

クラスターで読み解く クォーク・ハドロン階層構造

Elucidation of hierarchical structure
between quark and hadron phases
by means of quark clusters

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9 pages

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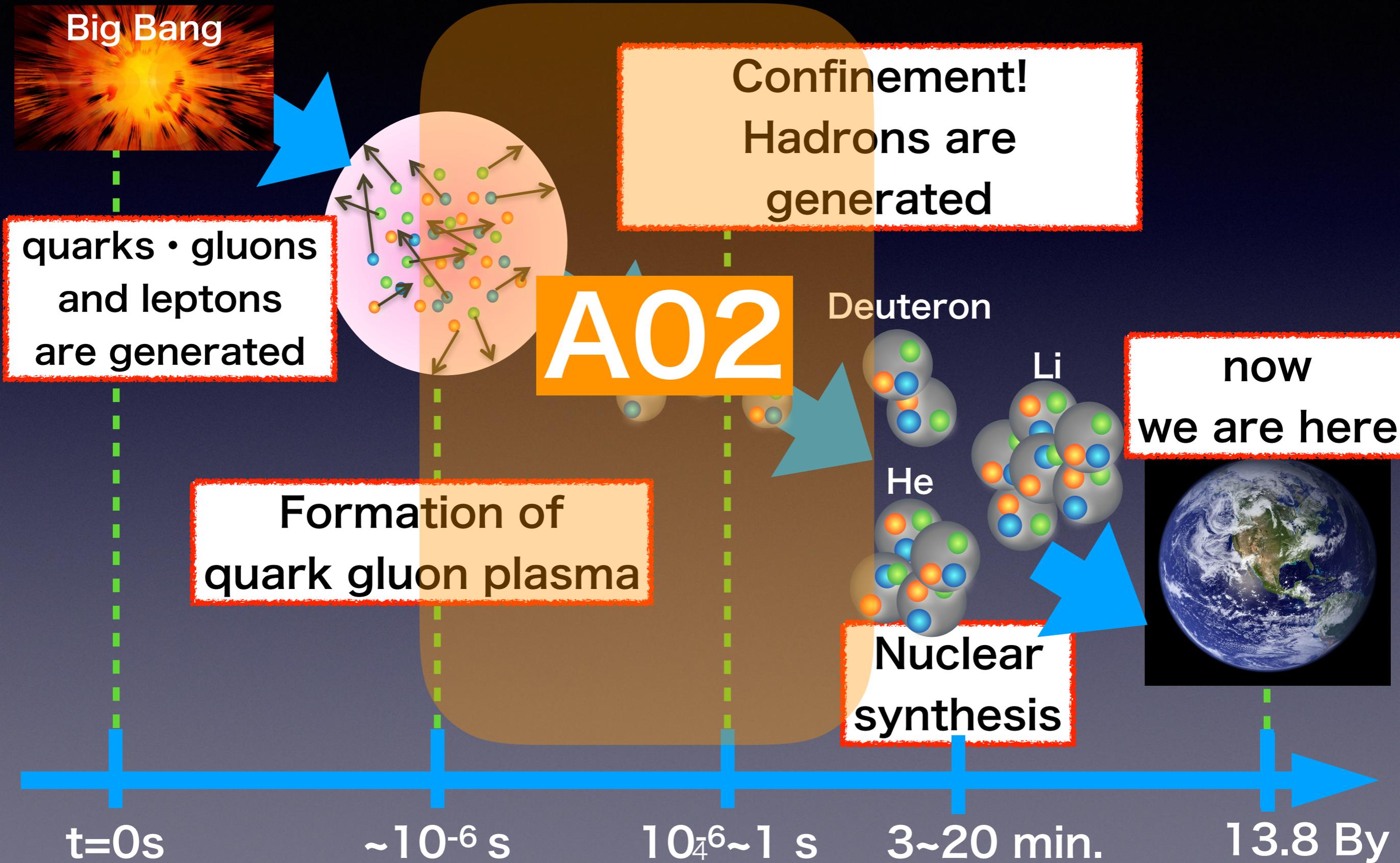
1 page

5. Summary

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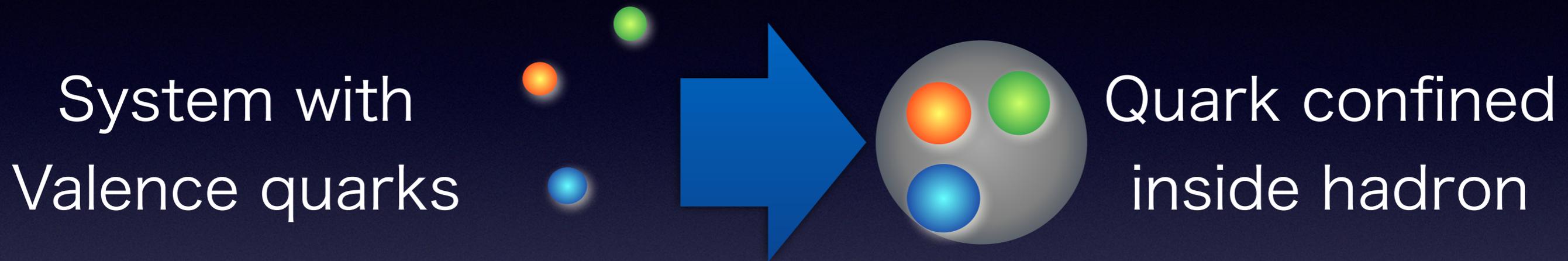
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History of our Universe



Topics of hadron physics

How the matter created via QCD



“bare” quark degree of freedom will be masked when hadrons are formed

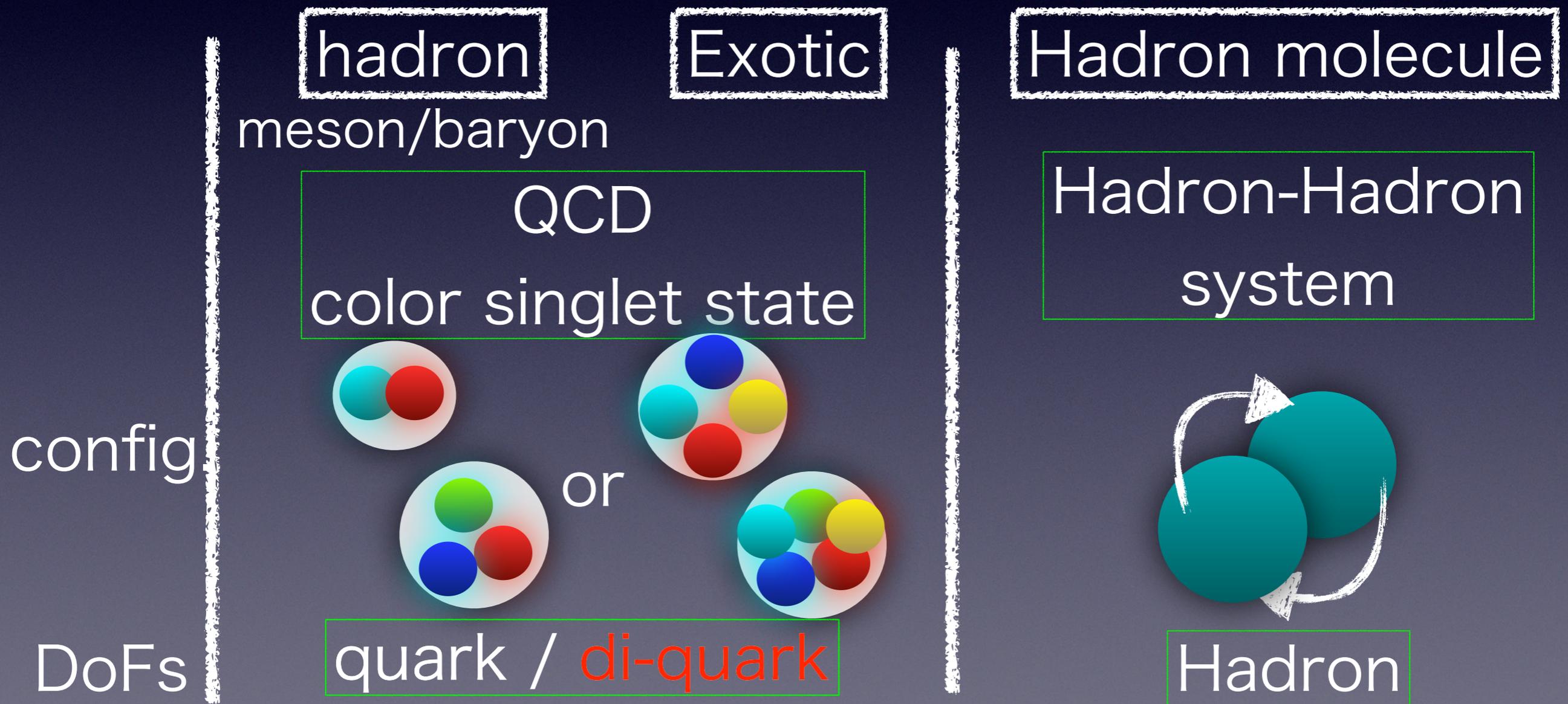


New hierarchy appears i.e. “World of Hadrons”

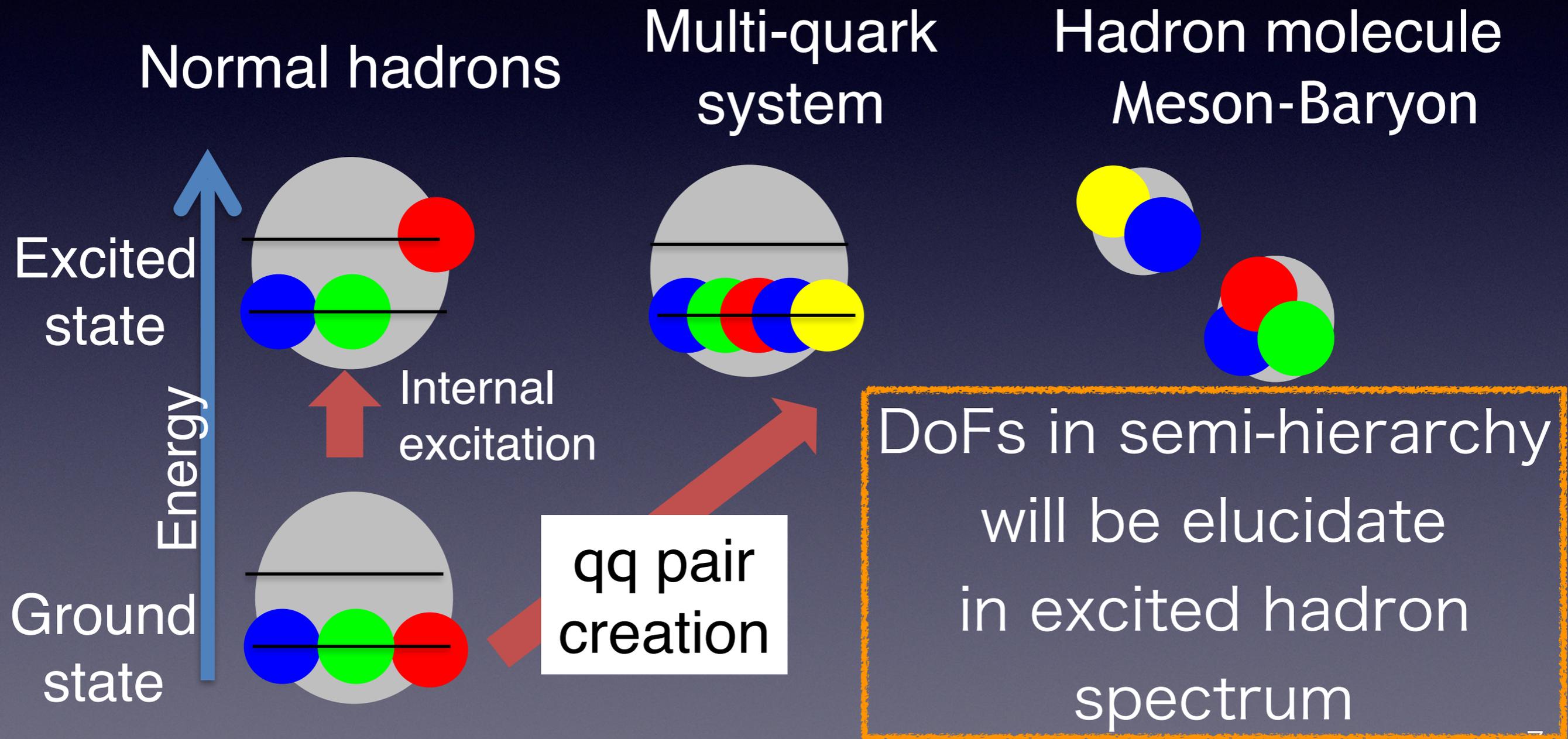
→ DoF for this hierarchy is “hadron”

Semi-hierarchy

- If Semi-hierarchy exist, then question will be, what is relevant DoF in the semi-hierarchy



Excitation of hadron and internal structure



Original picture draw by Dr. T.Hyodo

Di-quark correlation

- Inside hadron, for example baryons, strong two quark correlation out of three constituents is expected → di-quark correlation
- Source of the di-quark correlation, color magnetic interaction



$$V_{CMI} \sim \frac{\alpha_s}{m_i m_j} (\lambda_i \cdot \lambda_j) (\vec{\sigma}_i \cdot \vec{\sigma}_j)$$

Light baryon: m_i =almost equal
three di-quark correlation
could be equal each other
→ i.e. cannot distinguish!

The way to clarify effective DOFs inside hadron

- Embedded heavy quark(HQ) in hadron!
- interaction between HQ and light quark(q) will be suppressed due to Color magnetic interaction(CMI)



interaction(CMI)

$$V_{CMI} \sim \frac{\alpha_s}{m_i m_j} (\lambda_i \cdot \lambda_j) (\vec{\sigma}_i \cdot \vec{\sigma}_j)$$



$$V_{CMI} \sim 0, \quad \text{where } m \rightarrow \infty$$

i.e. **qq cluster appears in baryon**

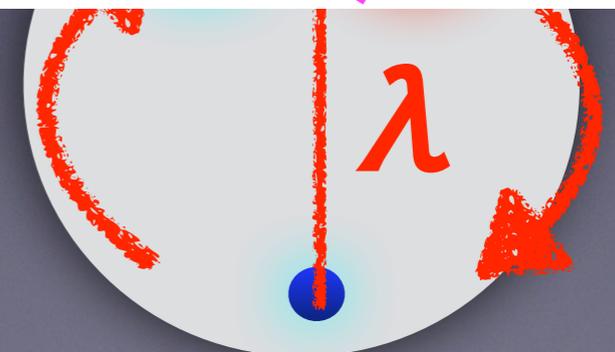
Di-quark correlation

two-modes in di-quark correlation
inside hadron will be separated
in energy spectrum of excited hadron
when one of the quark is getting heavy
hadron(qqq) existed states, but will be

Baryon spectroscopy

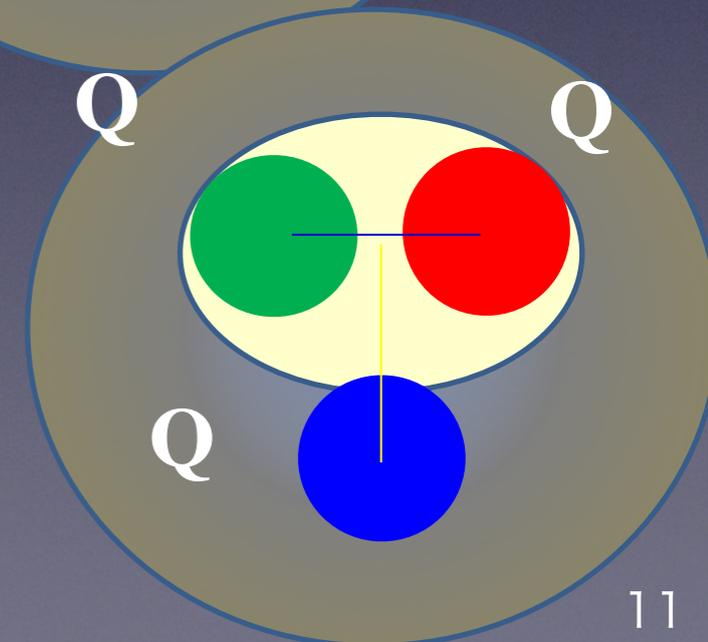
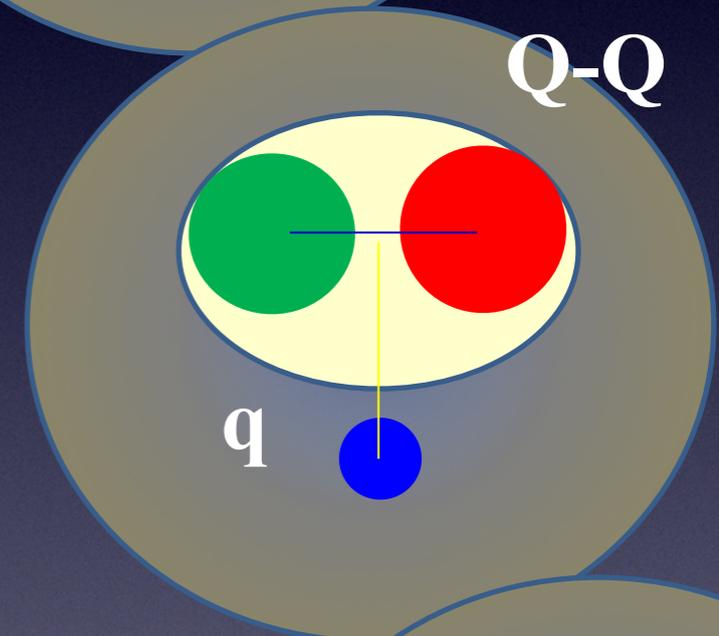
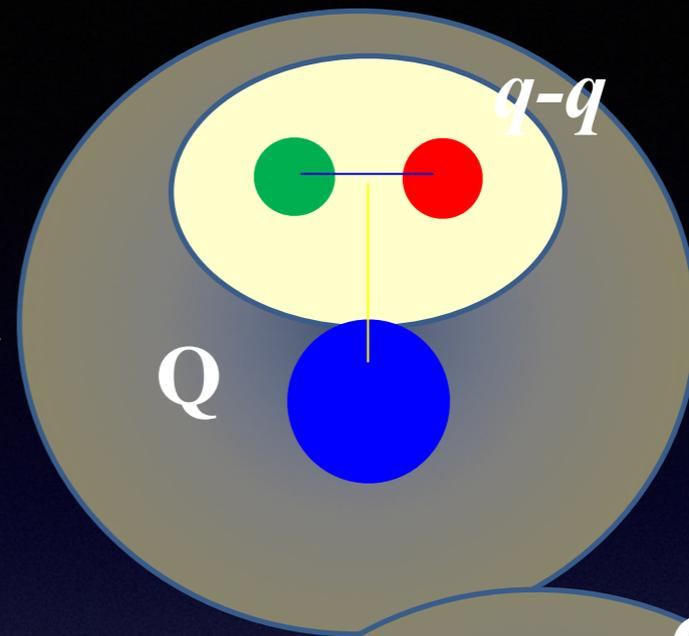
With hyperon and charmed baryons
(one strange/ one charm)

G.S.



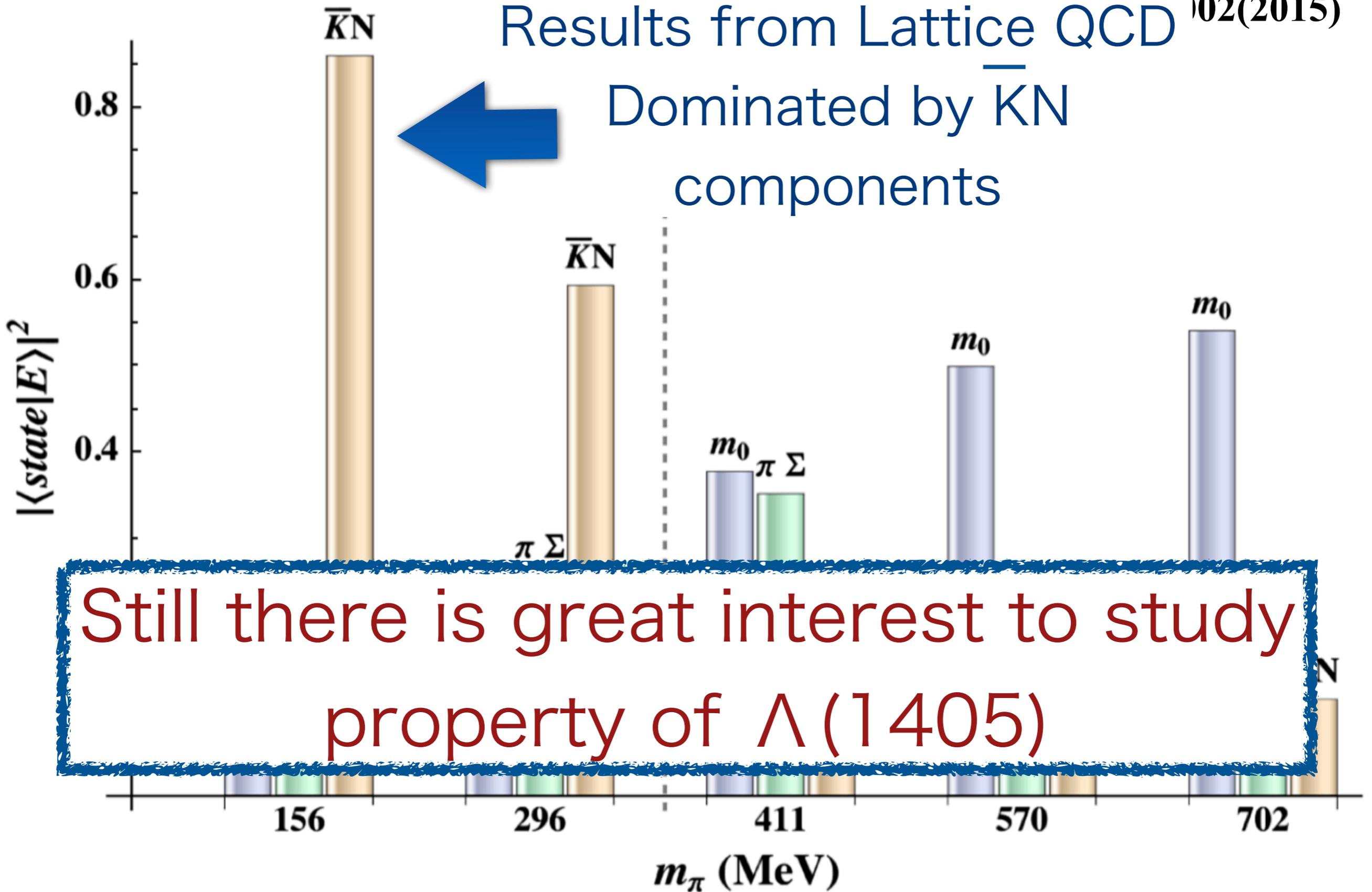
Baryon with strange quarks

- Λ/Σ : q - q + Q system
Similar to charmed baryon
Wide decay width
- Ξ : q + QQ system
2 Heavy Quark system
Narrow decay width
- Ω : QQQ system
3 Heavy Quark system
Narrow decay width



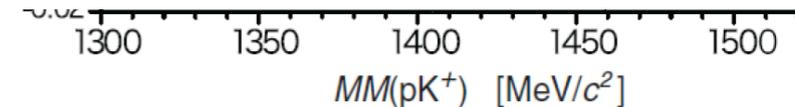
Hadron molecule?

Results from Lattice QCD ¹⁰⁰²⁽²⁰¹⁵⁾



Still there is great interest to study property of $\Lambda(1405)$

Lightest in negative parity baryon



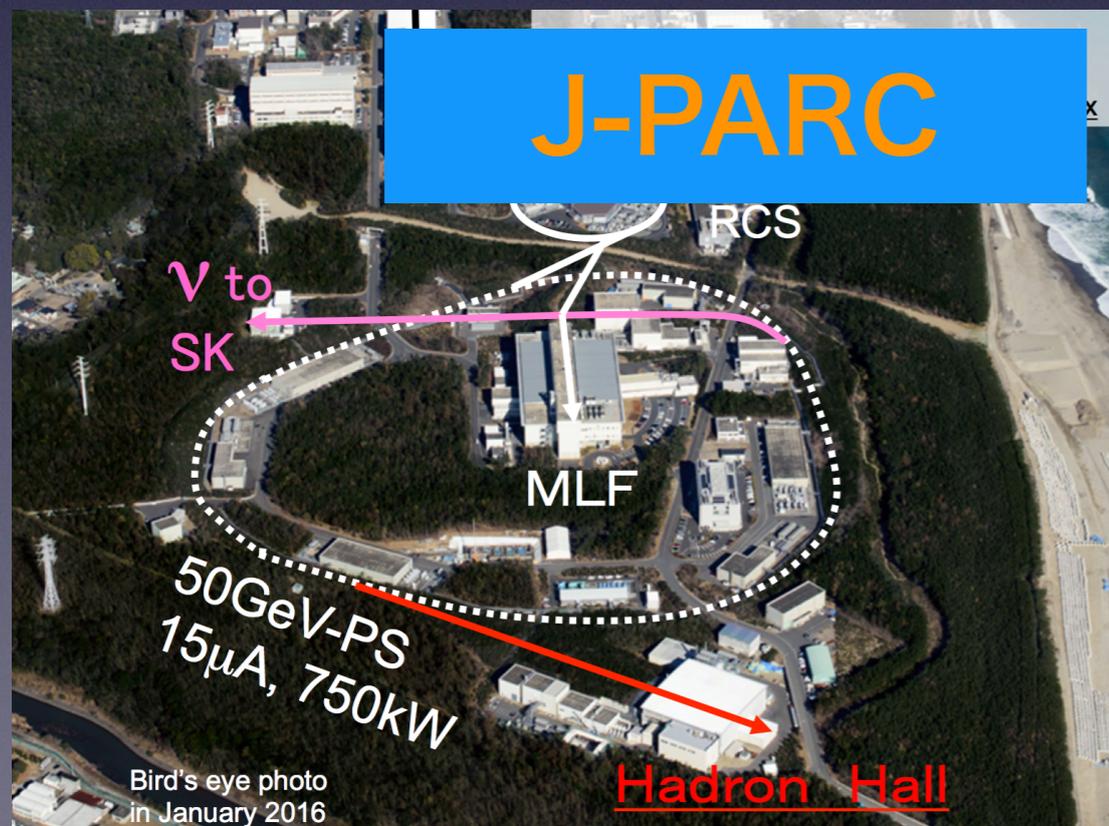
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A02 project

- Hadron spectroscopy and investigation for hadron-hadron interaction using meson and photon beam

Baryon spectroscopy
at J-PARC

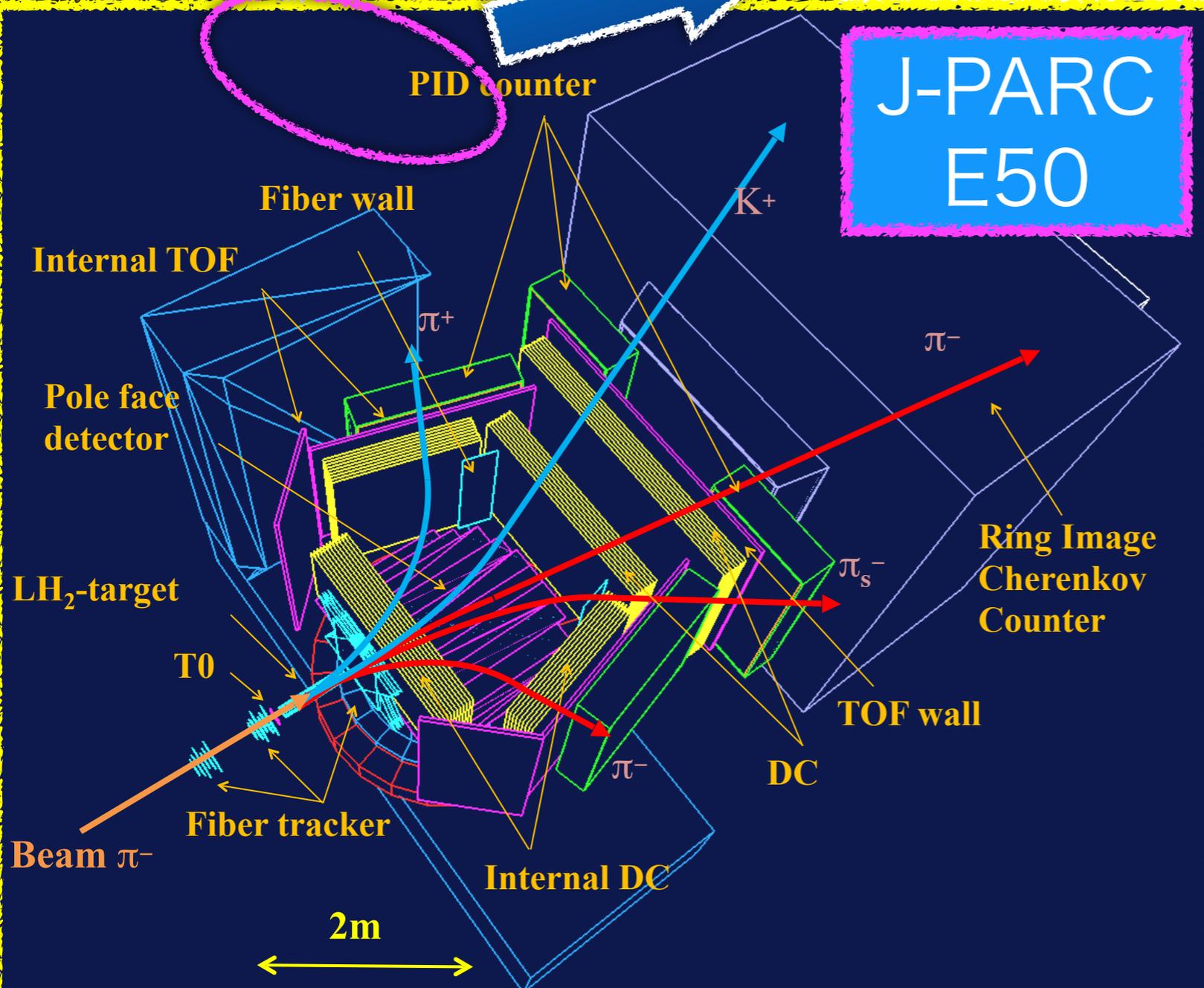
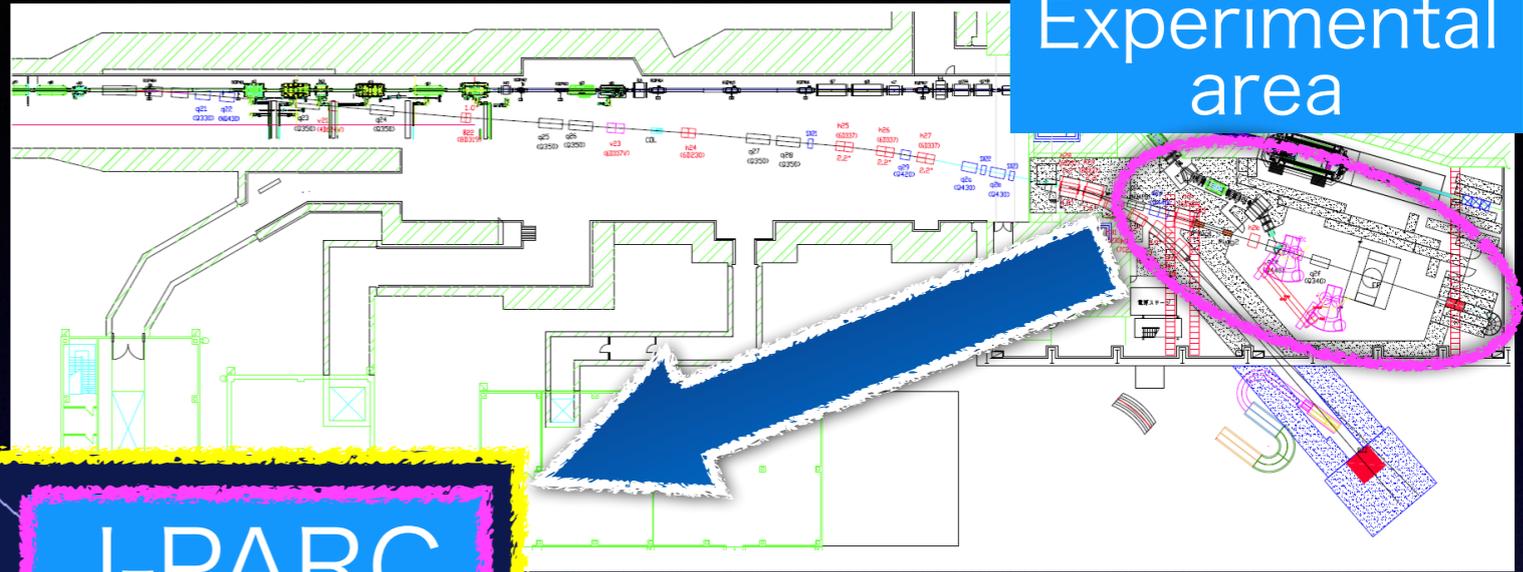
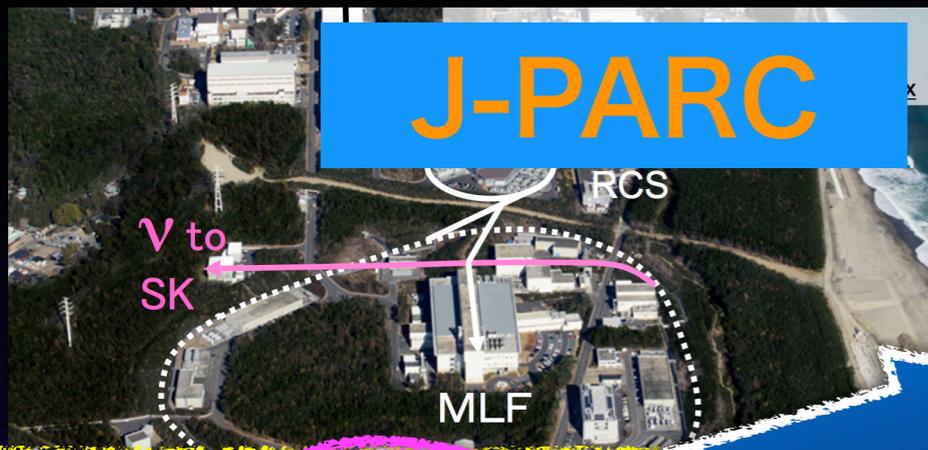


covered by
Niiyama-san

Baryon spectroscopy
at Spring-8



Baryon spectroscopy at J-PARC



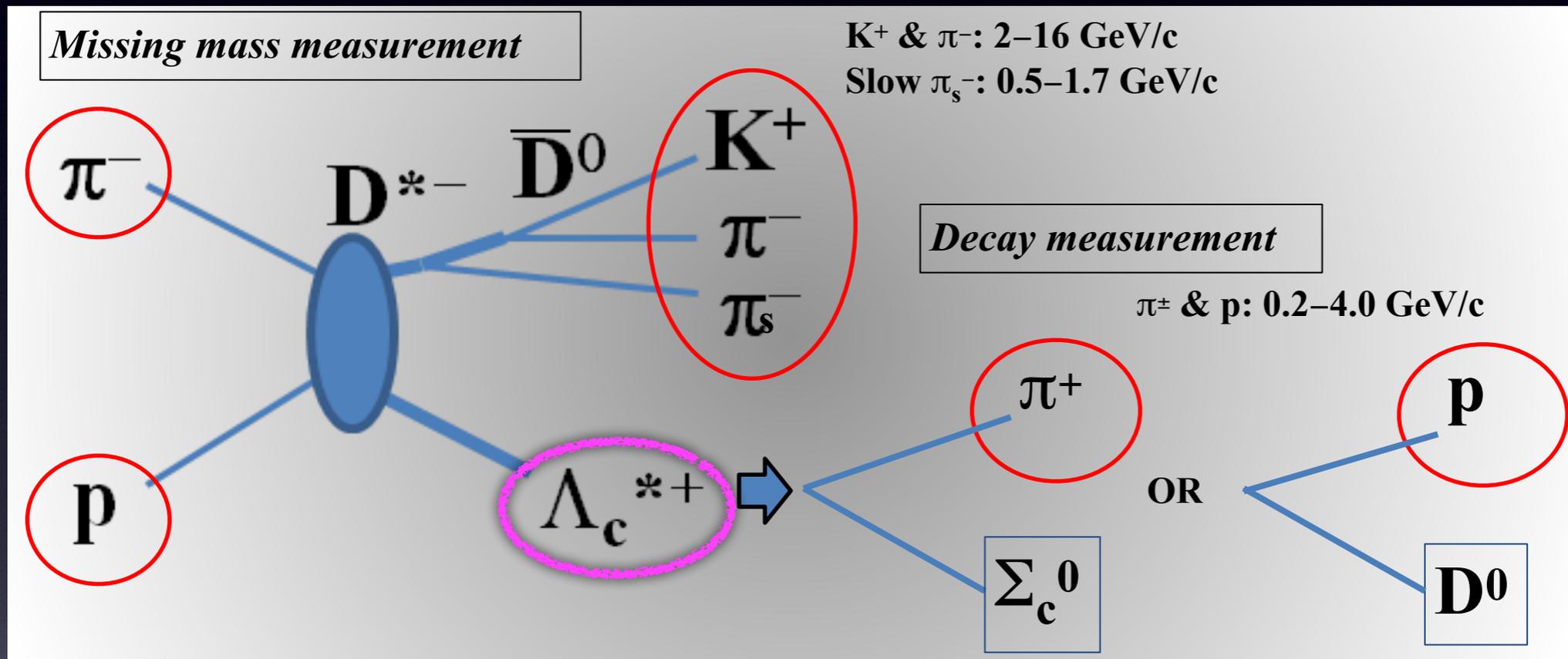
momentum beam line
 ω : $> 1.0 \times 10^7$ Hz π (< 20 GeV/c)
 ω : π / K / p_{bar}
 beam: $\Delta p/p \sim 0.1\%$ (rms)
 dispersive optics method

Charmed baryon Spectrometer

- Large acceptance spectrometer
- Data taking by Trigger-less DAQ system

Charmed baryon spectroscopy by E550

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



1. Missing mass spectroscopy

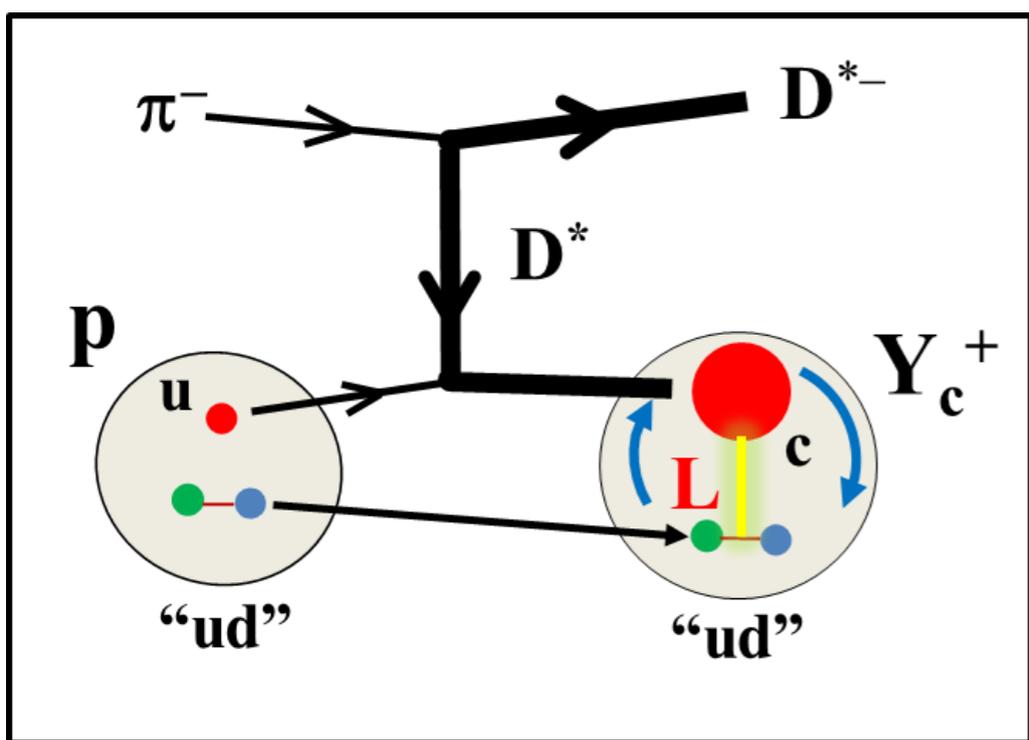
$D^{*-} \rightarrow D^0 \pi_s^- \rightarrow K^+ \pi^- \pi_s^- : D^{*-} \rightarrow D^0 \pi_s^- (67.7\%), D^0 \rightarrow K^+ \pi^- (3.88\%)$

2. With Decay measurement

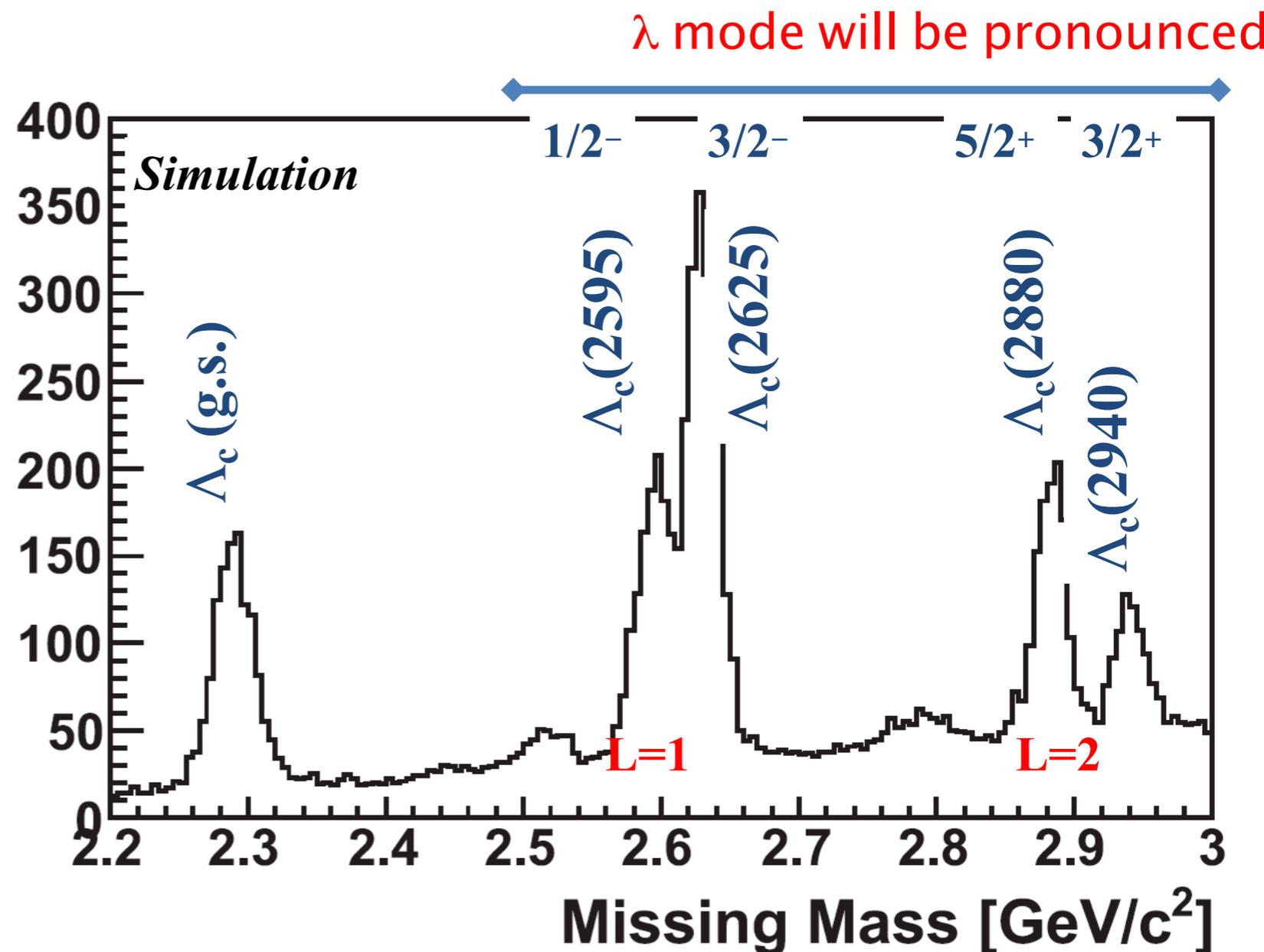
Decay particles (π^\pm & proton) from Y_c^*

Charmed baryon production

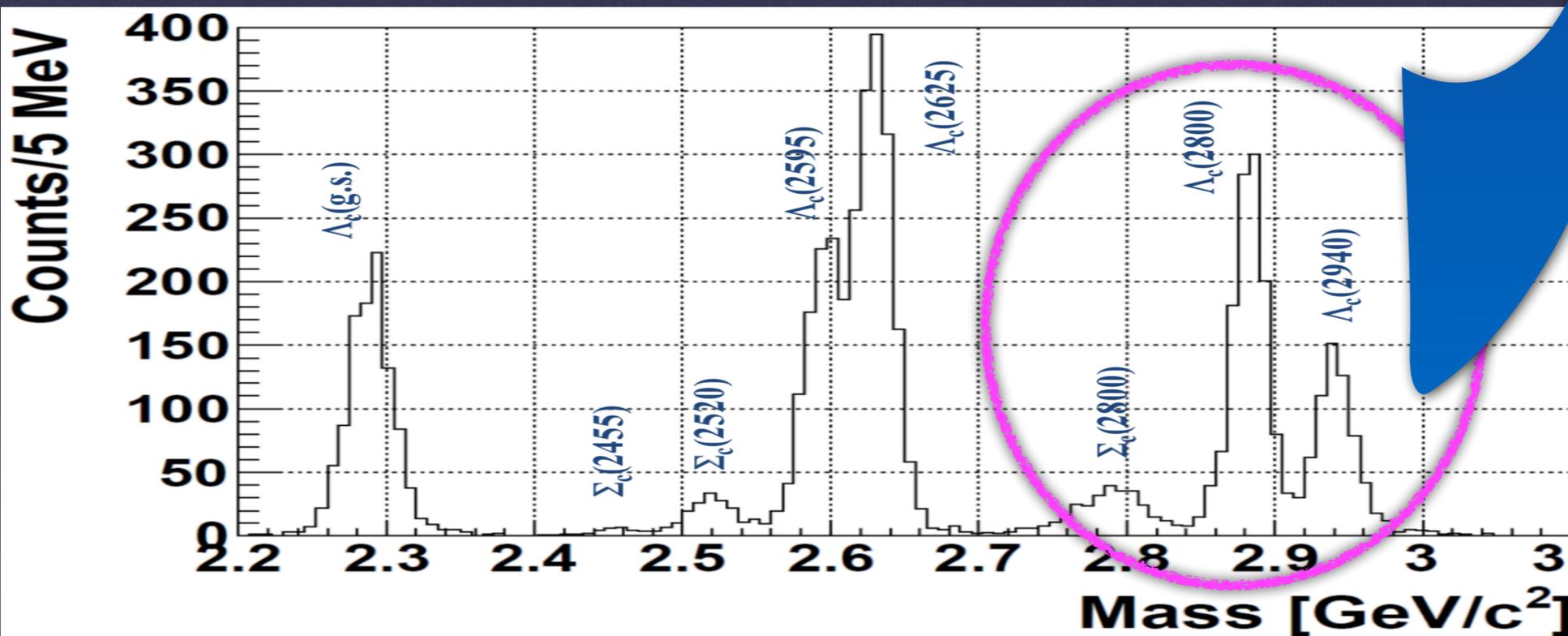
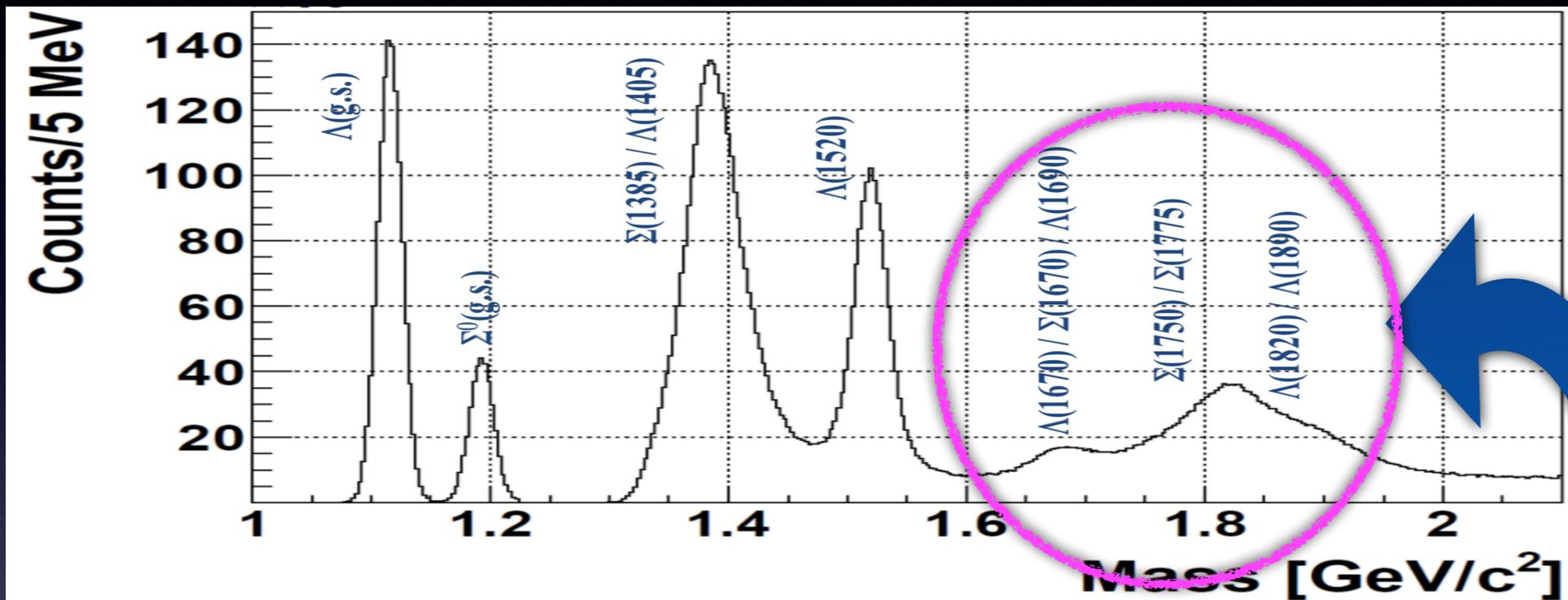
λ mode in charmed baryon expected to be enhanced by production ($\lambda \Leftrightarrow$ rotation mode btw qq-Q system)



e.g. charmed baryon prod.
 $\pi^- + p \rightarrow Y_c^{*+} + D^{*-}$ reac.



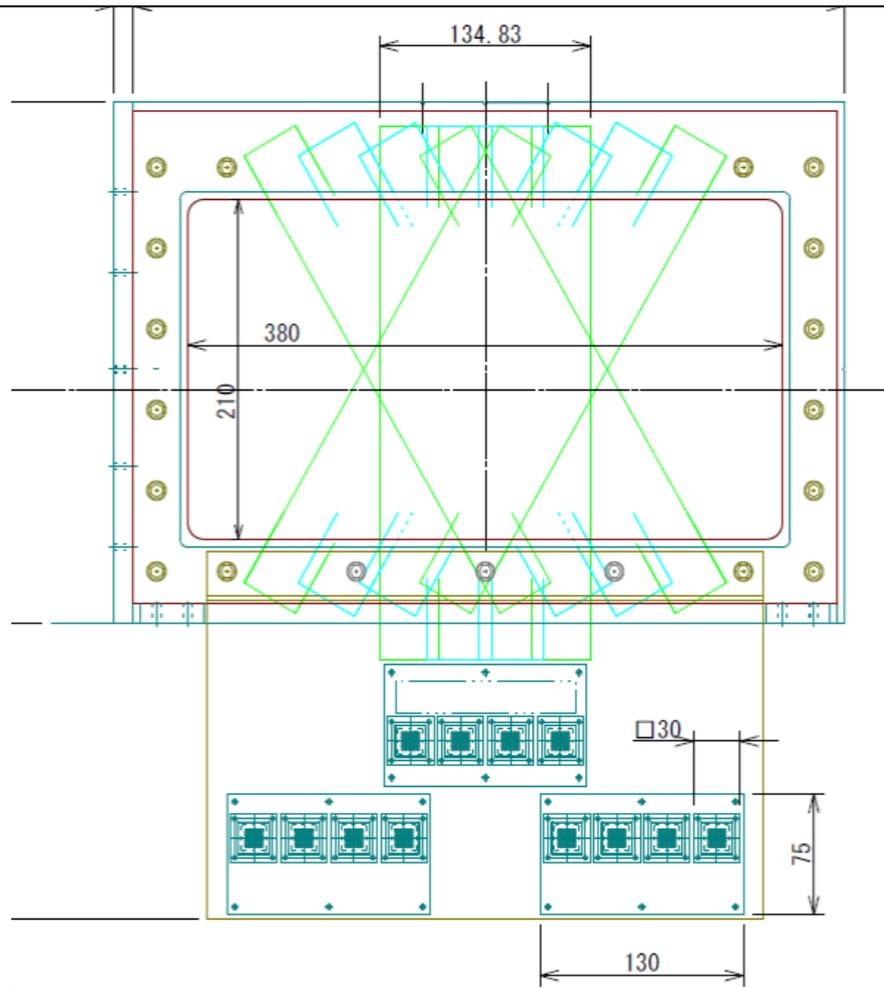
Charmed baryon vs. baryon with one strangeness



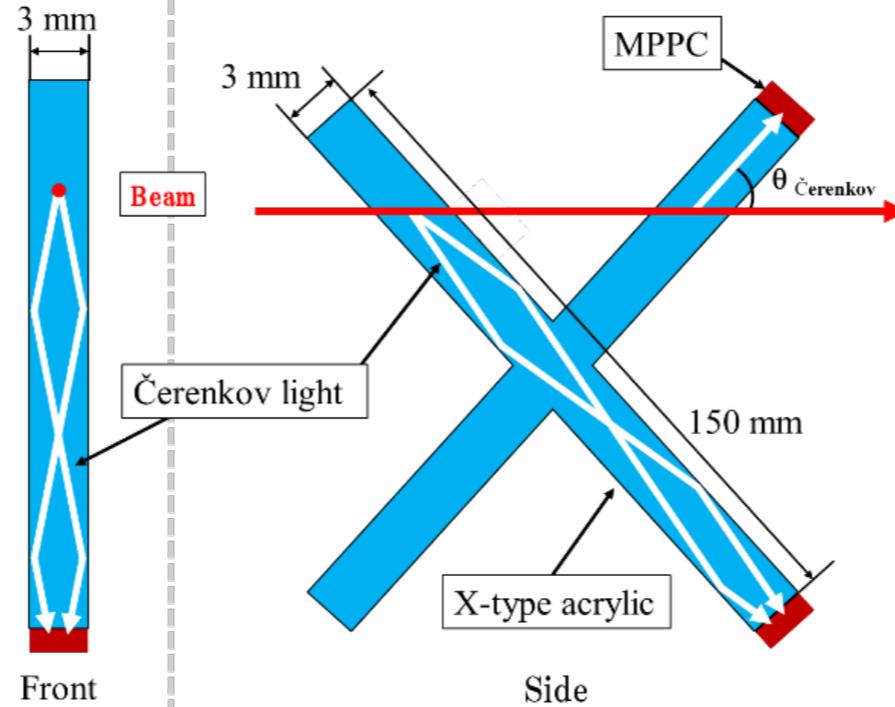
Spectrum in charmed baryon will reveal detail structure in $s=-1$ baryon spectrum

Preparation for E50 is in progress

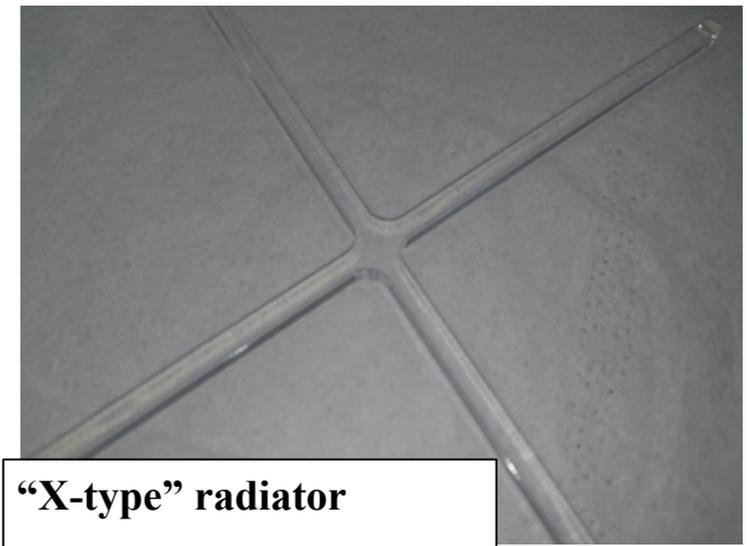
Scintillation fiber tracker: $\phi 0.5$ mm



Cherenkov timing counter
 $\Delta T \sim 50$ ps @ 3-5 MHz
3-mm width PMMA radiator



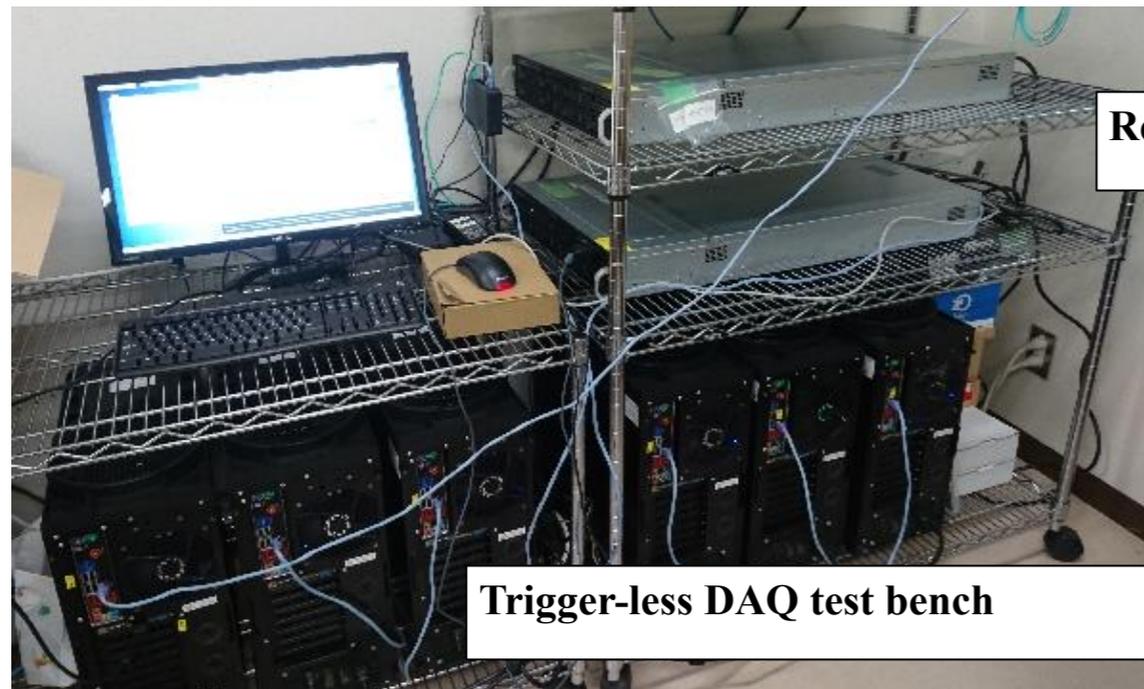
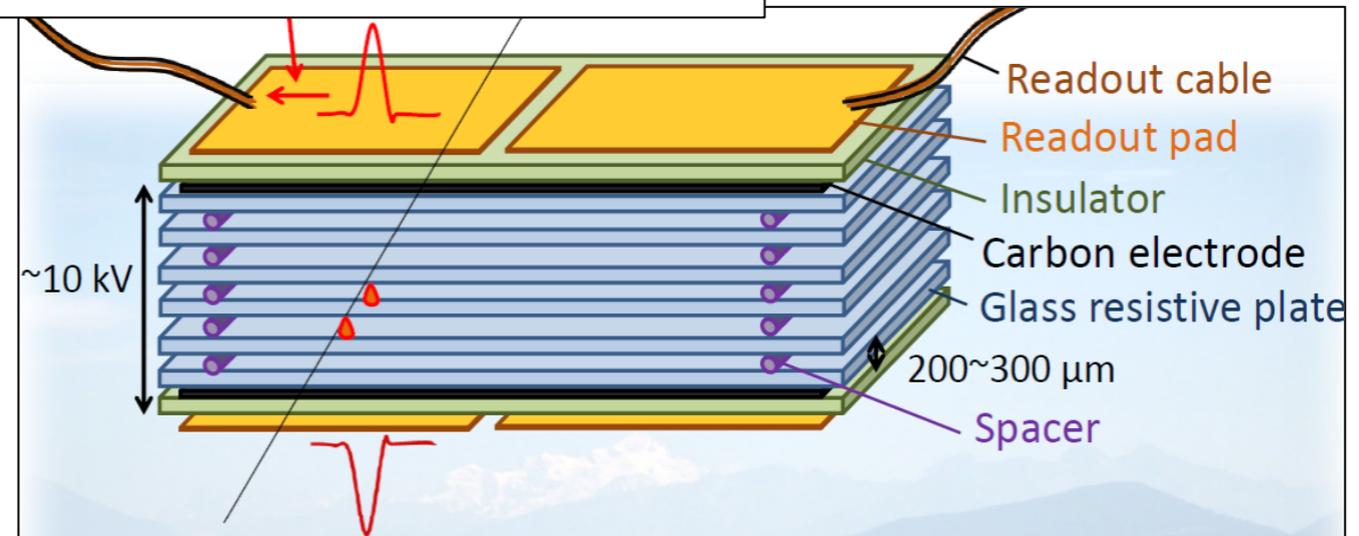
"X-type" radiator



Drift chamber production
Internal Barrel DC



Resistive Plate Chamber: $\Delta T \sim 60$ ps



Trigger-less DAQ test bench

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A02 project

Collaboration with A01, B01, B02, C01, C02, D01

J-PARC E50

Baryon spectroscopy
with Hadron beam

分担者
Prof. Noumi
Prof. Naruki
Dr. Aoki

Ohnishi

SPring-8 LEPS2

Baryon spectroscopy
with Photon beam

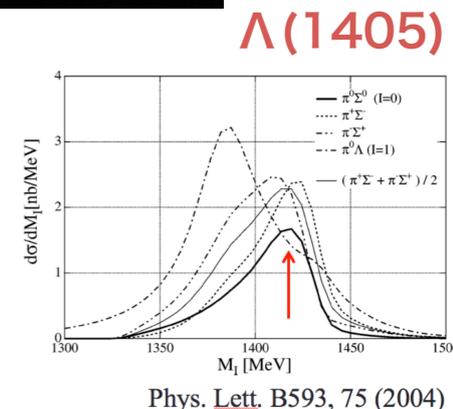
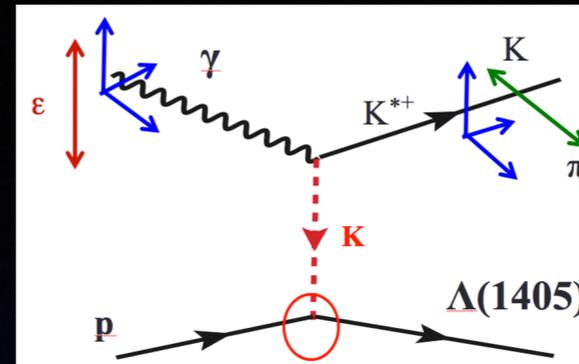
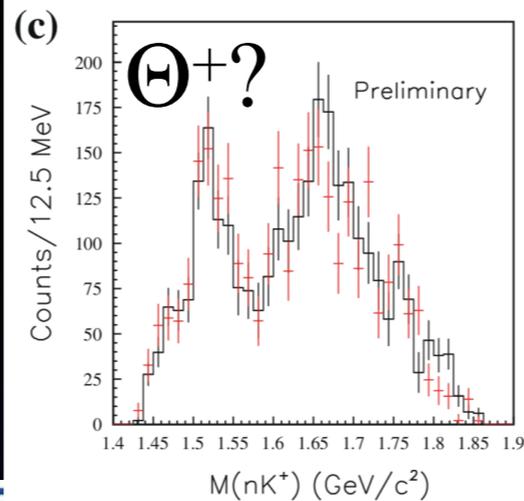
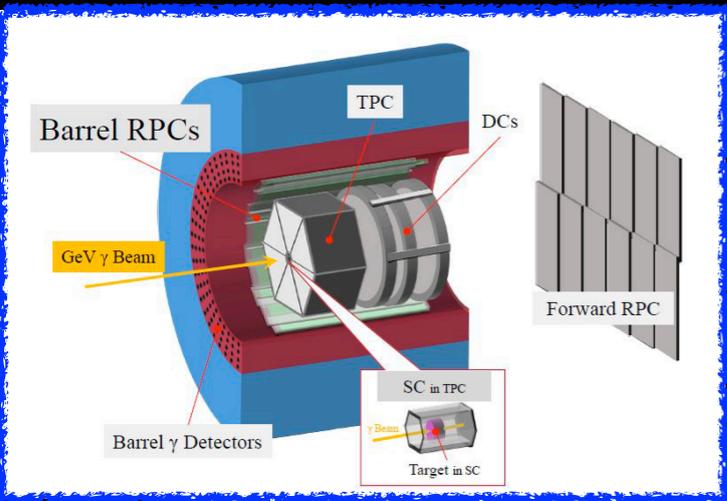
分担者
Prof. Yosoi
Prof. Niiyama

Ph.D students from

Kyoto Univ., Osaka Univ, Tohoku Univ.

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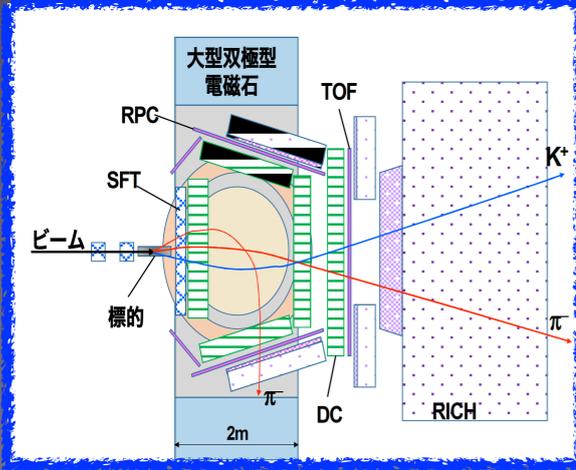
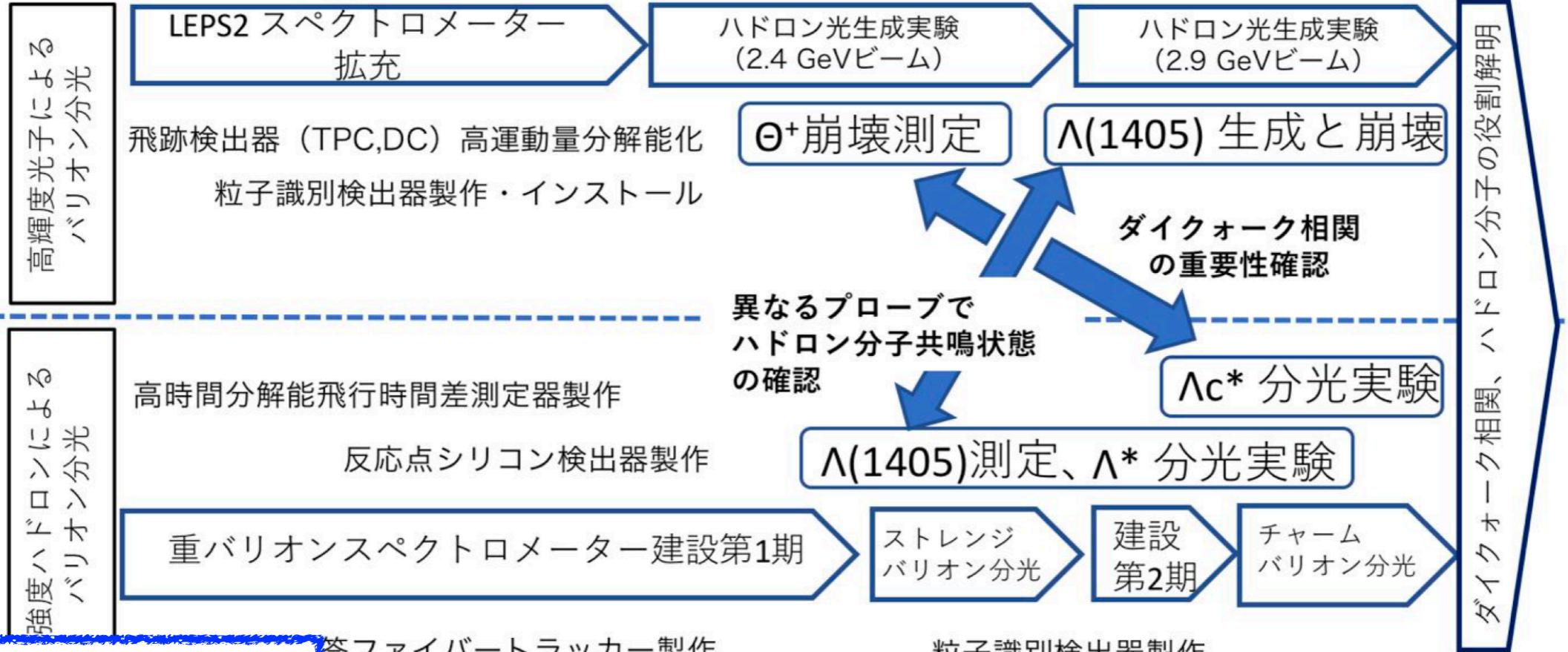
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H30年度

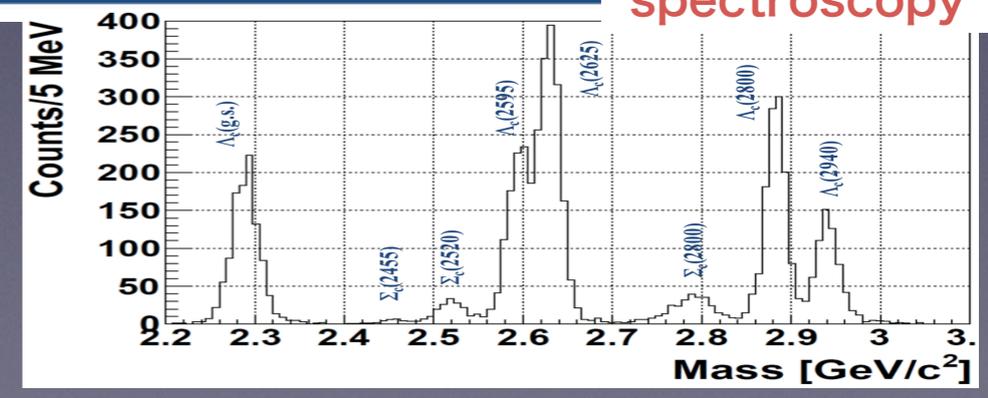
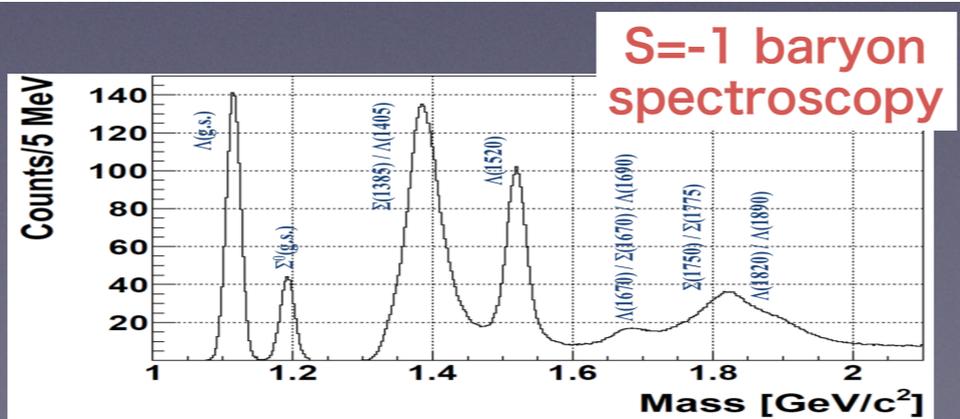
H31年度

最終年度



答ファイバートラッカー製作

粒子識別検出器製作



Charm baryon spectroscopy

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Summary

- Hadron spectroscopy reveal effective DoF which will be a main actor for semi-hierarchy between quark and hadron hierarchy
- A02 consists by two experimental programs
 - Hadron spectroscopy with meson beam (J-PARC)
 - Hadron spectroscopy with photon beam (SPring-8)
- Preparation for the experimental are in progress