

# A more precise measurement of $m_{D_s^+} - m_{D^+}$ through $D_{(s)}^+ \rightarrow K^+ K^- \pi^+$ decay

John Bodenschatz

Physics Capstone

Advisor: Dr. Michael Sokoloff

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## Why are meson mass difference measurements important to Quantum Chromodynamics (QCD)?

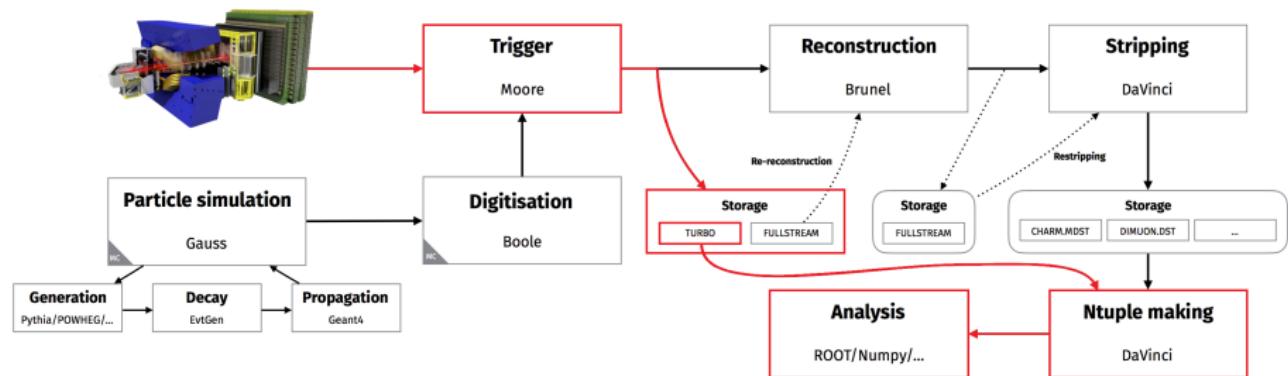
"...in a rather direct manner [meson mass differences] permit to extract the ratios of quark masses which are fundamental parameters of QCD.[1]"

Meson mass differences can help determine fundamental constants such as  $m_c/m_b$

$$\begin{aligned}|D^+\rangle &= |\bar{c}\bar{d}\rangle \\ |D_s^+\rangle &= |\bar{c}\bar{s}\rangle\end{aligned}$$

For the  $m_{D_s^+} - m_{D^+}$  measurement:

- Most recent precision measurement was conducted on LHC Run 1 data from 2011[2].  $98.68 \pm 0.03(\text{stat}) \pm 0.04(\text{syst})$  MeV
- Using data from Run 2 could reduce statistical error by a factor of 10+
- Reduce systematic uncertainty



Run 2 (2017)  $D_{(s)}^+ \rightarrow K^+ K^- \pi^+$  decay data: 1.28 TB

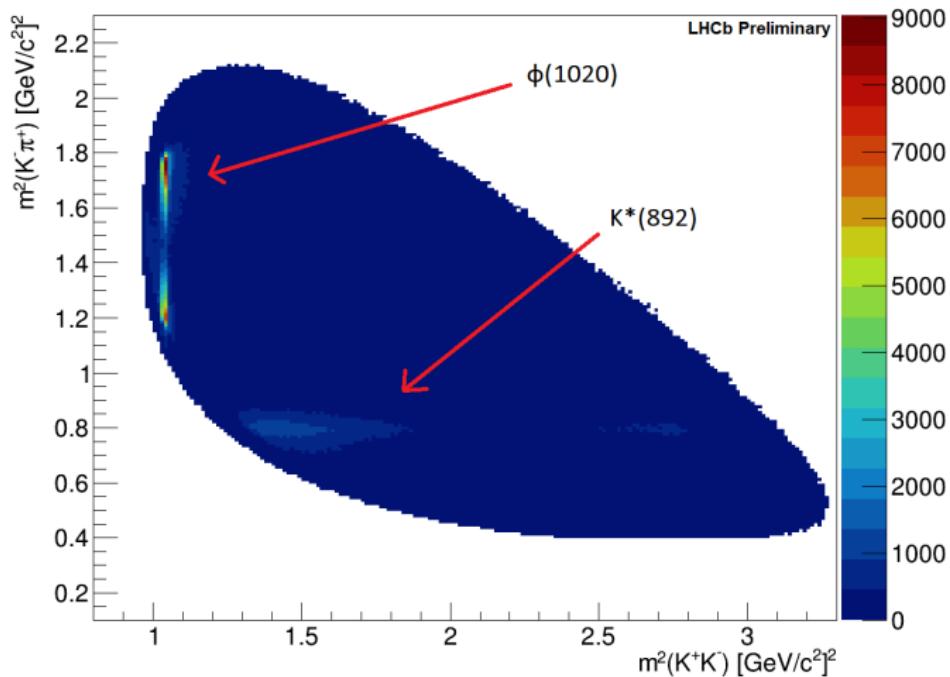
Image from LHCb StarterKit Lessons

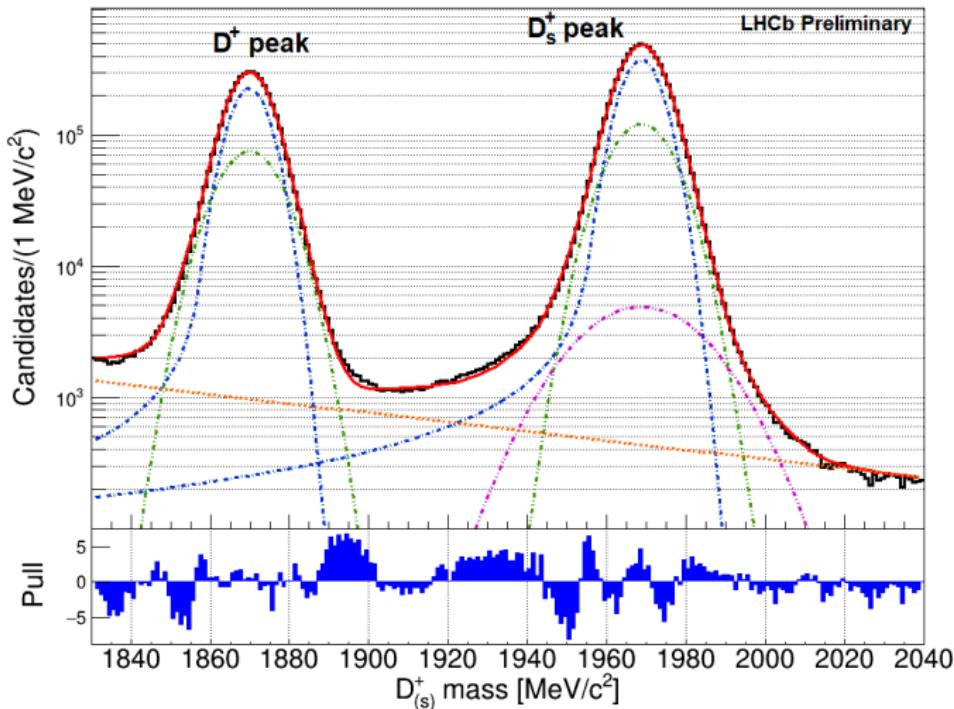
**Cuts:** set of selection criteria the events must meet to be selected for fitting. Isolate the signal peaks from background noise.

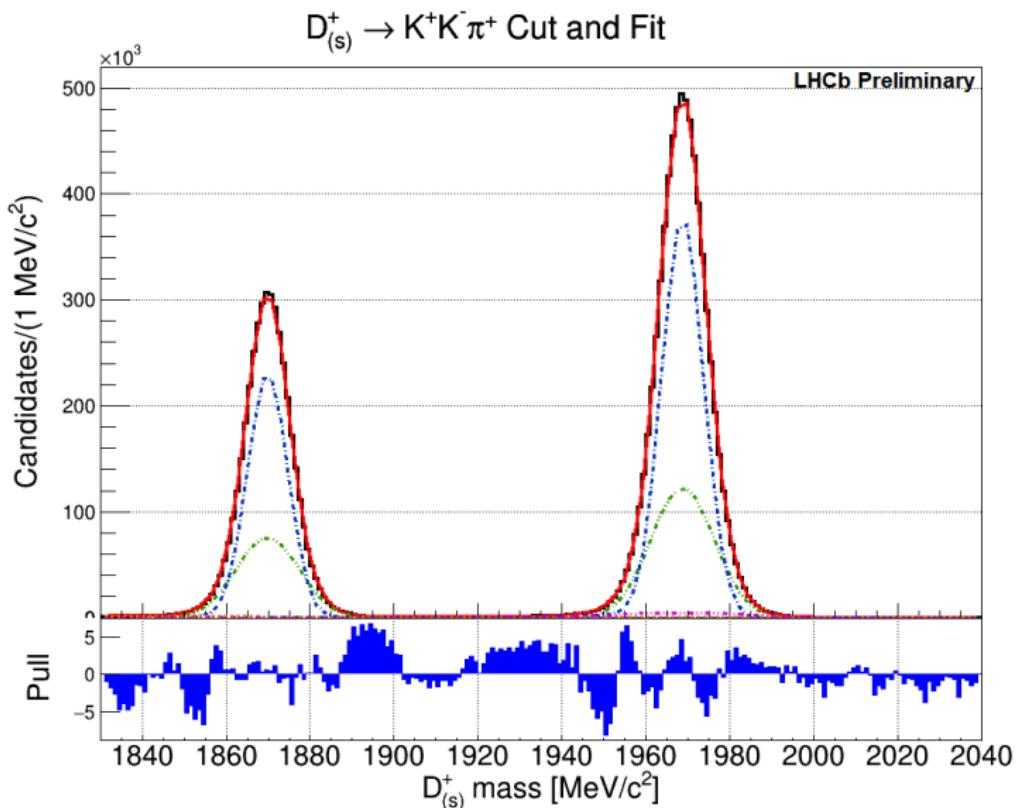
Examples of cuts used:

- $P(K^+), P(K^-) \geq 10,000 \text{ MeV}$
- PID probability cut on  $K^+$ ,  $K^-$ ,  $\pi^+$
- $D_{(s)}^+ \rightarrow \phi(1020)\pi^+ \rightarrow K^+K^-\pi^+$

After all cuts and variable reduction are applied: **380 MB** of data

$D^+ \rightarrow K^+ K^- \pi^+$  Dalitz Plot

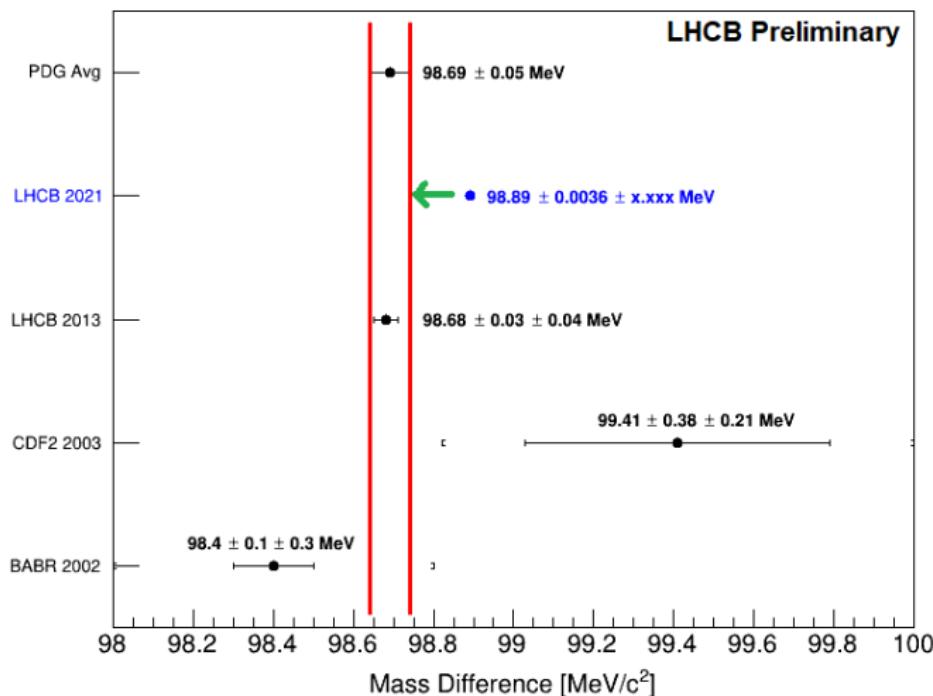
$D_{(s)}^+ \rightarrow K^+ K^- \pi^+$  Cut and Fit



# Other $D_{(s)}^+ \rightarrow K^+ K^- \pi^+$ analyses

| Organization | Year | $m_{D_s^+} - m_{D^+}$ [MeV]                                   | $D_s^+$ Signal Events  |
|--------------|------|---|------------------------|
| BaBar[3]     | 2002 | $98.4 \pm 0.1(\text{stat}) \pm 0.3(\text{syst})$              | $47,794 \pm 311$       |
| LHCb[2]      | 2013 | $98.68 \pm 0.03(\text{stat}) \pm 0.04(\text{syst})$           | $248,694 \pm 540$      |
| LHCb - UC    | 2020 | $98.97 \pm 0.1(\text{stat})$                                  | $12,529 \pm 1602$      |
| LHCb - UC    | 2021 | $98.89 \pm 0.0036(\text{stat}) \pm 0.\text{xxx}(\text{syst})$ | $8,524,400 \pm 17,505$ |

## $m(D_s^+) - m(D^+)$ Measurements



- Momentum scaling corrections
- Calculate other systematic errors
- Refine fit
- Publish!

- [1] Jose L. Goity, Chandana P. Jayalath, *Strong and Electromagnetic Mass Splittings in Heavy Mesons*, arXiv:hep-ph/0701245
- [2] LHCb Collaboration, R. Aaij *et al.*, *Precision measurement of D meson mass differences*, arXiv:hep-ex/1304.6865
- [3] BaBar Collaboration, B. Aubert *et al.*, *Measurement of  $D_s^+$  and  $D_s^{*+}$  production in B meson decays and from continuum  $e^+e^-$  annihilation at  $\sqrt{s} = 10.6$  GeV*, Phys. Rev. **D65** (2002) 091104,  
arXiv:hep-ex/0201041