HADRON2013, 4-8 Nov., 2013

Spectroscopic study of charmed baryon at J-PARC

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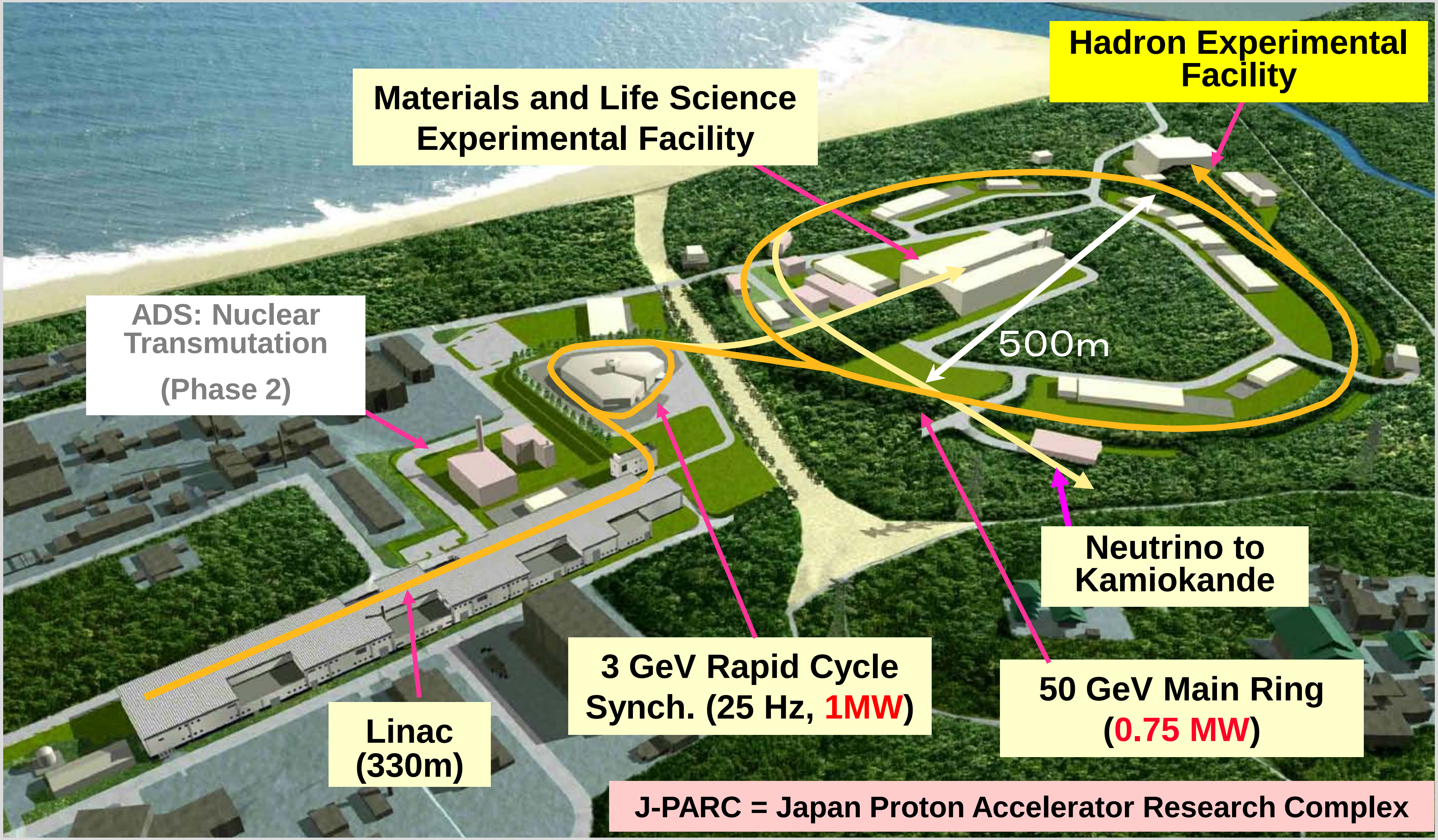
Outline:

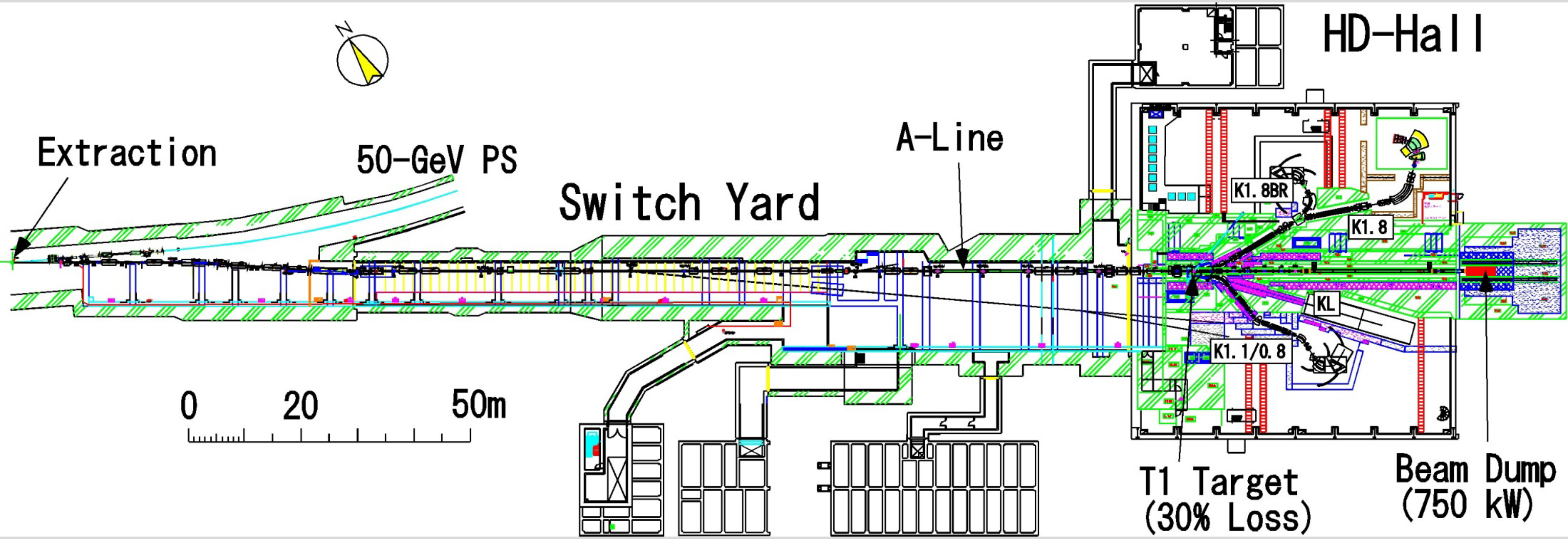
1. High Momentum Beam Line at J-PARC
2. Charmed Baryon Spectroscopy at J-PARC
3. Summary

J-PARC Facility



Joint Project between KEK and JAEA since 2001

HADRON BEAM LINE FACILITY



- Slow Extraction (SX) Beam :
  - Currently, the accelerator is operated at 30 GeV.
  - 1st phase: A design goal is 9μA (270 kW, 3.4×10^{14} /6s spill)

    SX Beam: step by step operation to increase extracted power

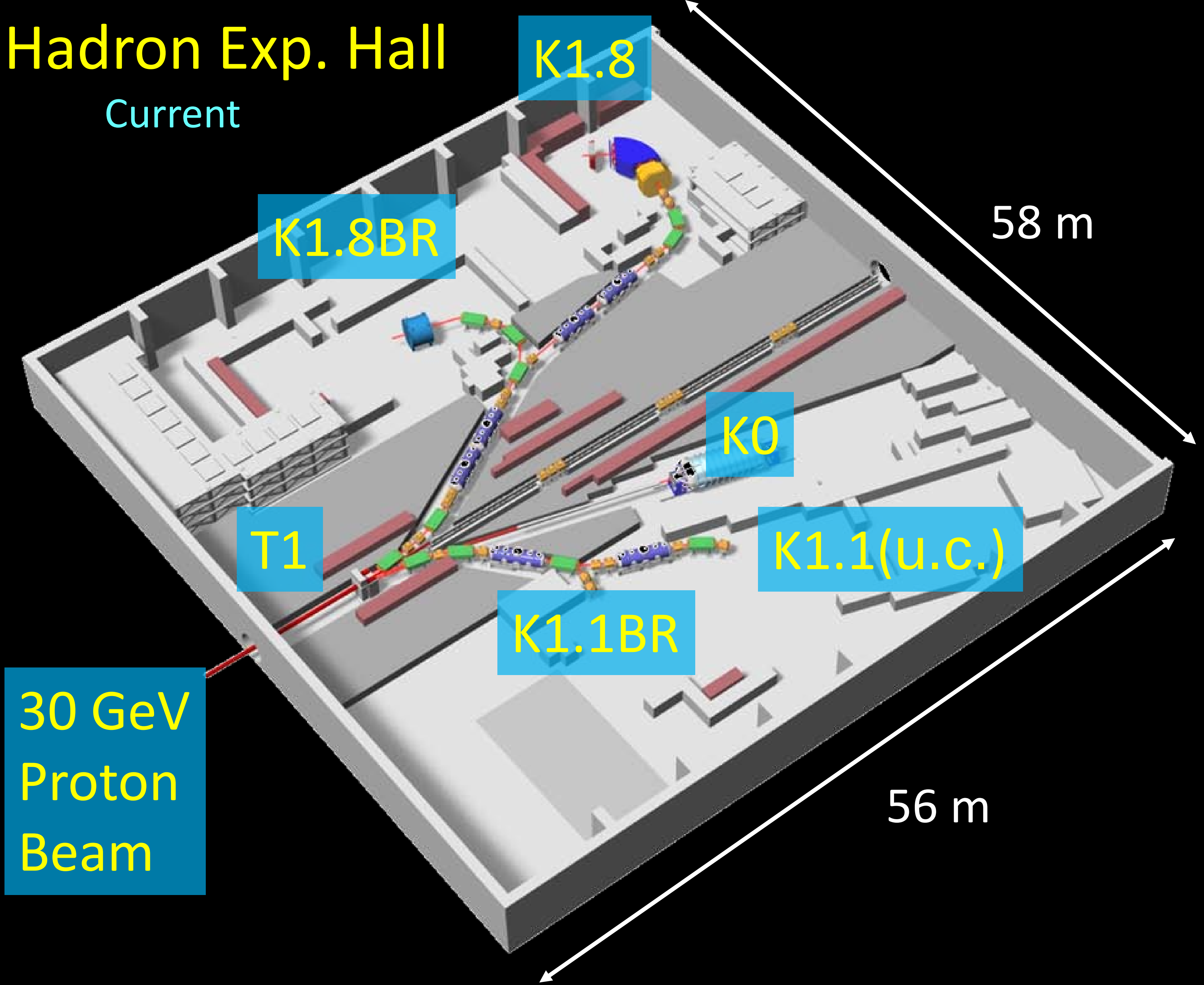
    1st Beam in 2009.
    ~3 kW (Feb. 2011)
    ~6 kW (June, 2012)
    ~15 kW in 2012
    >30 kW in 2013
    ~100 kW

99.6% Extraction efficiency is achieved!
- The World Highest Score -

For FX: >220kW has been achieved.

Hadron Exp. Hall

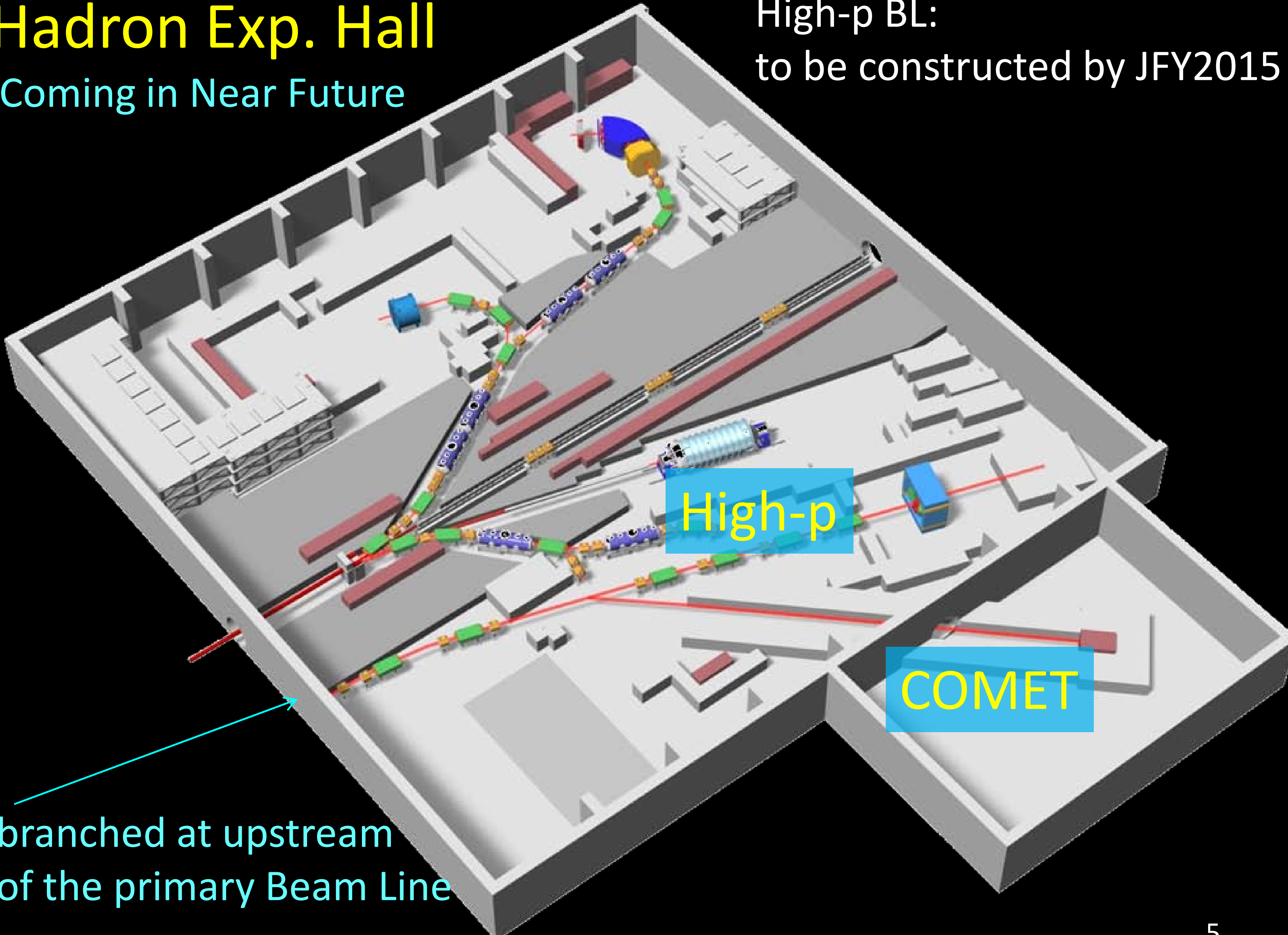
Current



Hadron Exp. Hall

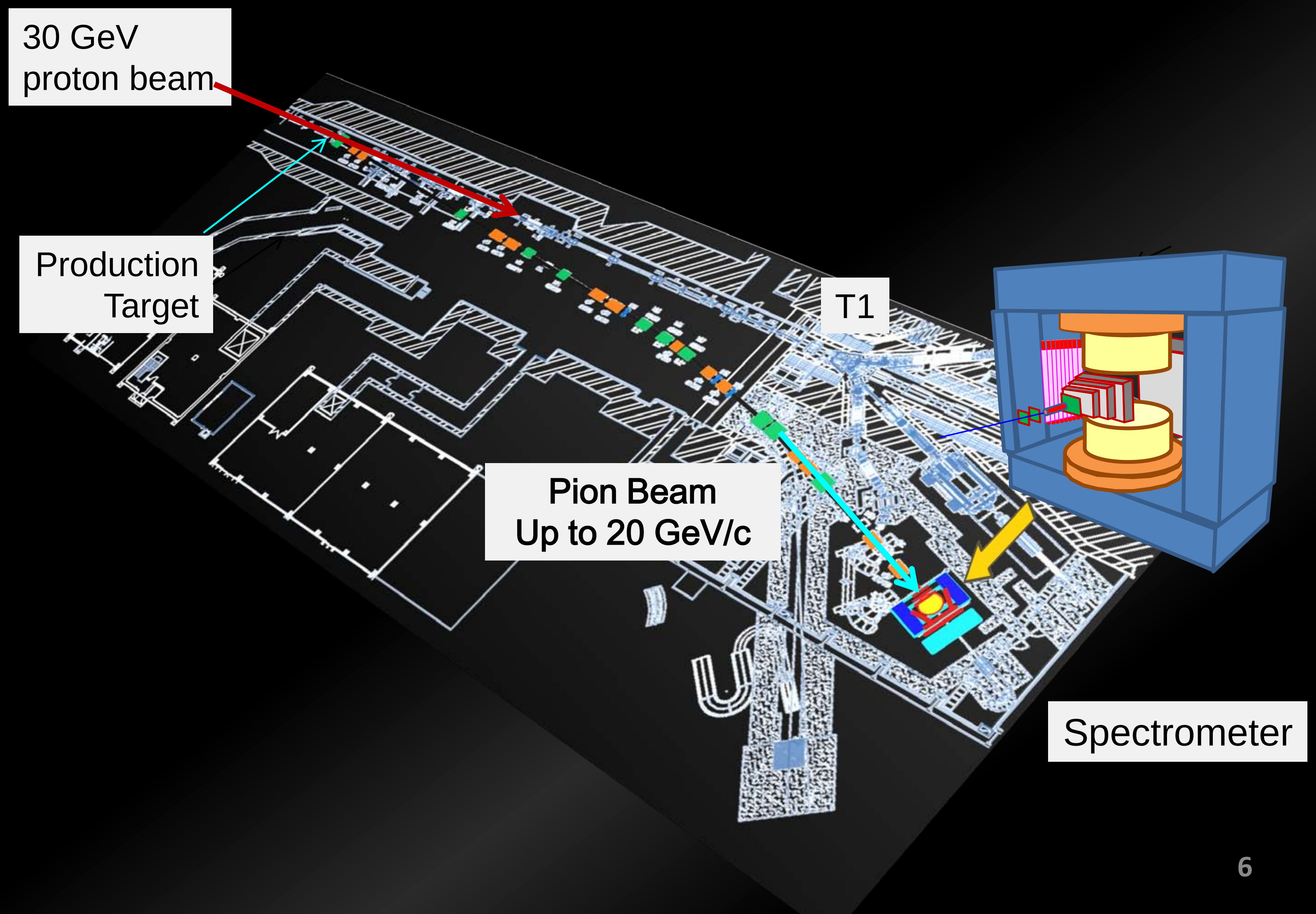
Coming in Near Future

High-p BL:
to be constructed by JFY2015



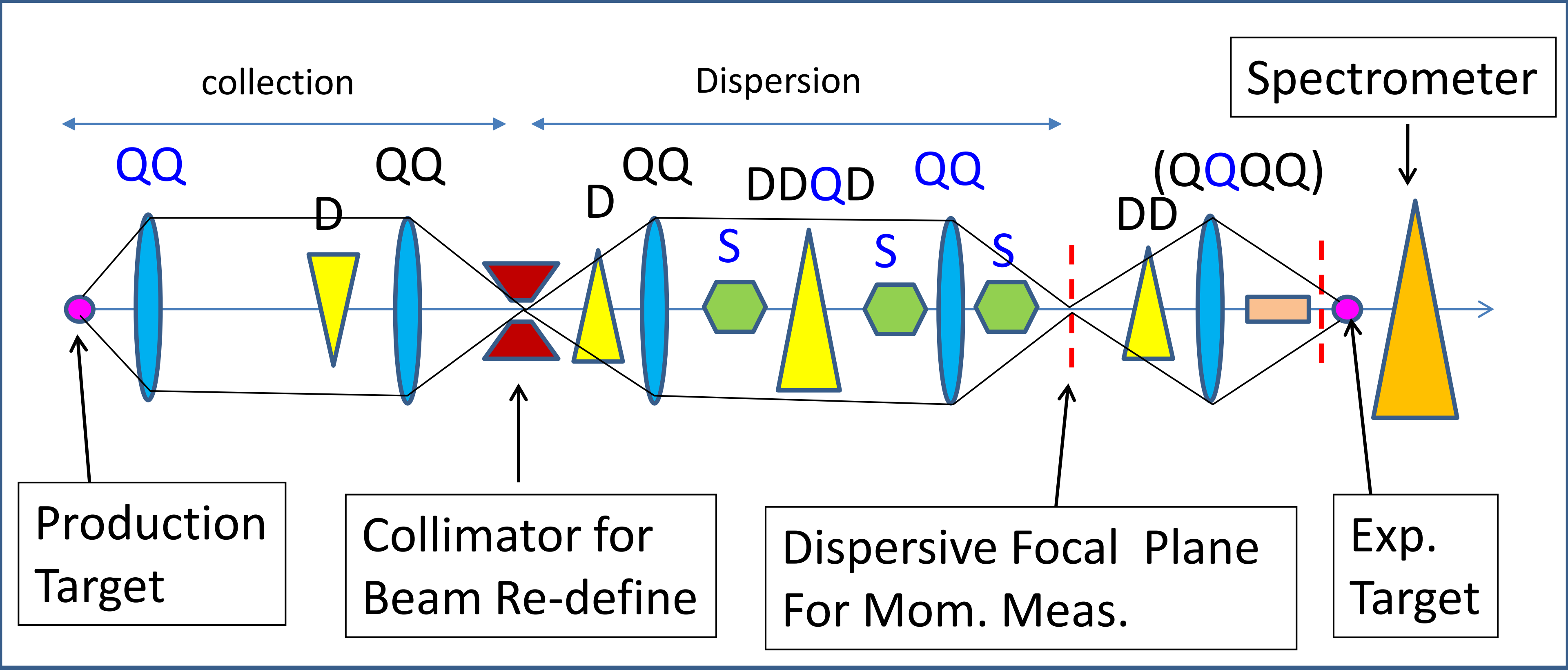
branched at upstream
of the primary Beam Line

High-momentum Beam Line



High-res., High-momentum Beam Line

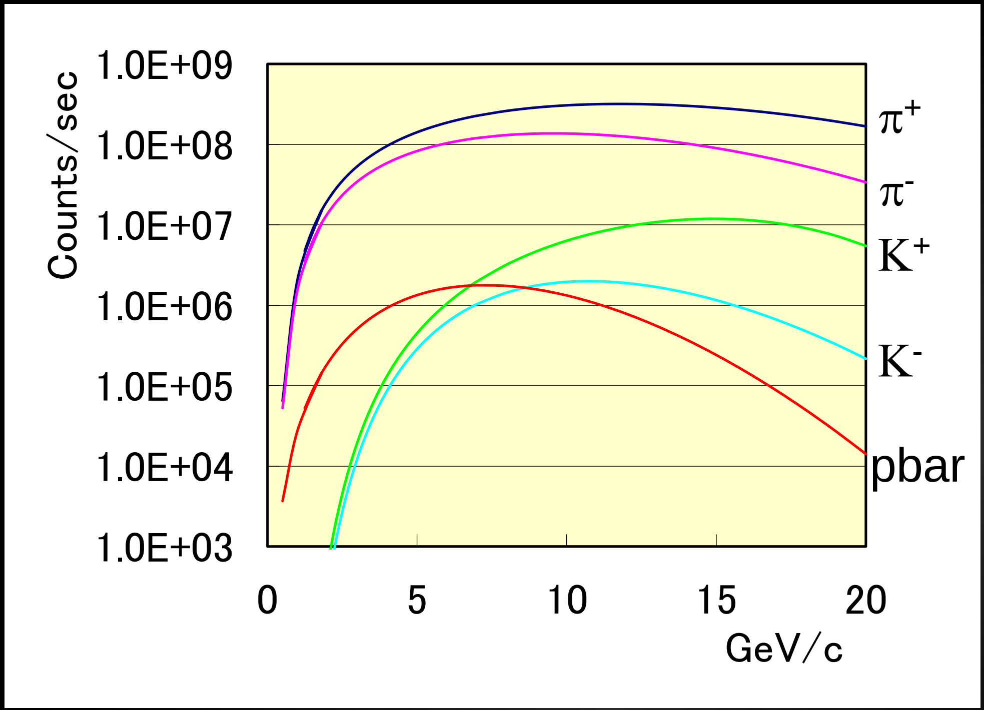
- High-intensity secondary Pion beam
- High-resolution beam: $\Delta p/p$~0.1%



High-res., High-momentum Beam Line

- High-intensity secondary Pion beam
  - 1.0 x 10^7 pions/sec @ 20GeV/c
- High-resolution beam: $\Delta p/p$~0.1%

→ Production of charmed particles

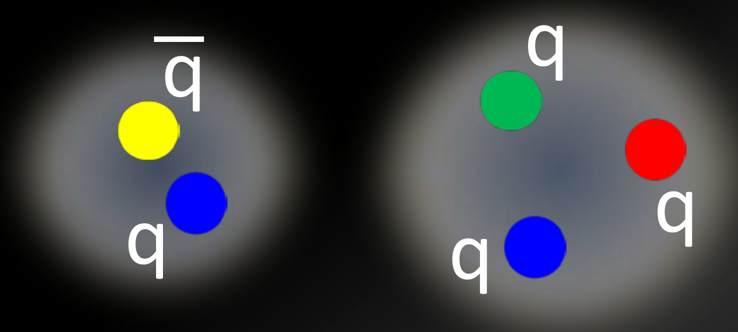


Sanford-Wang
Prod. Angle=0 degrees
15 kW Loss on Pt
Acceptance :2 msr%, 132 m

Charmed Baryon Spectroscopy at J-PARC

What are essential D.o.F. of baryons?

Constituent Quark



Hadron properties

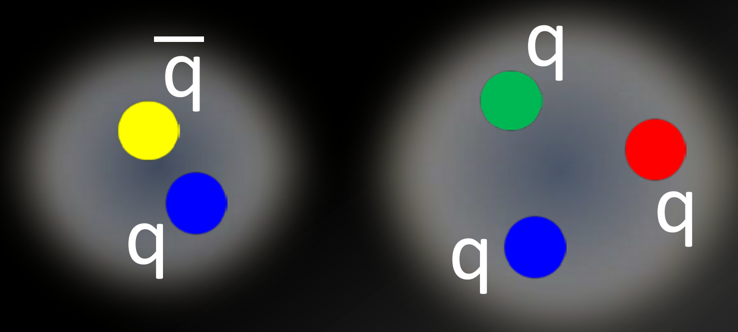
- Classification based on Spin/flavor symmetry
- Mass Relations, Magnetic Moments

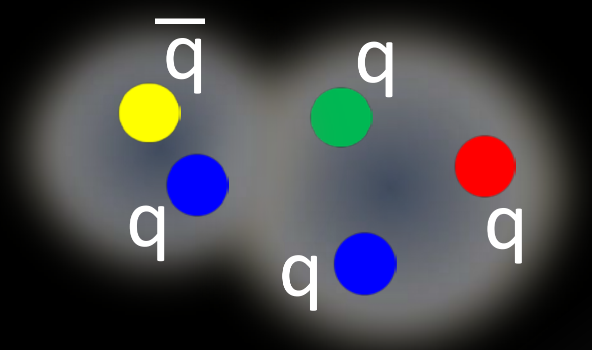
Failure in Resonant States

- Missing Resonances
- Exotics

What are essential D.o.F. of baryons?

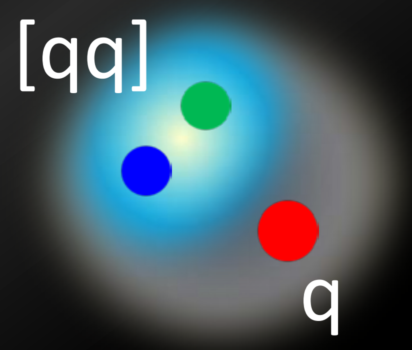
Constituent Quark



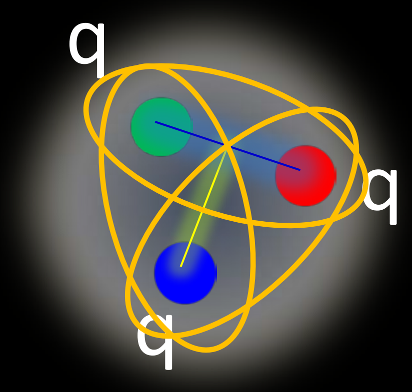


hadron (colorless cluster)

Diquark?
(Colored cluster)

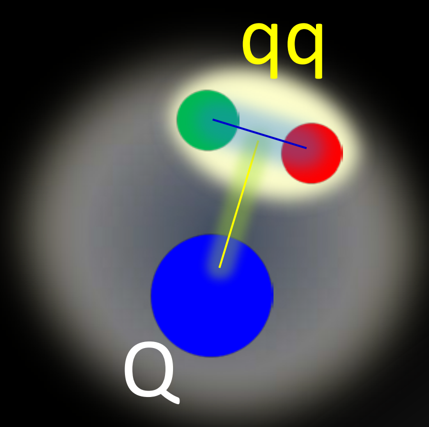


What are essential D.o.F. of baryons?



- Most fundamental question
- Interaction btwn quarks

Diquark correlations



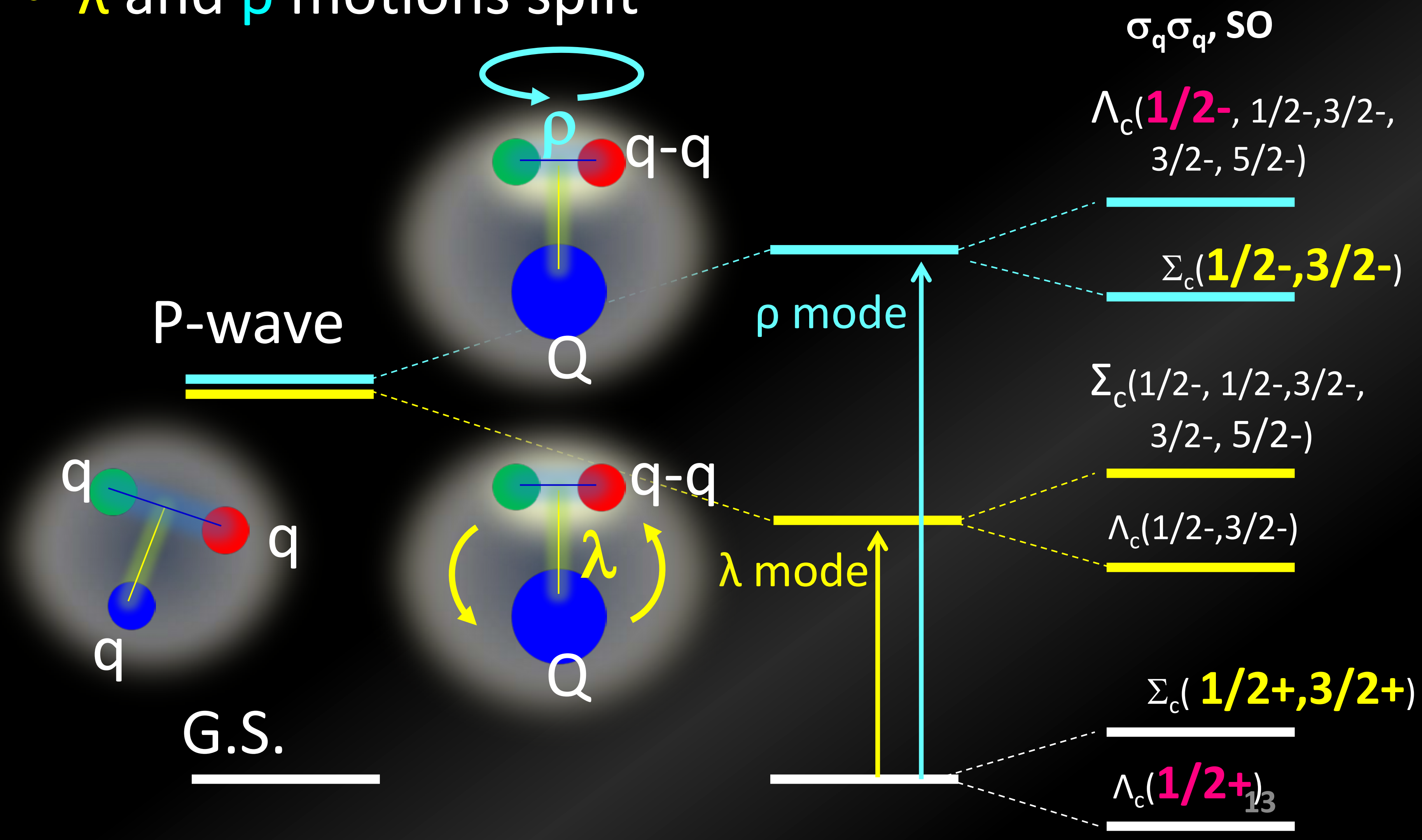
→ Charmed baryon

to close up diquark correlations

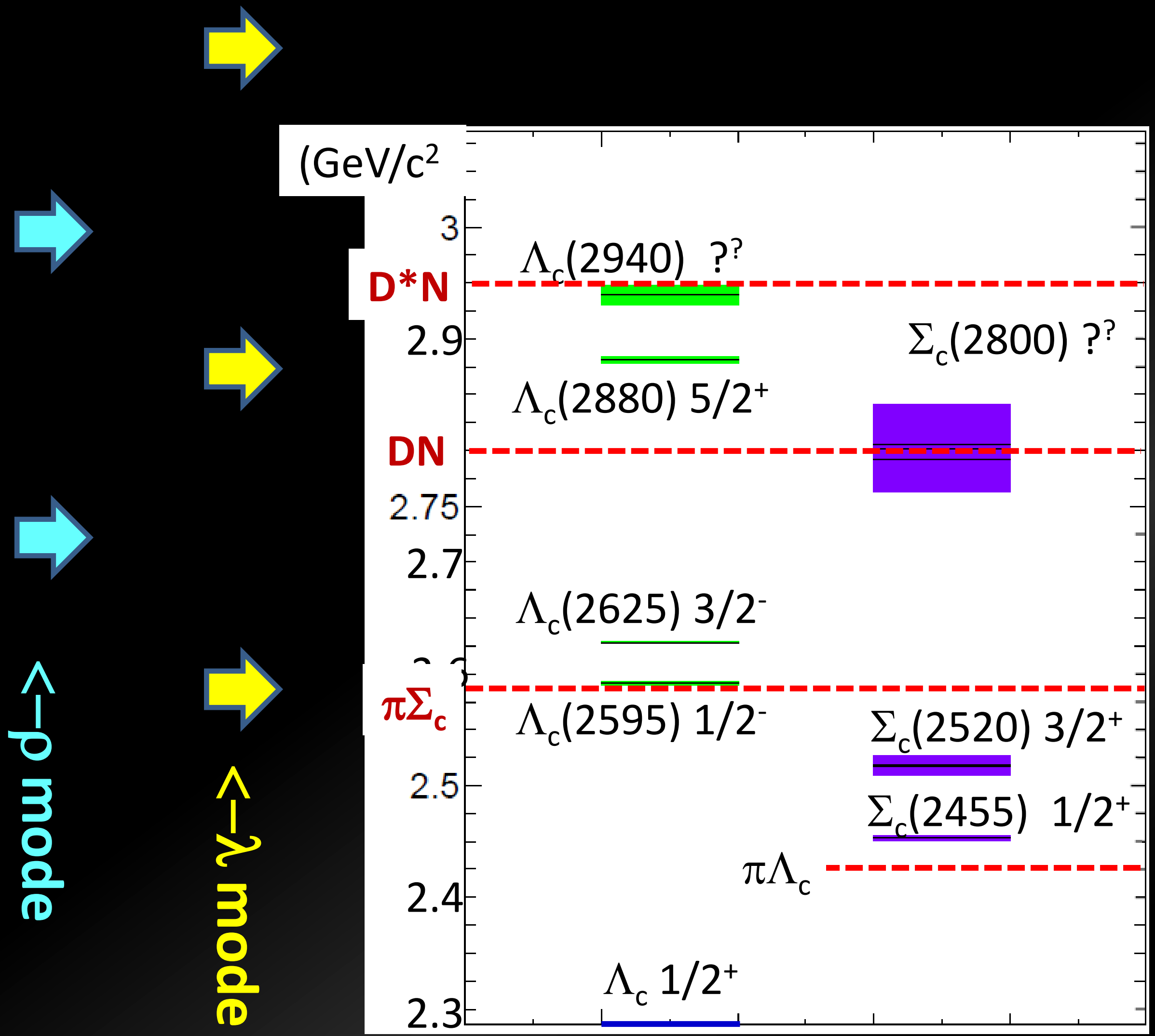
- Weak Color Magnetic Interaction with a heavy Quark

Level Structure of charmed baryons

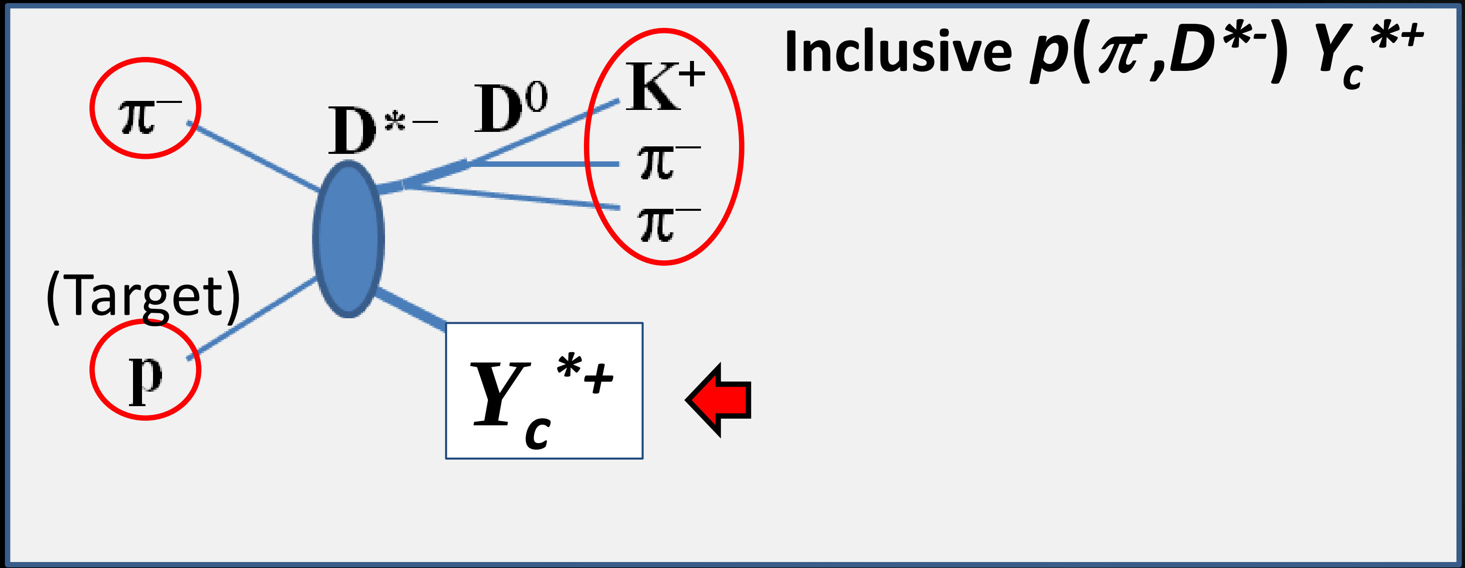
- λ and ρ motions split



Limited # of Charmed Baryons have been observed.



Charmed Baryon Spectroscopy Using Missing Mass Techniques

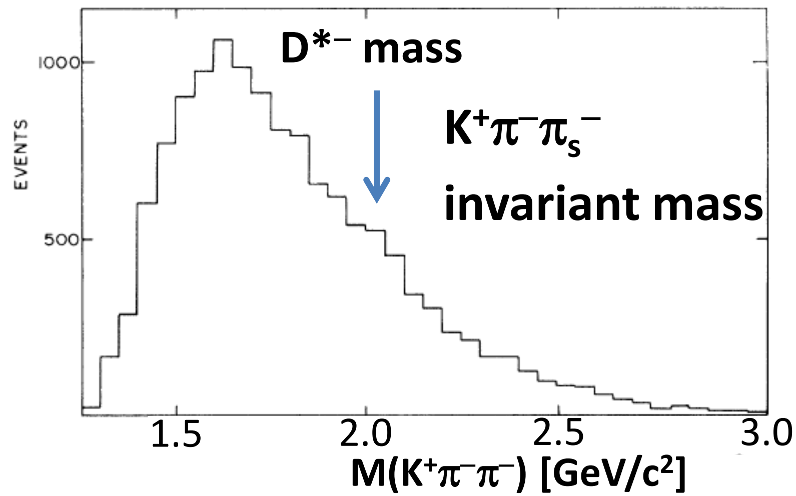


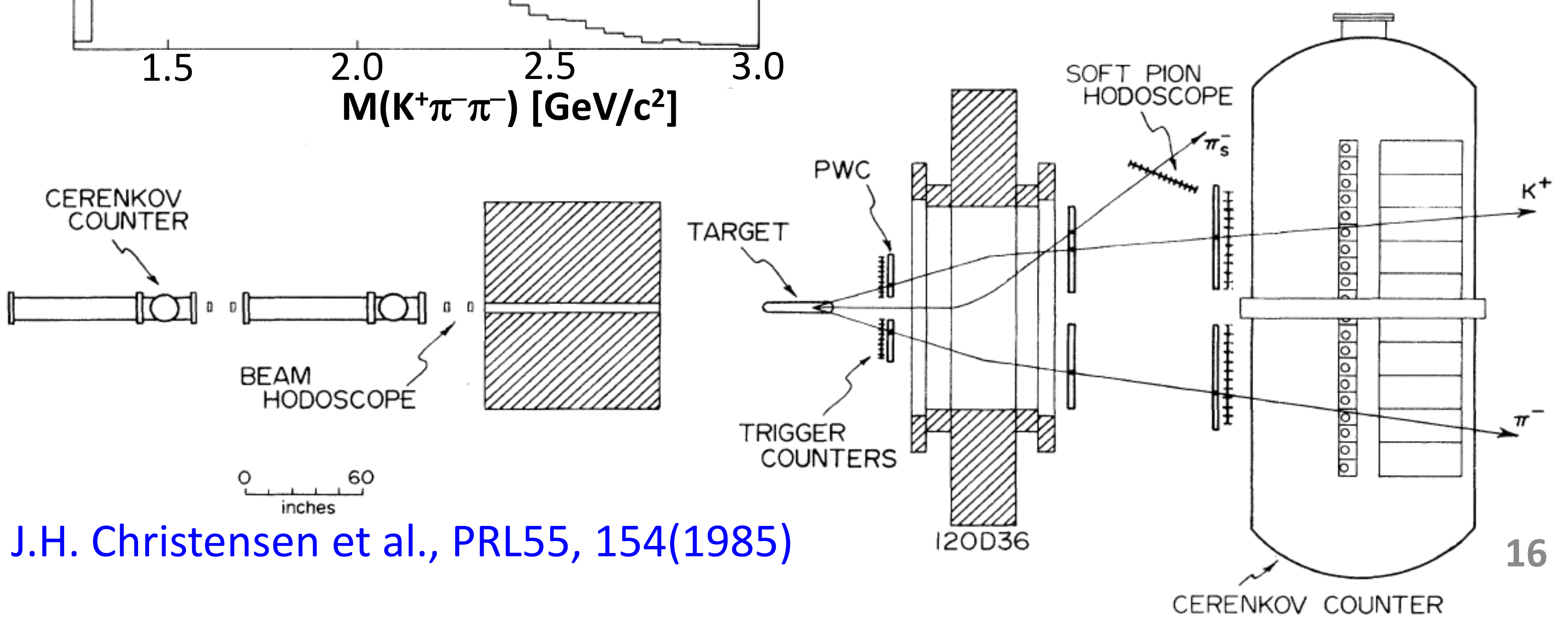
- inclusive (π^-,D^{*-}) spectrum
  - Level structure of Y_c^*
  - Production Rate
- Decay Particles
  - Decay Width/Decay Branching Ratios
  - Spin, Parity

charmed baryon meas. by $p(\pi^{-},D^{*-})Y_c$

- No exp. data for the $p(\pi^{-},D^{*-})\Lambda_c$ is available

  but σ<7nb at p_π=13 GeV/c at BNL (1985)



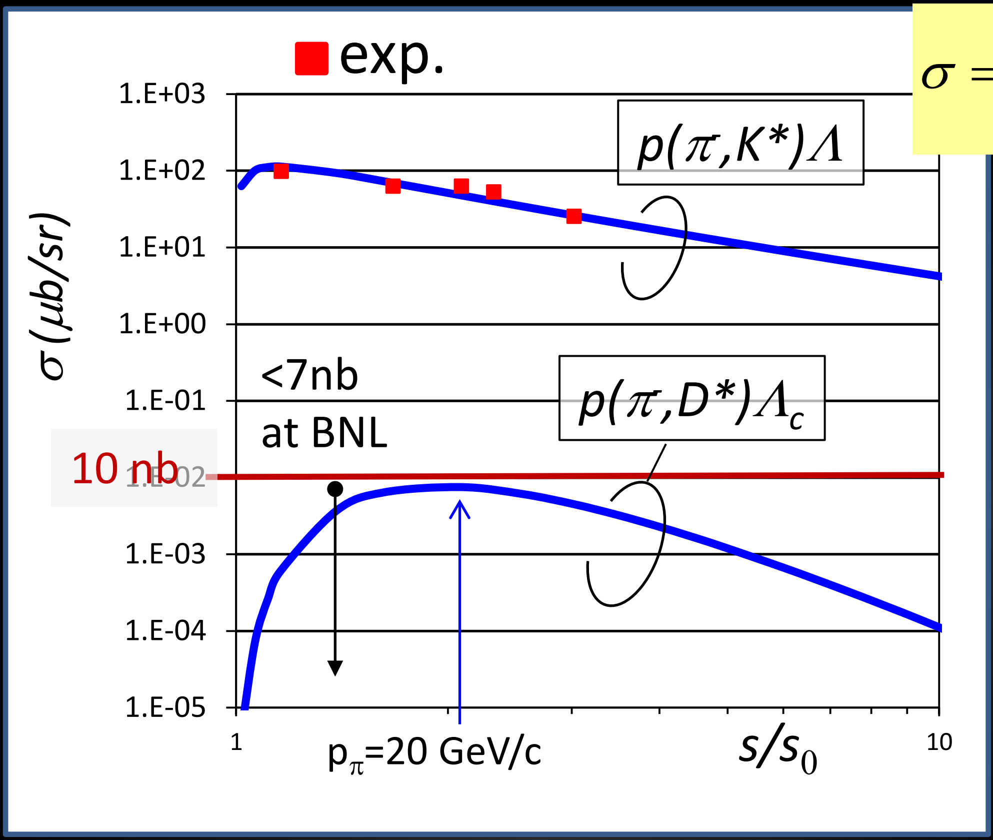


J.H. Christensen et al., PRL55, 154(1985)

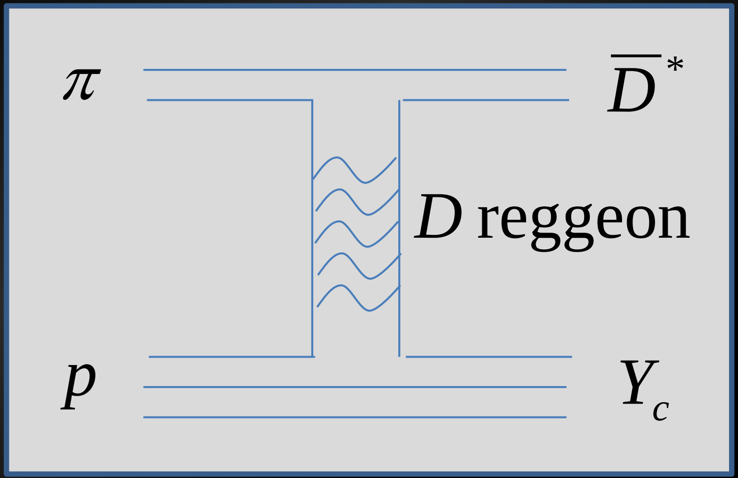
Production Cross Section

- Regge Theory: Binary Reaction at High E is well described
- Normalized to strangeness production, $p(\pi^-,K^{*0})\Lambda$
- Charm production: ~10^{-4} of strangeness production

  → $\underline{\sigma(p(\pi^-,D^{*-})\Lambda_c)}$ ~ a few nb at p_π=20 GeV/c

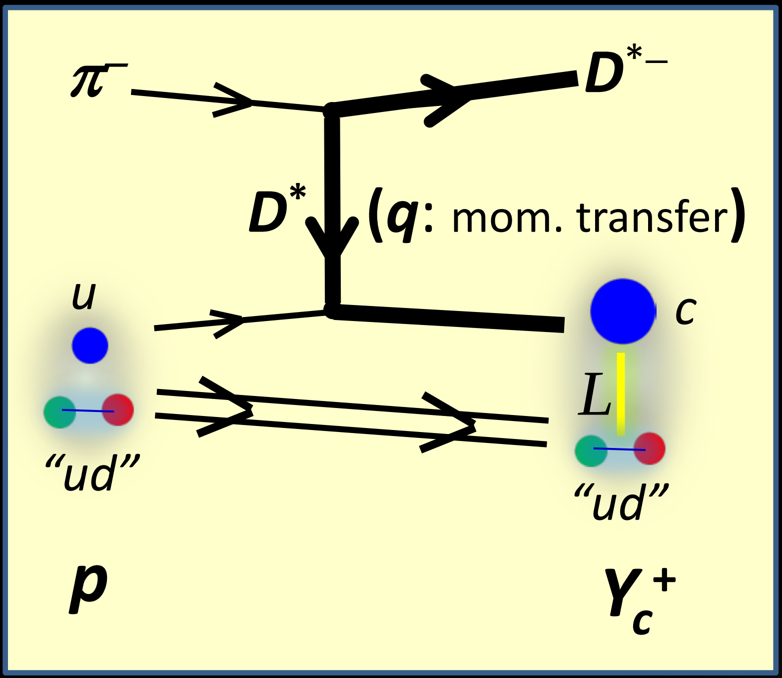


$$\sigma = \int \frac{1}{64\pi s(p_\pi^{cm})^2}\exp(2R^2t)(s/s_0)^{2\alpha(t)}dt$$



A.B. Kaidalov, ZPC12, 63(1982)
V.Yu. Grishina et al., EPJA25, 141(2005)

Production Rate



- t-channel D^* EX at a forward angle

Production Rates are determined by the overlap of WFs

$$R \sim \left\langle \varphi_f \left| \sqrt{2}\sigma_- \exp(i\vec{q}_{eff}\vec{r}) \right| \varphi_i \right\rangle$$

and depend on:

1. Spin/Isospin Config. of Y_c
   Spin/Isospin Factor
2. Momentum transfer (q_{eff})

$$I_L \sim (q_{eff}/A)^L \exp(-q_{eff}^2/2A^2)$$

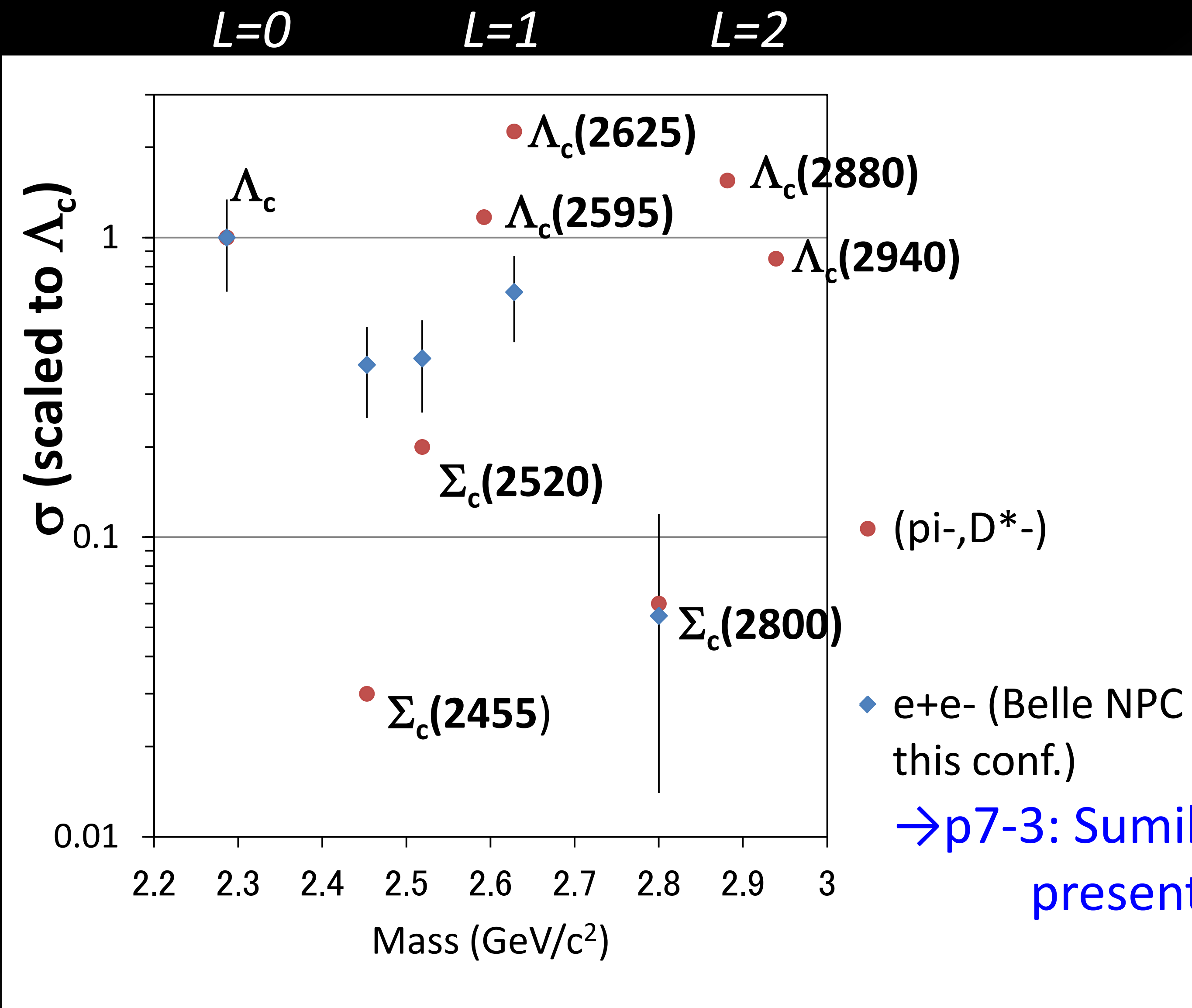
A~0.42 GeV ([Baryon size]$^{-1}$)
q_{eff}~1.4 GeV/c

Calculated production rates

	p_π=20 GeV/c	Mass (GeV/c)	"ud" isospin factor	Y_c^* Spin factor	q_{eff} (GeV/c)	Rate (Relative)
L=0	$\Lambda_c^{1/2+}$	2286	1/2	1	1.33	1
	$\Sigma_c^{1/2+}$	2455	1/6	1/9	1.43	0.03
	$\Sigma_c^{3/2+}$	2520	1/6	8/9	1.44	0.20
L=1	$\Lambda_c^{1/2-}$	2595	1/2	1/3	1.37	1.17
	$\Lambda_c^{3/2-}$	2625	1/2	2/3	1.38	2.26
	$\Sigma_c^{1/2-}$	2750	1/6	1/27	1.49	0.03
	$\Sigma_c^{3/2-}$	2820	1/6	2/27	1.50	0.06
	$\Sigma_c^{1/2-\prime}$	2750	1/6	2/27	1.49	0.07
	$\Sigma_c^{3/2-\prime}$	2820	1/6	56/135	1.50	0.33
	$\Sigma_c^{5/2-\prime}$	2820	1/6	2/5	1.50	0.31
L=2	$\Lambda_c^{3/2+}$	2940	1/2	2/5	1.42	0.85
	$\Lambda_c^{5/2+}$	2880	1/2	3/5	1.41	1.55

A. Hosaka, private comm. (2013)

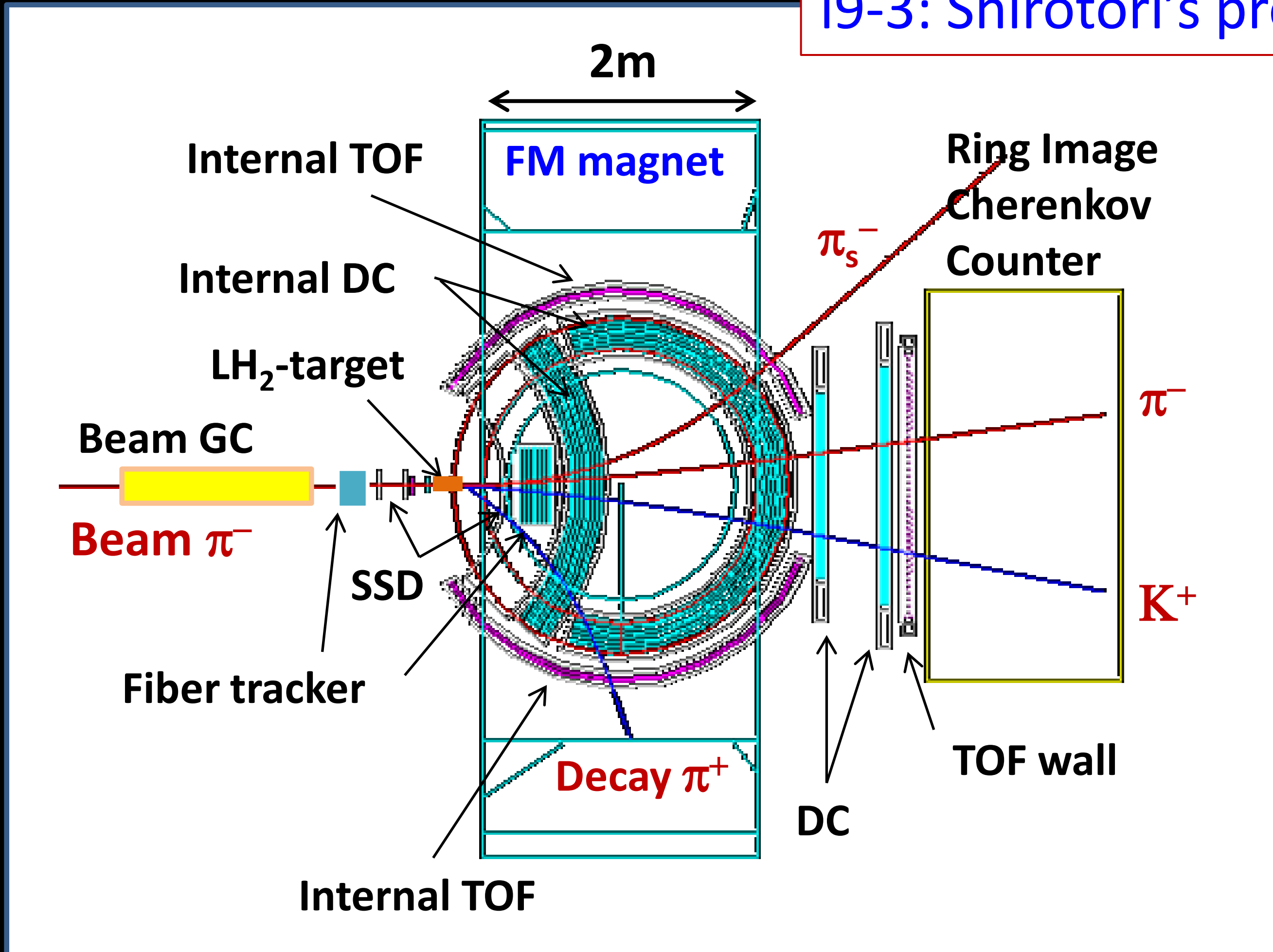
Calculated production rates



→p7-3: Sumihama's presentaion

Charmed Baryon Spectrometer

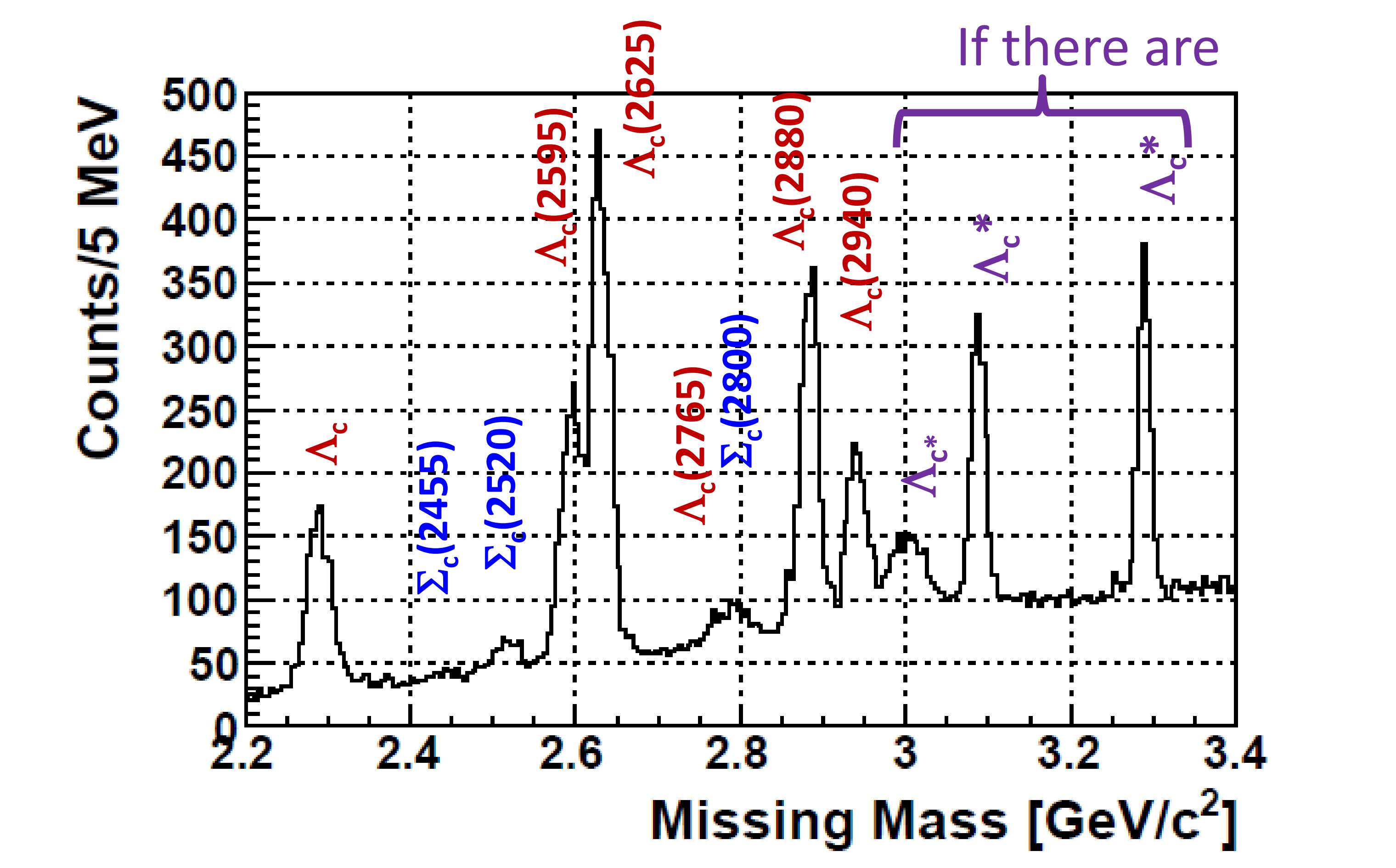
I9-3: Shirotori's presentaion



Large acceptance ~ 60% (for *D), $\Delta p/p$~0.2% at ~5 GeV/*c***

Expected spectrum: σ_{GS} = 1 nb

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



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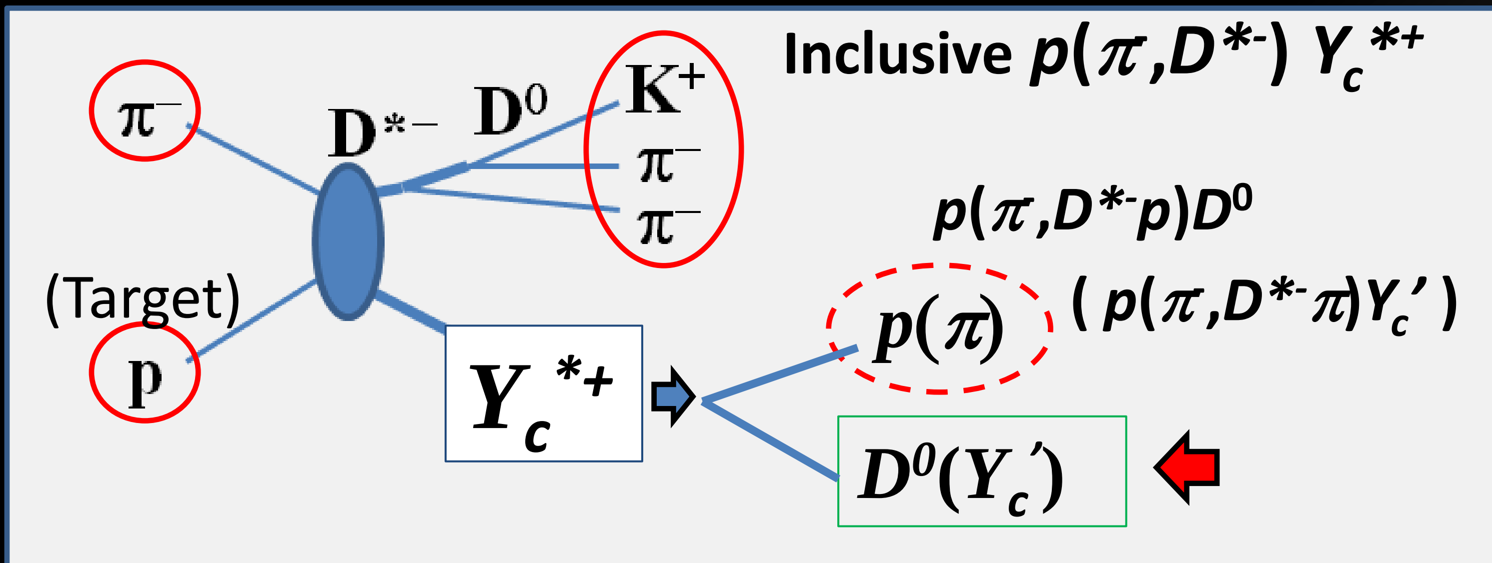

- inclusive (π^-,D^{*-}) spectrum
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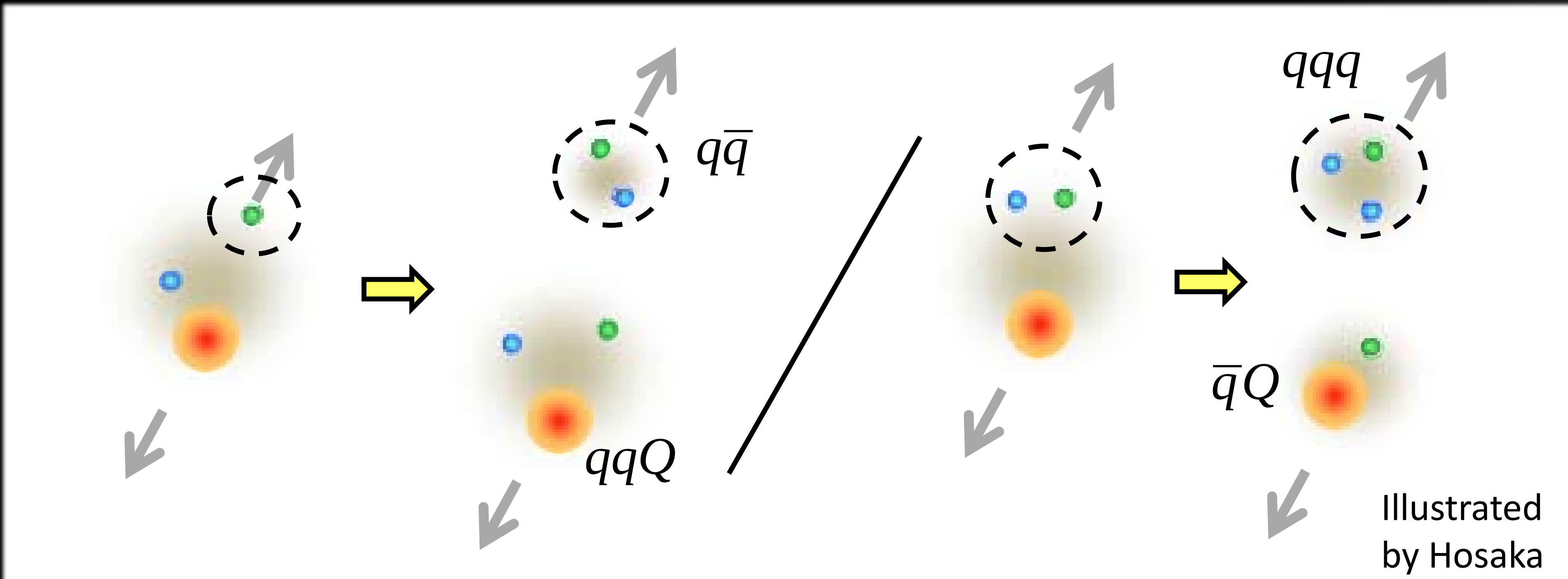
Structure and Decay Partial Width

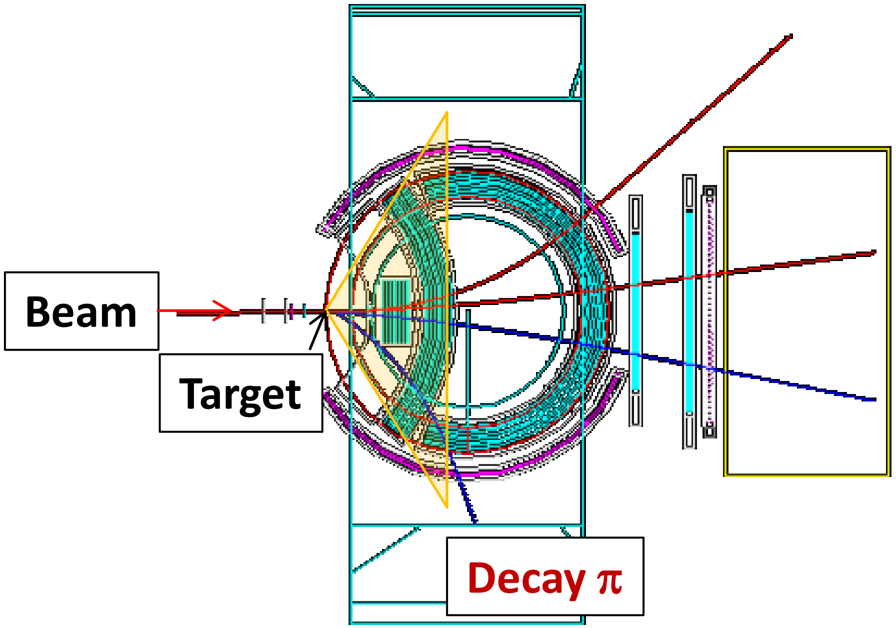


ρ mode (qq) λ mode [qq]

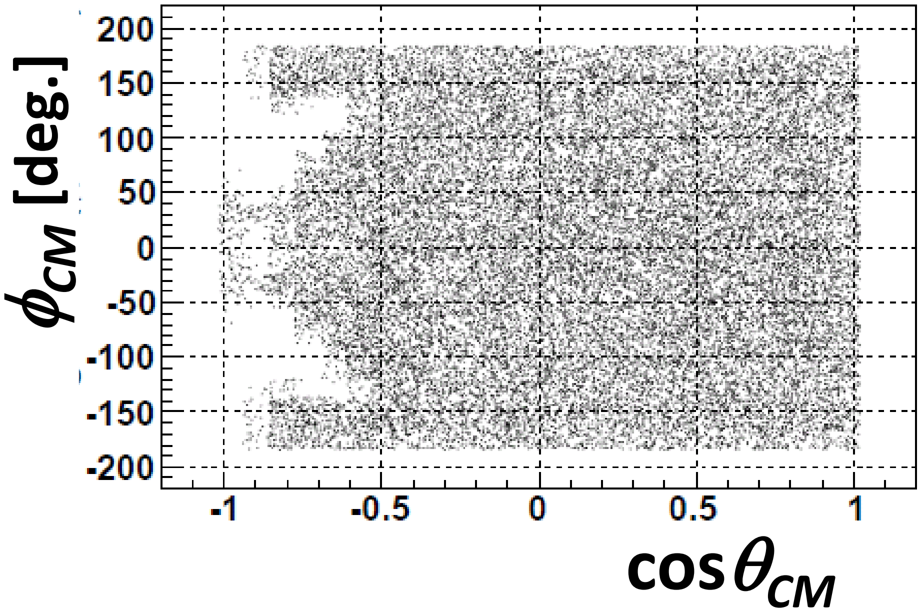
- $\Lambda(1520)$ -> $\Gamma(NK)>\Gamma(\pi\Sigma)$, similarly $\Lambda(1820)$, $\Lambda(2100)$
- Possible explanation of narrow widths of Charmed Baryons

Acceptance for decay particles: ~85 %

a wide range of the azimuthal (ϕ_{CM}) and polar (θ_{CM}) angles

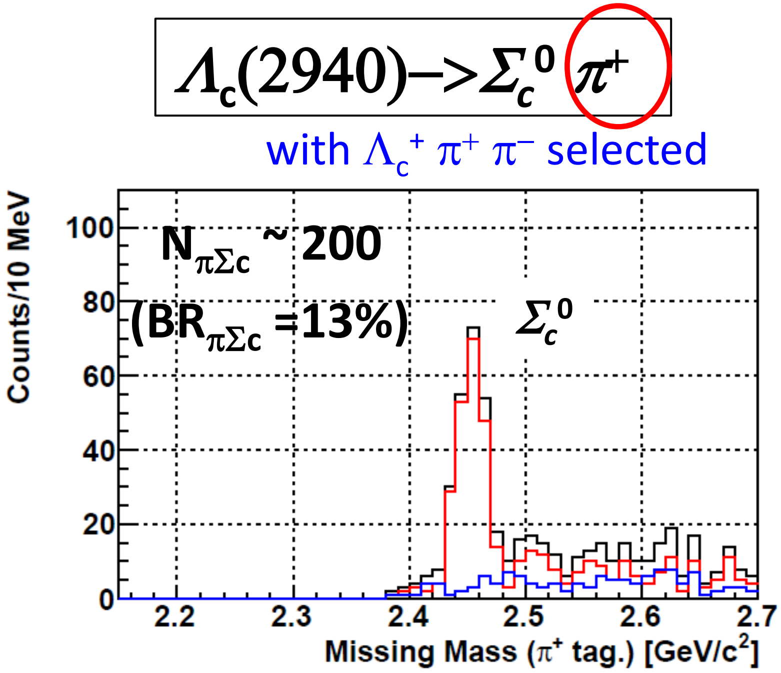


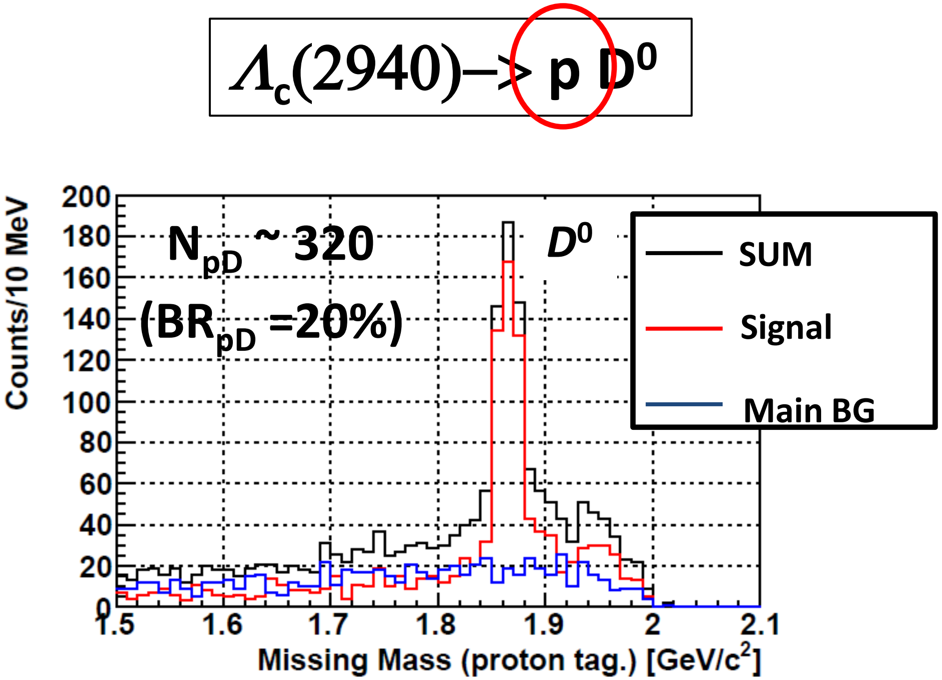
Coverage for decay π
($\Lambda_c(2940) \rightarrow \Sigma_c^0 \pi^+$)



* Decay products can be measured efficiently.

Decay Products





* Decay meas. strongly assists the missing mass spectroscopy.

- Branching ratios: Diquark corr. affects $\Gamma(\Lambda_c^* \rightarrow pD)/\Gamma(\Lambda_c^* \rightarrow \Sigma_c\pi)$.
- Angular distribution: Spin, Parity

Summary

- A High Momentum Beam Line is under construction at J-PARC
  - opens a new opportunity to study charmed baryons via the (π^-,D^{*-}) reaction
- A new project for charmed baryon spectroscopy
  - Under research cooperation btwn RCNP, IPNS/KEK, and the J-PARC Center
  - Proposal P50:

    "Charmed Baryon Spectroscopy via the (π^-,D^{*-}) reaction", submitted to PAC (2013)

    http://www.j-parc.jp/researcher/Hadron/en/Proposal_e.html#1301

    under investigation for approval