	± 1.8	–
y_D	<All modes>	± 1.1	–
y_{CP}	K^+K^-	± 3.8	–
y'	$K^+\pi^-$	± 4.9	–
x'^2	$K^+\pi^-$	± 4.9	–
x''	$K^+\pi^-\pi^0$	± 5.4	–
y''	$K^+\pi^-\pi^0$	± 5.0	–
TDDP (*CPV* allowed):			
BES III DP model	$K^0_S h^+h^-$	± 3.7	± 1.8
Super$B$ DP model	" "	± 2.7	± 1.5
SL Asymmetries a_{SL}:			
75 ab^{-1} at $\Upsilon(4S)$	$X\ell\nu_\ell$	± 10	
500 fb^{-1} at $\psi(3770)$	$K\pi$	± 10	
500 fb^{-1} at $\psi(3770)$	$X\ell\nu_\ell$	TBD	

Precision of a_{SL}

Uncertainty from a signal *S* over background *B* is

$$\sigma(a_{SL}) = \frac{\sqrt{S+B}}{B}$$

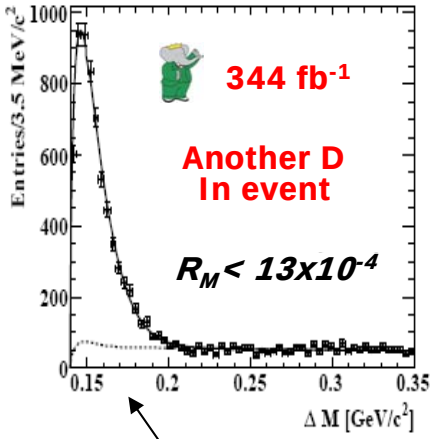
$$\longrightarrow \sigma(|q/p|) = 0.5\ \sigma(a_{SL})$$

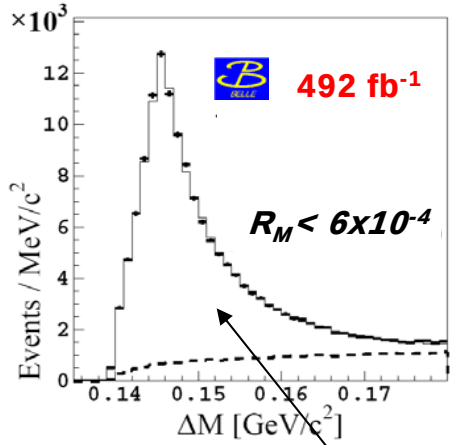
Background “spoils” asymmetry measurements.

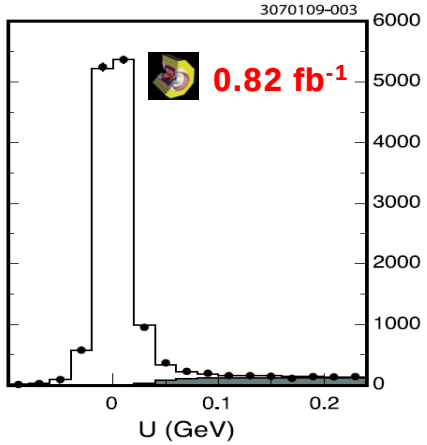
Measurement of a_{SL} – Needs $\psi(3770)$ Data!

- Decays to wrong-sign (WS) leptons proceed through mixing
  - Rate is very small $R_M=(x^2+y^2)/2 \times 10^{-4} \sim 5 \times 10^{-5}$ and not yet observed:

Right-sign (RS) Decays $D^0 \rightarrow K^- e^+ \nu_e$ + c.c.







Υ(4S): D^0 tagged by $D^{*+} \rightarrow D^0 \pi^+$
ν_ε not reconstructed
Background limits WS data

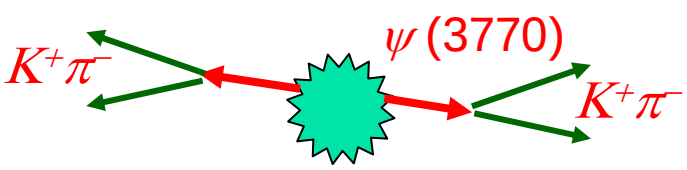
$\psi(3770)$: D^0 tagged
ν_ε fully reconstructed
Include Hadronic decays*

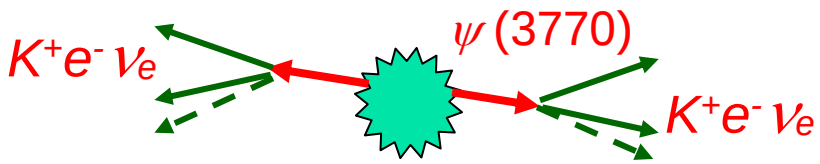
σ (a_sl) for 75 ab-1 ~ 0.20 | ***σ (a_sl) for 75 ab-1 ~ 0.80*** | ***σ (a_sl) for 500 fb-1 ~ 0.20***

*At $\psi(3770)$. We need CLEO-c data to refine our knowledge of backgrounds we can expect.

a_{SL} from $\psi(3770)$ Data (Needs evaluation from simulation)

- Two un-ambiguous possibilities.

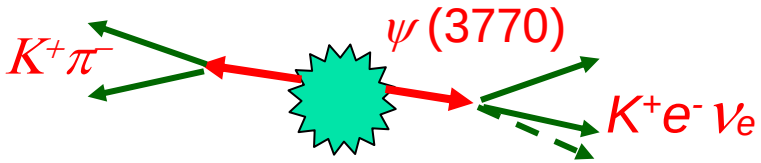




Can we do this anyway?

Bose statistics requires that one D^0 had to mix

- One ambiguous possibility.



(coherent)

$D^0 \rightarrow K^+\pi^-$ 5 x more likely to be *DCS* than $D^0 \rightarrow K^+e^-\nu_e$ is from mixing

- Could resolve ambiguity using difference in time-dependence of mixing (t^2e^{-t}) vs. direct DCS decay (e^{-t}).

Rare Decays

$D^0 \rightarrow \gamma\gamma$, $D^0 \rightarrow$ "invisible"
and $D^0 \rightarrow \mu^+\mu^-$, etc.

Other Thresholds

Ikaros Bigi

... willing to grow a beard if CPV is not observed in D decays by 2017!

Get well soon, Ikaros !!