

# CP violation in $D^0$ mixing

## LHCb Introduction

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**Theory parameter**

**Observable**

**Relation**

**Comment**

$\delta_{K\pi\pi\pi\pi}$

$K\pi\pi\pi\pi$

Dalitz

$\delta_{K\pi\pi}$

$K\pi\pi$

$\sim R_D + \sqrt{(R_D)y'\Gamma t + (x^2 + y^2)/4(\Gamma t)^2}$

$\delta_{K\pi\pi\pi^0}$

$K\pi\pi^0$

Dalitz,  $\pi^0$

$R_D$

$x$

$y$



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$K\pi\pi\pi^0$

Dalitz,  $\pi^0$

$R_D$

$x$

$Kl\nu$

$\sim (x^2 + y^2)/4$

$\nu$ , time-integrated

$y$

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Dalitz,  $\pi^0$

$R_D$

$Kl\nu$

$\sim (x^2 + y^2)/4$

$\nu$ , time-integrated

$x$

$y_{CP}$

$= y \cos\phi - A_m/2 x \sin\phi$

$y$

$A_\Gamma$

$= A_m/2 y \cos\phi - x \sin\phi$

$|q/p|$

$\phi$



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$\sim R_D + \sqrt{(R_D)y' \Gamma t + (x^2 + y^2)/4(\Gamma t)^2}$

$\delta_{K\pi\pi\pi^0}$

$K\pi\pi\pi^0$

Dalitz,  $\pi^0$

$R_D$

$x$

$Kl\nu$

$\sim (x^2 + y^2)/4$

$\nu$ , time-integrated

$y$

$\gamma_{CP}$

$= y \cos\phi - A_m/2 x \sin\phi$

$|q/p|$

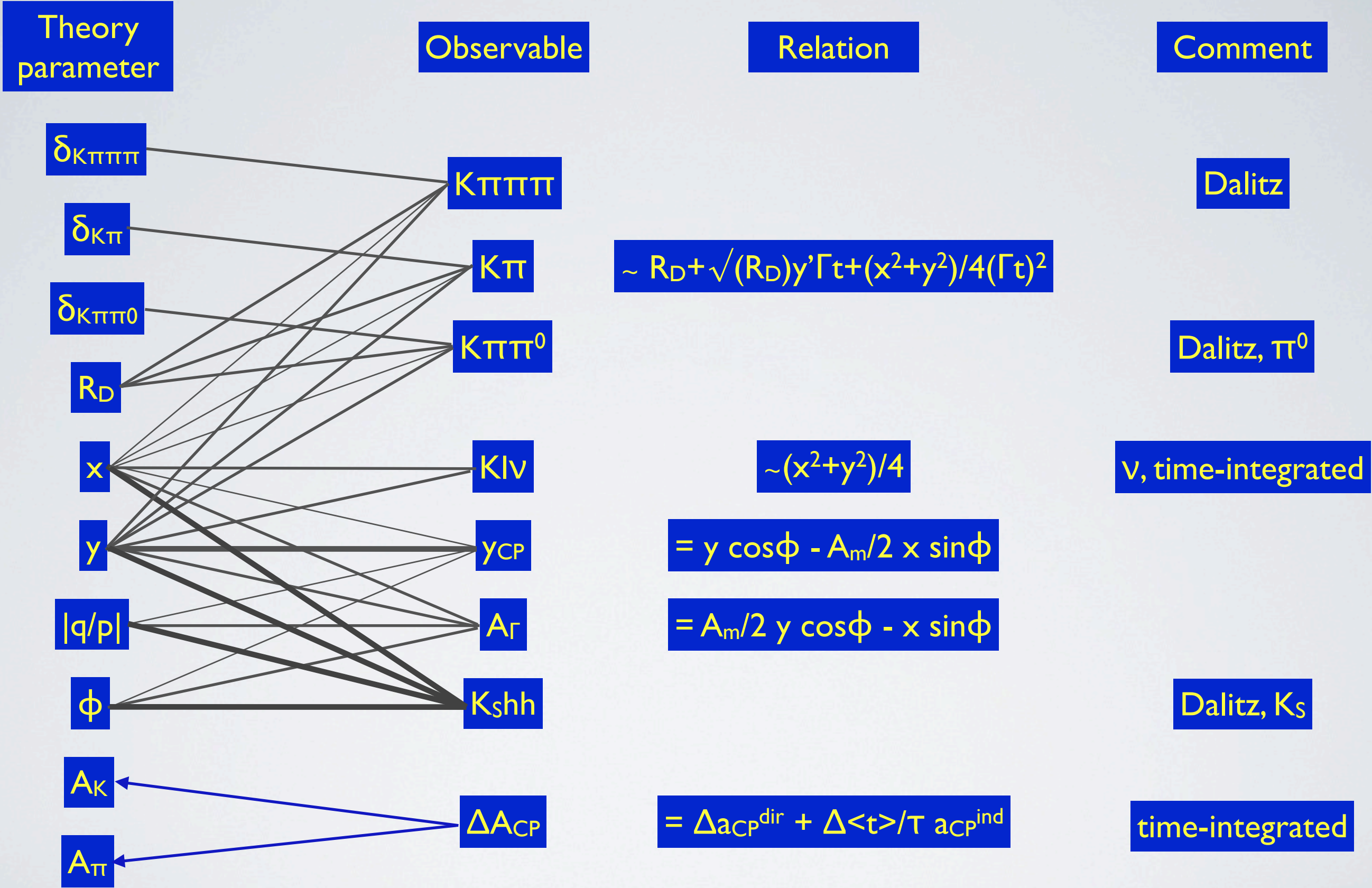
$A_\Gamma$

$= A_m/2 y \cos\phi - x \sin\phi$

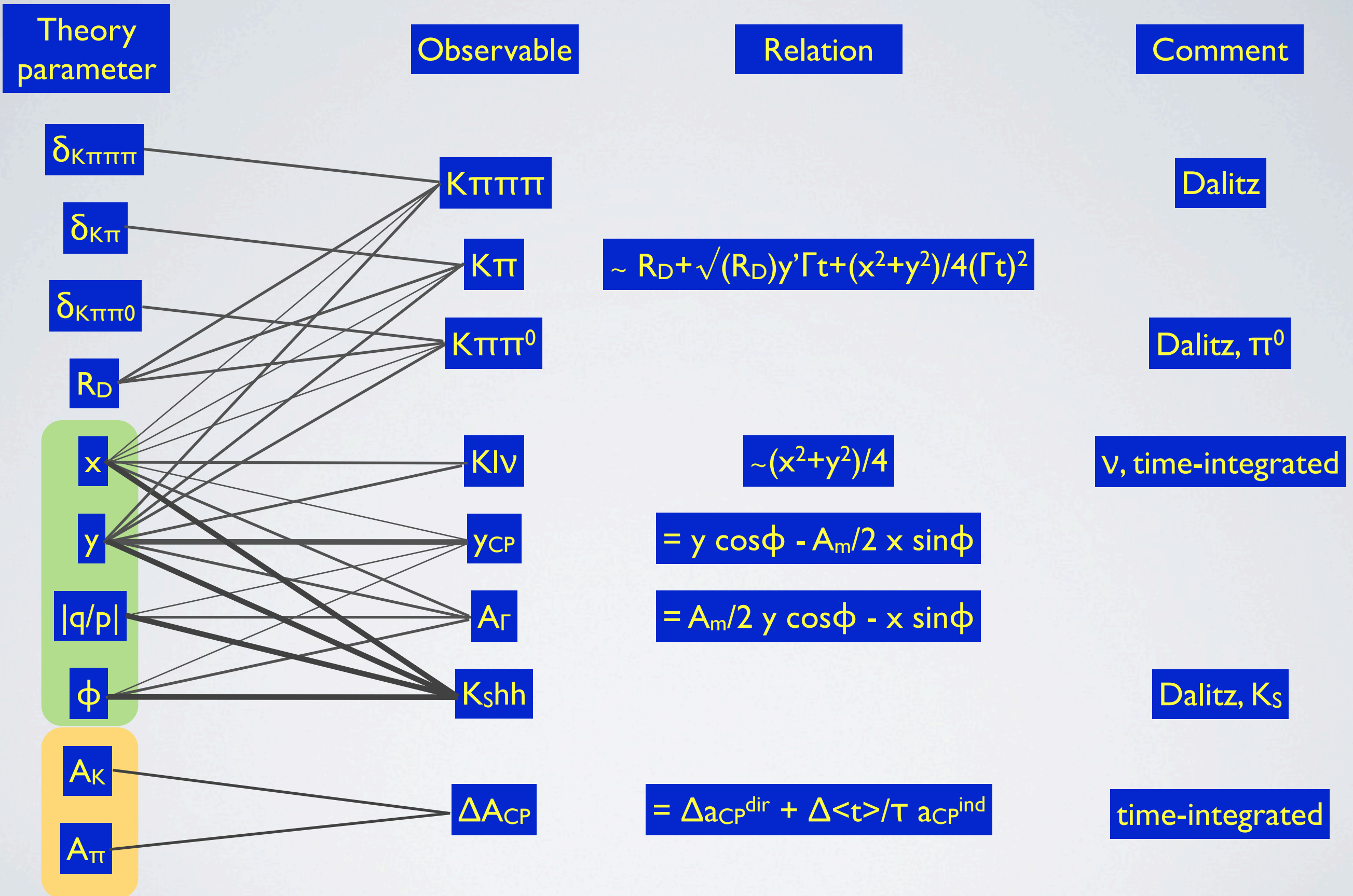
$\phi$

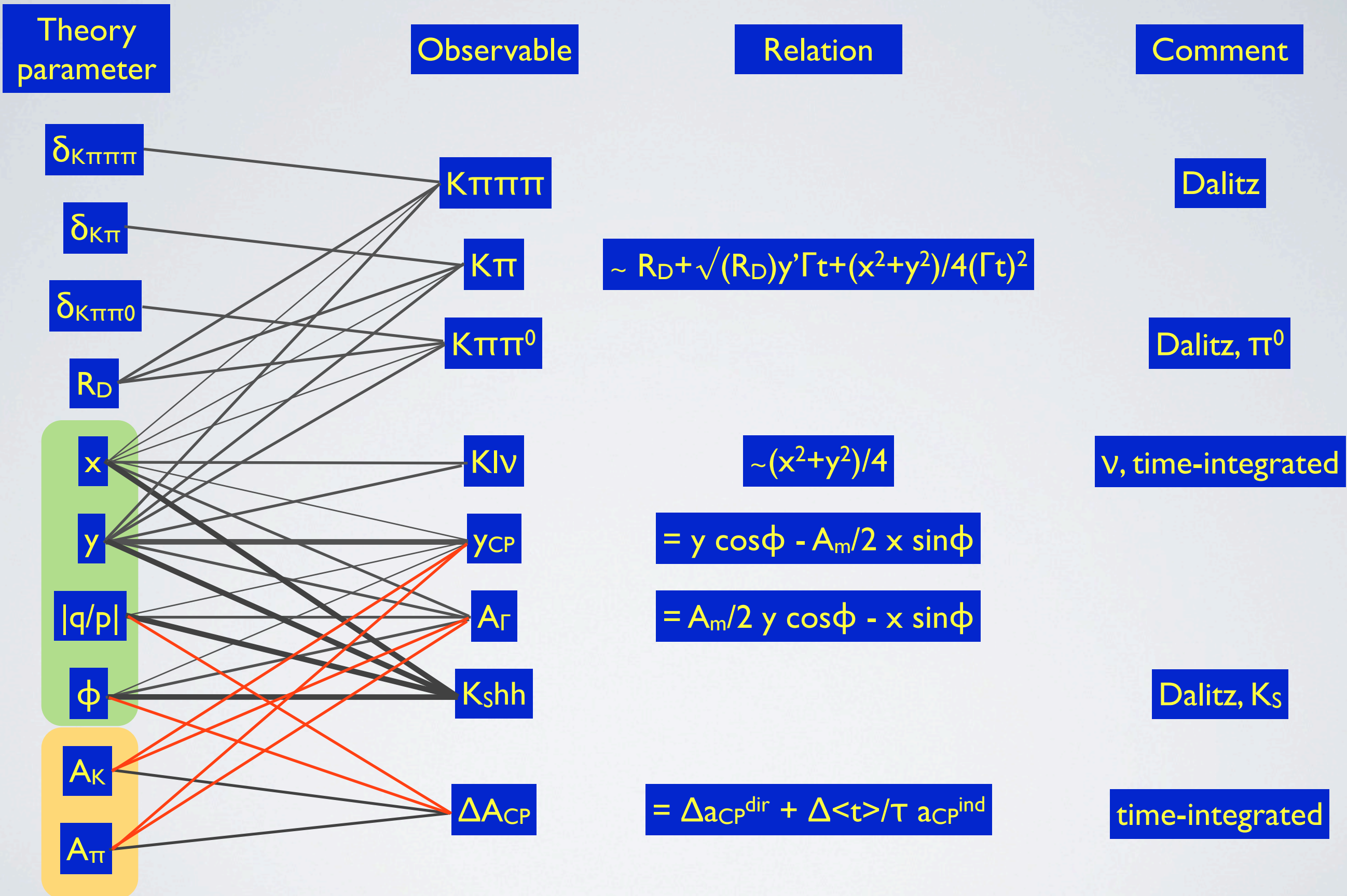
$Kshh$

Dalitz,  $K_S$





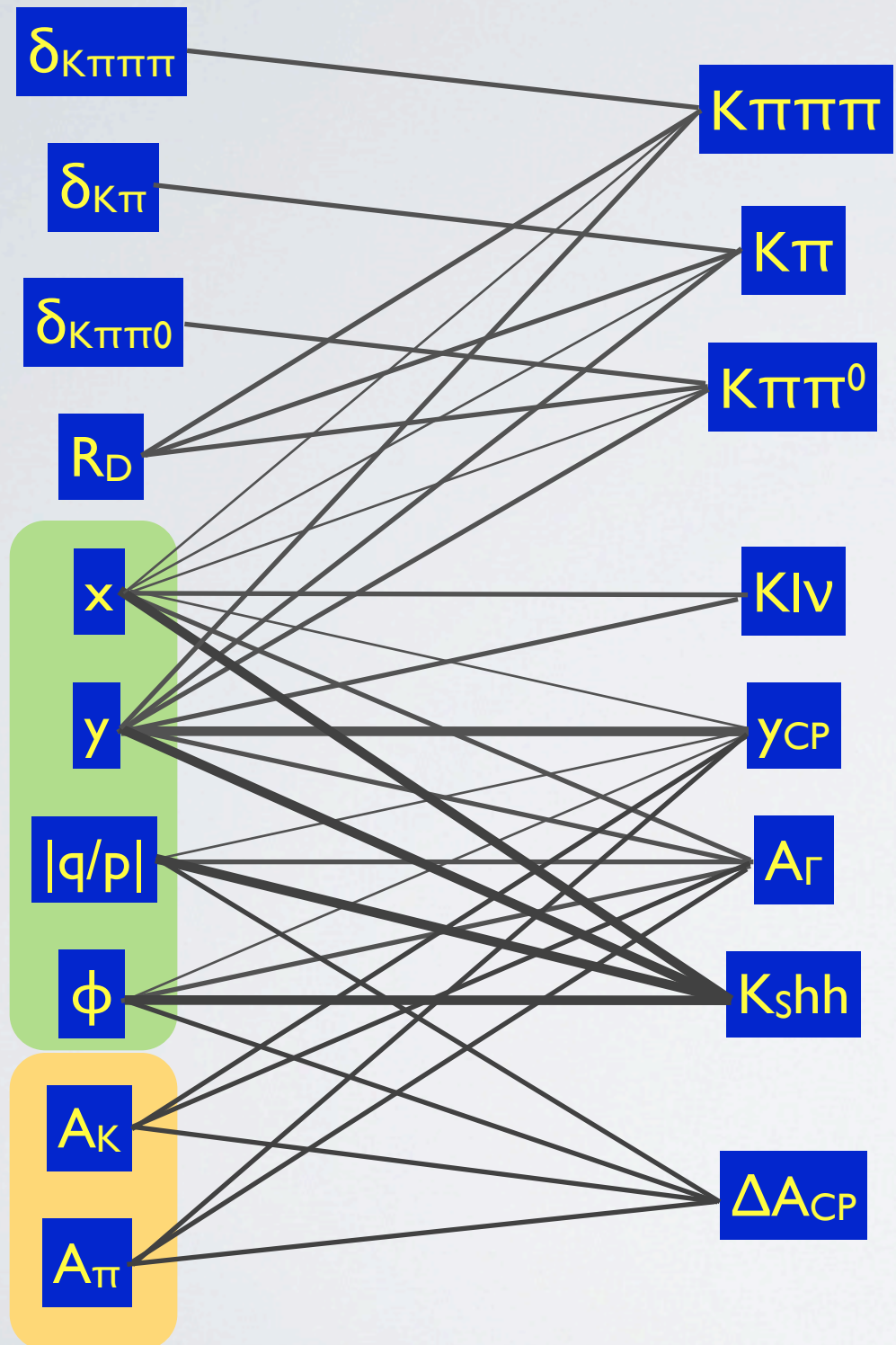






Theory parameter

Observable

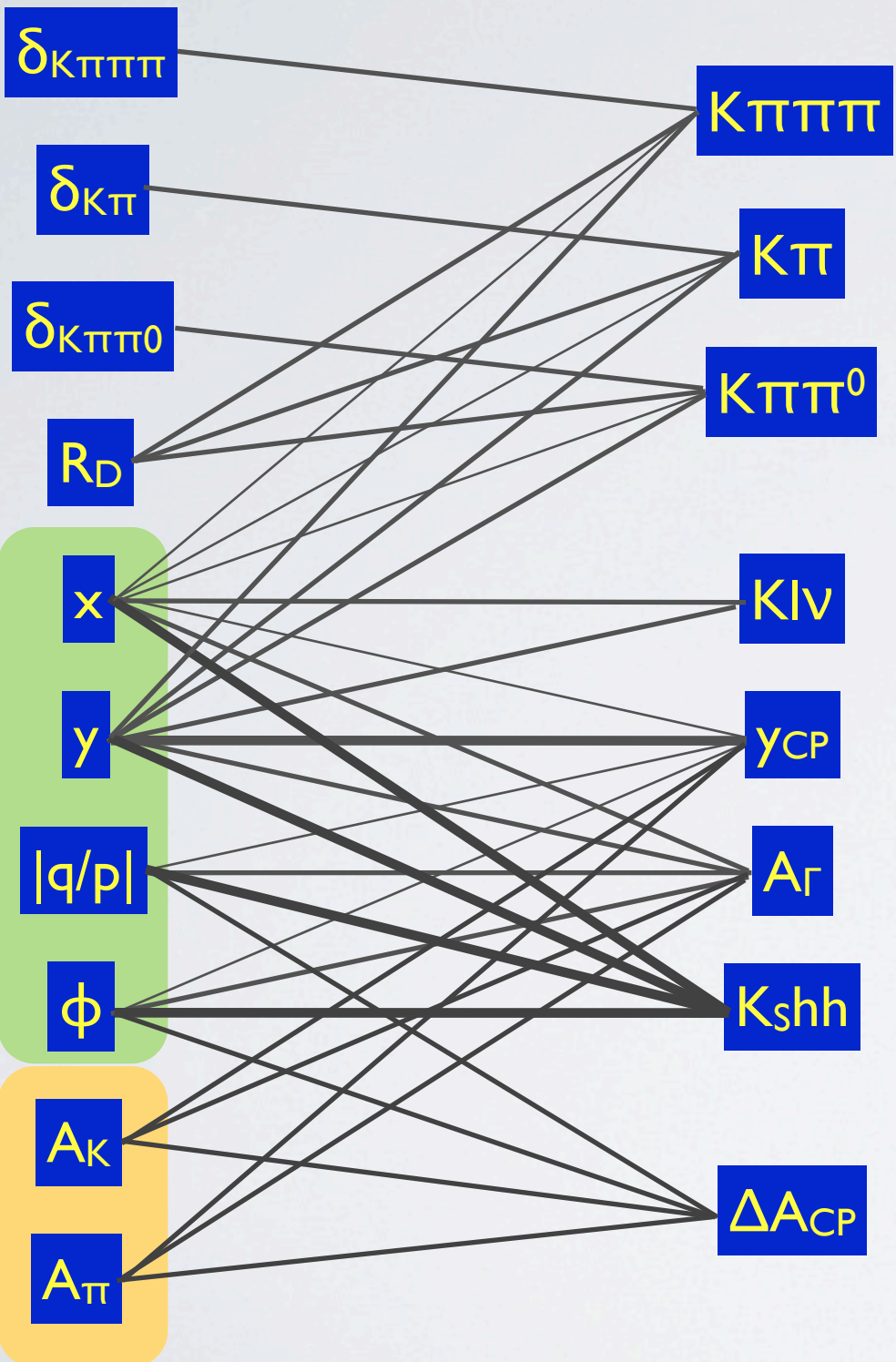


Bottom line:  
 $A_\Gamma$  &  $\Delta A_{CP}$  are discovery modes  
 For theoretical interpretation  
 need to measure all together

**Theory parameter**

**Observable**

**Existing LHCb measurements based on 2010 data**



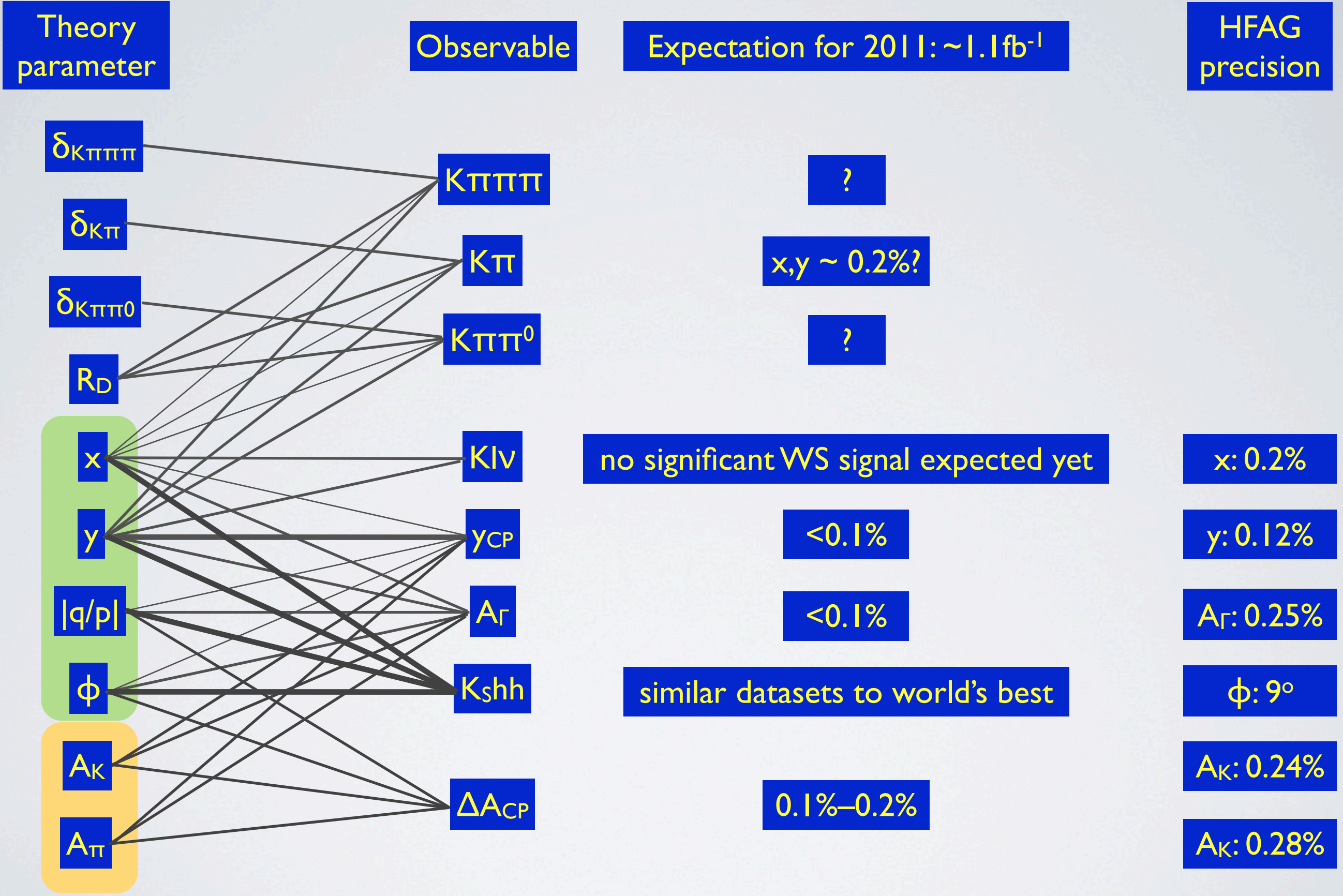
**Time-integrated RS/WS ratio** LHCb-CONF-2011-029

$(0.55 \pm 0.63_{\text{stat}} \pm 0.41_{\text{syst}})\%$  LHCb-CONF-2011-054

$(-0.59 \pm 0.59_{\text{stat}} \pm 0.21_{\text{syst}})\%$  LHCb-CONF-2011-046

$(-0.28 \pm 0.70_{\text{stat}} \pm 0.25_{\text{syst}})\%$  LHCb-CONF-2011-023





# CONCLUSION

- Transition from discovery to precision era is ahead of us
- 2011 data allow  $10^{-3}$  level measurements
- Need precise SM prediction to distinguish NP from SM in precision measurements:

**SM expectations for CPV in D mixing**

*KAGAN, alexander*

*Filtration Plant, CERN*

11:10 - 11:25

**Long-distance methods for  $M_{12}$  and  $\Gamma_{12}$**

*PETROV, Alexey*

*Filtration Plant, CERN*

11:30 - 11:50

**The HQE-approach to charm mixing**

*BOBROWSKI, Markus*

*Filtration Plant, CERN*

11:55 - 12:15



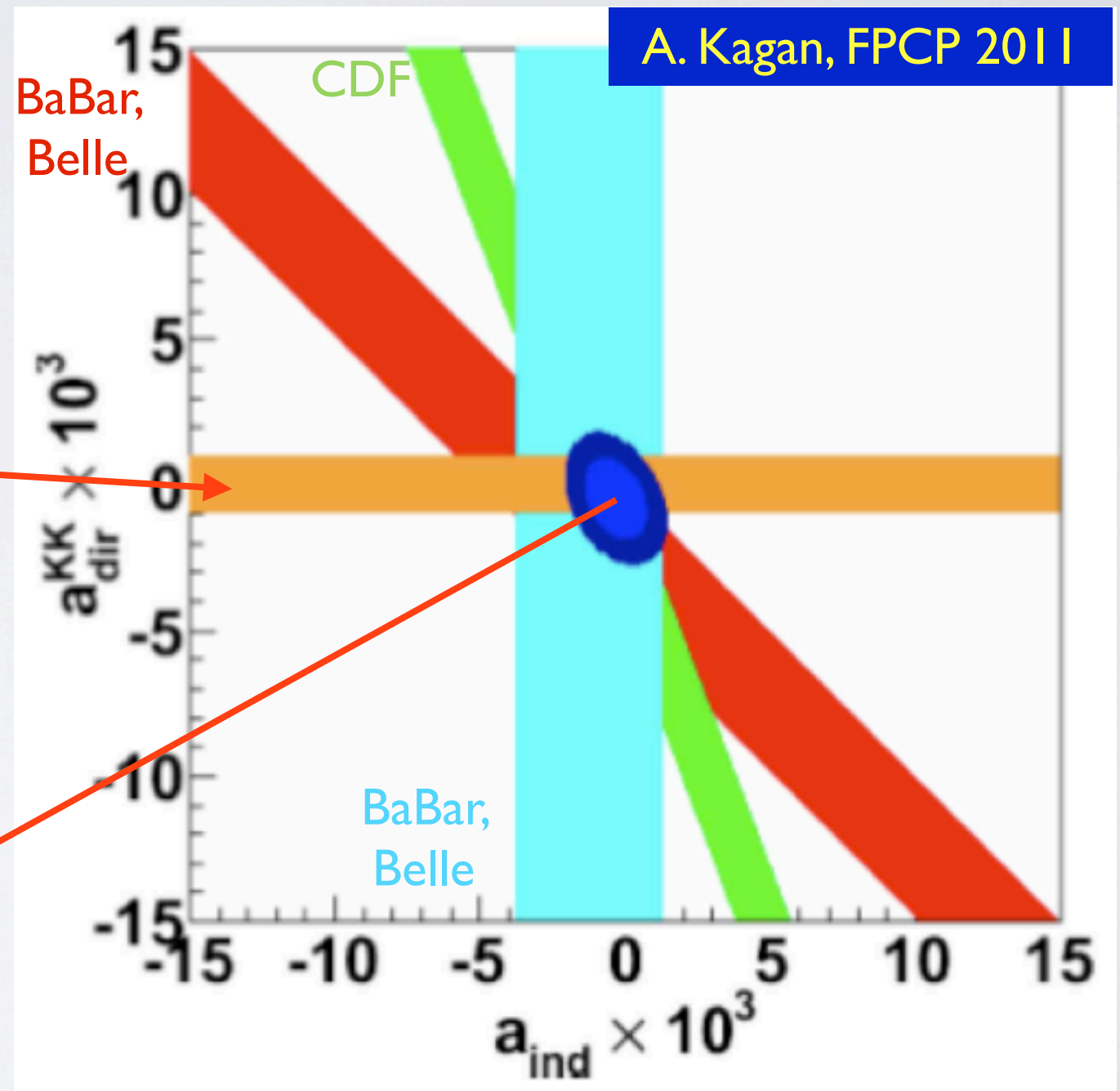
BACKUP

# DIRECT - INDIRECT CPV

For models with negligible new weak phases in decay, e.g. SM:

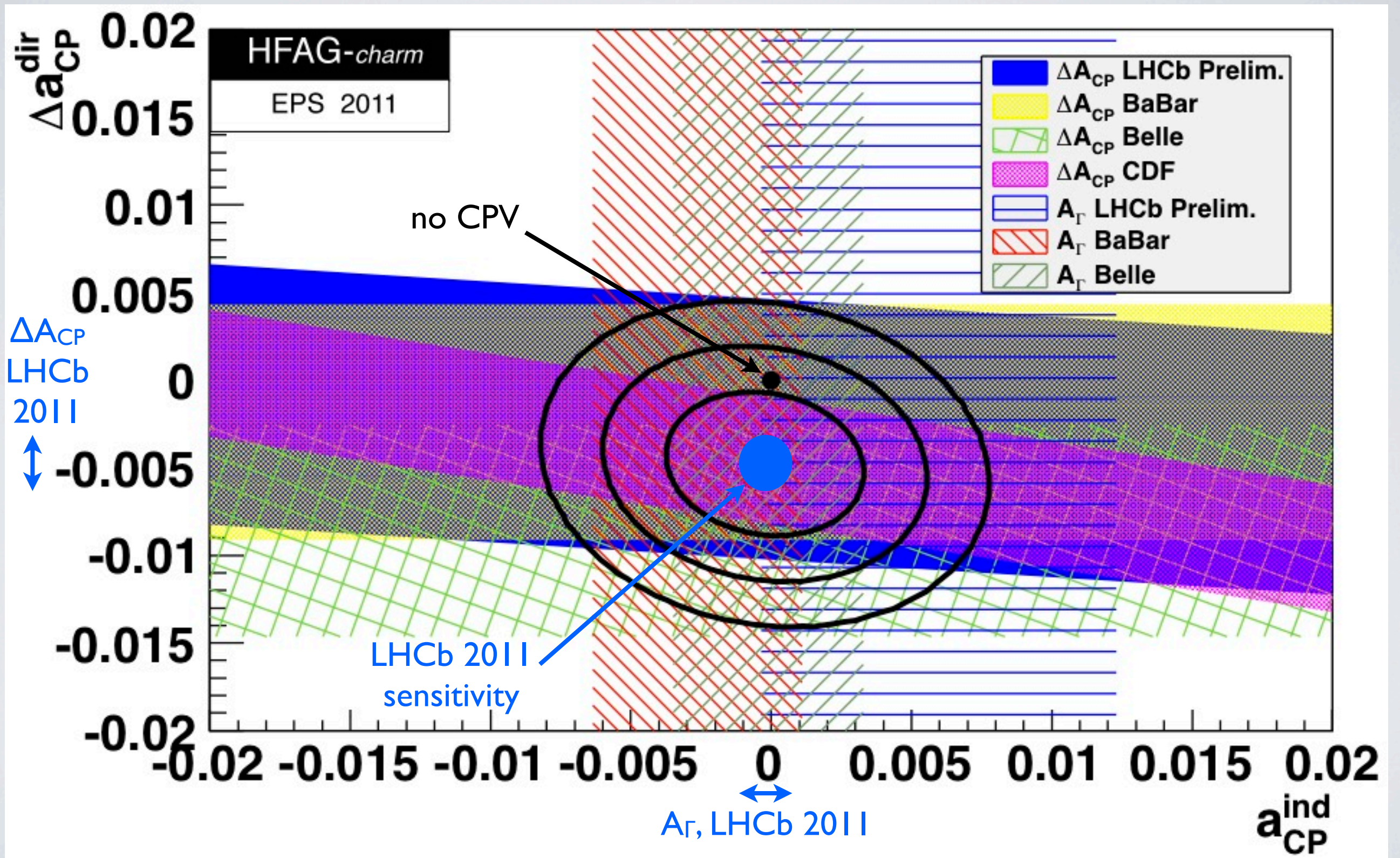
$$|a_{KK,\pi\pi}^{\text{dir}}| < 0.2\%$$

$$a^{\text{ind}} = (-0.023 \pm 0.09)\%$$





# DIRECT - INDIRECT CPV II





# LATEST HFAG FIT RESULTS

Parameter	No $CPV$	No direct $CPV$	$CPV$ -allowed	$CPV$ -allowed 95% C.L.
$x$ (%)	$0.65^{+0.18}_{-0.19}$	$0.63 \pm 0.19$	$0.63^{+0.19}_{-0.20}$	[0.24, 0.99]
$y$ (%)	$0.74 \pm 0.12$	$0.75 \pm 0.12$	$0.75 \pm 0.12$	[0.52, 0.99]
$\delta$ ( $^\circ$ )	$21.3^{+9.8}_{-11.1}$	$22.5^{+9.9}_{-11.2}$	$22.4^{+9.7}_{-11.0}$	[-2.2, 40.9]
$R_D$ (%)	$0.3308 \pm 0.0080$	$0.3306 \pm 0.0080$	$0.3311 \pm 0.0081$	[0.315, 0.347]
$A_D$ (%)	—	—	$-1.7 \pm 2.3$	[-6.3, 2.8]
$ q/p $	—	$1.02 \pm 0.04$	$0.89^{+0.17}_{-0.15}$	[0.61, 1.24]
$\phi$ ( $^\circ$ )	—	$-1.05^{+1.89}_{-1.94}$	$-10.1^{+9.4}_{-8.8}$	[-27.2, 8.6]
$\delta_{K\pi\pi}$ ( $^\circ$ )	$18.0^{+21.7}_{-22.8}$	$19.4^{+21.8}_{-22.9}$	$19.5^{+21.8}_{-22.9}$	[-26.1, 61.8]
$A_\pi$	—	—	$0.22 \pm 0.28$	[-0.34, 0.76]
$A_K$	—	—	$-0.20 \pm 0.24$	[-0.67, 0.27]
$x_{12}$ (%)	—	$0.63 \pm 0.19$	—	[0.25, 0.99]
$y_{12}$ (%)	—	$0.75 \pm 0.12$	—	[0.52, 0.99]
$\phi_{12}$ ( $^\circ$ )	—	$2.5^{+5.2}_{-4.6}$	—	[-7.1, 15.8]