Spectroscopy at LHCb

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symmetry topics

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A joint Fermilab/SLAC publication

LHCb discovers longest-lived exotic matter yet

08/04/21 | By Sarah Charley

The newly discovered tetraquark provides a unique window into the interactions of the particles that make up atoms.







Outline





- This is very short talk \rightarrow I will only cover just a set of recent results
- The LHCb experiment is an extraordinary gym for spectroscopy both for "conventional" SM and "exotic"
- LHCb offers excellent tracking, PID and trigger efficiency + benefit from high cross-sections at LHC
- Shopping list:
 - Observation of a new T_{cc}⁺ state

• Evidence for a new structure in the $J/\psi p(\bar{p})$ systems in $B_s^o \rightarrow J/\psi p\bar{p}$ decays arXiv:2108.04720

- Observation of two new excited Ξ_b^o states decaying to $\Lambda_b^o K^- \pi^+$
- Observation of excited Ω_c^{o} baryons in $\Omega_b^- \rightarrow \Xi_c^+ K^- \pi^-$ decays

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Paper in Preparation

Paper in Preparation

arXiv:2107.03419

Observation of a new T_{cc}^+ state

- Presented at <u>EPS-HEP</u> for the first time
- Double heavy spectroscopy is now a fact in the LHCb physics program!
- Charged state with double charm content (two D meson with same "charge" in the same final state)
- Very narrow peak just above the threshold with striking significance over background

29 July 2021: Observation of an exceptionally charming tetraquark.

This week at the <u>European Physical Society conference on high energy physics, EPS-HEP 2021</u> the LHCb Collaboration presented the first observation of a doubly charmed tetraquark, T_{cc}^+ , with a new quark content ccud. The newly discovered particle containing two heavy charm quarks is manifestly exotic, *i.e.* beyond the conventional pattern of hadron formation found in mesons and baryons. The tetraquark particle manifests itself as a narrow peak in the D⁰D⁰π⁺ meson mass spectrum, just below D^{*+}D⁰ mass threshold, with a statistical significance exceeding 20 standard deviations. The full Run 1 and Run 2 dataset was used to obtain this discovery.



A lot of hype generated!

Paper in Preparation

LHCb-PAPER-2021-031





Observation of a new T_{cc}^+ state

- T_{cc}^+ , with a new quark content ccud
- Charged double-charmed state is manifestly exotic
- Narrow peak in the $D^{o}D^{o}\pi^{+}$ meson mass spectrum
- The new state is just below D*+D° mass threshold
- Sample is extremely pure
- Subtract fake-D background using 2D fit to $(m_{K\pi}, m_{K\pi})$
- No evidence in opposite sign sample





Paper in Preparation LHCb-PAPER-2021-031

$Observation \ of \ a \ new \ T_{cc}{}^+ \ state$

- This search nicely complements previous studies on states with double heavy quark content
- E.g. in July 2020, LHCb announced the possible discovery of a four-charm quark tetraquark in J/ Ψ J/ Ψ



- Also new searches ongoing on other states in the available dataset
- No signal is found and Upper Limits are set on the relevant mass window

Search for the doubly charmed baryon Ω_{cc}^+ $\Omega_{cc}^{++} \rightarrow \Xi_c^+ K^- \pi^+$

arXiv:2104.04759

Search for the doubly heavy baryons $arOmega_{bc}^0$ and $arepsilon_{bc}^0$ decaying to $\Lambda_c^+\pi^-$ and $arepsilon_c^+\pi^-$

New structure in J/ ψp : B_s⁰ \rightarrow J/ $\psi p\bar{p}$ decays

- New analysis involving pentaquark searches
- LHCb has investigated many modes in the past involving the J/ ψ p system (but in baryons)
- This analysis: amplitude analysis of flavour-untagged $B_s^o \rightarrow J/\psi p \bar{p}$
- Decay observed and reported by LHCb in 2019 \rightarrow now amplitude analysis
- Very interesting final state because of the symmetry of the Dalitz plot
- Sample of 797 ± 31 signal events



arXiv:2108.04720 NEW posted on arXiv last week



New structure in J/ ψp : B_s⁰ \rightarrow J/ $\psi p\bar{p}$ decays

- Evidence for a new structure in the J/ ψp and J/ $\psi \bar{p}$ systems
- Significance in the range of 3.1σ to 3.7σ , depending on the assigned J^p hypothesis
- There could be even a "glueball" contribution in pp, but nothing significant is found

arXiv:2108.04720 NEW posted on arXiv last week



The mass and width of this new pentaquark-like state are measured to be

$$M_{P_c} = 4337 \,{}^{+7}_{-4} \,{}^{+2}_{-2} \,\text{MeV},$$

$$\Gamma_{P_c} = 29 \,{}^{+26}_{-12} \,{}^{+14}_{-14} \,\text{MeV},$$

Lomonosov 2021

Observation of two new excited $\Xi_b{}^0$ states decaying to $\Lambda_b{}^0\,K^-\,\pi^+$

- New b-hadron resonances are being observed by the LHCb experiment
- Thanks to the very abundant samples of Λ_b saved on disk
- Use both:
 - $\Lambda_b \rightarrow \Lambda_c \pi$
 - $\Lambda_b \rightarrow \Lambda_c \pi \pi^+ \pi^-$



- Two narrow peaks in the Λ_b K- $\pi \!\!\!\!+$ mass spectrum are observed





Paper in Preparation

LHCb-PAPER-2021-025

Observation of two new excited Ξb^0 states decaying to $\Lambda_b{}^0\,K^-\,\pi^+$



Observation of excited Ω_c^0 baryons in $\Omega_b^- \rightarrow \Xi_c^+ K^- \pi^-$ decays

- New mode considered, first observation
- Four excited Ωc baryons are observed in the $\Xi_{c}^{+}K^{-}$ mass projection
- Their relative production rates, masses and natural widths are measured
- Precise mass measurement $6044.3 \pm 1.2 \pm 1.1 \pm 1.1 \pm 0.19 \text{ MeV}$



arXiv:2107.03419

Observation of excited Ω_c^0 baryons in $\Omega_b^- \rightarrow \Xi_c^+ K^- \pi^-$ decays



arXiv:2107.03419



Conclusions



- This was a very short talk containing only the very latest results
- All results exploiting the large dataset collected during Run1 and Run2
- More research is ongoing + Upgrade effort speeding up
- A bright future ahead for both conventional and exotica when more data will be available

Please stay tuned!