# Observation of the decay $D^0 \to K^-\pi^+e^+e^-$

# FCNC and GIM mechanism

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## Weak Interactions with Lepton-Hadron Symmetry*

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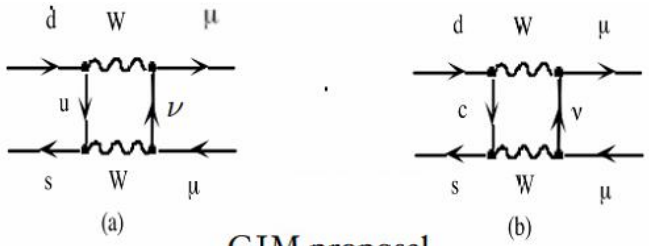
We propose a model of weak interactions in which the currents are constructed out of four basic quark fields and interact with a charged massive vector boson. We show, to all orders in perturbation theory, that the leading divergences do not violate any strong-interaction symmetry and the next to the leading divergences respect all observed weak-interaction selection rules. The model features a remarkable symmetry between leptons and quarks. The extension of our model to a complete Yang-Mills theory is discussed.



GIM proposal

Shan: What caused the FCNC?

- flavour changing neutral current process observed experimentally
- GIM mechanism proposed to explain rare K decays.
- FCNC is forbidden at tree level.
- **sensitive to new physics**
  - predicted the exsistence of charmed quark.

# breaking news recently

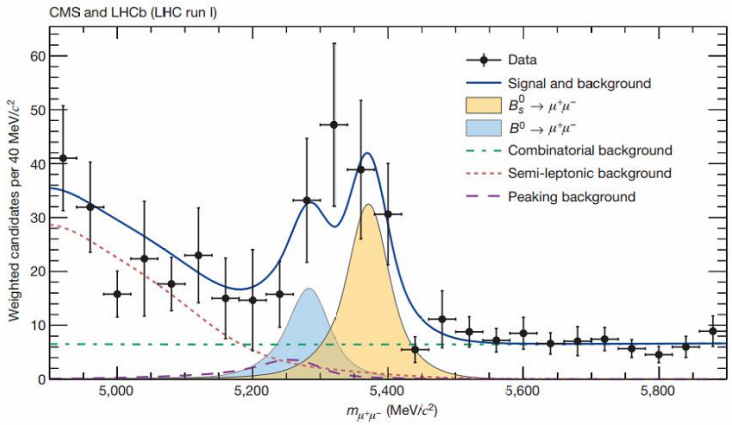



**Figure 2 | Weighted distribution of the dimuon invariant mass, $m_{\mu^+\mu^-}$, for all categories.** Superimposed on the data points in black are the combined fit (solid blue line) and its components: the $B_s^0$ (yellow shaded area) and $B^0$ (light-blue shaded area) signal components; the combinatorial background (dash-dotted green line); the sum of the semi-leptonic backgrounds (dotted salmon line); and the peaking backgrounds (dashed violet line). The horizontal bar on each histogram point denotes the size of the binning, while the vertical bar denotes the 68% confidence interval. See main text for details on the weighting procedure.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日本語要約


## Observation of the rare $B_s^0 \to \mu^+\mu^-$ decay from the combined analysis of CMS and LHCb data


CMS Collaboration & LHCb Collaboration

Affiliations | Contributions | Corresponding authors



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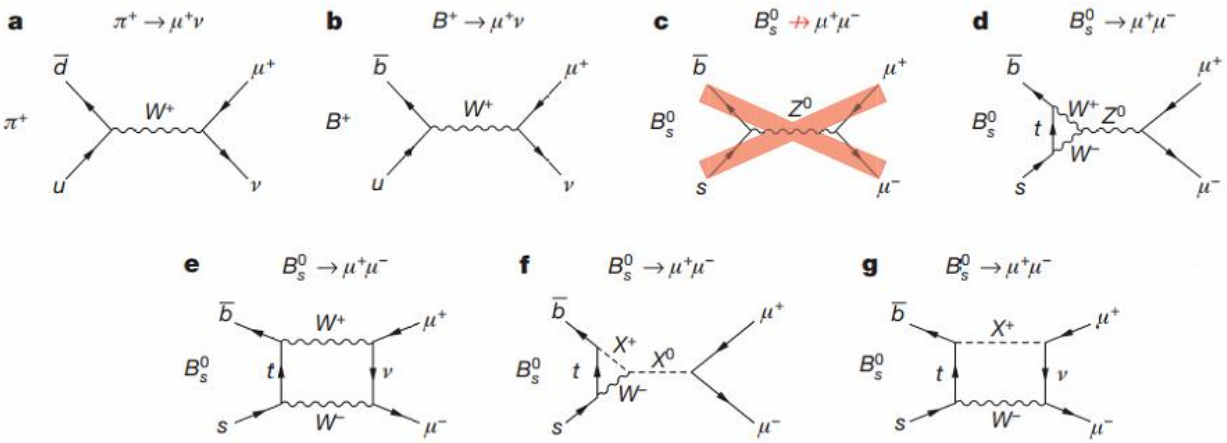



**Figure 1 | Feynman diagrams related to the $B_s^0 \to \mu^+\mu^-$ decay. a**, $\pi^+$ meson decay through the charged-current process; **b**, $B^+$ meson decay through the charged-current process; **c**, a $B_s^0$ decay through the direct flavour changing neutral current process, which is forbidden in the SM, as indicated by a large red 'X'; **d**, **e**, higher-order flavour changing neutral current processes for the $B_s^0 \to \mu^+\mu^-$ decay allowed in the SM; and **f** and **g**, examples of processes for the same decay in theories extending the SM, where new particles, denoted $X^0$ and $X^+$, can alter the decay rate.

# FCNC at charm sector

- **Xin**: What are the “Short-distance contribution” and “long-distance contribution” to the D0->Kpi ee process?
- **Ryuta**: Is that is there any special reason to pick up the channel, D0->K-pi+e+e- , comapred with the other channels ?

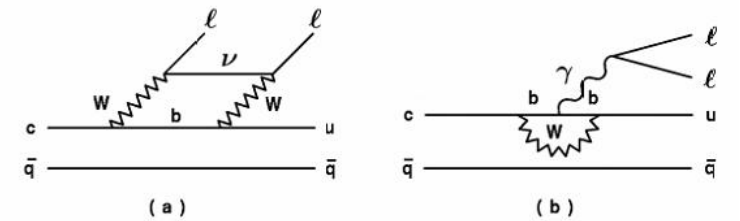



FIG. 1. Short distance contributions to FCNC decays in $D$ mesons due to (a) box and (b) penguin diagrams.

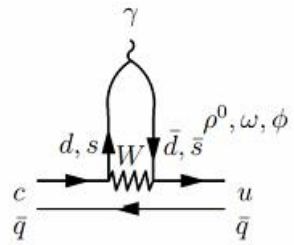



Figure 1.3: The long distance penguin contribution to the meson decays with the flavour structure $c\bar{q} \to u\bar{q}\gamma$. The intermediate quark pairs $d\bar{d}$ and $s\bar{s}$ hadronize to the neutral vector mesons $\rho^0$, $\omega$, $\phi$ and finally convert to a photon.

- mumu channel has been observed by LHCb, need to be confirmed
- good enviroment to calibrate long-distance calculations.
- sensitive to new physics
- very important reference channel for measurements of c->ull processes, such as D0->pipi ll.  easier to obtain precise branching fractions.

# Question from Xin

**Xin**:Some BSM predict the BR as O(10^-5), at the end of this paper, the measurement is 4.0 x 10^-6. Does this veto those BSM predictions?

- those BSM predictions not been ruled out.
- uncertainties in theoretical predictions are large
- inclusive calculation could not been ruled out by a special channel. For new physics, we do not know which kind of process is more sensitive.

# Suyu

Why do they treat the uncertainty in branching fraction of normalization channel as a dependent(?) one, not a part of systematic uncertainty?

- as mentioned above, this channel is an very important reference channel in the FCNC channels
- for the external uncertainty, the results could be updated conviniently when having new results of D0->K pi pi pi.

| $m(e^+e^-)$ ($\mathrm{GeV}/c^2$) | $N_{\mathrm{sig}}$ (cands.) | $\hat{\epsilon}_{\mathrm{sig}}$ (%) | $\mathcal{B}(D^0 \to K^-\pi^+e^+e^-)$ ($\times 10^{-6}$) |
|---|---|---|---|
| $0.100 - 0.200$ | $175 \pm 14$ | $5.0 \pm 0.2$ | – |
| $>0.100$ | $308 \pm 18$ | $5.9 \pm 0.2$ | – |
| $>0.200$ | $134 \pm 13$ | $8.0 \pm 0.2$ | $8.8 \pm 0.8 \pm 0.4 \pm 0.2$ |
| $0.200 - 0.675$ or $>0.875$ | $59 \pm 9$ | $6.4 \pm 0.2$ | $4.8 \pm 0.7 \pm 0.3 \pm 0.1$ |
| $0.675 - 0.875$ | $68 \pm 9$ | $8.9 \pm 0.2$ | $4.0 \pm 0.5 \pm 0.2 \pm 0.1$ |

# yuhang

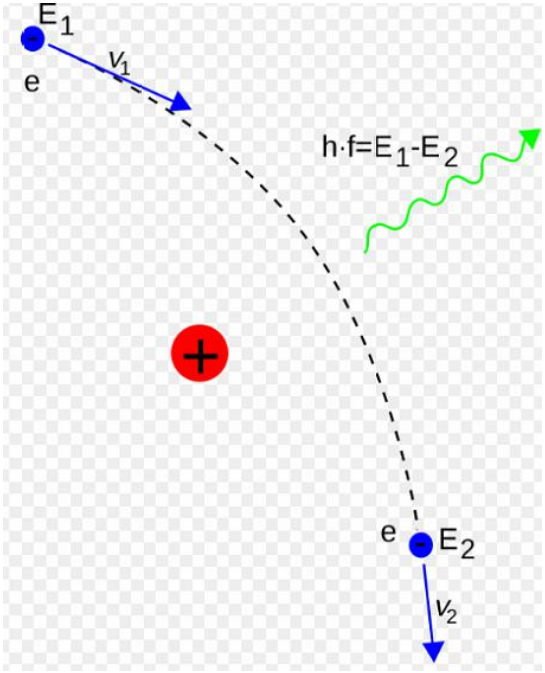
what's the sPlot technique.

- they already shown the reference of sPlot in the paper, where details could be found.
- designed to treat data samples populated by several sources of events.
- able to unfold the contributions of the different sources to the distribution of a data sample in a given variable.

# shan

In this sentence"This asymmetric function is used in order to describe bremsstrahlung emission of photons by the electrons."

- Can you explain "bremsstrahlung emission "?




- 韧致辐射
- electromagnetic radiation produced by the deceleration of a charged particle when deflected by another charged particle, typically an electron by an atomic nucleus.
- The moving particle loses kinetic energy, which is converted into radiation (i.e., a photon), thus satisfying the law of conservation of energy.

# amit

- Question-1: What kind of likelihood function they used in this paper to fit the result?

- Question-2: What is the meaning of systematic uncertainty which is associated with luminosity ratio 0.8%. They have mentioned the overall systematic uncertainty which 5.3% and uncertainty in normalized mode to be 3.6%. could you please explain to me?

1.1% per kaon [27]. A systematic uncertainty of 0.8% is associated with the knowledge of the luminosity ratio, $\mathcal{L}_{\rm norm}/\mathcal{L}_{\rm sig}$ [25].

The overall systematic uncertainty in the yields is 5.3% for the signal and 3.6% for the normalization mode. As

The $D^0 \to K^-\pi^+e^+e^-$ branching fraction is determined relative to that of the normalization decay channel $D^0 \to K^-\pi^+\pi^+\pi^-$ using

$$\frac{\mathcal{B}(D^0 \to K^-\pi^+e^+e^-)}{\mathcal{B}(D^0 \to K^-\pi^+\pi^+\pi^-)} = \frac{\hat{\epsilon}_{\rm norm}}{N_{\rm norm}} \frac{\mathcal{L}_{\rm norm}}{\mathcal{L}_{\rm sig}} \sum_i^{N_{\rm sig}} \frac{1}{\epsilon^i_{\rm sig}}, \quad (1)$$

where $\mathcal{B}(D^0 \to K^-\pi^+\pi^+\pi^-)$ is the branching fraction of the normalization mode [35], and $N_{\rm norm}$ and $\hat{\epsilon}_{\rm norm}$ are the $D^0 \to K^-\pi^+\pi^+\pi^-$ fitted yield and the reconstruction efficiency calculated from simulated $D^0 \to K^-\pi^+\pi^+\pi^-$

# personal comment and discussion

- **could we conclude that we observed long distance contribution?**
- probably not.
  - D0->Kpi omega  3 * 10^-2
  - omega->ee  7.4* 10^-5
  - then, D0-> K pi omega, omega-> ee  2* 10 ^-6
  - which is a Cabbibo-favored process.
- **what do you think the highlight of this paper is?  what makes them have the confidence to submit to PRL?**
- this paper started with :

> The decay $D^0 \to K^-\pi^+e^+e^-$ [1] is an example of a flavor-changing neutral-current (FCNC) process, which is expected to be very rare in the standard model (SM) as it cannot occur at tree level and is suppressed by the Glashow-Iliopoulos-Maiani (GIM) mechanism at loop

do you agree that this decay is a FCNC process?

  - I personally doubt it.

**thanks**