

~~Interplay of measurements and long
term world-average perspectives*~~
Latest world averages and their
possible evolution**

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*this title was imposed upon me

**and then this

Recent changes

- LHCb γ_{CP} from μ -tagged decays
➔ WA: $(0.84 \pm 0.16)\% \rightarrow (0.72 \pm 0.11)\%$
- LHCb $K_S \pi \pi$ (bin flip)
- Removal of old preliminary Belle results on $A_{CP}(KK/\pi\pi)$
- LHCb ΔA_{CP} full Run 1+2 result

The numbers

CHARM 2018

Moriond 2019

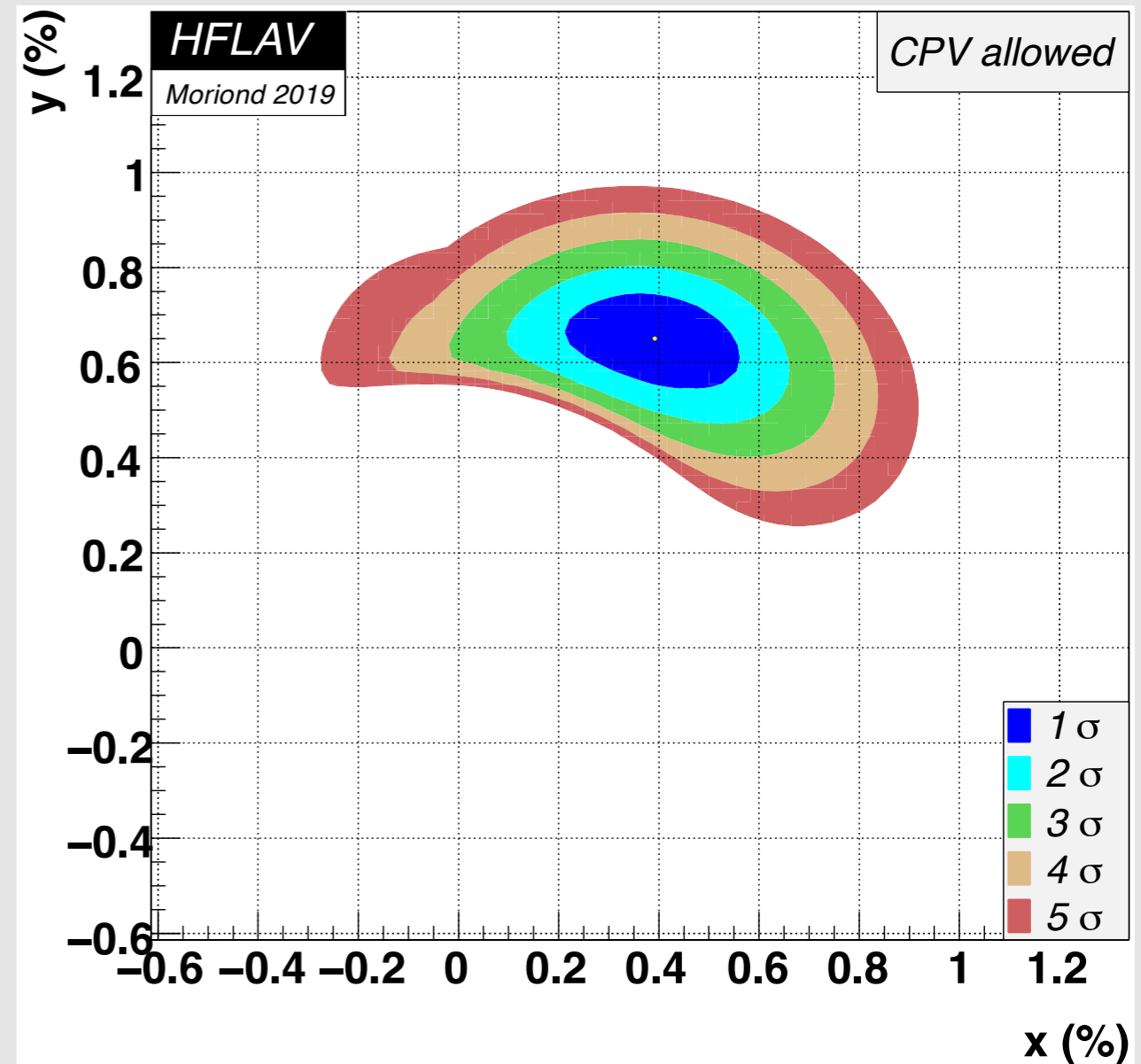
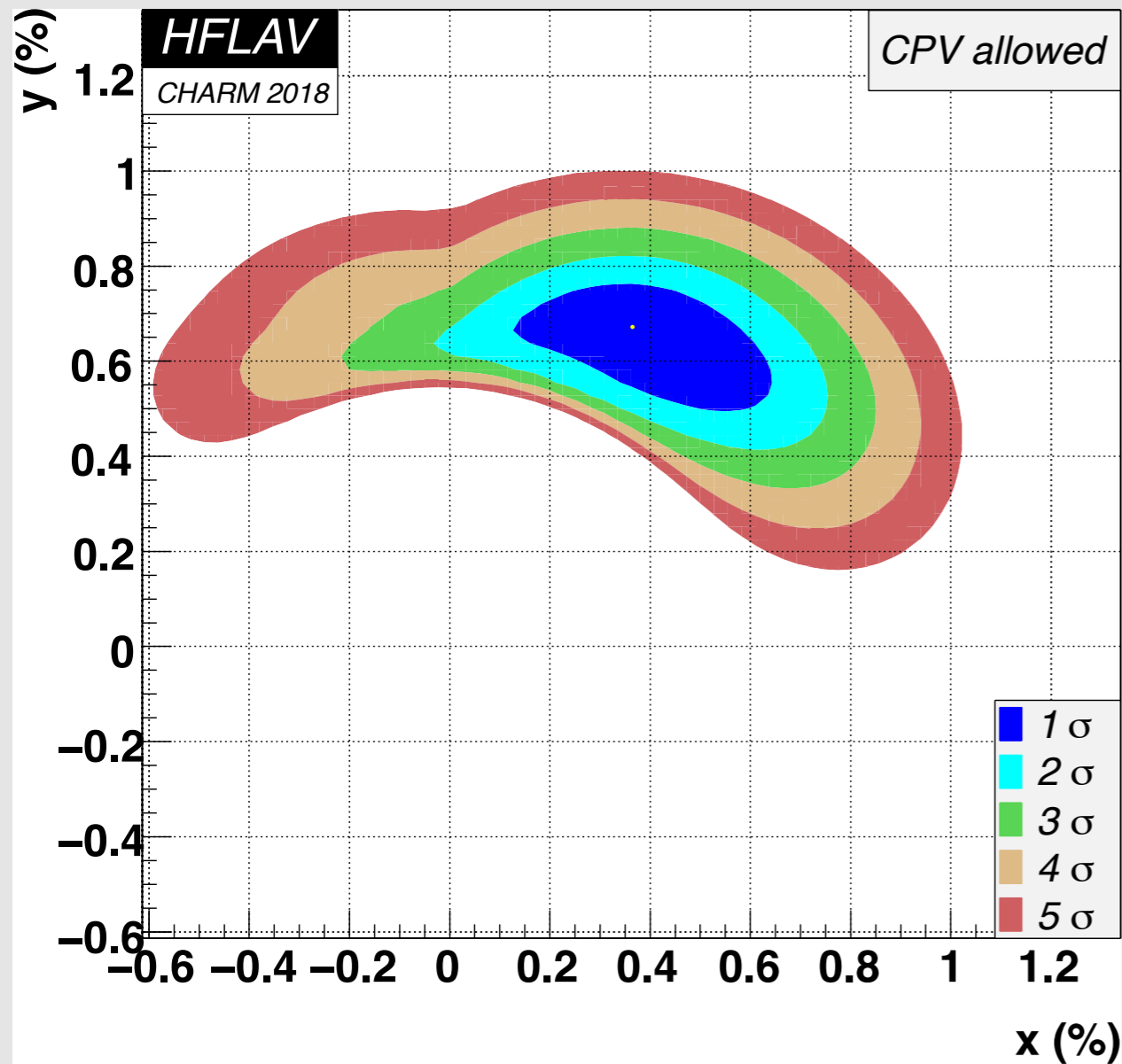
Parameter	<i>CPV</i> -allowed	<i>CPV</i> -allowed
x (%)	$0.36^{+0.21}_{-0.16}$	$0.39^{+0.11}_{-0.12}$
y (%)	$0.67^{+0.06}_{-0.13}$	$0.651^{+0.063}_{-0.069}$
$\delta_{K\pi}$ ($^\circ$)	$14.7^{+8.4}_{-17.6}$	$12.1^{+8.6}_{-10.2}$
R_D (%)	0.344 ± 0.002	0.344 ± 0.002
A_D (%)	$-0.73^{+0.84}_{-0.67}$	$-0.55^{+0.49}_{-0.51}$
$ q/p $	$0.94^{+0.17}_{-0.07}$	$0.969^{+0.050}_{-0.045}$
ϕ ($^\circ$)	$-7.2^{+14.7}_{-9.6}$	$-3.9^{+4.5}_{-4.6}$
$\delta_{K\pi\pi}$ ($^\circ$)	$28.4^{+24.3}_{-28.8}$	$25.8^{+23.0}_{-23.8}$
A_π (%)	$0.03^{+0.13}_{-0.14}$	0.06 ± 0.16
A_K (%)	-0.10 ± 0.13	-0.09 ± 0.16

Improved precision
through y_{CP} and $K_S\pi\pi$

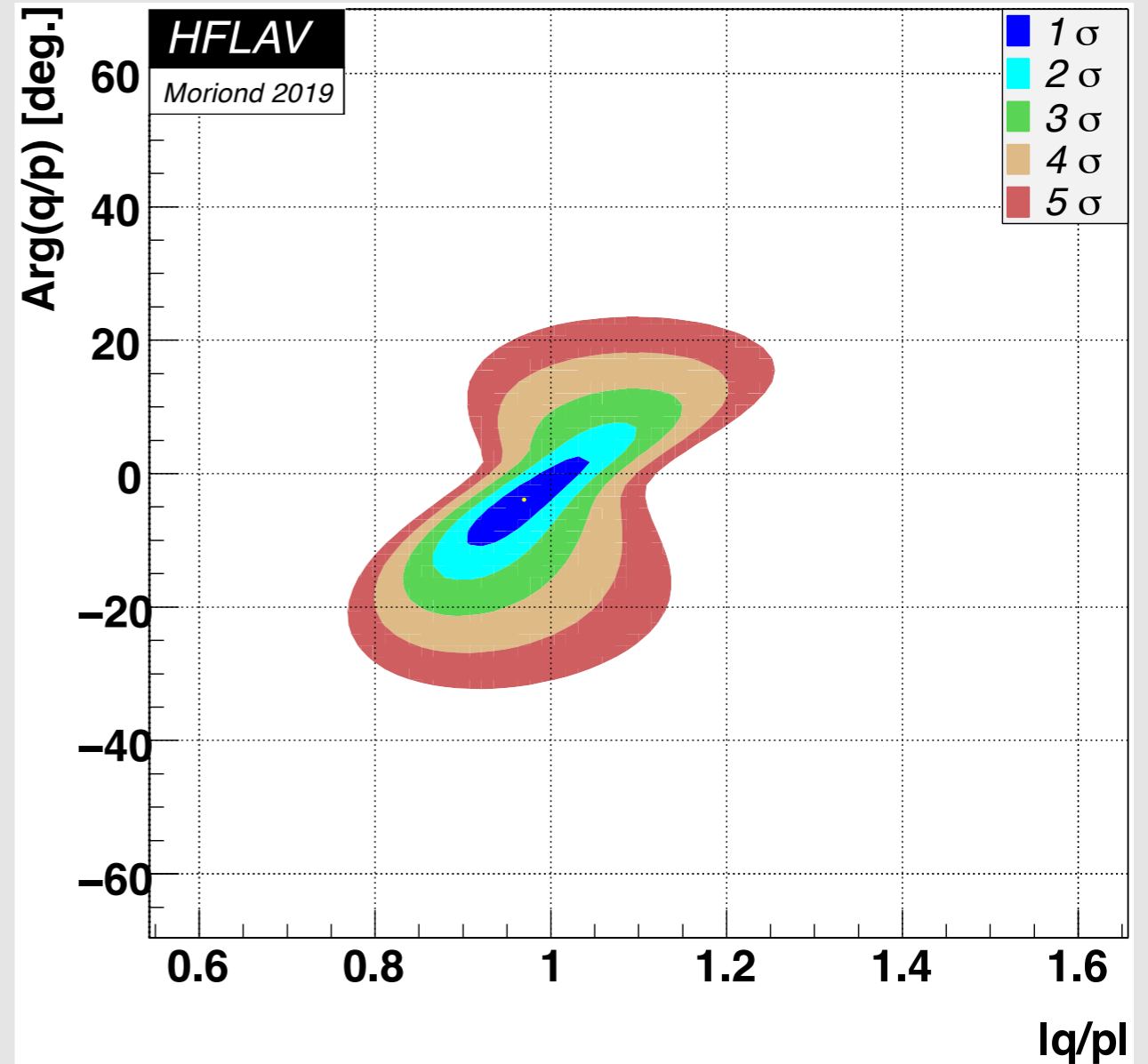
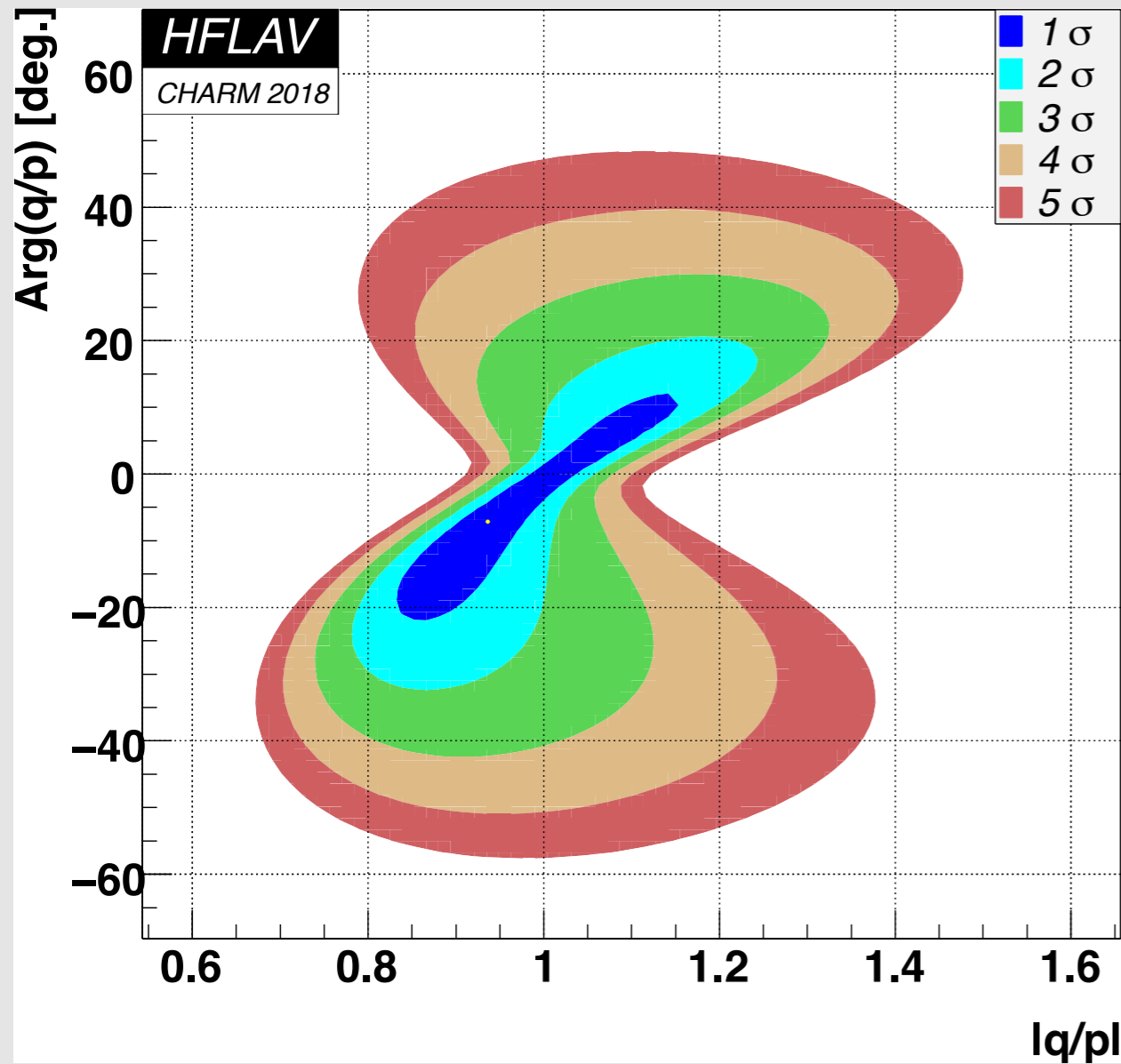
Indirect improvement

Massive improvement
through $K_S\pi\pi$

Mixing averages



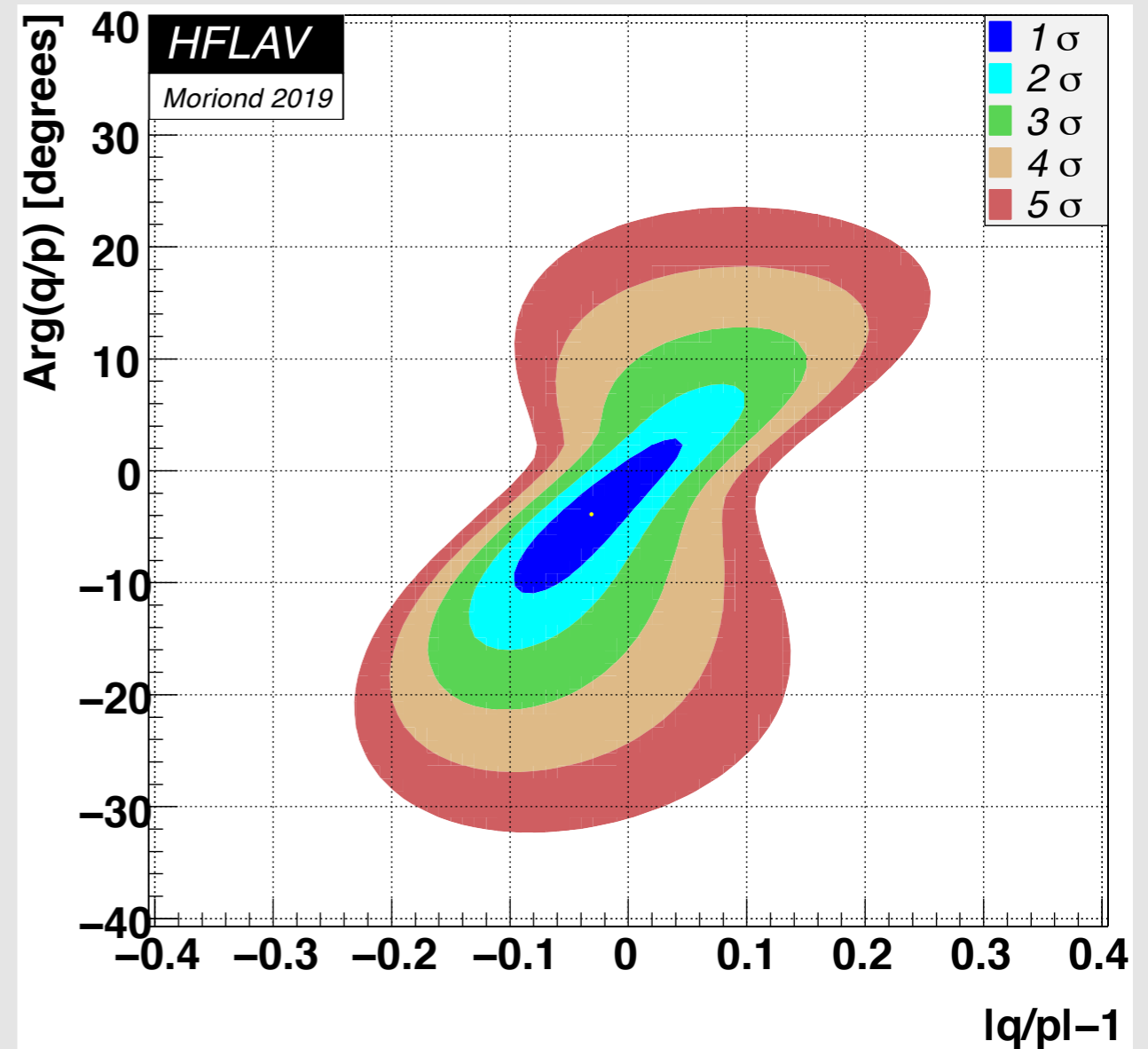
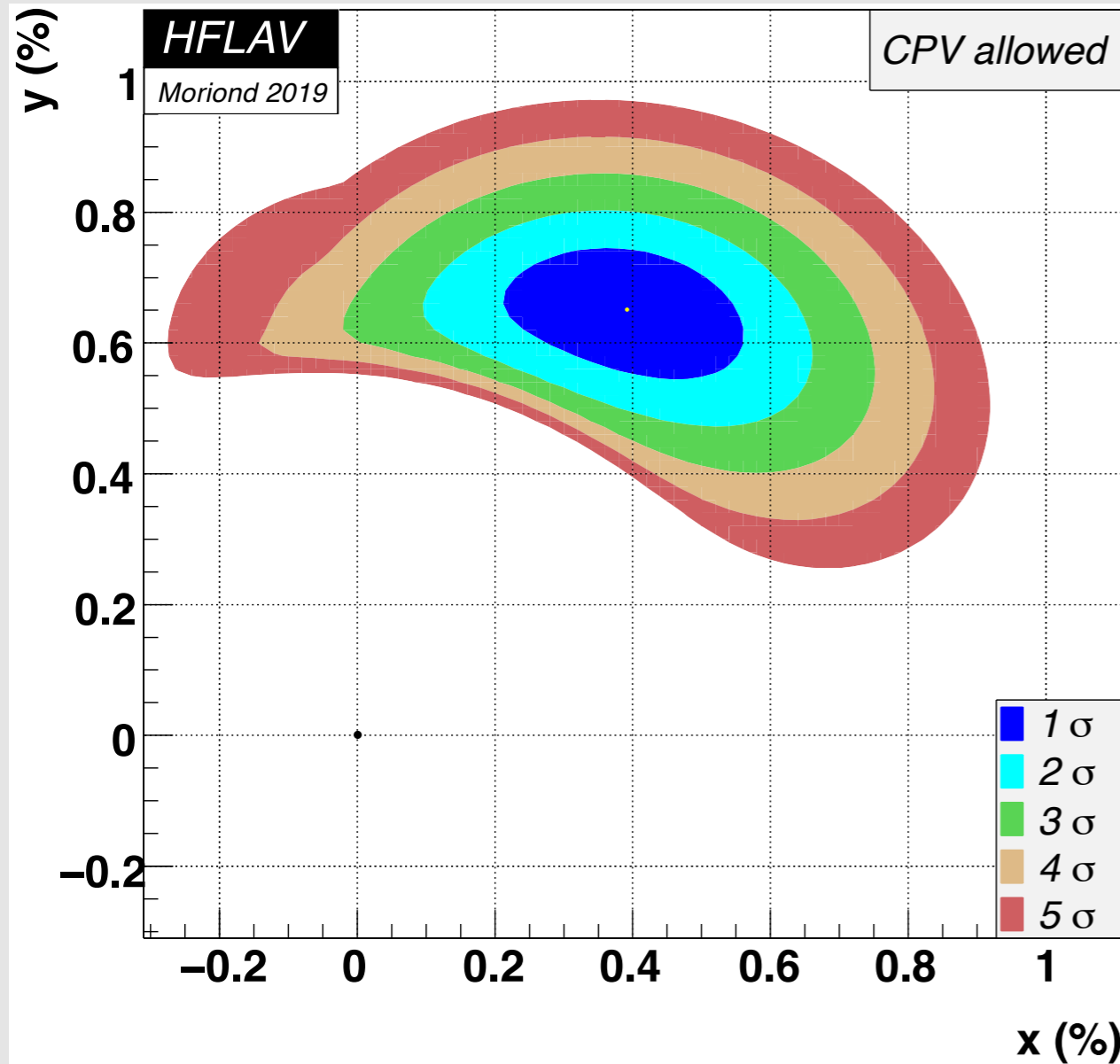
CPV averages



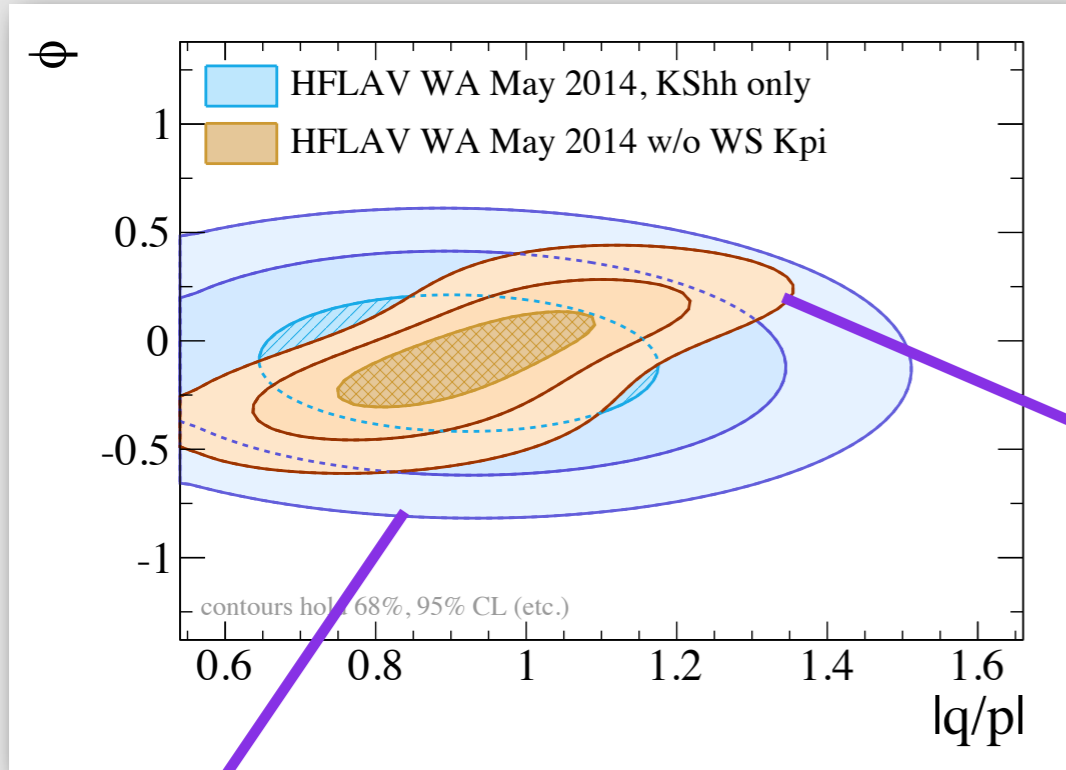
LHCb $K_S\pi\pi$, LHCb-PAPER-2019-001

$$\begin{array}{l} |q/p| \\ \phi \end{array} \begin{array}{l} 1.05^{+0.22}_{-0.17} \\ -0.09^{+0.11}_{-0.16} \end{array} = (-5_{-9}^{+6})^\circ$$

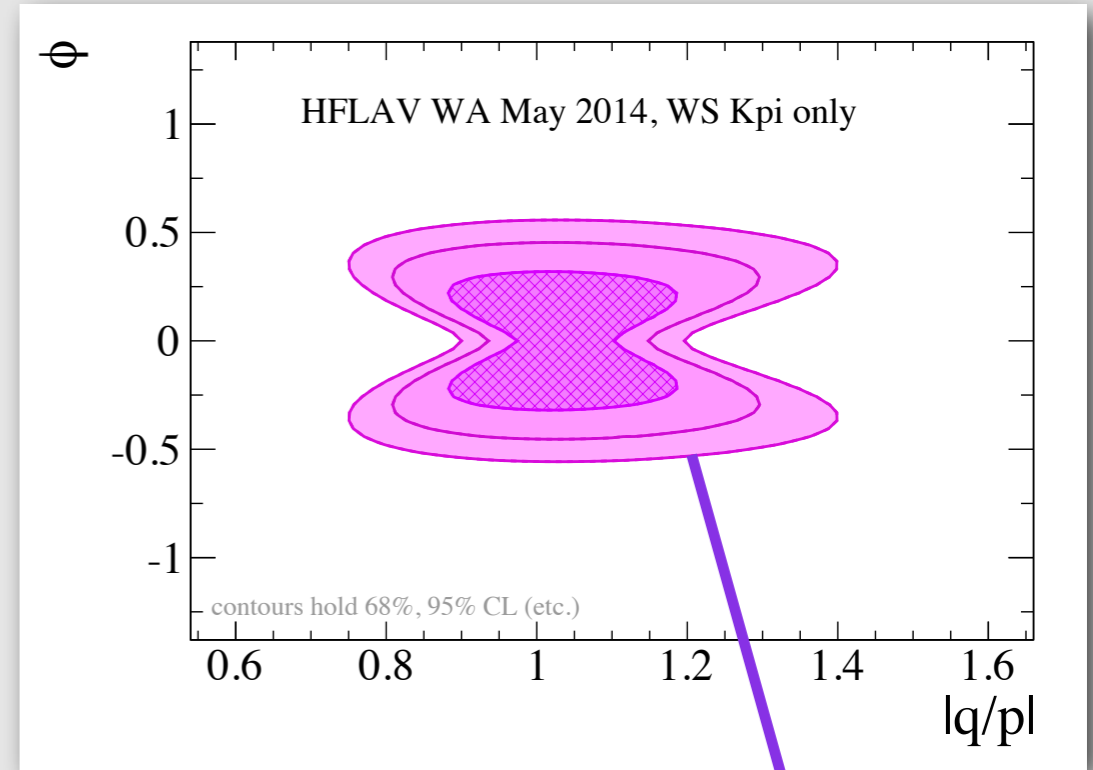
New scales



Contributions to CPV

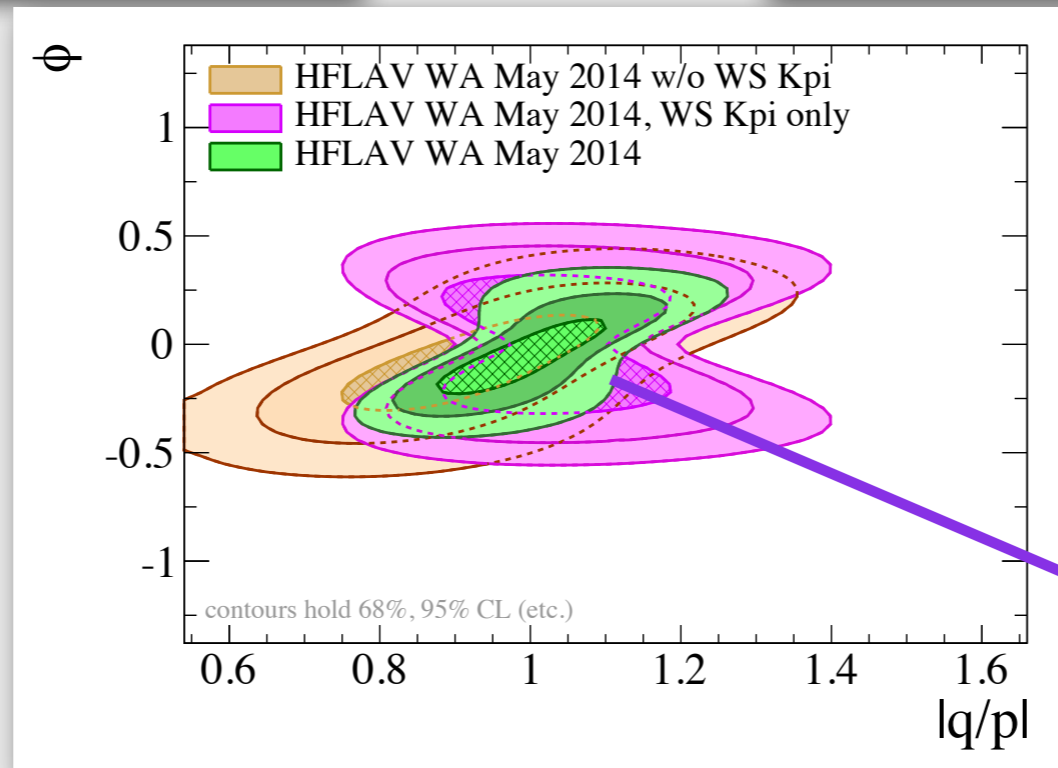


Precise constraints if x and y provided, mostly from A_Γ



Direct access to lq/pl and ϕ from K_{shh}

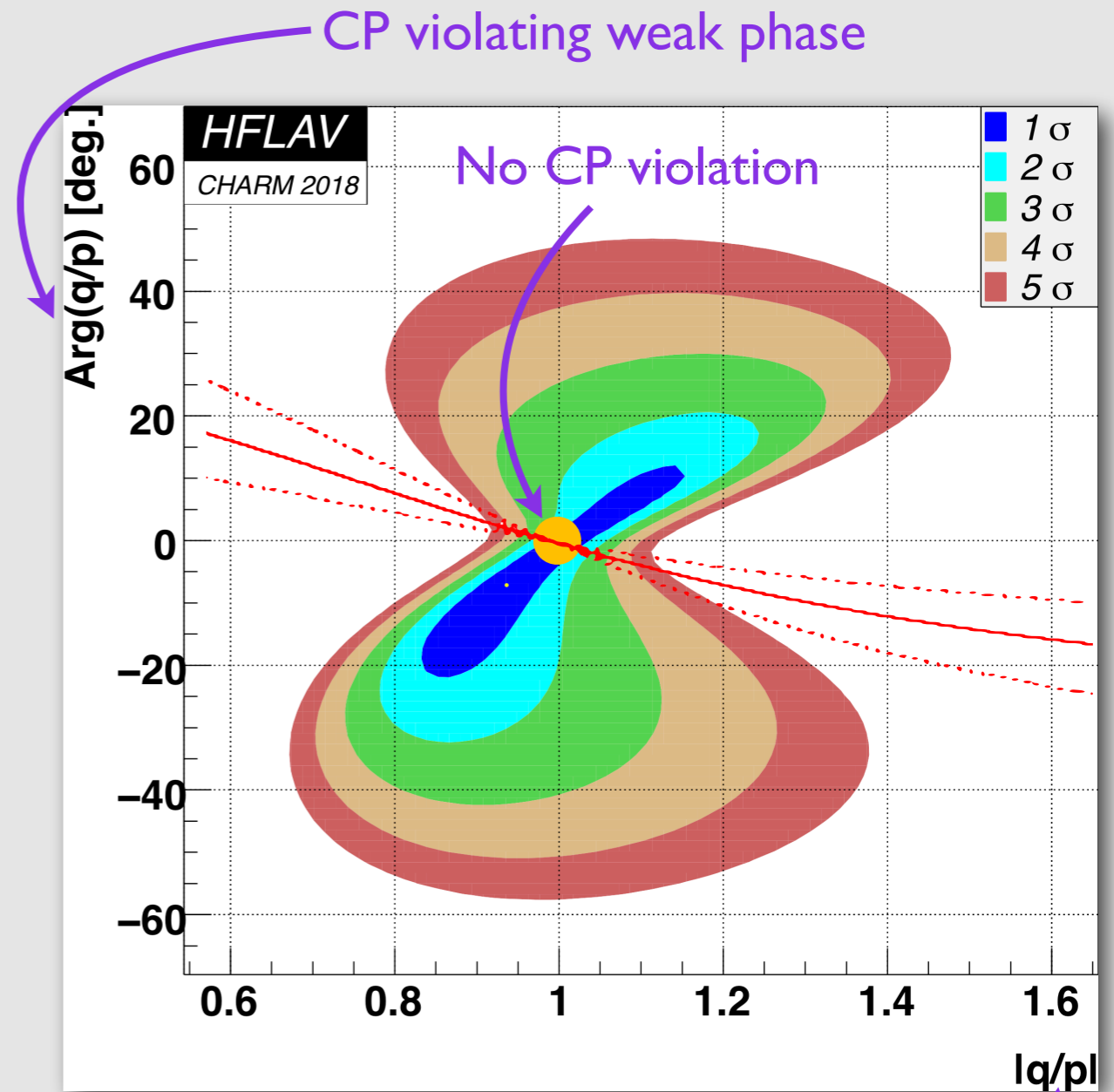
WS $K\pi$: symmetric in ϕ , good sensitivity to lq/pl for small ϕ



Full average following intersection of contours

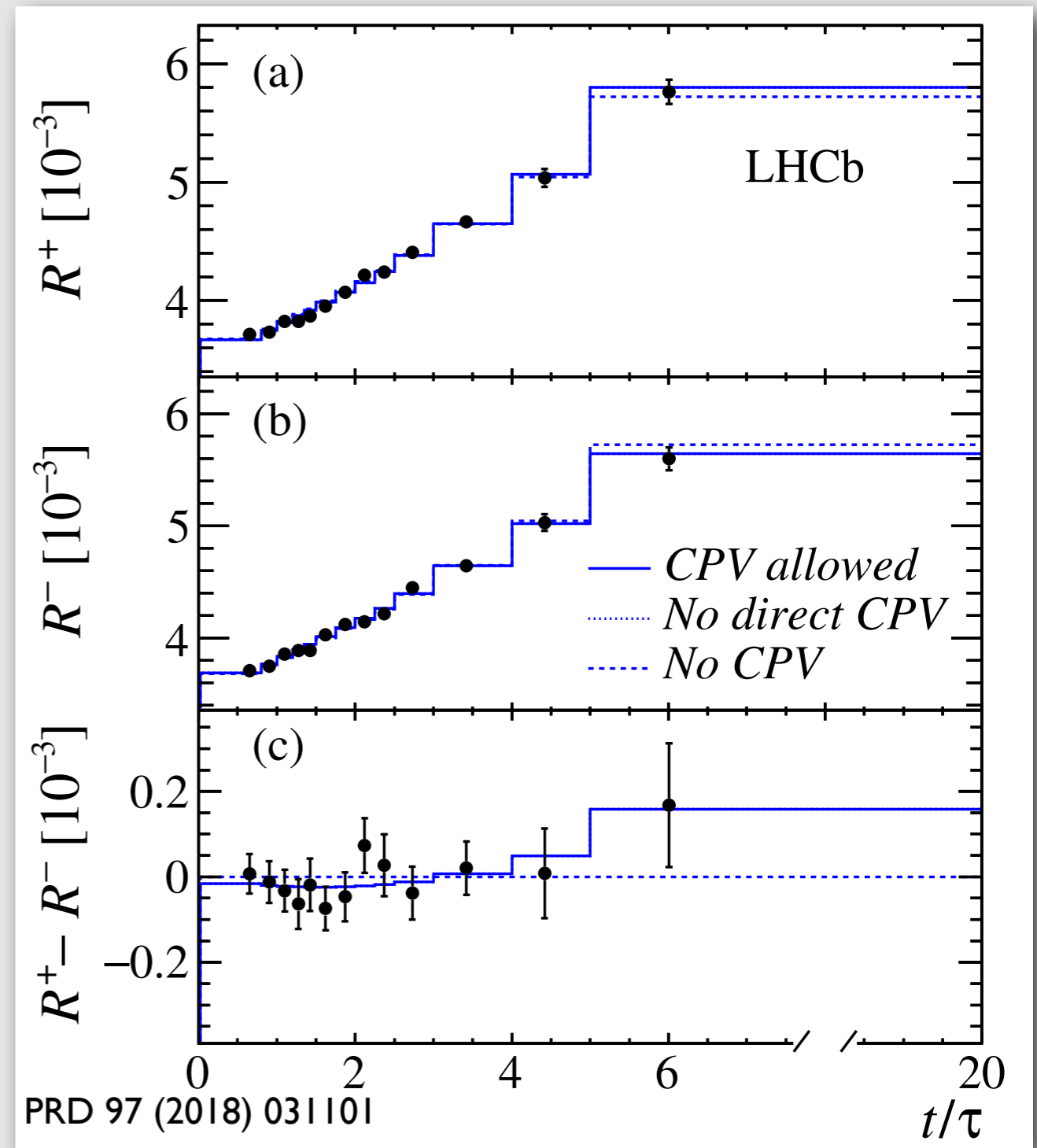
Can we do better?

- Superweak constraint
 - ➔ Assumes no new decay-specific weak phase
 - ➔ Cuichini et al. (2007)
 - ➔ Kagan, Sokoloff (2009)
- Reducing to 3 parameters
 - ➔ $\tan\Phi \approx (1-|q/p|)x/y$
- Consider WS measurement with $\Phi \approx 0$
 - ➔ $y'^{\pm} = |q/p|^{\pm 1} (y' \cos\Phi \mp x' \sin\Phi)$
- Different parametrisation
 - ➔ $x_{12}, y_{12}, \Phi_{12}$
- Current sensitivity already very good
 - ➔ $\sigma(\Phi_{12}) = 1.7^\circ$



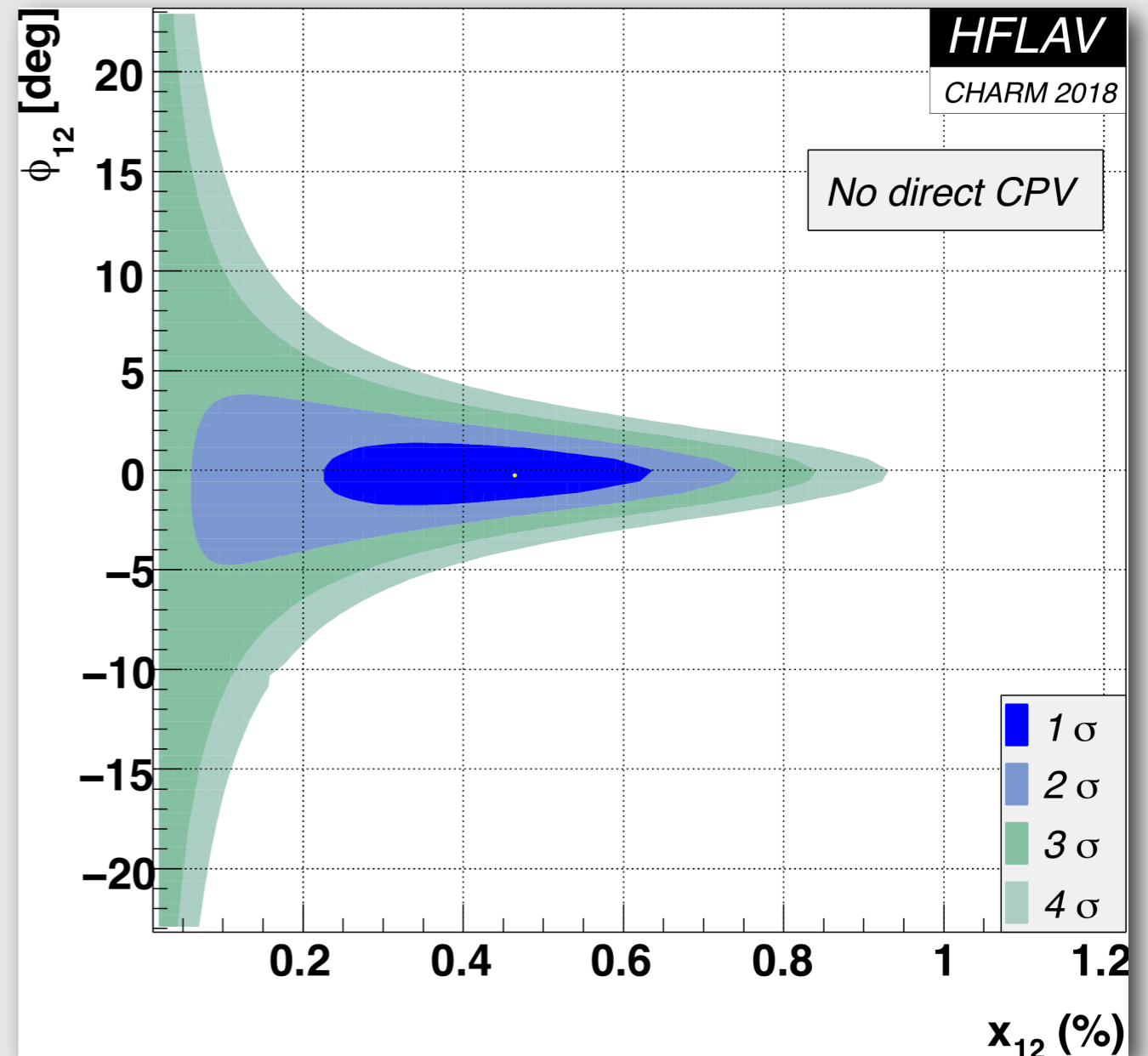
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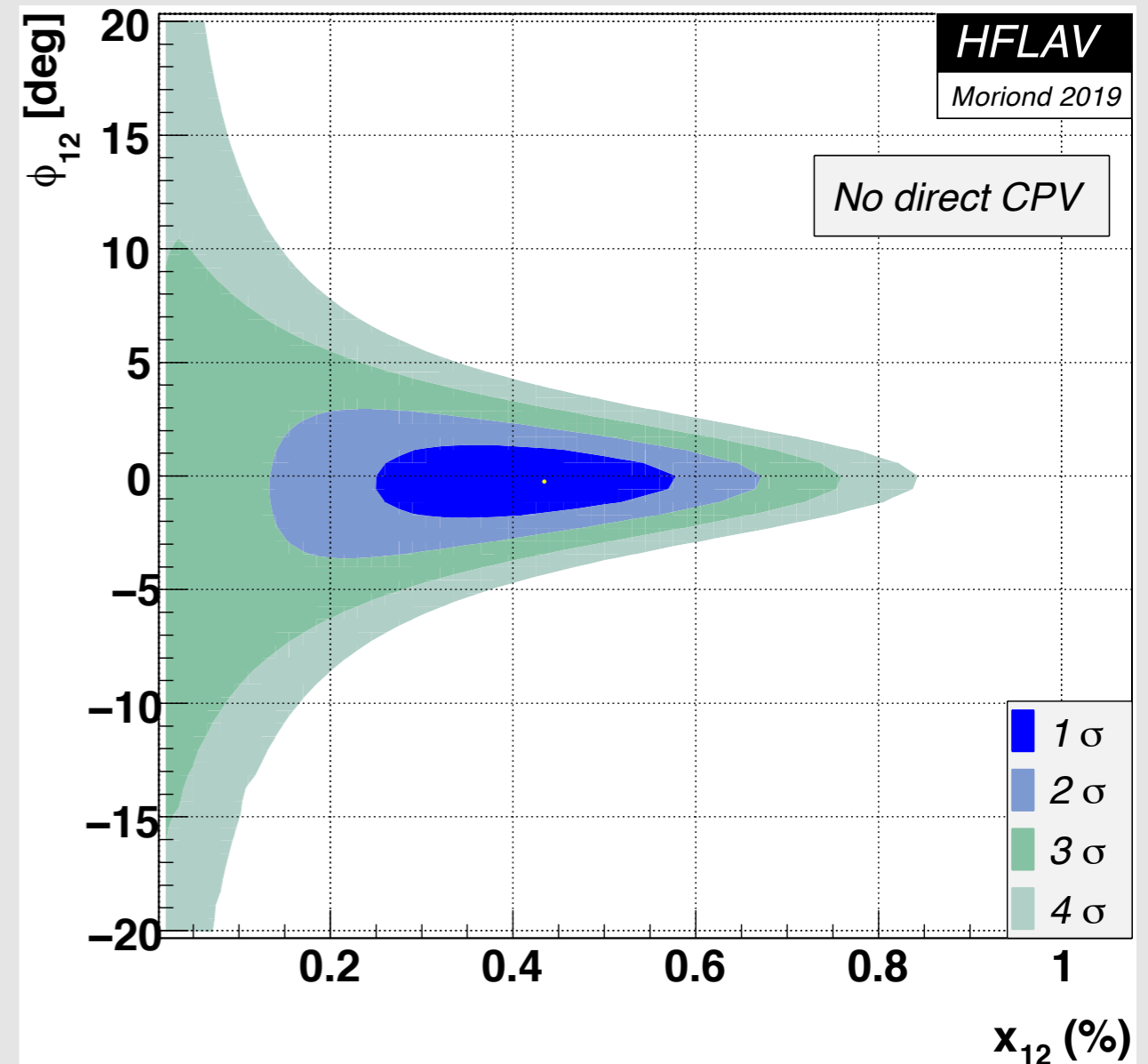
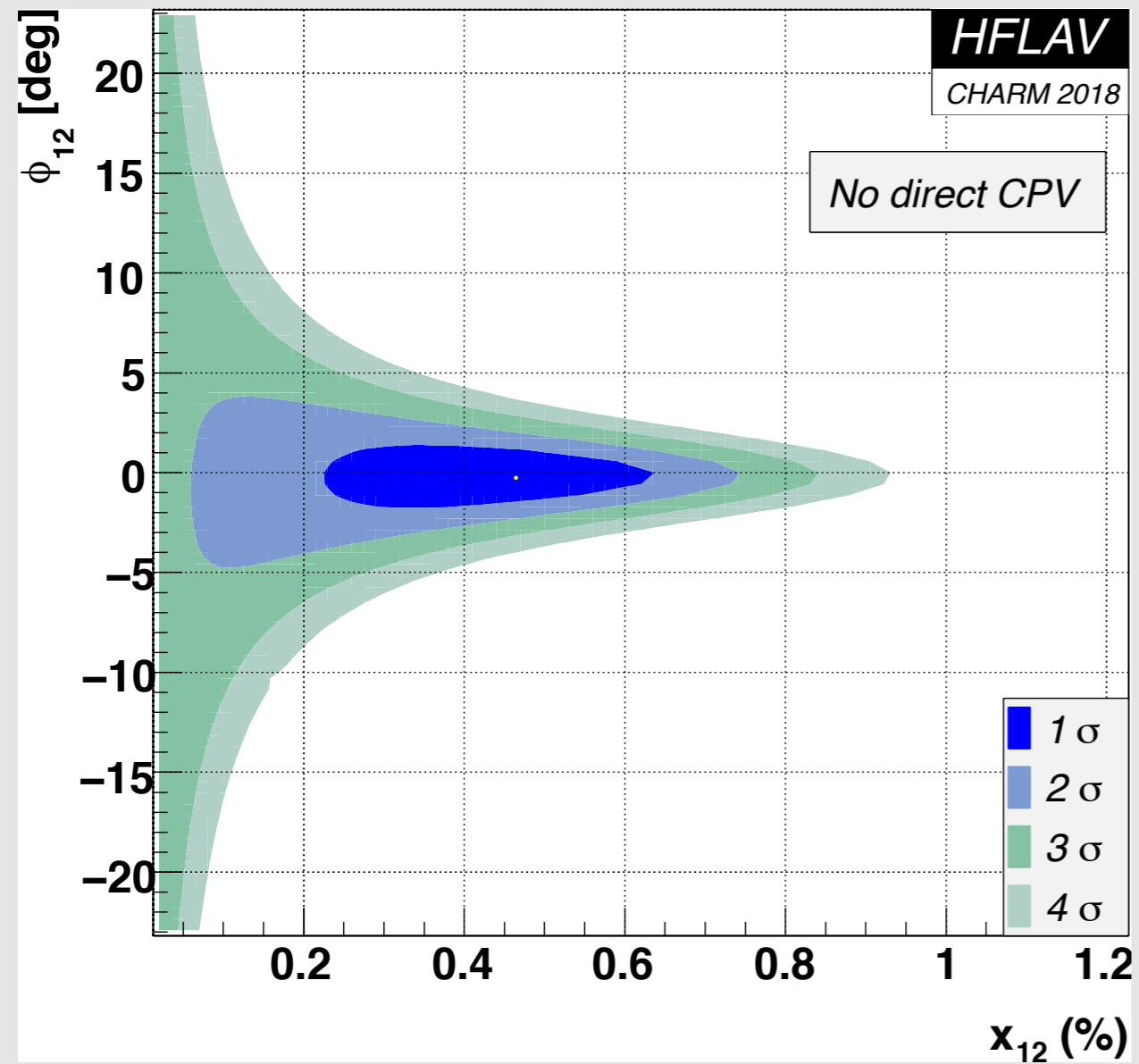


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Super-weak changes



x_{12} (%)

$0.46^{+0.12}_{-0.13}$

y_{12} (%)

0.62 ± 0.07

ϕ_{12} ($^{\circ}$)

$-0.25^{+0.90}_{-0.94}$

$0.43^{+0.10}_{-0.11}$

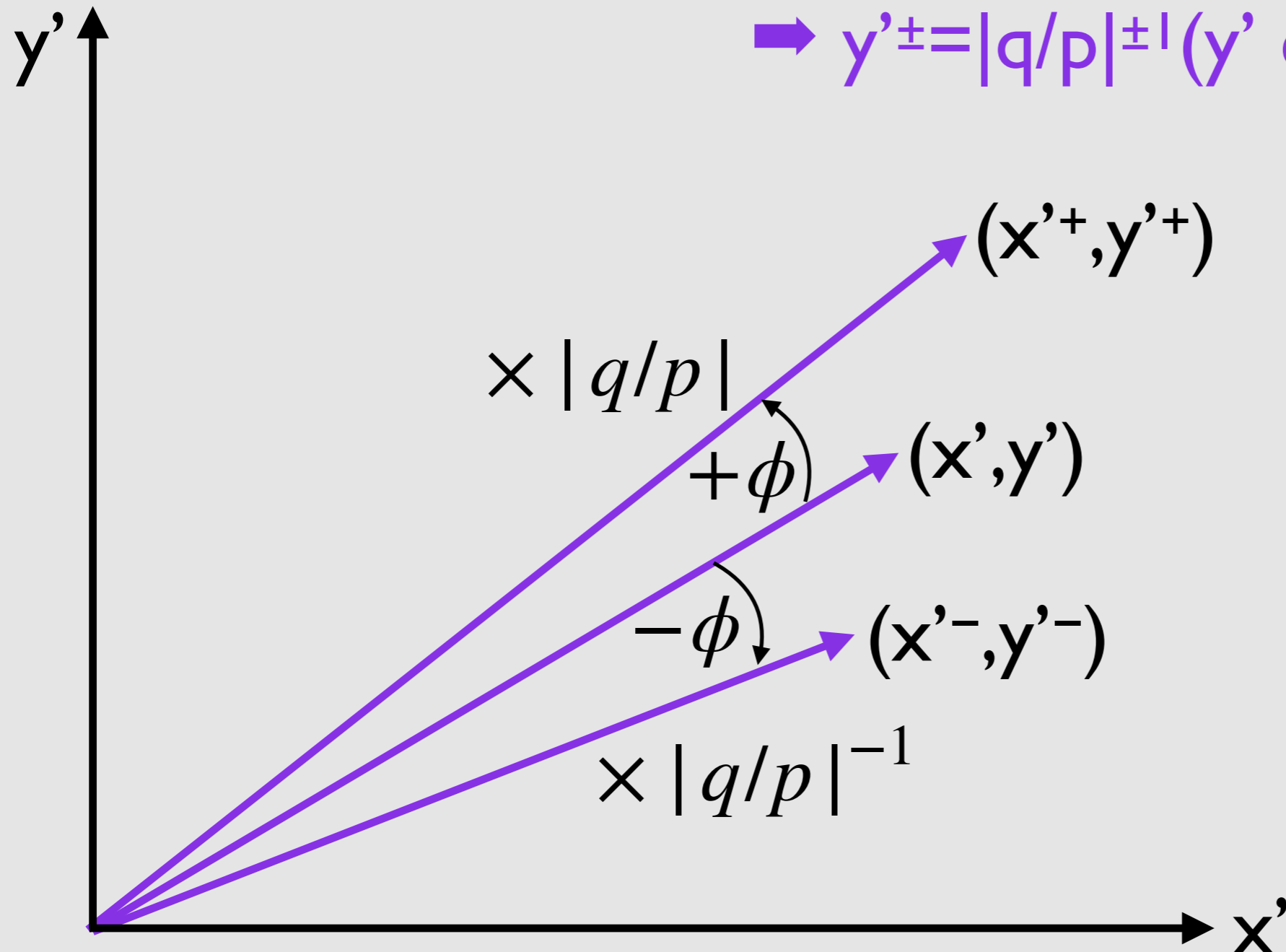
0.63 ± 0.06

$-0.25^{+0.96}_{-0.99}$

CPV from WS $K\pi$

$$\rightarrow x'^{\pm} = |q/p|^{\pm 1} (x' \cos\Phi \pm y' \sin\Phi)$$

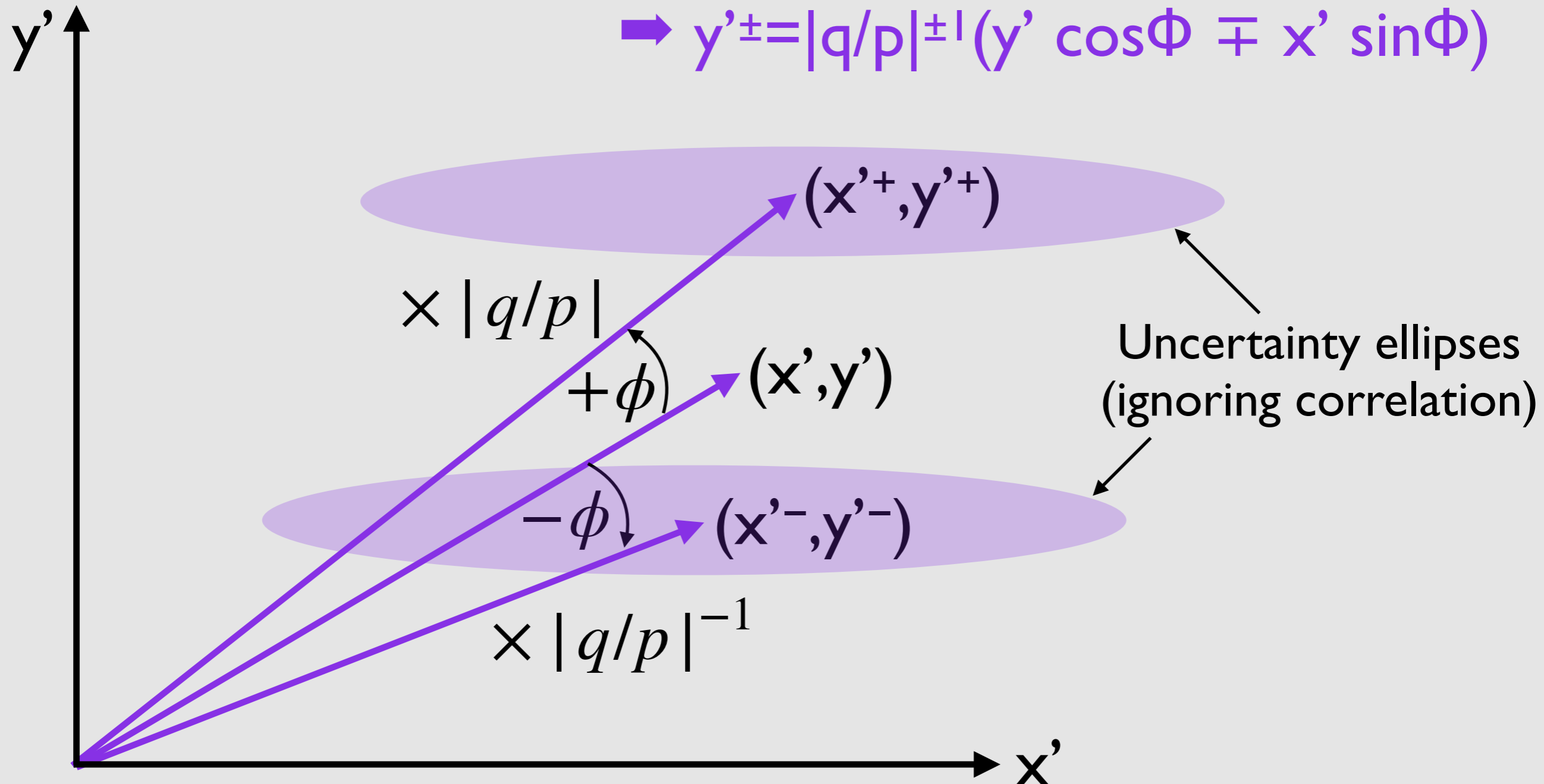
$$\rightarrow y'^{\pm} = |q/p|^{\pm 1} (y' \cos\Phi \mp x' \sin\Phi)$$



CPV from WS $K\pi$

$$\Rightarrow x'^{\pm} = |q/p|^{\pm 1} (x' \cos\Phi \pm y' \sin\Phi)$$

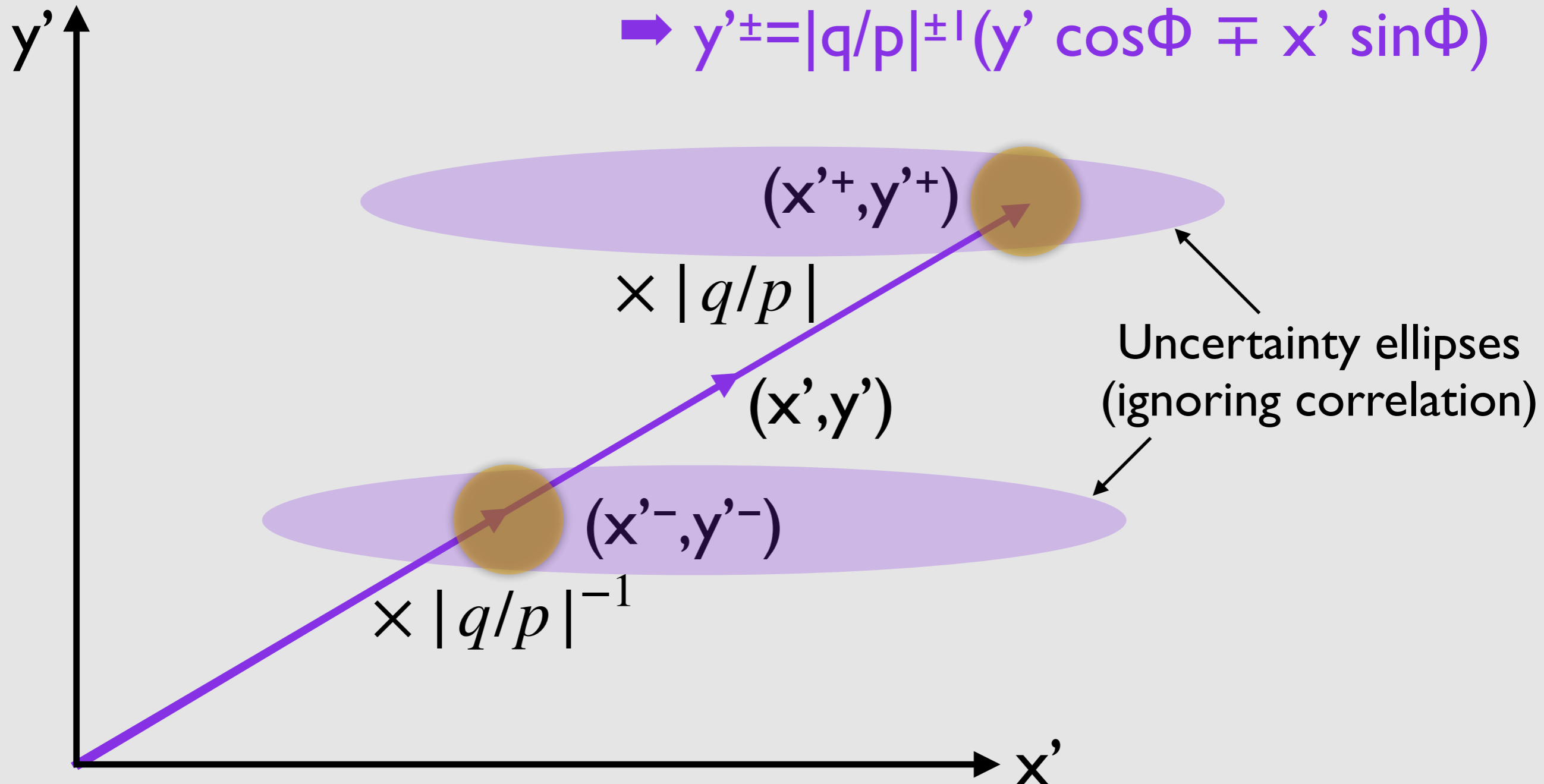
$$\Rightarrow y'^{\pm} = |q/p|^{\pm 1} (y' \cos\Phi \mp x' \sin\Phi)$$



Adding super-weak

$$\rightarrow x'^{\pm} = |q/p|^{\pm 1} (x' \cos\Phi \pm y' \sin\Phi)$$

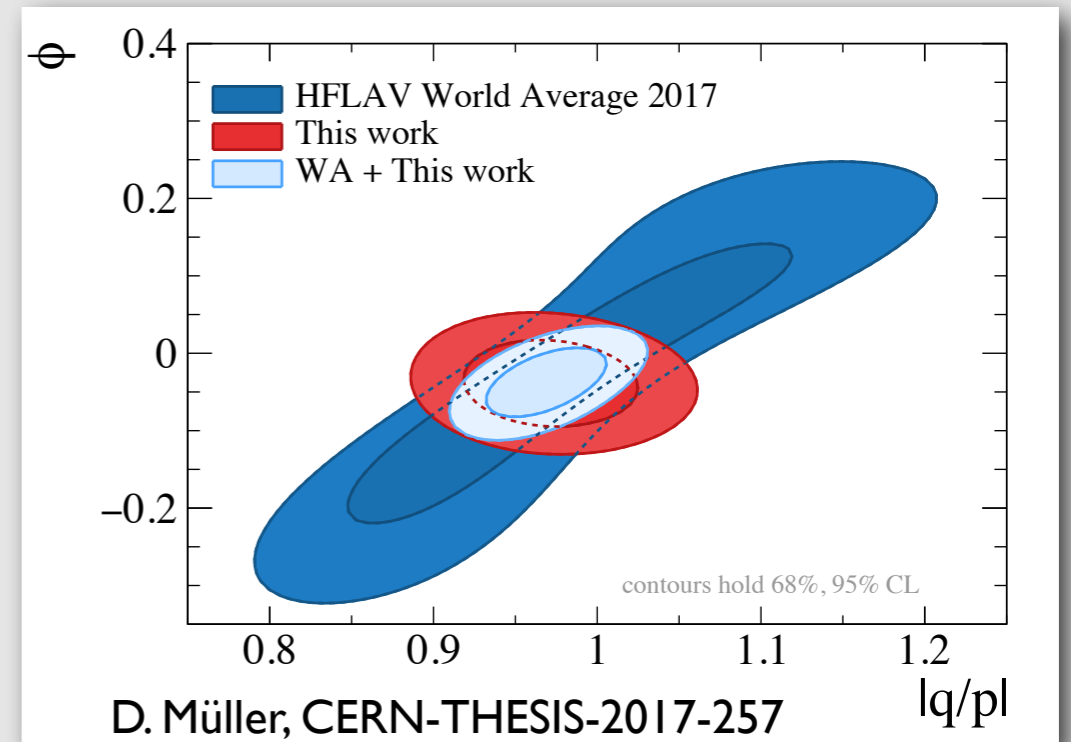
$$\rightarrow y'^{\pm} = |q/p|^{\pm 1} (y' \cos\Phi \mp x' \sin\Phi)$$





- Doubly Cabibbo-suppressed decay
 - ➔ Equivalent to WS $K\pi$ but with phase space (4-body = 5-dimensional)
- No simultaneous access to CF decay
 - ➔ Mixing parameters are rotated by strong phase difference
 - ➔ But retain linear access to x' through phase variations
- Great potential for CP violating parameters
- Similar story for other $c \rightarrow d\bar{s}u$ decays, e.g. $D^0 \rightarrow K^+ \pi^- \pi^0$
 - ➔ Potential for Belle II

Potential of $D^0 \rightarrow K^\pm \pi^\mp \pi^+ \pi^-$ at LHCb



Ultimate sensitivity

- Ultimate sensitivity obviously from combination of results
- Need to ensure that individual inputs have optimal sensitivity
 - ➔ Don't take avoidable shortcuts
 - ▶ Simplified methods that sacrifice precision
 - ➔ Harness power of combined measurements
 - ▶ $\pi+\mu$ tagged VVS $K\pi$ to cover full decay time spectrum
 - ▶ Similar benefits may lie in joined BESIII-LHCb measurements
 - Need access to data and expertise of BESIII after conclusion of experiment
 - Future T -c factory?

Conclusions

