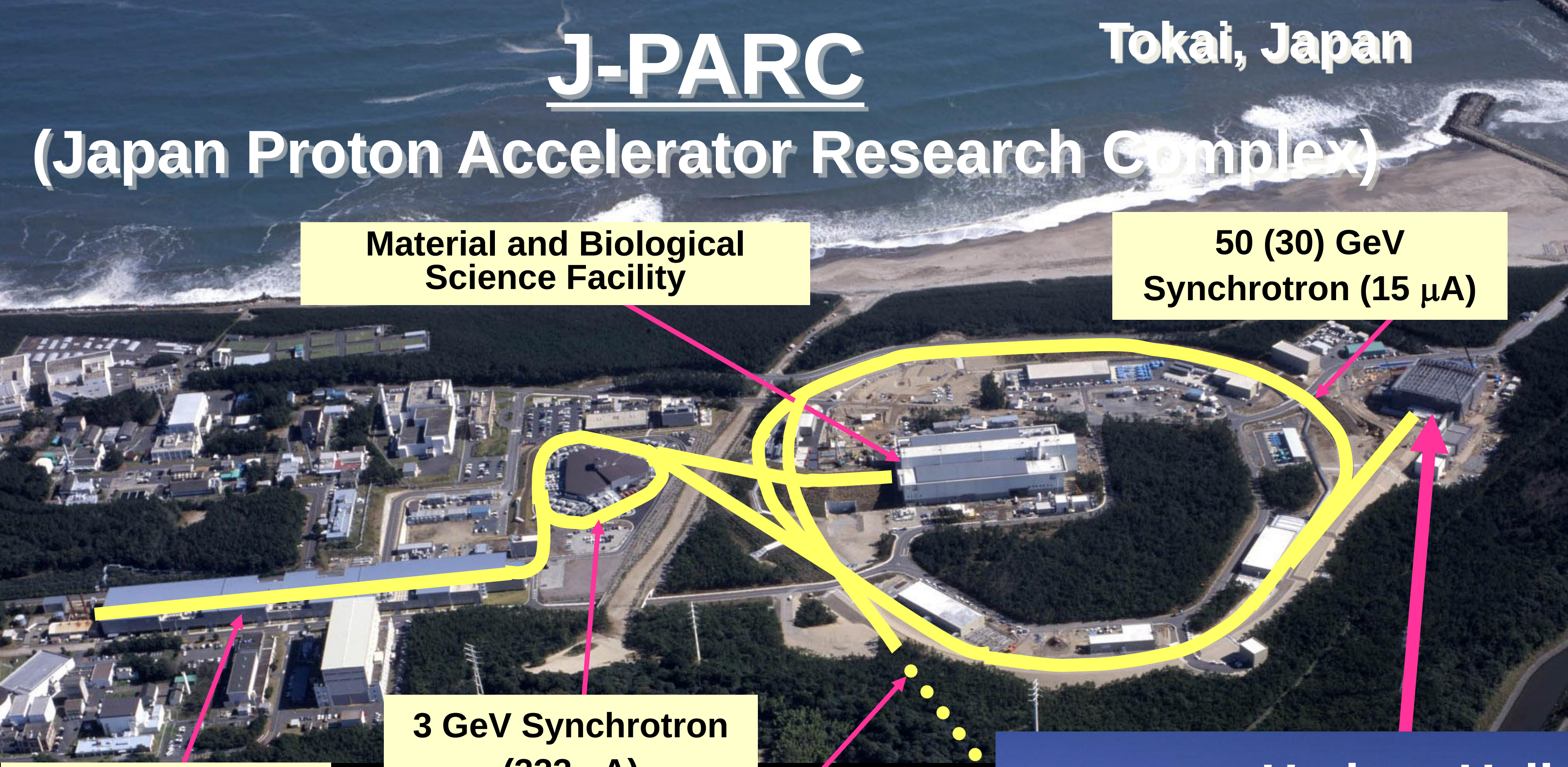
Experiments of charm physics at J-PARC

K. Ozawa
KEK

J-PARC

Tokai, Japan

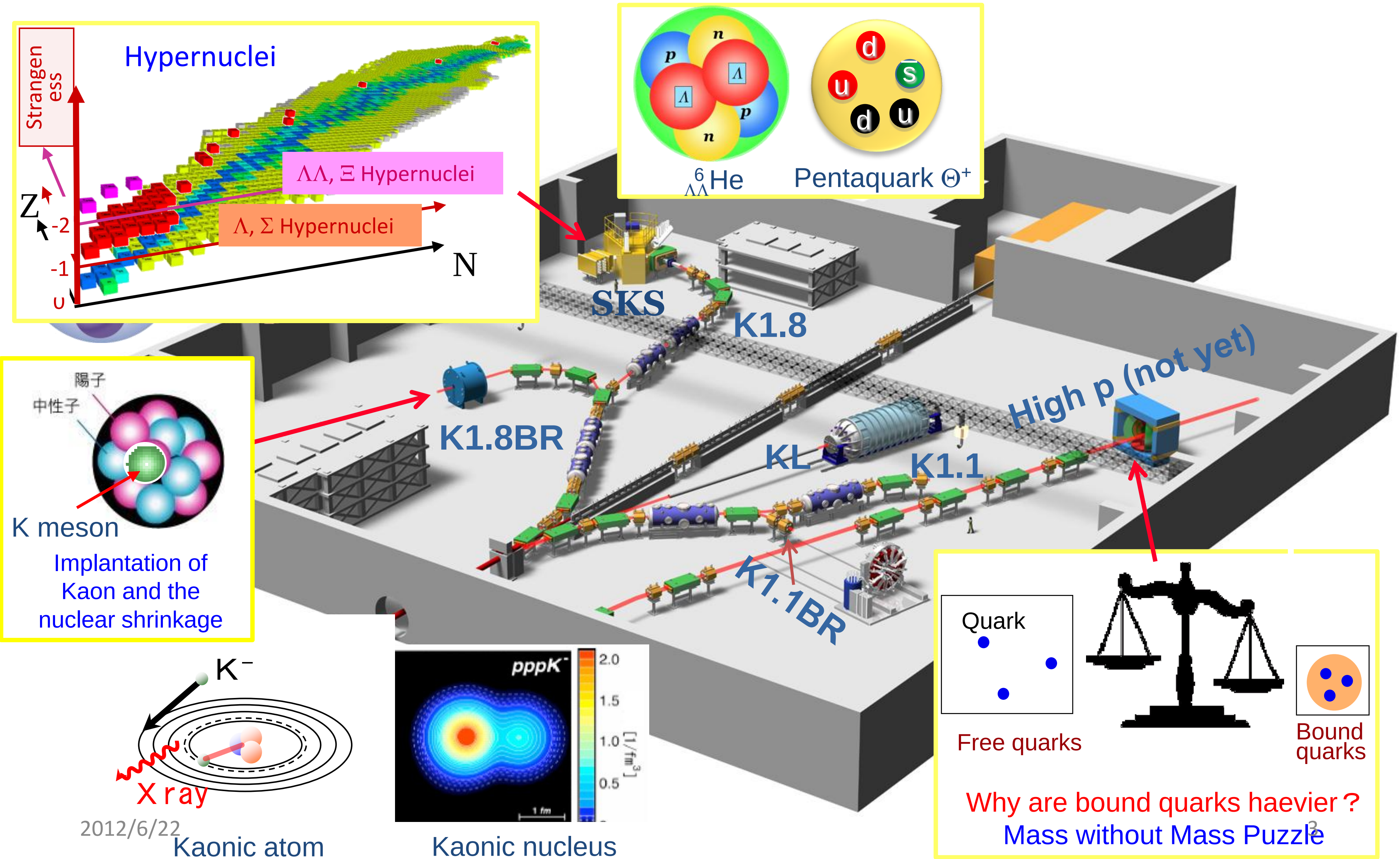
(Japan Proton Accelerator Research Complex)



World-highest beam intensity : ~1 MW

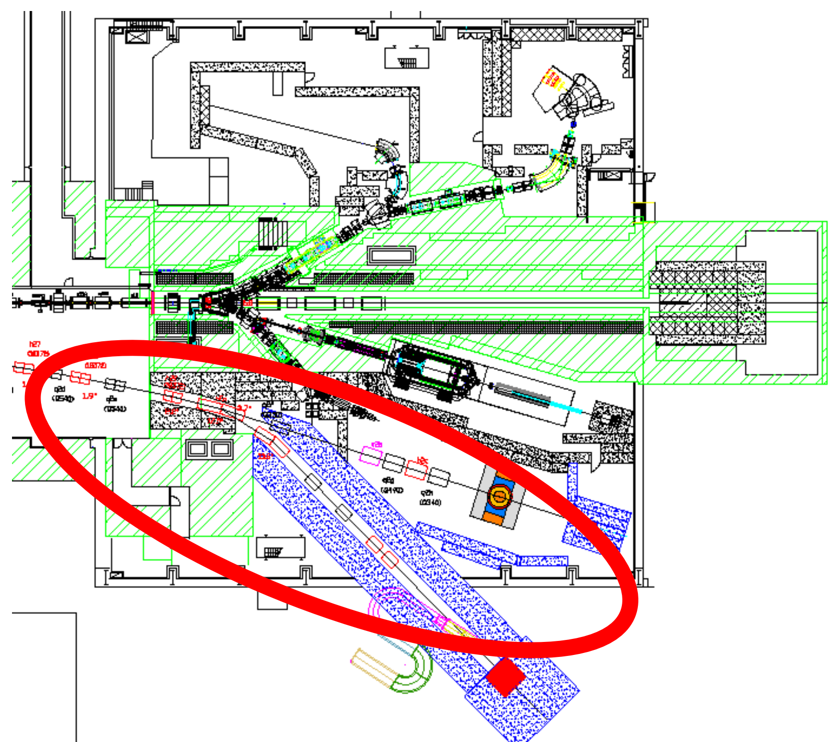
x10 of BNL-AGS, x100 of KEK-PS

Nuclear & Hadron Physics at J-PARC



J-PARC charm capability

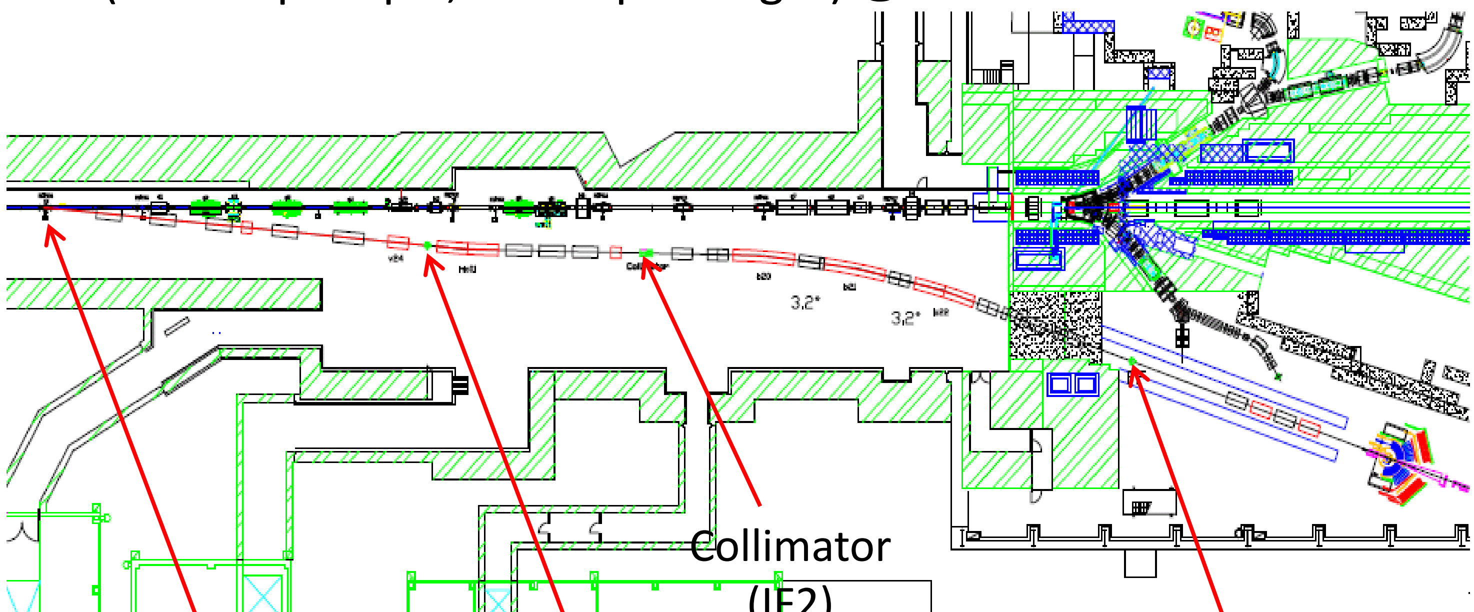
- High momentum beam line
  - Primary proton beam (currently, 30 GeV)
  - Secondary un-separated beam (up to 15 GeV/c)
    - Mainly, π beam
  - Will be constructed within a few years
- Physics
  - **Charmed baryon spectroscopy**
  - DN interactions
  - Nucleus with Charm



New high momentum beam line

Details of Beam line

- Good momentum resolution: $\Delta p/p$~0.1%
  - Dispersive beam at FF
  - Eliminate O(2) aberrations
- High Intensity Secondary Beam :
  - 1.6 msr・%
  - 1.0 x 10^6 Hz (6 x 10^6 per spill, 6 sec spill length) @ 15GeV π

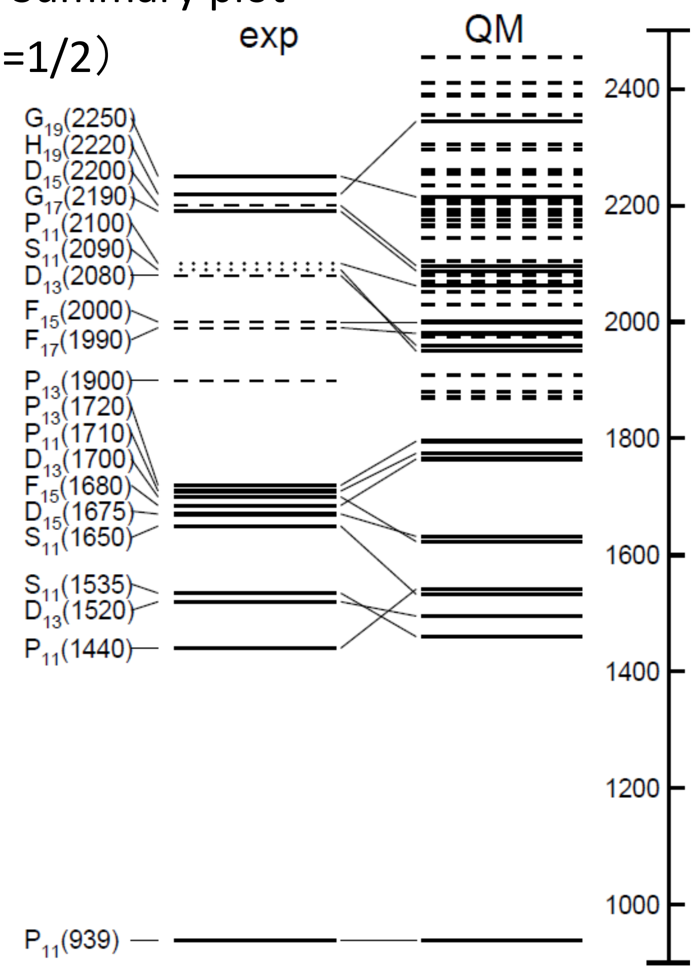


Inside structure of Baryon

- Inside of Baryon
  - Interesting phenomena which are not easily explained by a quark model
    - Missing resonances
      - may indicate importance of other degree of freedom such as di-quark.
    - Roper, Λ(1405)
- Clear understandings are difficult due to complicated issues
  - (Spin dependent) strong quark correlation.
  - Strong coupling to π meson (NG bosons).
- Use charmed baryons (Λ^{+}_{c}, Σ_c) information.
  - Charm quark inside hadron is heavy and easy to handle.
  - Interactions are simplified.

PDG, Summary plot

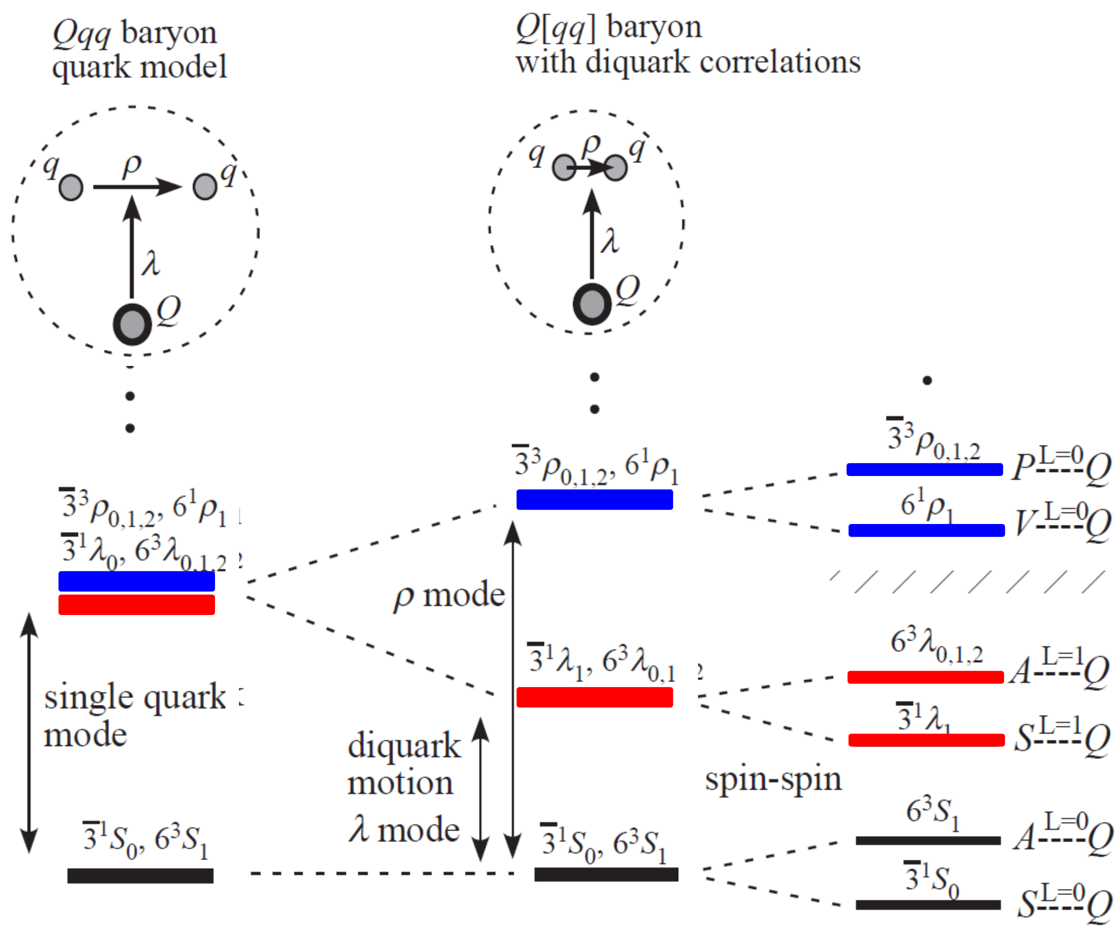
N（I=1/2）



Mass[MeV/c^2]

Heavy quark baryon

λ: orbital motion
ρ: di-quark correlation



- When single quark picture is still a good picture, excited states are degenerated.
- If Cqq (q=u,d) system is considered as C and di-quark correlations, orbital motion of λ is lowered due to the collectivity of the di-quark motion.
- Spin correlations between light quarks give additional level separations.

Level pattern tell us:

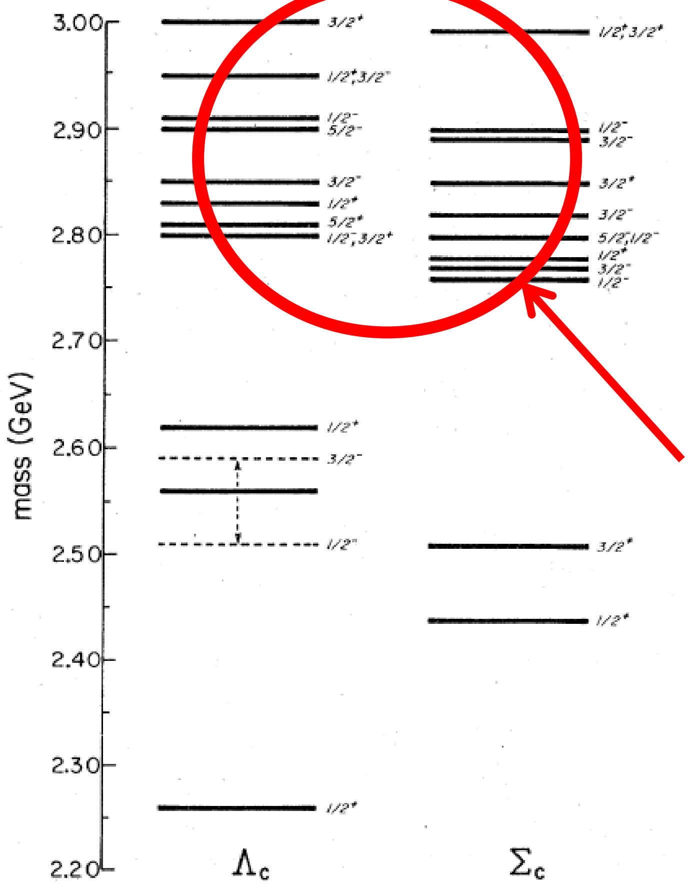
✓Mass of di-quark
✓Strength of di-quark correlation
✓Spin dependent correlation between light quarks

Measurements of all levels are important

Charmed Baryon Spectroscopy

Example of predicted states

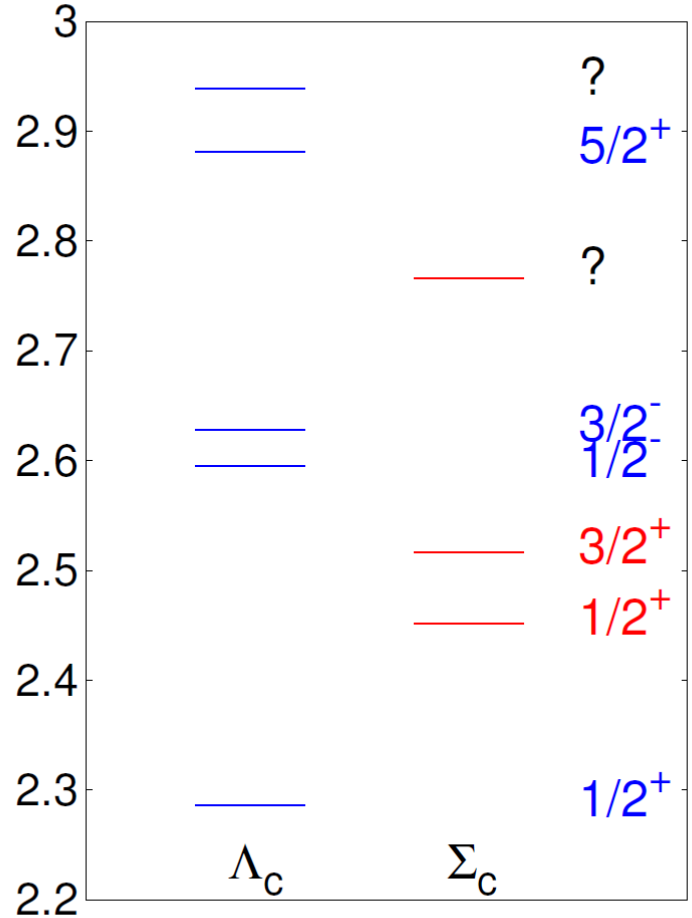
(L.A. Copley et. al, Phys. Rev. D 20 (1979) 768)



Many states are unknown

Measure level pattern in this region

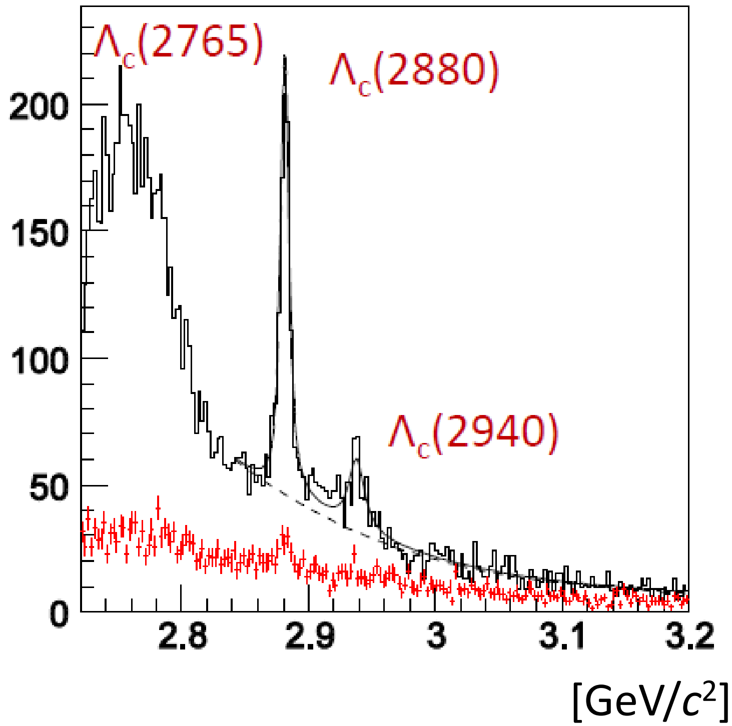
Observed charmed baryons



Study level structure of charmed baryon below 3 GeV.

Observations in e^+e^- (BELLE)

Belle: $M(\Sigma_c\pi)$@553fb^{-1}



$\Lambda_c(2880)^+$

Spin/Parity Determination

$$R = \frac{Br(\Lambda_c(2880) \to \Sigma_c(2520))}{Br(\Lambda_c(2880) \to \Sigma_c(2455))} = 0.225 \pm 0.062 \pm 0.025$$

Prediction by **Heavy Quark Spin Symmetry**

R=0.23 for $5/2^+$

R=1.45 for $5/2^-$

$\Lambda_c(2940)$

$M = 2938.0 \pm 1.3^{+2.0}_{-4.0}$

$\Gamma = 13^{+8}_{-5}{}^{+27}_{-7}$

Several good results already exists.

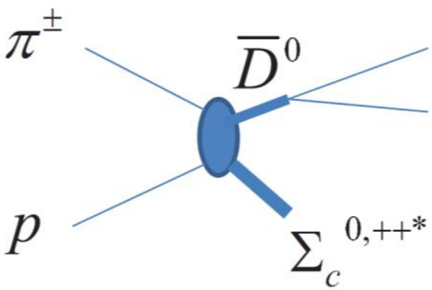
At J-PARC?

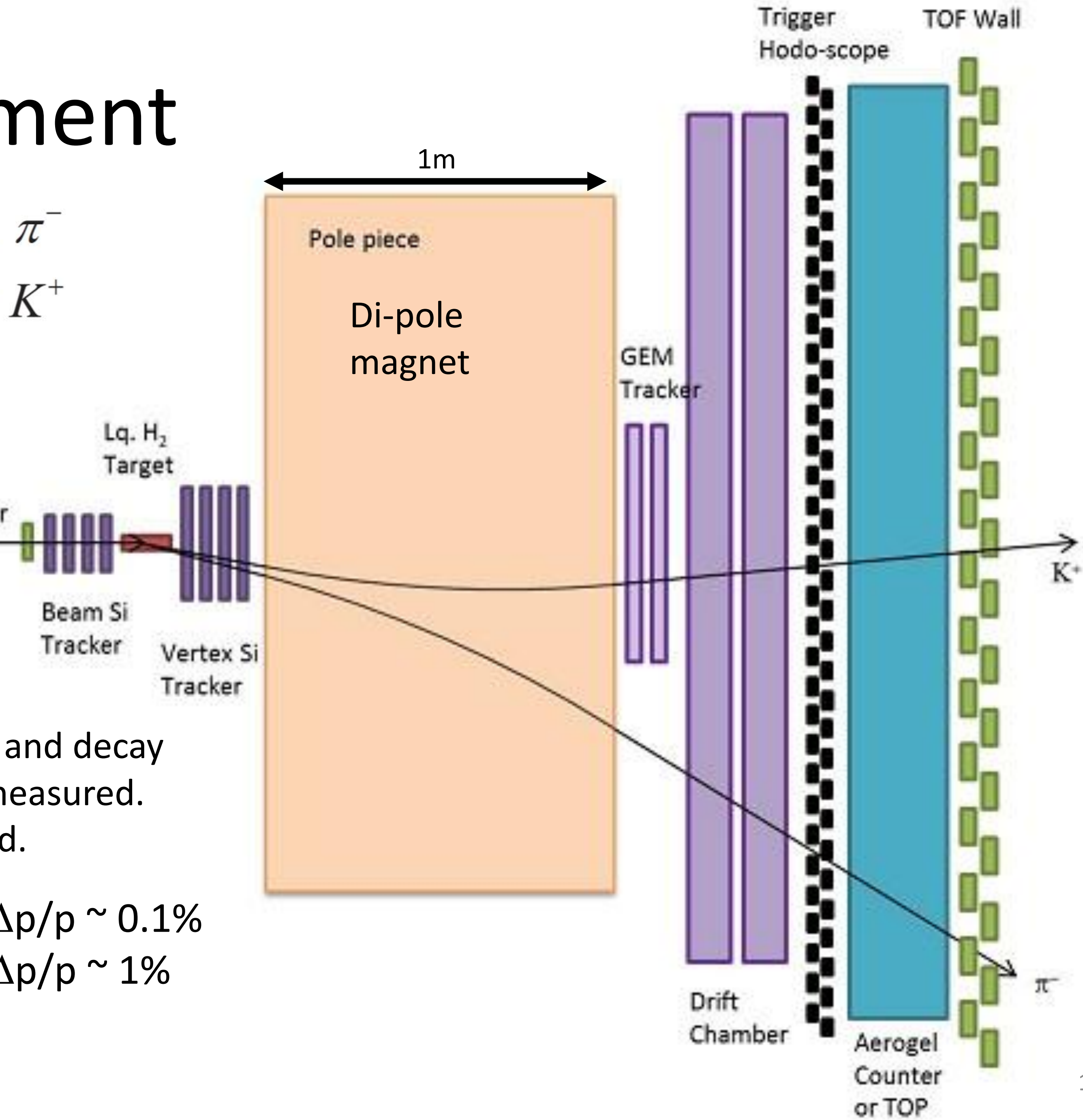
Experimental method is different

- Decay and Invariant mass method at Belle
  - Large statistics
    - e.g. Belle and LHC-heavy ion
  - Several excited states can’t be recognized
    - States with large intrinsic width
    - Low resolution for neutral particles
- Missing mass method at J-PARC
  - All levels can be searched
    - Independent to decay mode
    - Large intrinsic width states are recognized
  - Relatively small detector

Missing mass method is suitable to study level structure of charmed baryon

Experiment





Momenta of beam and decay particles (Kπ) are measured.

K ID is required.

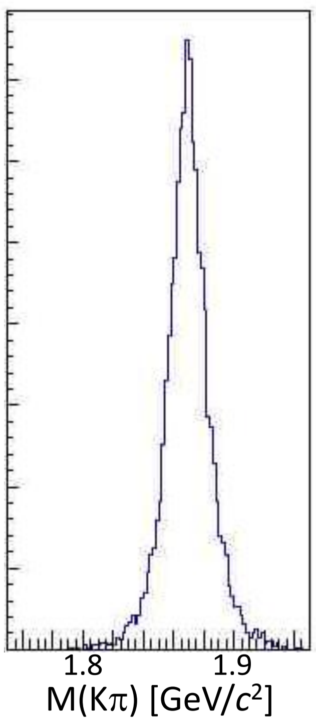
Beam: $\Delta p/p \sim 0.1\%$

Decay Particle: $\Delta p/p \sim 1\%$

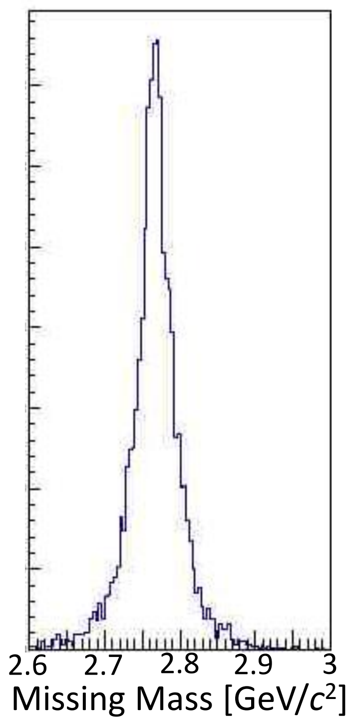
Final expected Spectra

D meson is reconstructed and identified using measured momenta of π and K.
Then, calculate missing mass using momenta of D meson and π beam.

Reconstructed D meson

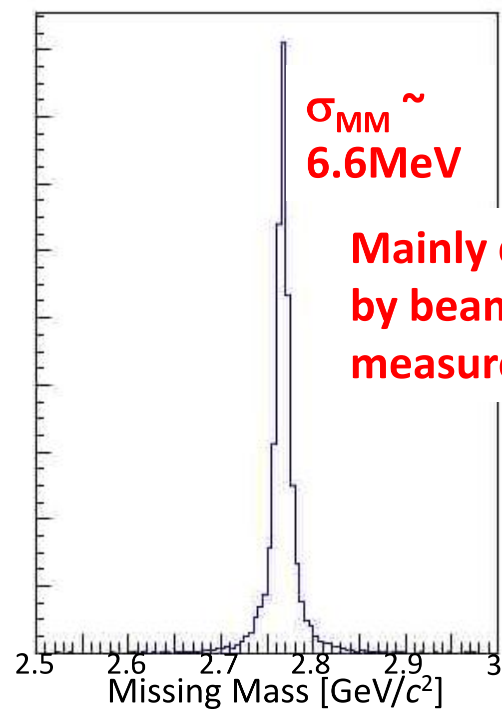


Missing mass spectrum



Resolution is determined by decay measurements.

Correction:
$M_{D\ meson}$ is known.
Measured $K\pi$ momenta are corrected to reproduce nominal D meson mass.



σ_{MM} ~ 6.6MeV

Mainly determined by beam measurements.

Old "No" result @ BNL

- 13.0, 16.0 GeV/c unseparated beam from the D* production channel

  J.H. Christenson et al., PRL 55, 154 (1985)

  - π^-: 10^7/spill, 3×10^{12} π^- @ Hydrogen target
    - $\Delta p/p \sim 0.25\%$
  - Forward spectrometer
    - $\Delta p/p \sim 1\% \Rightarrow \Delta M = 9$ MeV/c^2
    - PID by gas Cherenkov

    $\Rightarrow$Threshold: π = 2 GeV/c, K= 8 GeV/c

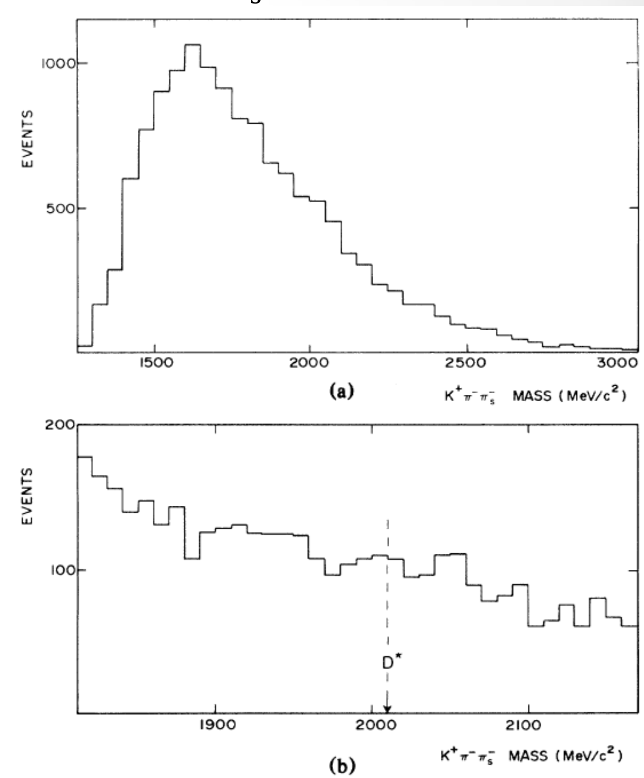
✱ D^{*-} production detected

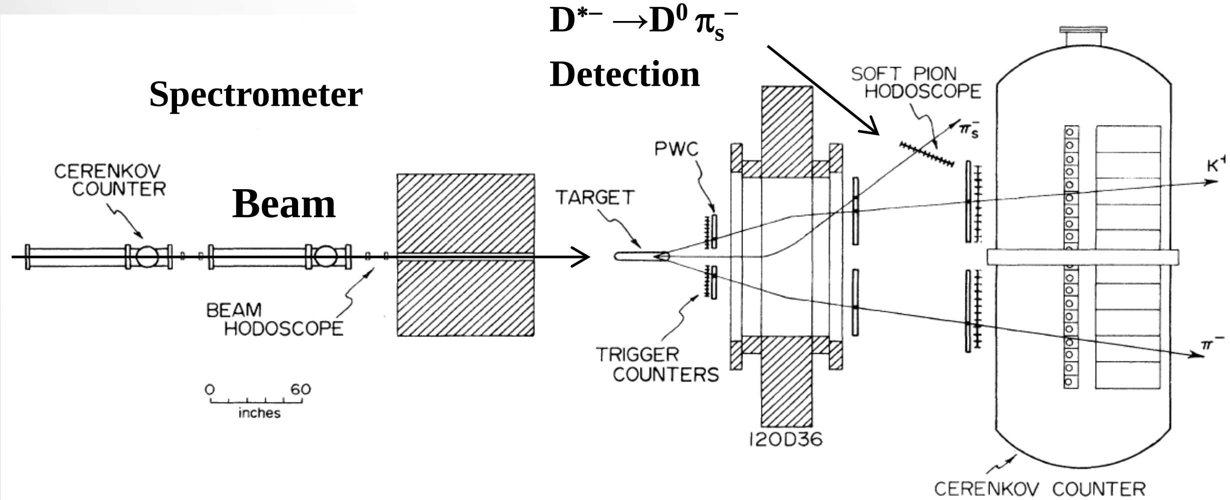
$\Rightarrow$Better S/N by detecting π_s^- from $D^{*-} \rightarrow D^0 \pi^-$

$\sigma\times BR$ =7 nb, M_{D^*} : 1.99-2.03 GeV/c^2

($\pi^- p \rightarrow \Lambda_c^+ D^{*-}$ and $\pi^- p \rightarrow \Sigma_c^+ D^{*-}$)

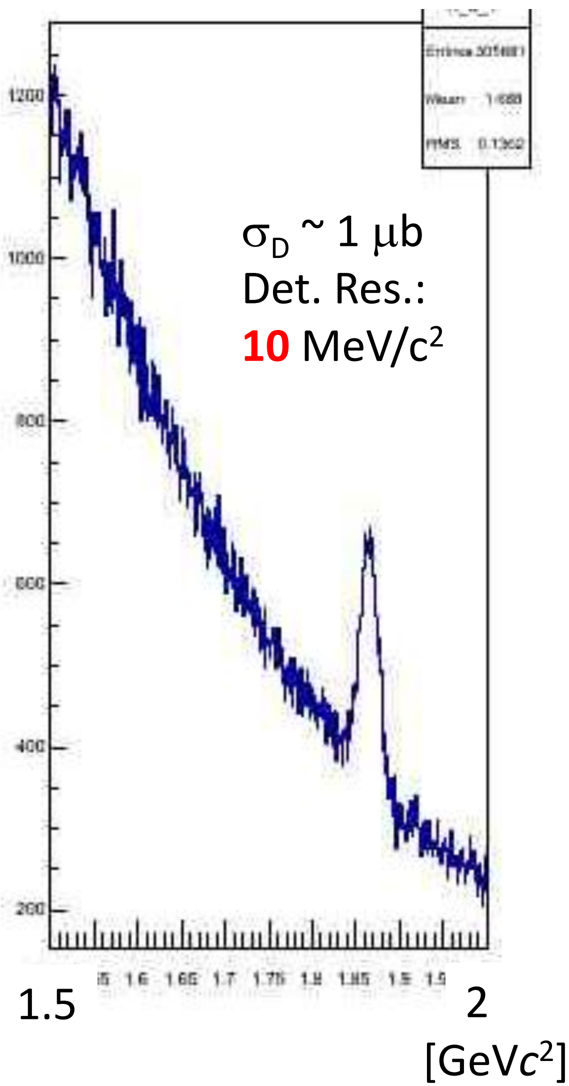
$K^+\pi^-\pi_s^-$ invariant mass

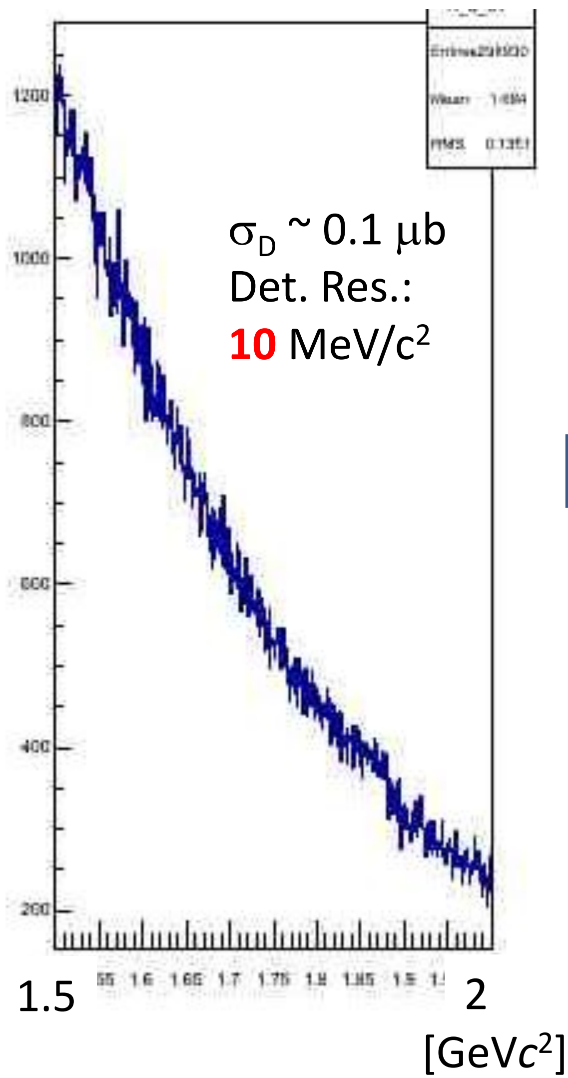


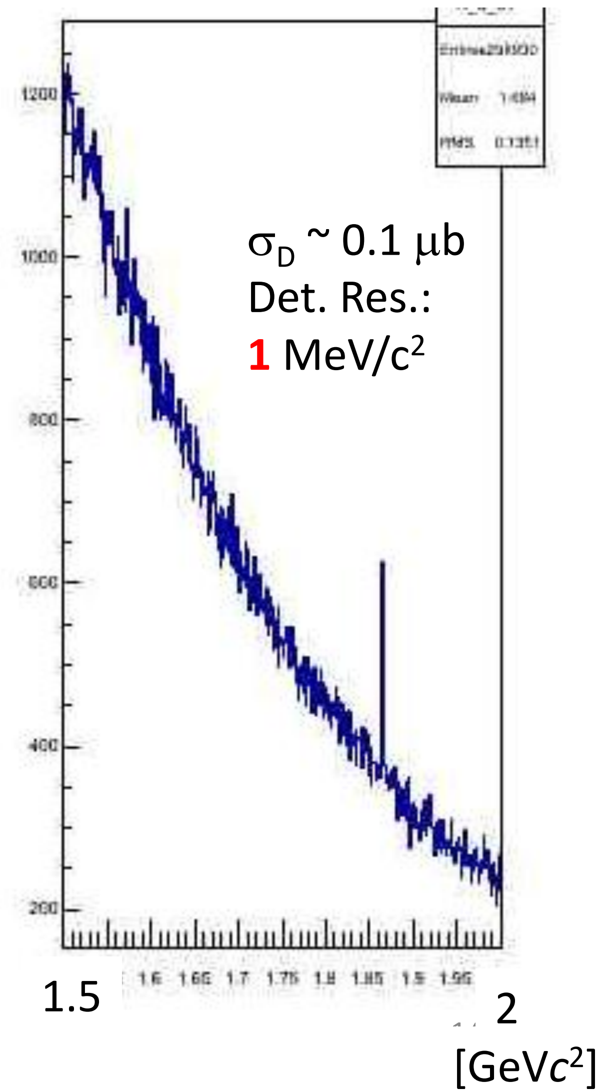


Need some improvements…

Toy Monte Carlo
- Intensity ~ 10^6 Hz
- 6s spill, 1 week data
- Fully accepted
- Branch Ratio took into account



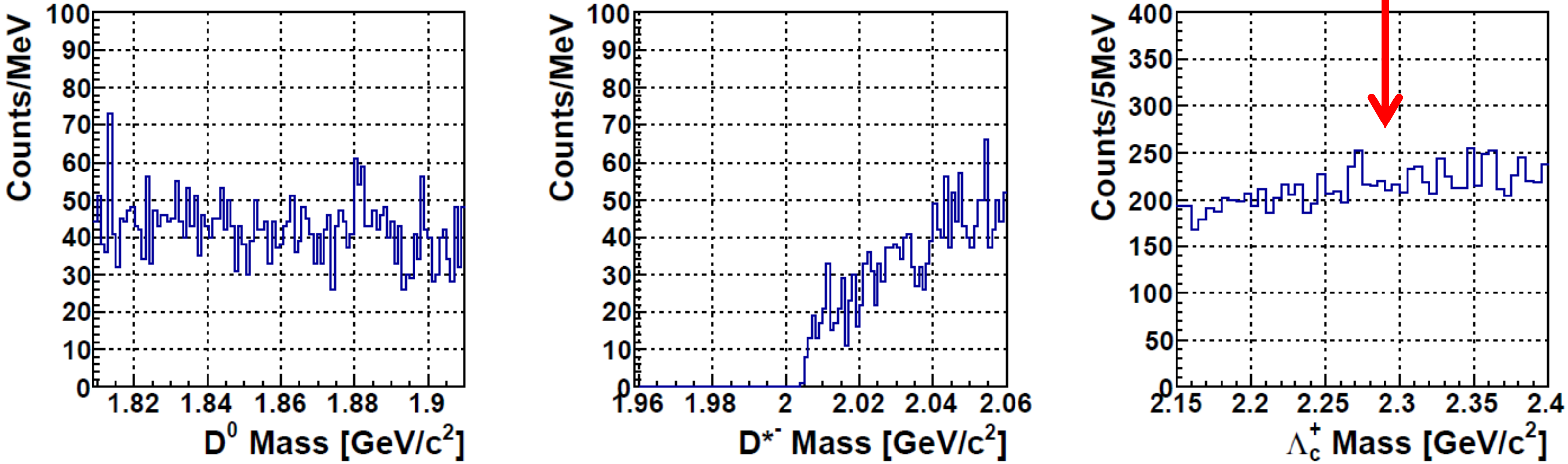




More simulation works underway

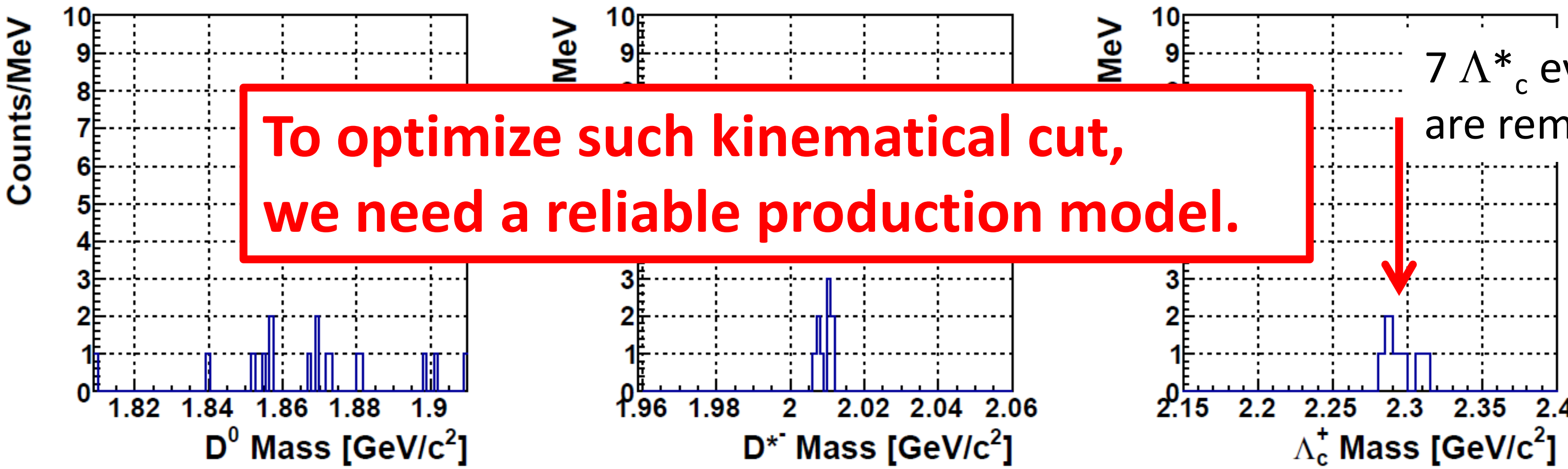
Non-correlated pair background rejection

20 Λ^*_c events are included.



D - D* mass correlation cut is applied.

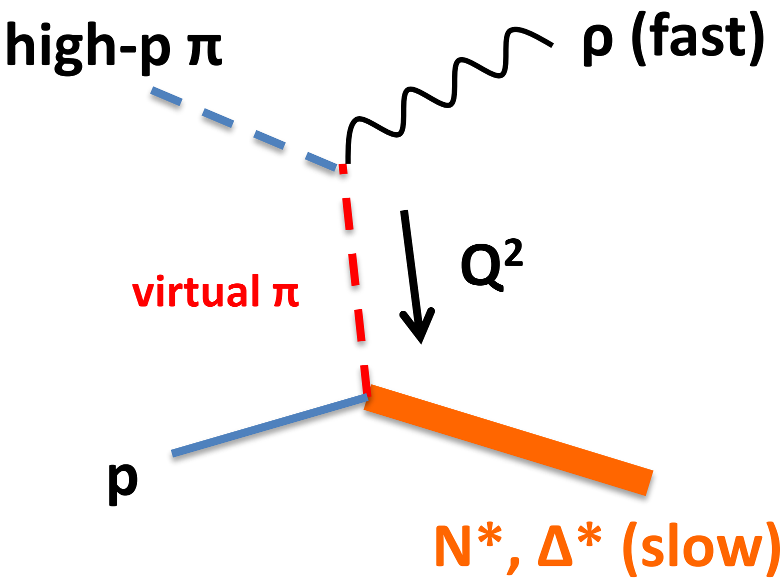
7 Λ^*_c events are remaining.

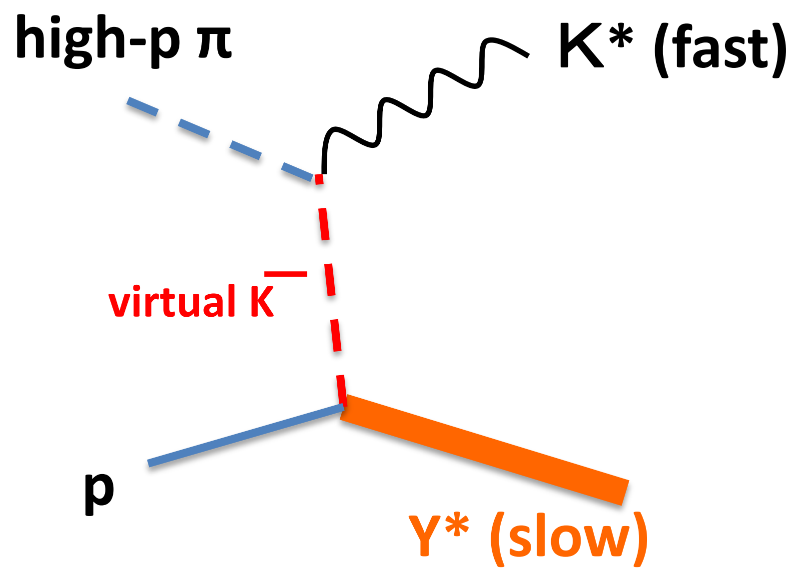


To optimize such kinematical cut, we need a reliable production model.

Other related exp. (not charm)

前方でMulti Particleを捉える実験を行うことで、今まで得られなかった情報が得られる。
たとえば、以下のような反応のρ、K*の崩壊粒子を前方で捉える。



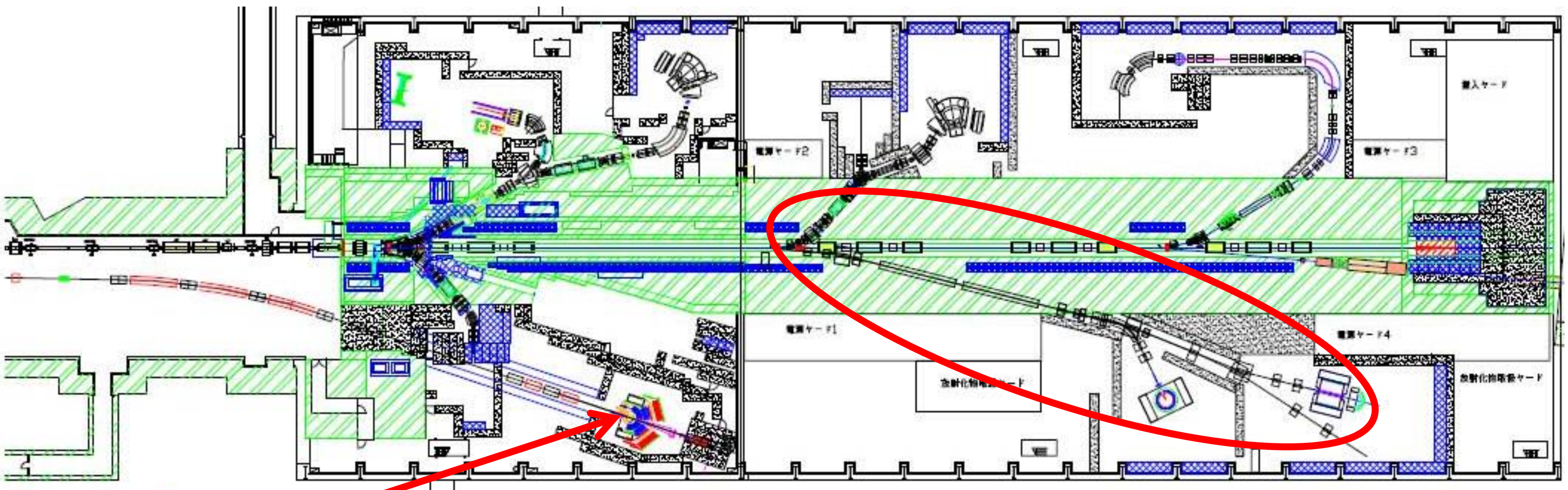


- ✓ **N-N* 軸性遷移形状因子のQ²依存性の決定**
- ✓ **K̄N しきい以下 Λ(1405) の領域も問題なくおさえられる！**
- ✓ **fast-slow の部分は切り離して考えられ、理論的にも取り扱いやすい系と期待できる。**

高運動量領域で高分解能での前方測定は、ハドロン物理における新たな分野を開拓できる。

In Future

We are planning to extend the hadron hall.
Physics Program is under discussions. Your supports are essential!



In far future,
Heavy Ion Beam is in our scope.
Experiments can be done using the primary beam line.

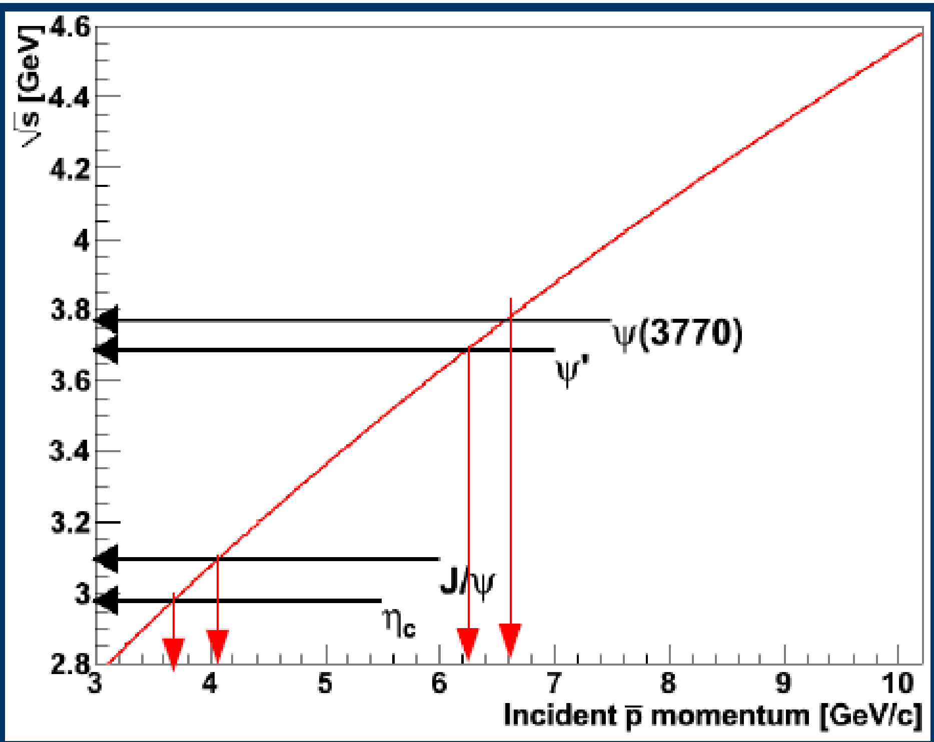
50GeV primary beam can create doubly charmed baryons

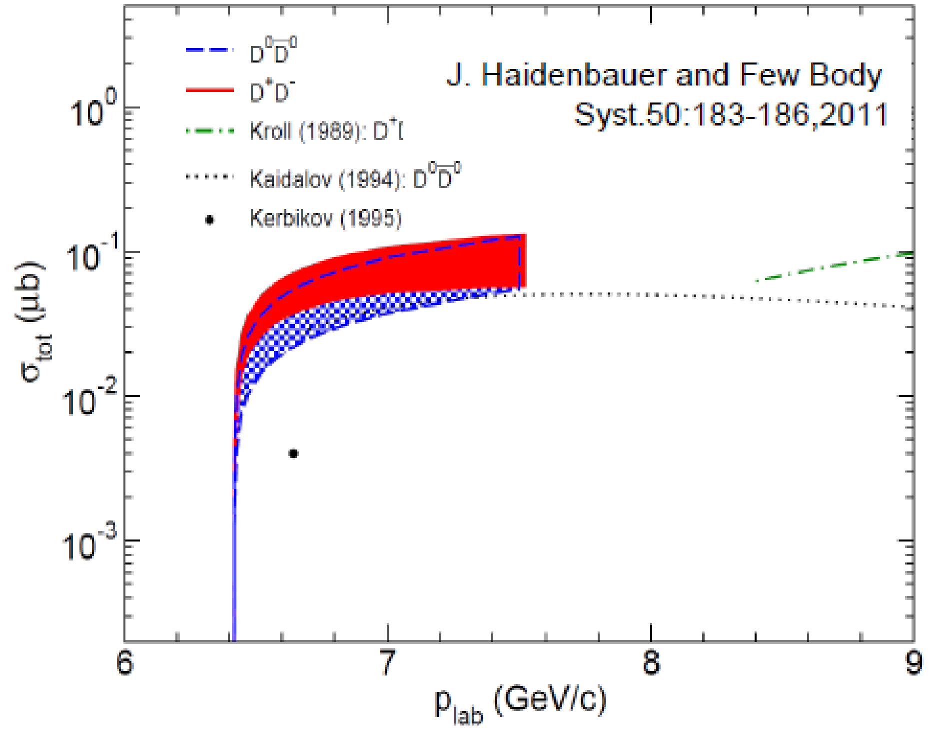
Separated High momentum Beam line
Kaon and Anti-proton Beam up to 10GeV/c

J/ψ, ψ', X(3872)

Ξ_c spectroscopy

Physics with p-bar





Charmonium Production threshold

$\bar{p}p \rightarrow J/\Psi$ @ 4.05 GeV/c

$\bar{p}p \rightarrow \Psi(3770)$ @ 6.6 GeV/c

$\bar{p}p \rightarrow X(3872)$ @ 7.0 GeV/c

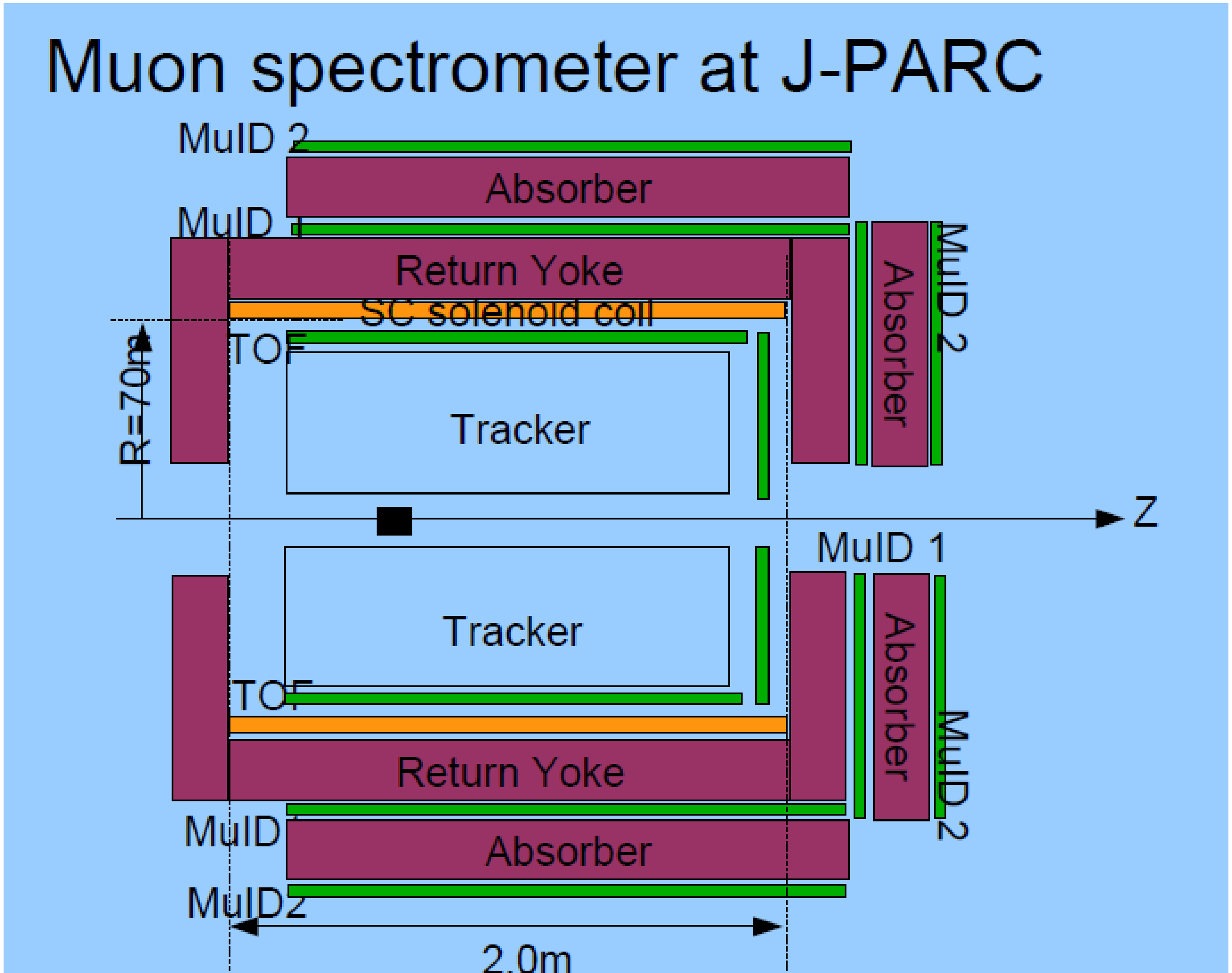
Open charm cross section

$\bar{p}p \rightarrow D^0\bar{D}^0$ @ 6.4 GeV/c

$\sigma_{D\bar{D}} \sim 100$ nb;

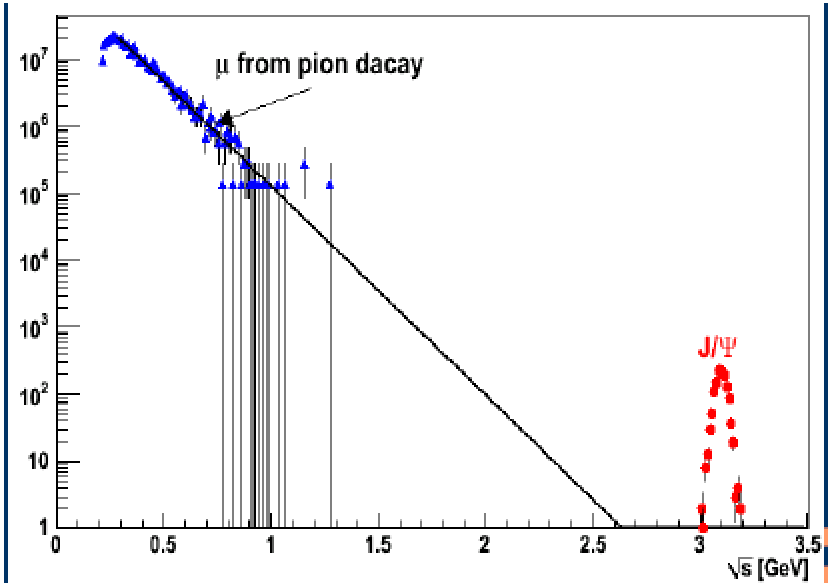
Experiment in extended hadron hall.

Proposed Detector system



Yield estimation

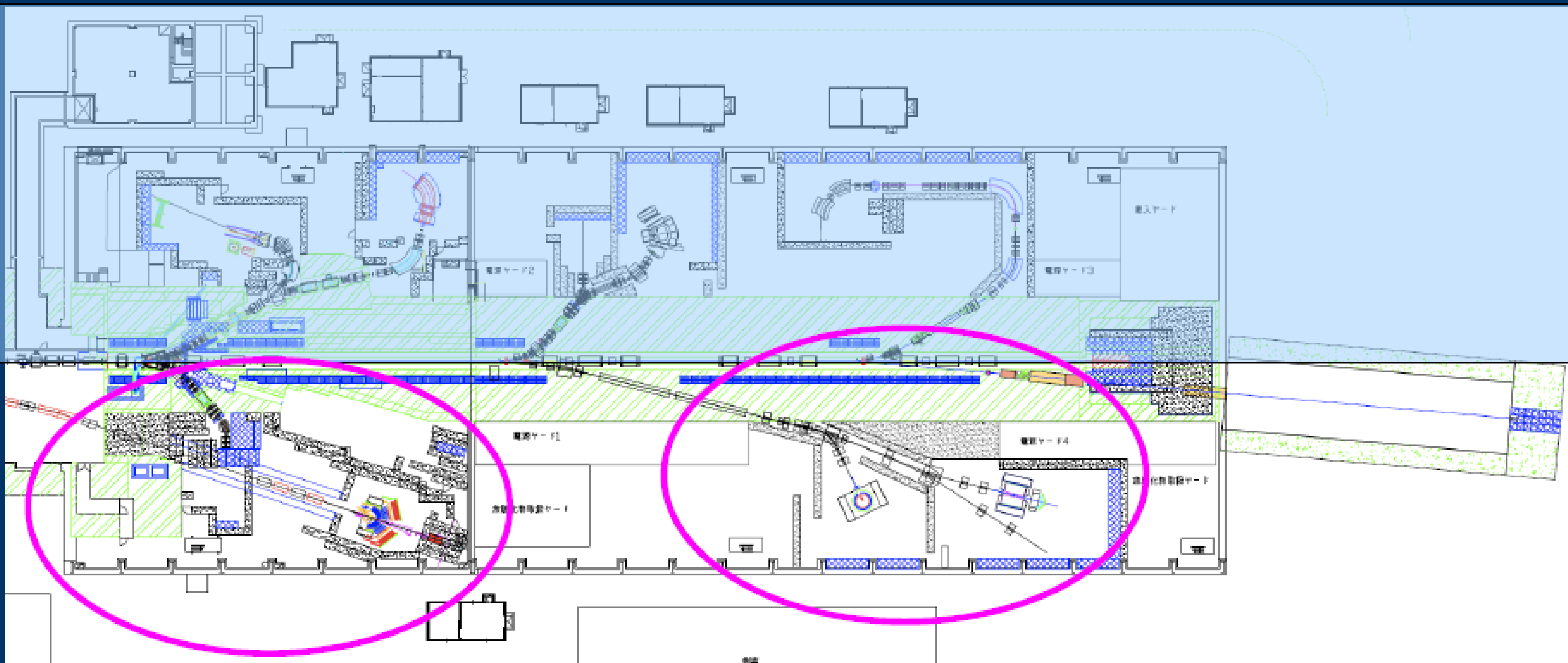
- Production cross section including μ branching ratio
  - 300 nb
- efficiency*acceptance
  - 30%
- 1400 J/ψ →μμ / month



- Under the same assumption
  - ψ' →μμ 50 / month
  - X(3872) → J/ψ →μμππ 100 / month

We can have some reasonable amount of statistics.

Extended hadron hall to enhance new physics capability



Charmed baryon spectroscopy
with in 3-4 years

S=-2,-3 Baryon specctroscopy
Charmed meson/baryon in nucleus
with in 5-6 years

Summary

- J-PARC has several capabilities to study charm related physics.
- Still, we need a minor or major upgrades and attractive physics lists. More collaborative works are essential.
- New experiment to study hadron structure is being proposed. The experiment measures level structure of excited charmed baryons.
- In future, anti-proton experiment will be done.