Hadron Spectroscopy with High-momentum Secondary Beam

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Hadron Physics Symposium, 2014/4/19

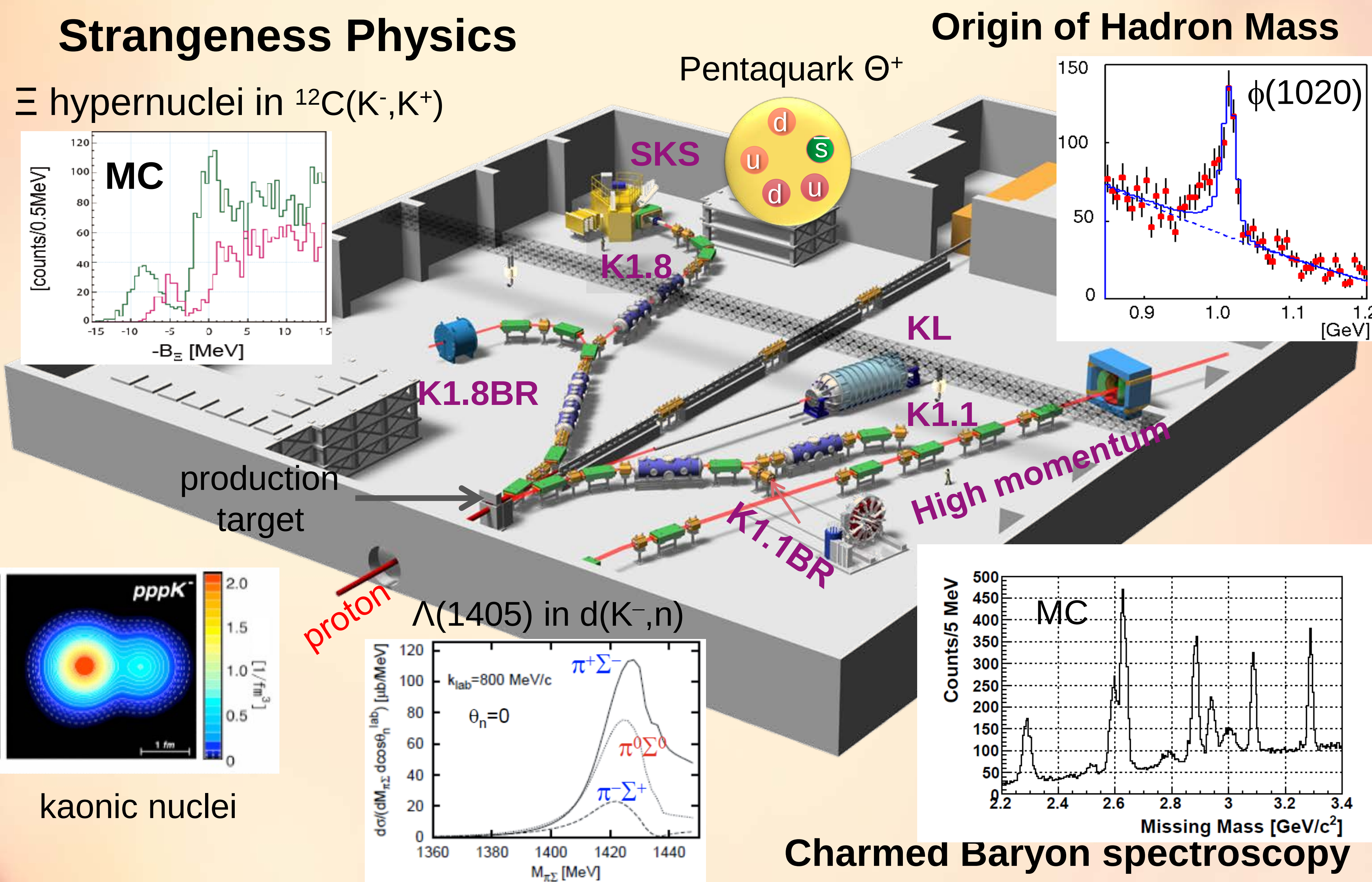
Contents

- Introduction
  - overview of J-PARC Hadron Facility
- Near Future Project : Baryon Spectroscopy
  - explore hadron structure with high-momentum secondary beams
  - strange to charm

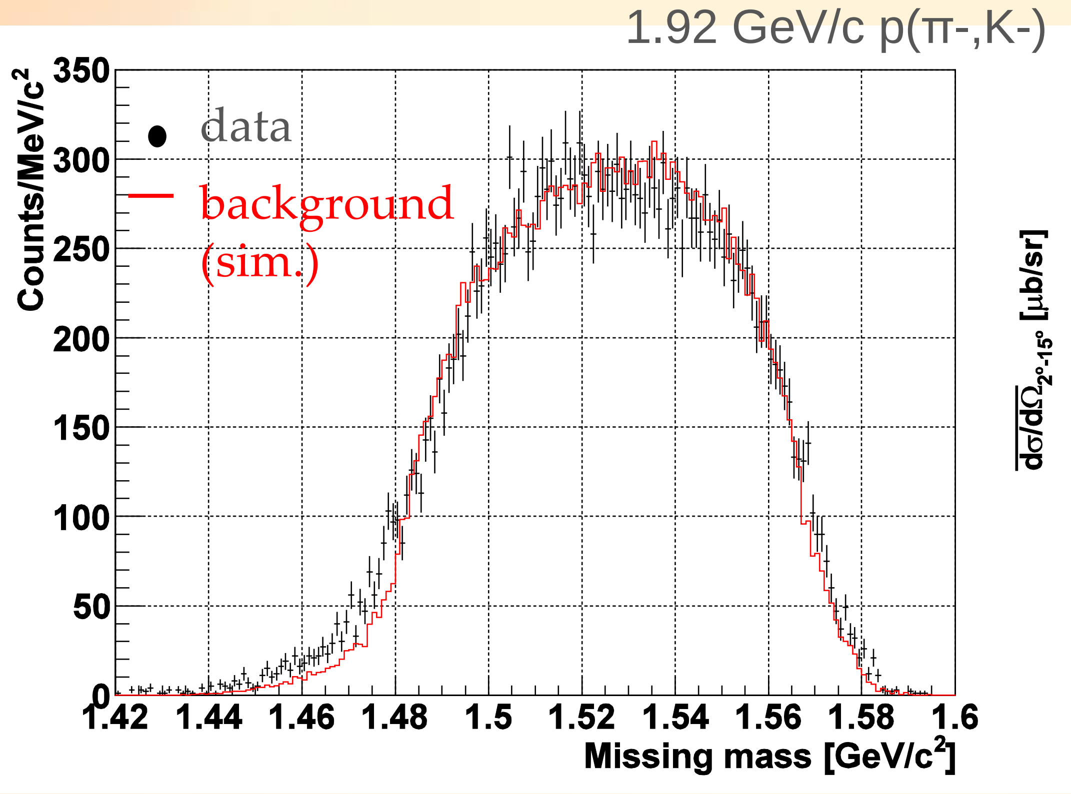
J-PARC bird's-eye view

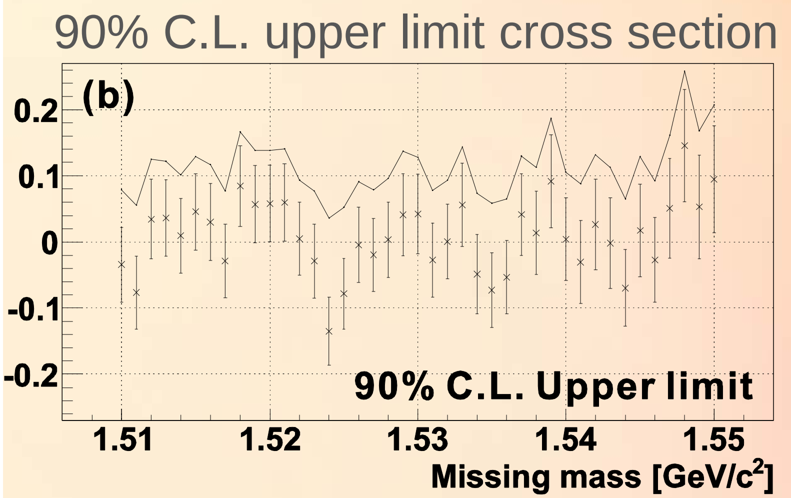
Tokai, Ibaraki, Japan

Nuclear & Hadron Physics at J-PARC



Search for Θ+ in π-p→K-X reaction

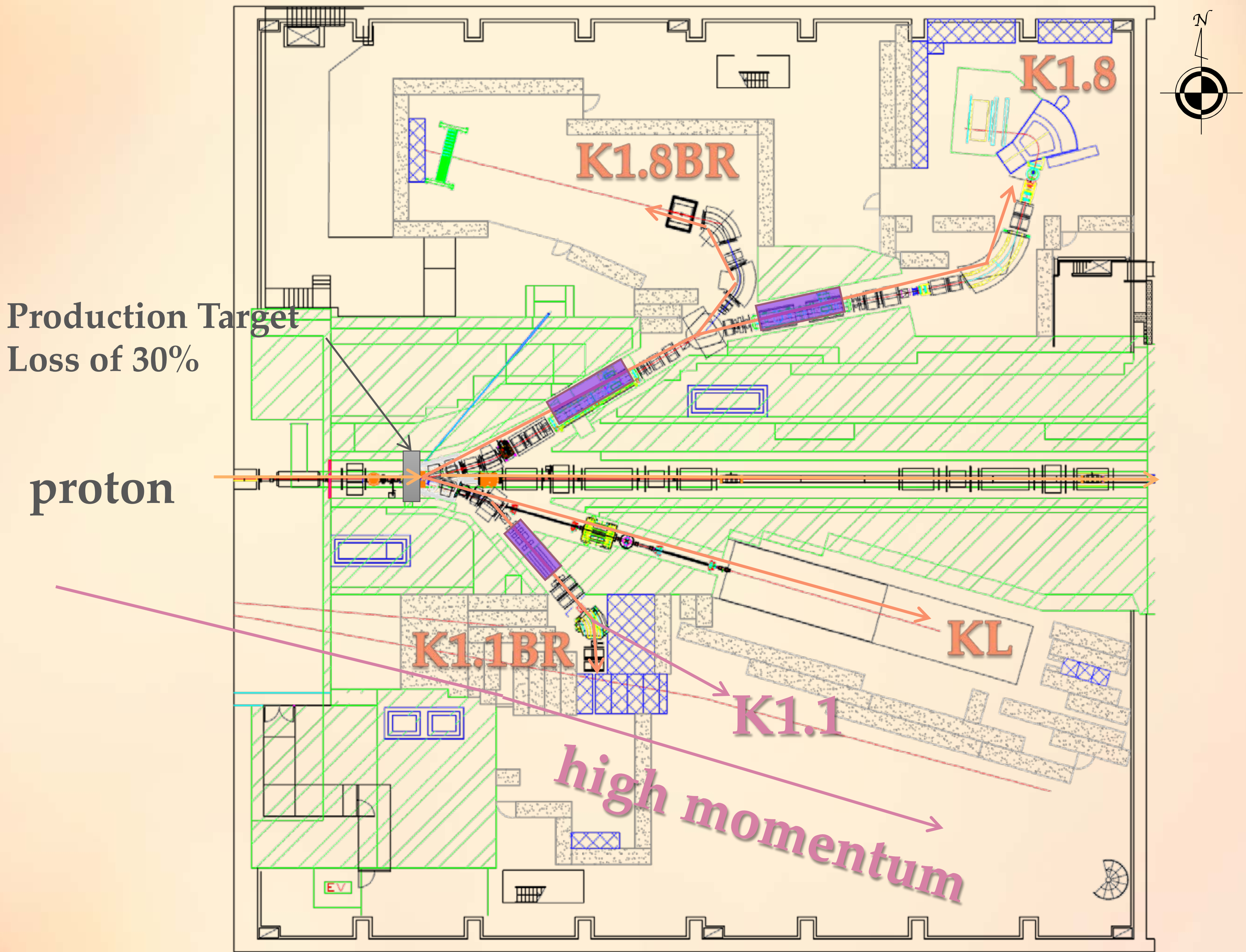




K. Shirotori *et al.*, PRL109 (2012) 132002

- no significant structure has been observed.
- upper limit is 0.26μb/sr (90%C.L.) cf. 2.9μb/sr (E522)

Beam lines at Hadron Hall



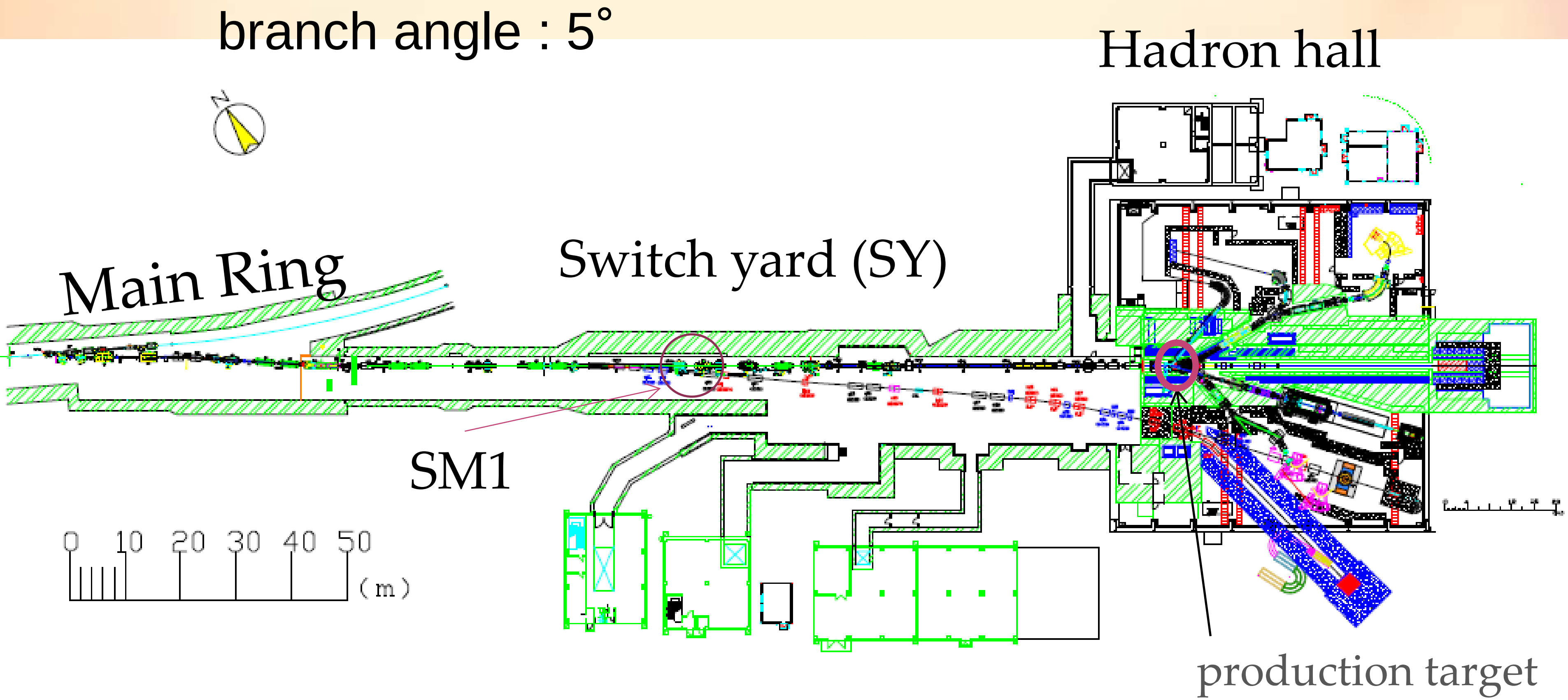
Beam line specifications

Name	Particles	P_{max}	Intensity
K1.8	π, K, p	2.0 GeV/c	10^6 K^-'s
K1.8BR	π, K, p	1.1 GeV/c	10^6 K^-'s
KL	neutral K		
K1.1BR	π, K, p	0.8 GeV/c	10^6 K^-'s
K1.1	π, K, p	1.1 GeV/c	10^6 K^-'s
High-p	proton	30 GeV/c	10^{10} p
High-p secondary	π/K/p (unseparated.)	20 GeV/c	10^6 K^-'s

new (K1.1, High-p, High-p secondary)

$\sqrt{s}$ = 2.2 GeV → $\sqrt{s}$ = 6.2 GeV in 20GeV/c πp/Kp reactions

High-momentum beam line



at SM1 high-p beam branches off from the primary line

- 30 GeV primary proton (10^{10}/s, 10^{12}/s)
- 8 GeV primary proton for COMET
- secondary particles (~20 GeV/c)

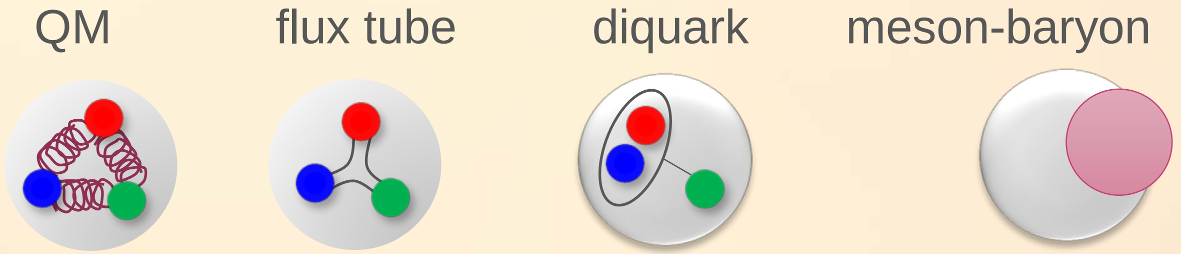
unsolved problems in QCD

- confinement
- chiral symmetry breaking

- Approaches at J-PARC
  - Dilepton measurement
  - Baryon spectroscopy
  - Properties of Exotics

Baryon spectroscopy

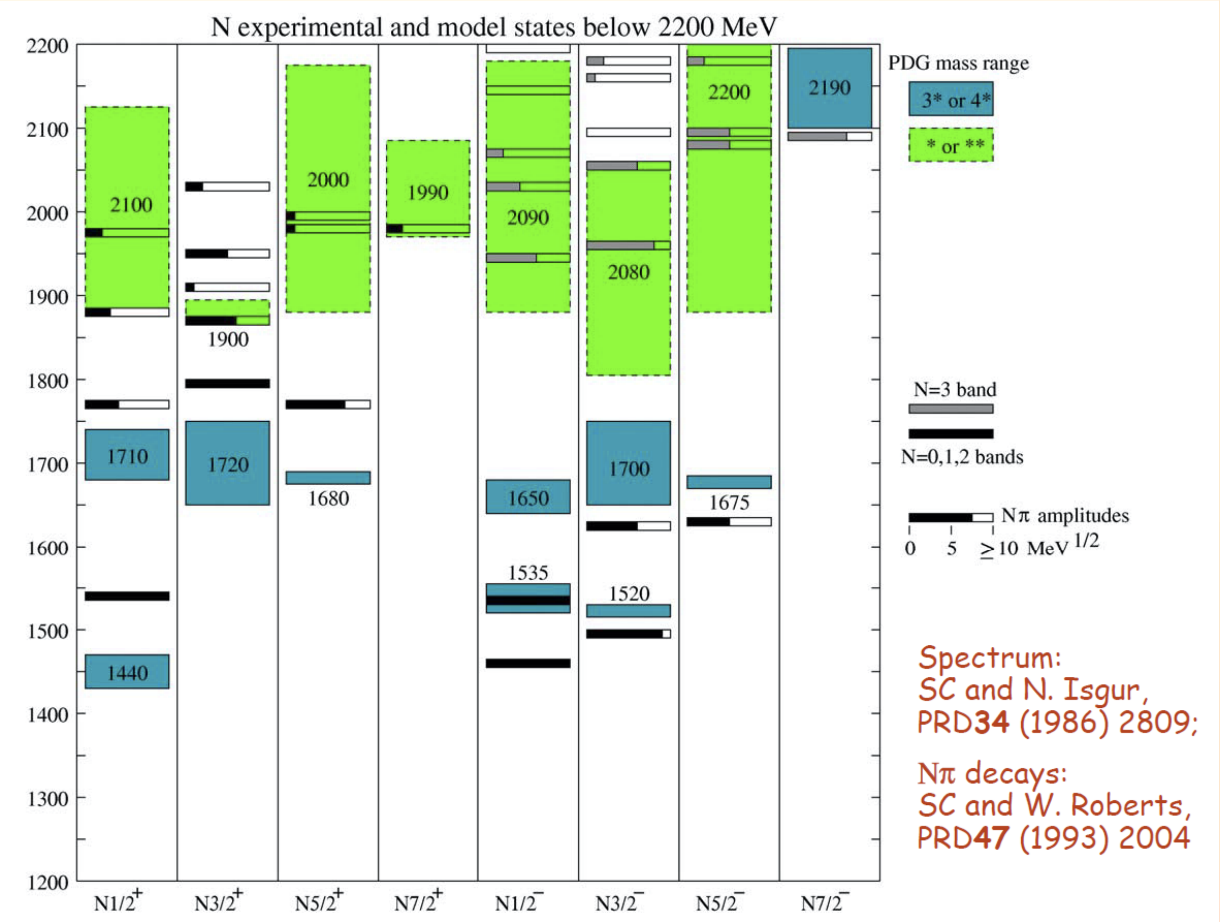
- Baryon : building blocks of our world
- description based on QCD with spectroscopy
  - understand underlying degree-of-freedom and interaction between them



needs theoretical interpretation to connect experimental observables to QCD

Comparison with QM

- Missing resonances
- Experimental difficulties in N*/Δ resonances
  - Mixture of different isospin states
  - Overlap of broad resonances of various spins



Spectrum:
SC and N. Isgur,
PRD**34** (1986) 2809;

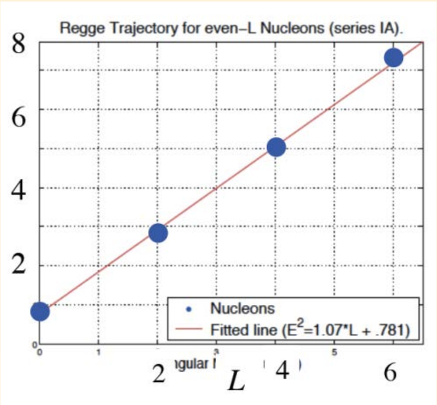
Nπ decays:
SC and W. Roberts,
PRD**47** (1993) 2004

Diquark correlations

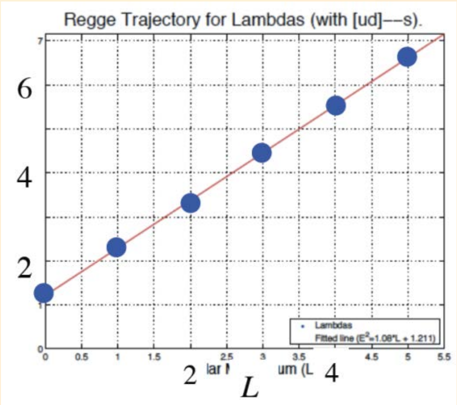
as a new building block of the Quark Model?

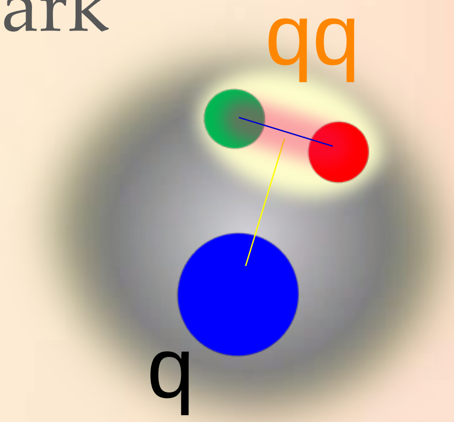
- qq : $\bar{3}_c\ \bar{3}_f$, 0> : scaler
- number of missing resonance is lower
- effective at large L / with heavy quark

N*

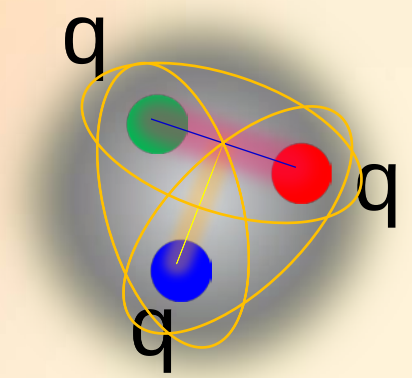


Λ*





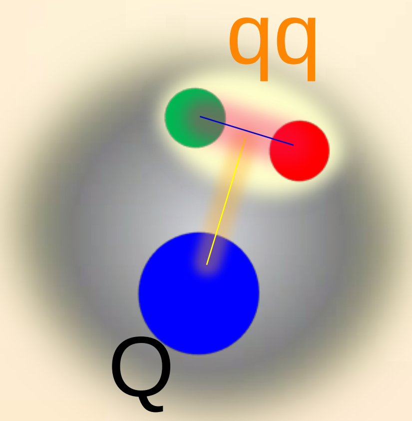
Baryon with Heavy Quark



Most fundamental question

Interaction btwn quarks

Diquark correlations



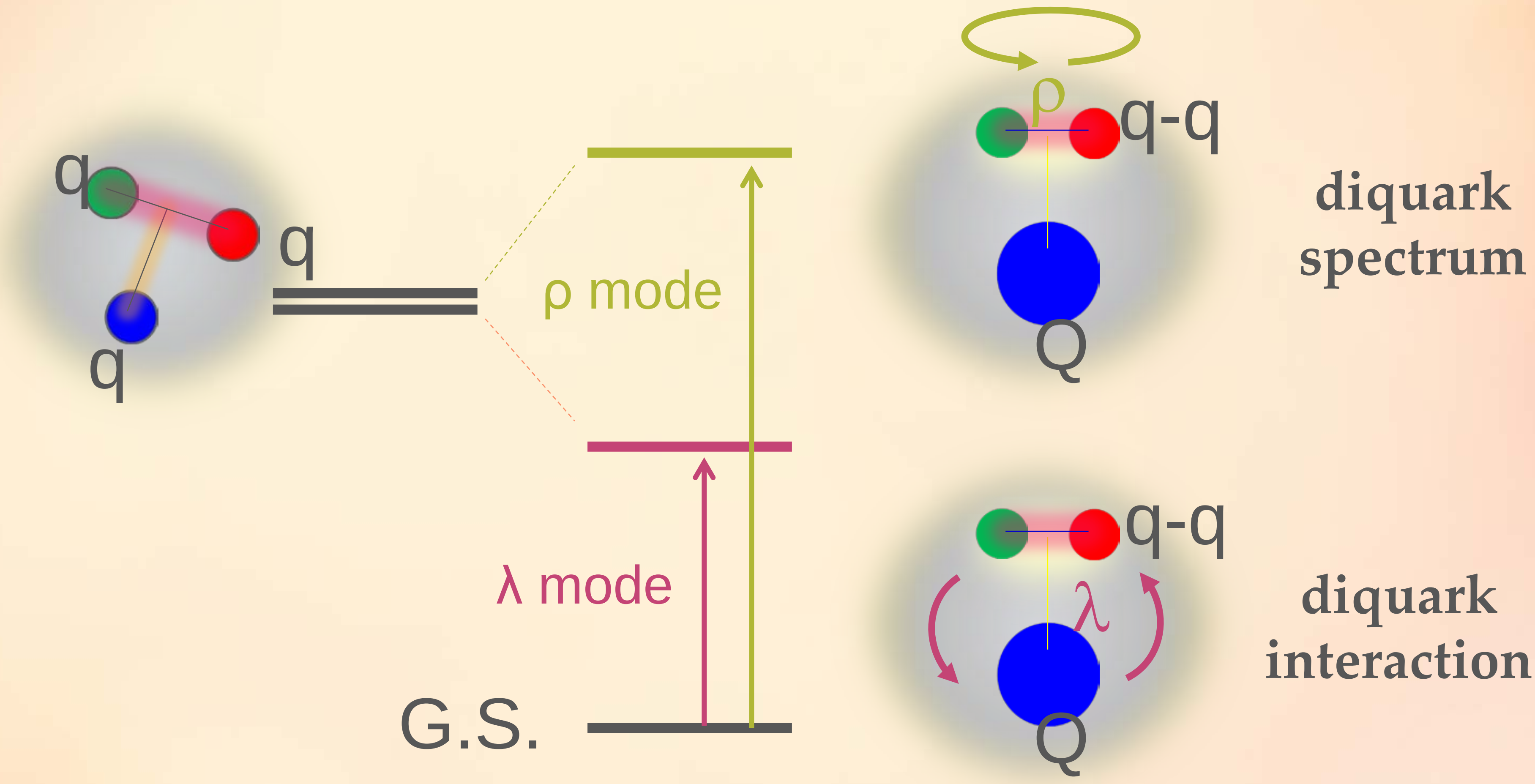
→ Charmed baryon

to close up diquark correlations

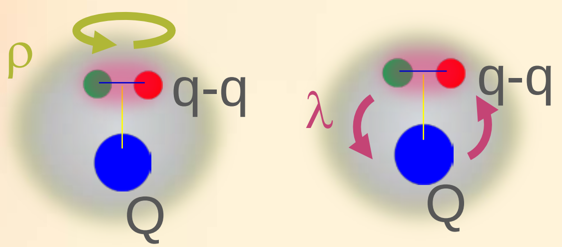
- Weak Color Magnetic Interaction with a heavy Quark

Heavy Baryon – strange to charm

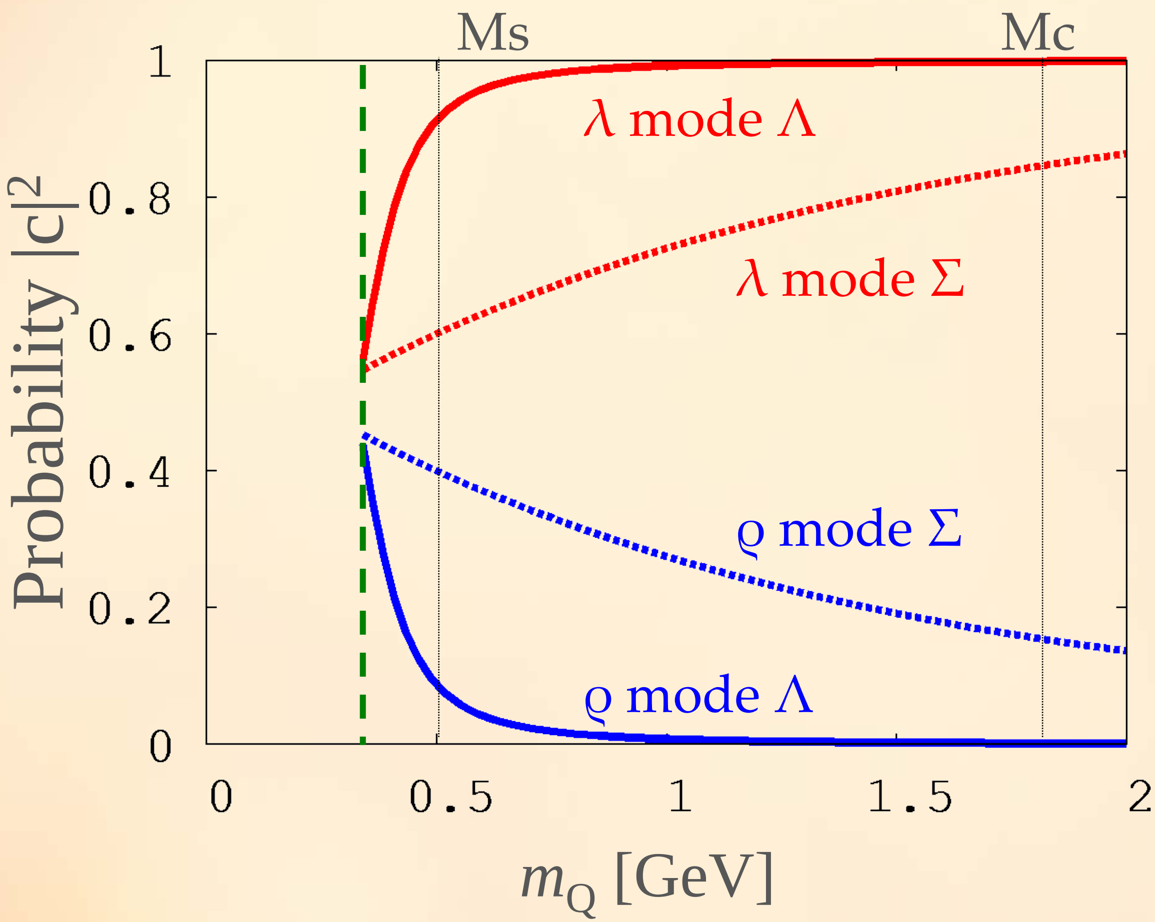
- λ and ρ motions split in heavy baryons



Negative-parity Baryon



QM calculation by
Yoshida, Sadato, Oka, Hosaka



Λ_c is pure λ mode

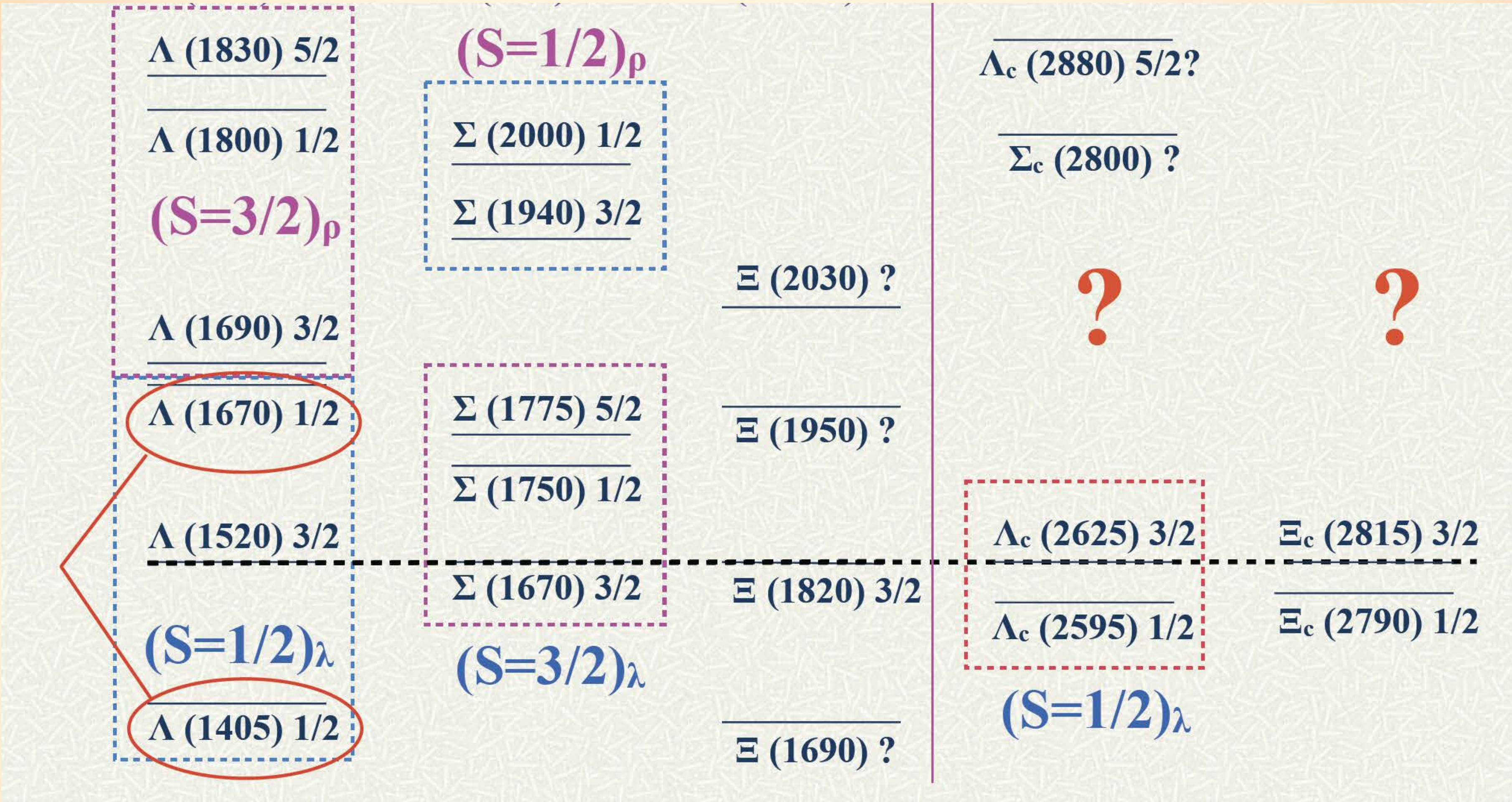
Λ_s is almost λ mode

Ξ will be almost ρ mode

Ξ_{cc} will be pure ρ mode

Experimental Data

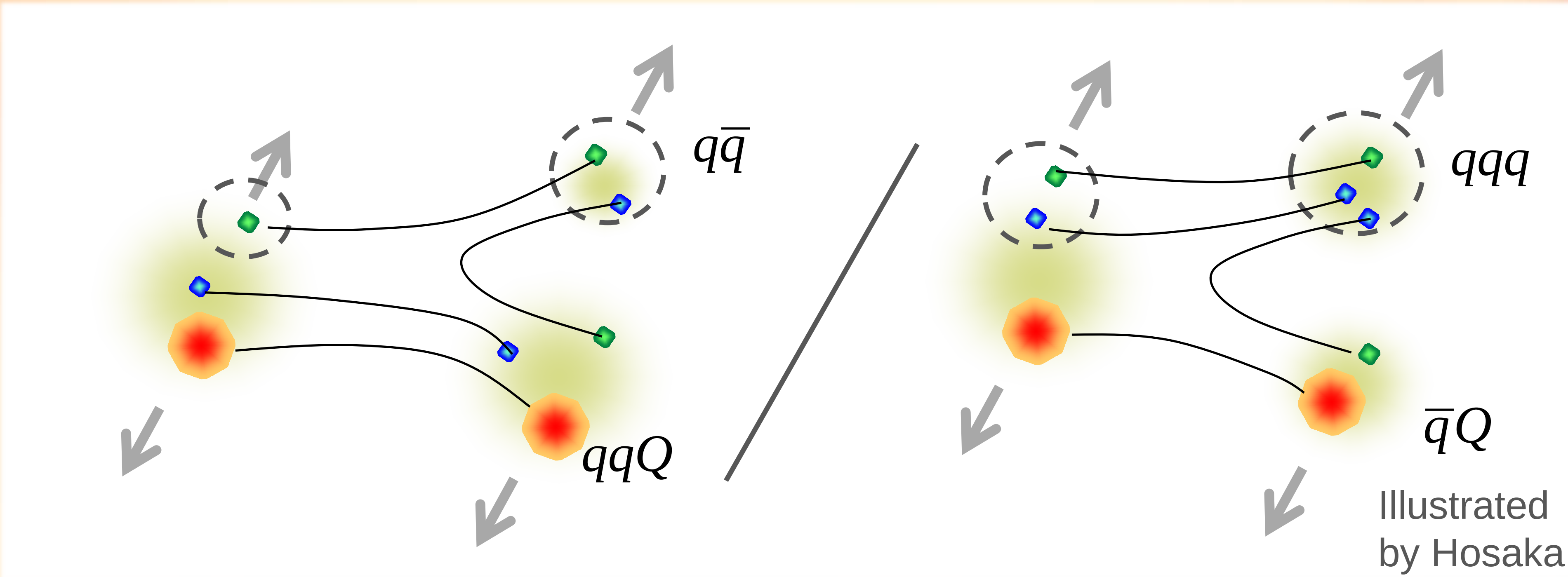
slide by Oka-san



sud sqq ssq cud csq

↑ lack of kaon beam

Structure and Decay Partial Width

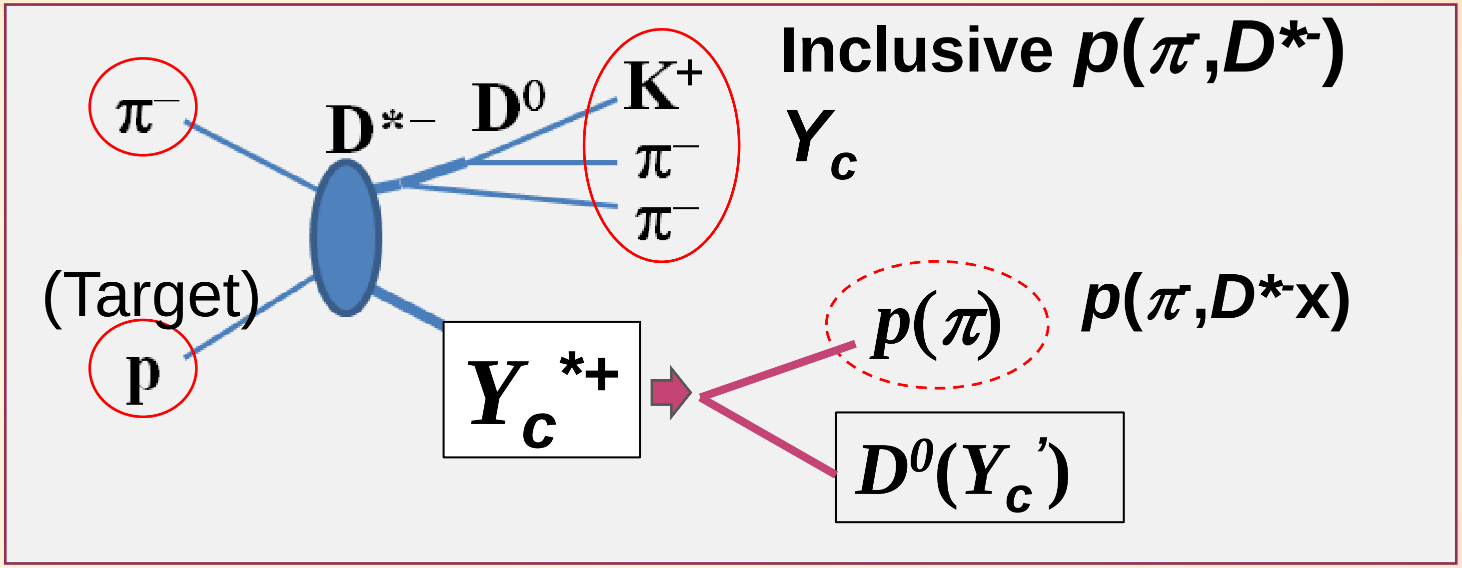


No correlation diquark corr.

- $\Lambda(1520)$ -> NK (D wave!)>$\pi\Sigma$, similarly $\Lambda(1800)$, $\Lambda(2100)$
- Possible explanation of narrow widths of Charmed Baryons

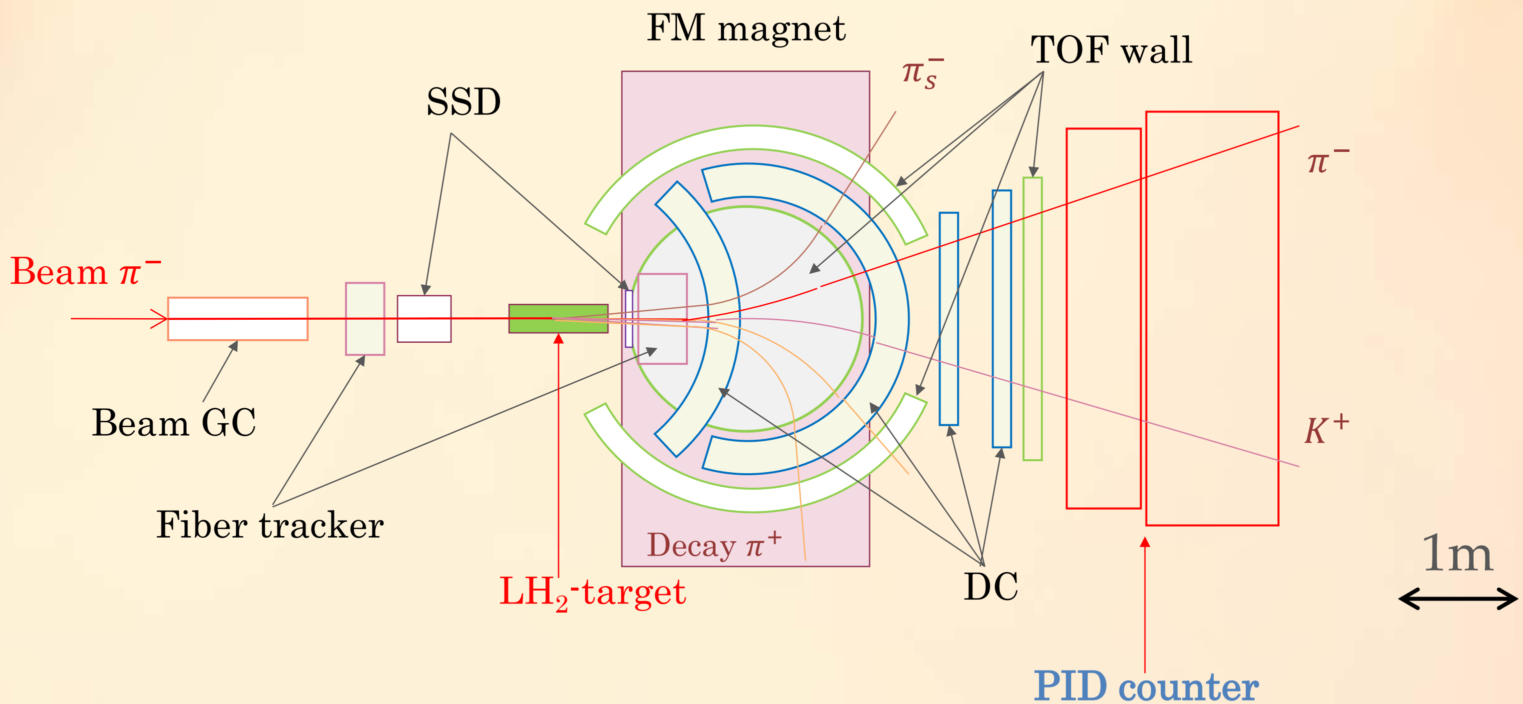
Charmed Baryon Spectroscopy

Using Missing Mass Techniques



* Decay measurement in coincidence w/ $p(\pi^-,D^{*-})$ assists the missing mass spectroscopy.
* Decay Branches:
  diquark correlation affects $\Gamma(\Lambda_c^*\text{->}pD)/\Gamma(\Lambda_c^*\text{->}\Sigma_c\pi)$.
* Angular Distribution: spin, parity

Spectrometer setup



High resolution & Large acceptance spectrometer

- Larget acceptance (60% for D*)
- Detector configuration for high-resolution (dp/p=0.2%)
  - Possible decay mode measurement: $Y_c^* \to Y_c + \pi$…
- Multi-particle detection in the high rate environment

production cross section

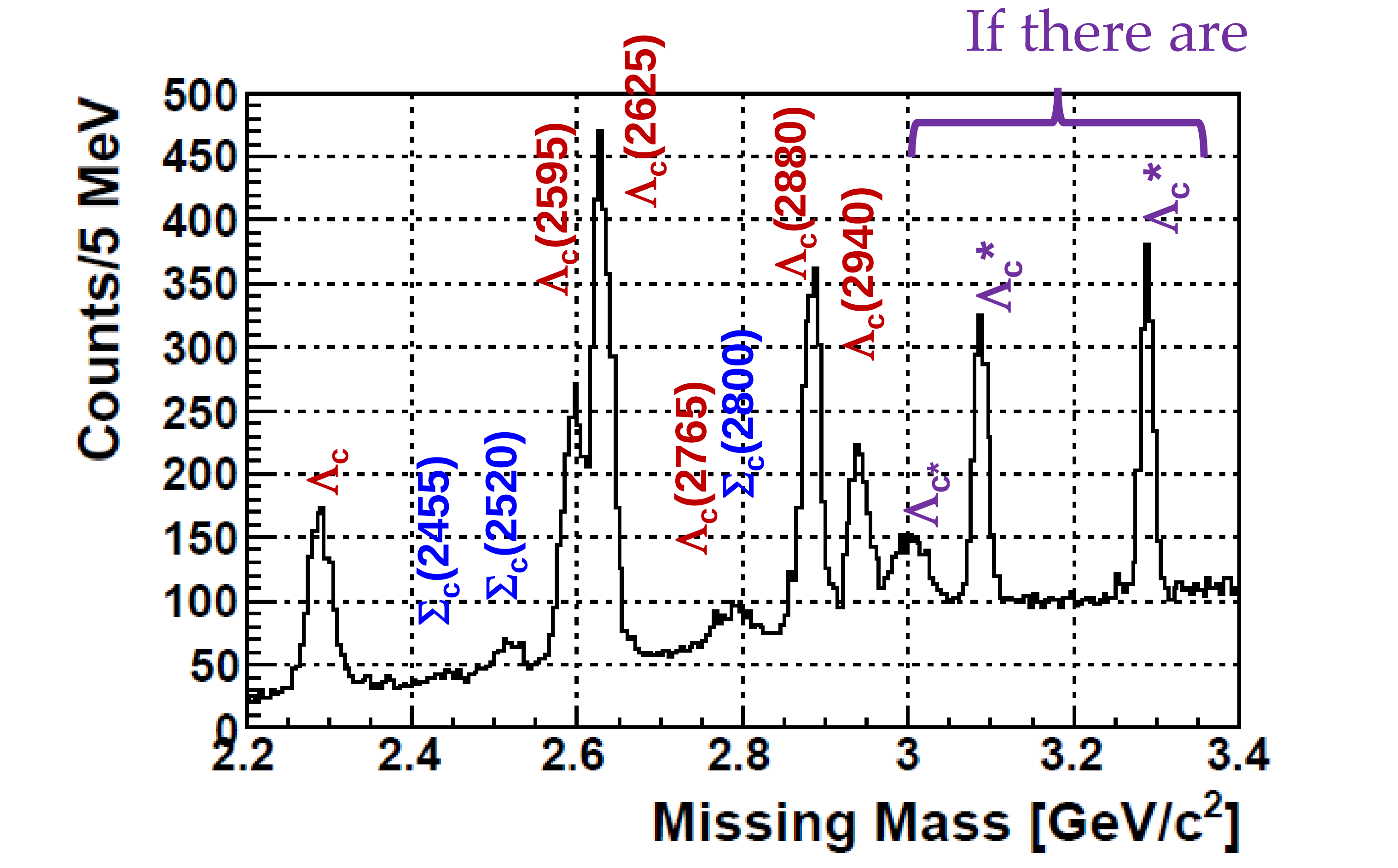
- Experiment
  - $\sigma(\pi p \rightarrow D^* \Lambda c) < 7$ nb at $p_\pi = 13$ GeV/c [BNL, ′85]
  - $\sigma(\pi N \rightarrow J/\psi X) = (3 \pm 0.6)$ nb at $p_\pi = 22$ GeV/c [BNL, ′79]
  - $\sigma(\gamma p \rightarrow \Lambda c \bar{D} X) = (44 \pm 7 + 11 - 8)$ nb at $E\gamma = 20$ GeV [SLAC, ′86]
- Theory
  - Regge Model
    - Production rate of charm relative to strangeness
  - t-channel D* exchange model
    - The model independent ratio of the production cross section

$\sigma(p(\pi^-, D^{*-})\Lambda_c)$ ~ a few nb

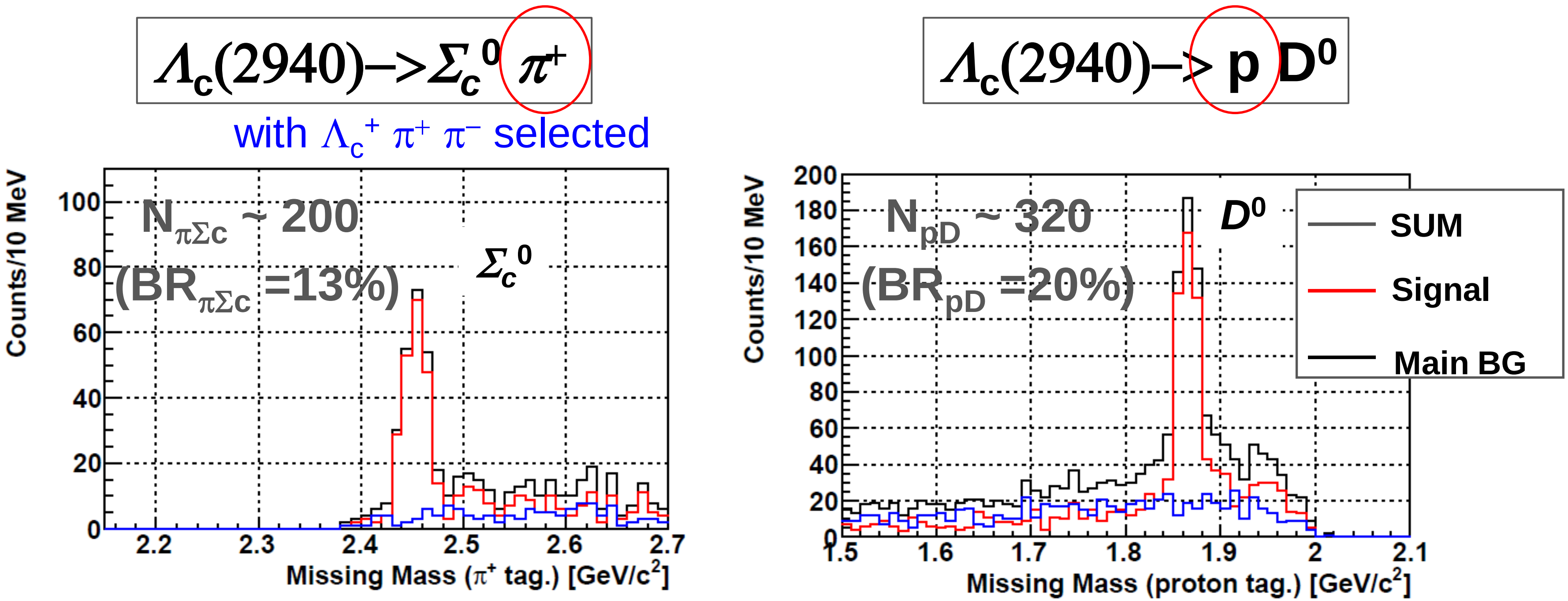
Higher L states are produced in the same order as g.s.

Expected spectra: $\sigma(\pi p \rightarrow D^{*-} Y_c)$ = 1 nb

N(Yc*)~1000 events/1nb/100 days
Sensitivity: ~0.1 nb (3σ, *Γ*~100 MeV)



Decay Products



* decay products can be seen clearly

* strongly assists the missing mass spectroscopy.

- Branching ratios: $\Gamma(\Lambda_c^*\text{->}pD)/\Gamma(\Lambda_c^*\text{->}\Sigma_c\pi)$.
- Angular distribution: Spin, Parity

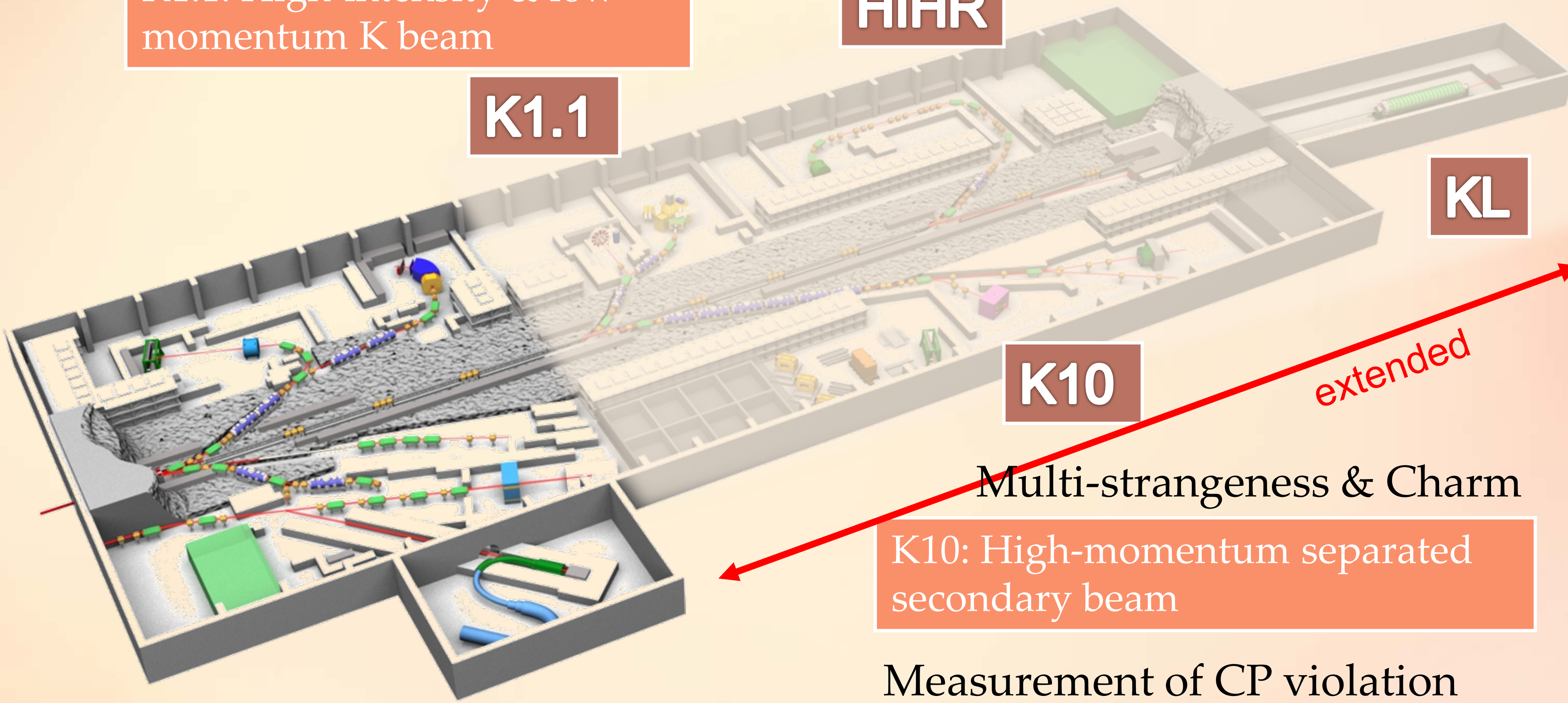
Hadron Hall Extension

Precise Spectroscopy of Hypernuclei

HIHR: High resolution intense secondary beam

Systematic Study for Hypernuclei (S=-1)

K1.1: High-intensity & low-momentum K beam



Multi-strangeness & Charm

K10: High-momentum separated secondary beam

Measurement of CP violation

KL: high intensity neutral kaons

J-PARC Symposium

2nd International Symposium on Science at J-PARC (J-PARC 2014)

July 12-15, 2014, Tsukuba, Japan

http://j-parc.jp/symposium/j-parc2014/

The deadline of the abstract submission was extended to May 7

Satellite Workshop & Get-together Party in Honor of Professor Shoji Nagamiya

16th July 2014

Back Up Slides

Calculated production rates