

# Measuring $\gamma$ in $B^\pm \rightarrow (K^+ K^- \pi^+ \pi^-)_D K^\pm$ decays

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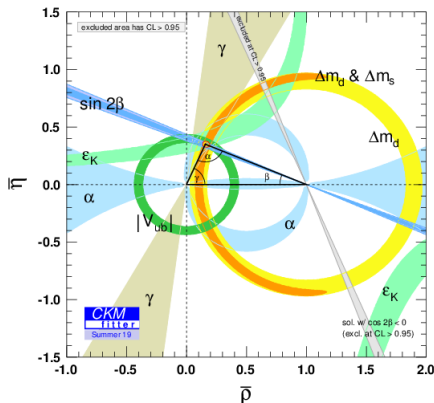
- 1 Background
- 2  $\gamma$  and the unitary triangle
- 3 The  $D \rightarrow K^+ K^- \pi^+ \pi^-$  decay
  - The ch
- 4 Using chemistry packages with  $\text{\LaTeX}$ 
  - Chemical equations with `mhchem`
- 5 Where to go next...

- 4-year MPhys in Oxford
  - Performance of monolithic CMOS sensors
  - Prof Daniela Bortoletto
- CERN Summer Student 2019
  - Beam loss reduction in TT20 transfer line
  - Dr Yann Dutheil, Dr Matthew Fraser
- Oxford Summer Student 2018
  - Study of PDF uncertainties in W-boson mass measurement
  - Prof Chris Hays
- RAL Summer Student 2018
  - Bending magnets in accelerator simulations (Dr Chris Rogers)

# $\gamma$ and the unitary triangle

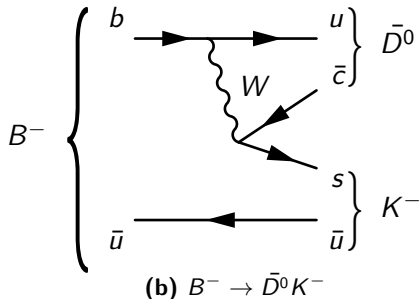
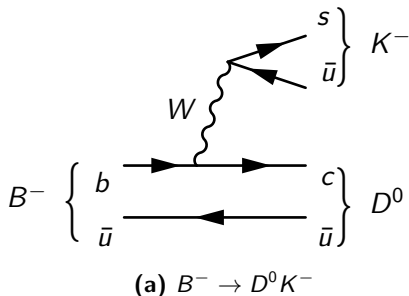
Unitarity of CKM matrix:  $V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$

$$\text{Define } \gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$



CKMfitter Group (J. Charles et al.), Eur. Phys. J. C41, 1-131 (2005)

# $b \rightarrow u$ and $b \rightarrow c$ interference



Similar diagrams for  $B^+ \rightarrow DK^+$ , with  $\gamma \rightarrow -\gamma \Rightarrow$

Interference when  $D^0$  and  $\bar{D}^0$  decay into a common final state

Single most precise measurement:  $\gamma = (68.7^{+5.2}_{-5.1})^\circ$  [arXiv:2010.08483](https://arxiv.org/abs/2010.08483)

$B^\pm \rightarrow DK^\pm$ ,  $B^\pm \rightarrow D\pi^\pm$ ,  $D \rightarrow K_S^0 h^+ h^-$

# The $D \rightarrow K^+ K^- \pi^+ \pi^-$ decay

- Estimated 2000 events from LHCb Run 1 and 2
- First proposed by G. Wilkinson and J. Rademacker (arXiv:hep-ph/0611272)
  - Estimated  $\gamma$  precision:  $14^\circ$  with 1000 events
  - Amplitude analysis: Isobar model
- CLEO amplitude analysis (arXiv:1201.5716)
  - Estimated  $\gamma$  precision:  $11^\circ$  with 2000 events
- LHCb amplitude analysis (arXiv:1811.08304)
  - AmpGen for generating events and unbinned fit
- Other 4-body decay studies:
  - Binned analysis of  $K_S^0 \pi^+ \pi^- \pi^0$  by Belle [arXiv:1908.09499](#)
  - Inclusive analysis of  $h^\pm \pi^\mp \pi^+ \pi^-$  [arXiv:1906.08297](#), [arXiv:1709.05855](#), [arXiv:1603.08993](#) by LHCb

# The chemistry packages

We focus on two L<sup>A</sup>T<sub>E</sub>X chemistry packages:

## The chemfig package

This package provides the command which draws molecules. Created by Christian Tellechea, a detailed user guide can be found here:

[www.tex.ac.uk/ctan/macros/generic/chemfig/chemfig\\_doc\\_en.pdf](http://www.tex.ac.uk/ctan/macros/generic/chemfig/chemfig_doc_en.pdf)

## The mhchem package

The mhchem package provides simple commands for typesetting chemical molecular formulae and equations. Created by Martin Hensel, a detailed user guide can be found here:

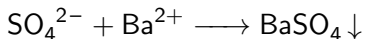
<http://mirror.ox.ac.uk/sites/ctan.org/macros/latex/contrib/mhchem/mhchem.pdf>

# Chemical equations with mhchem

- The mhchem package lets you write chemical equations in L<sup>A</sup>T<sub>E</sub>X with the minimum of effort.
- The example below shows how the standard representation of a reaction (on the left) is created from the simple code on the right:

$\text{CO}_2 + \text{C} \longrightarrow 2 \text{CO}$  is created with `\ce{C02 + C -> 2C0}`

- More complicated reactions are still easy to write:



is created with

`\ce{S04^2- + Ba^2+ -> BaS04 v}`



# Where to go next...

- This short example was designed to introduce you to using Overleaf for scientific presentations.
- This is made possible by the many great packages that have been developed for  $\text{\LaTeX}$ , including the two we focused on here (plus the Beamer package used for the overall presentation style).
- For more help on using  $\text{\LaTeX}$ , see the links on the Overleaf help page: [www.overleaf.com/help](http://www.overleaf.com/help) or check out our free introductory course: [www.overleaf.com/blog/7](http://www.overleaf.com/blog/7).

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Happy  $\text{\LaTeX}$ ing!