Charmed baryon spectroscopy experiment at J-PARC

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What is a building block of hadrons?

Constituent Quark

Exotic hadron

$q-q$ correlation (diquark)
Charmed baryon spectrum: “Excitation Mode”

Heavy Quark: Weak color-magnetic interaction
⇒”q-q” isolated and developed: “q-q + Q”
Decay property

\[ \Gamma_{\pi\Sigma_c} > \Gamma_{ND} \]

\[ \Gamma_{\pi\Sigma_c} < \Gamma_{ND} \]

- Decay measurement: \( \Gamma_{\pi\Sigma_c} \leftrightarrow \Gamma_{ND} \)
  - \( \pi^- + \Sigma_c^{++}, \pi^+ + \Sigma_c^0 \)
  - \( p + D^0 \)

\[ \rho \text{-mode decay} \]
\[ \Lambda_c^* \rightarrow \pi + \Sigma_c \]

\[ \lambda \text{-mode decay} \]
\[ \Lambda_c^* \rightarrow N + D \]
Production cross section

Hadronic production: $\pi^- + p \rightarrow Y_c^{**} + D^{*-}$

* Production rates $\Leftrightarrow$ Excitation mode
  - Forward angles: $\lambda$ mode

⇒ Study from “Reaction dynamics”

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$I_L / I_{g.s.} \sim (q_{eff}/A)^L$

$q_{eff}$: Momentum transfer
$A$: (baryon size parameter)$^{-1}$

Charmed baryon spectroscopy

**J-PARC E50 experiment**
- Investigate charmed baryons by Missing Mass spectroscopy
- Systematic measurement
  - Excited states search
  - Excitation energy
  - Decay property
  - Production cross section
  ⇒ Diquark correlation
  - Excitation mode

**Observed charmed baryons in PDG**

- \( \Lambda_c(2595) \) 1/2-
- \( \Lambda_c(2625) \) 3/2-
- \( \Lambda_c(2880) \) 5/2
- \( \Lambda_c(2940) \) ??
- \( \Sigma_c(2455) \) 1/2+
- \( \Sigma_c(2520) \) 3/2+
- \( \Sigma_c(2800) \) ??
- \( \Lambda_c(2940) \) ??
- \( \Lambda_c(2880) \) 5/2+
- \( \Sigma_c(2800) \) ??

**Mass [GeV/c^2]**

- 2.3
- 2.4
- 2.5
- 2.6
- 2.7
- 2.75
- 2.8
- 2.9
High-momentum beam line for 2ndary beam

- **High-intensity beam:** \( > 1.0 \times 10^7 \text{ Hz } \pi (< 20 \text{ GeV/c}) \)
  - Unseparated beam
- **High-resolution beam:** \( \Delta p/p \sim 0.1\% \text{(rms)} \)
  - Momentum dispersive optics method

Diagram:
- 15kW Loss Target (SM)
- Collimator
- Dispersive Focal Point (IF) \( \Delta p/p \sim 0.1\% \)
- Exp. Target (FF)
Experiment

\[ \pi^- + p \rightarrow Y_c^{*+} + D^{*-} \] reaction @ 20 GeV/c

1) Missing mass spectroscopy
   - \[ D^{*-} \rightarrow \bar{D}^0 \pi^- \rightarrow K^+ \pi^- \pi_s^- \]: \[ D^{*-} \rightarrow \bar{D}^0 \pi_s^- (67.7\%), \bar{D}^0 \rightarrow K^+ \pi^- (3.88\%) \]

2) Decay measurement
   - Decay particles (\( \pi^\pm \) & proton) from \( Y_c^* \)

\( K^+ \) & \( \pi^- \): 2–16 GeV/c

Slow \( \pi_s^- \): 0.5–1.7 GeV/c

\( \pi^\pm \) & p: 0.2–1.5 GeV/c
Large Acceptance Multi-Particle Spectrometer

- Acceptance: ~50% for $D^*$
- Mass resolution: $M_{\Lambda^*_c} = 10$ MeV(rms) @ 2.7 GeV/c$^2$
Expected spectra

- $\Lambda_c$: 1 nb production cross section
  - Production ration for excited states
- Background generated by the hadronic reaction code
  - Background level and reductions were precisely studied.

* Achievable sensitivity of 0.1–0.2 nb: $(3\sigma$ level, $\Gamma < 100$ MeV)*
Expected spectra

- $\lambda$-mode excitation doublets: Production enhanced
  $\Rightarrow$ Internal structure of charmed baryons

* Diquark correlation: $\lambda$-mode excitation
Summary

• Charmed baryon spectroscopy
  – Diquark correlation: $\lambda$ and $\rho$ mode excitation
  – Inclusive measurements by missing mass spectroscopy

• Experiment at the J-PARC high-$p$ beam line
  – Spectrometer
    ○ Large acceptance and high resolution spectrometer
  – Experimental feasibility being checked by simulation
    ○ Background study: Enough reduction
    ○ Decay measurement to help missing mass measurement

• Systematic study of charmed baryons at J-PARC
  – Excitation energy, production, decay
  – With strangeness sector: $Y^*$ and $\Xi^*$
New projects at J-PARC

Hadron Experiment
at the J-PARC High-p beam line

Let’s do it together!

Thank you for your attention