A search for Charmed Nuclei

quarks

Next flavor

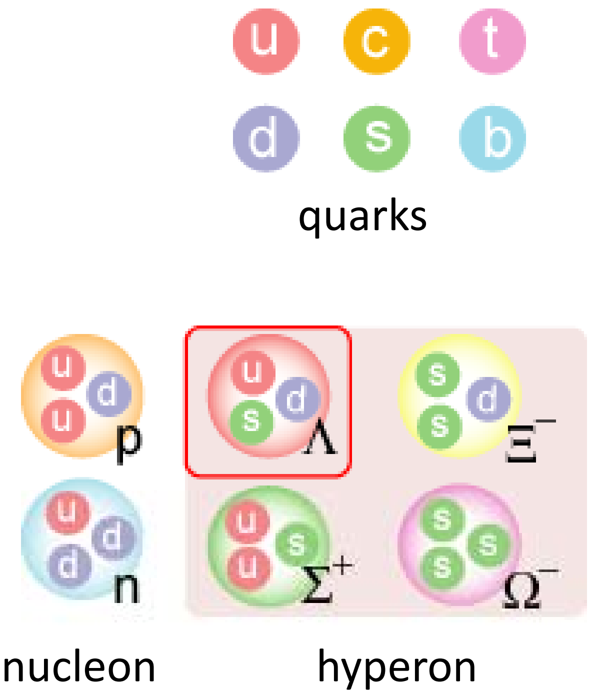
Charm

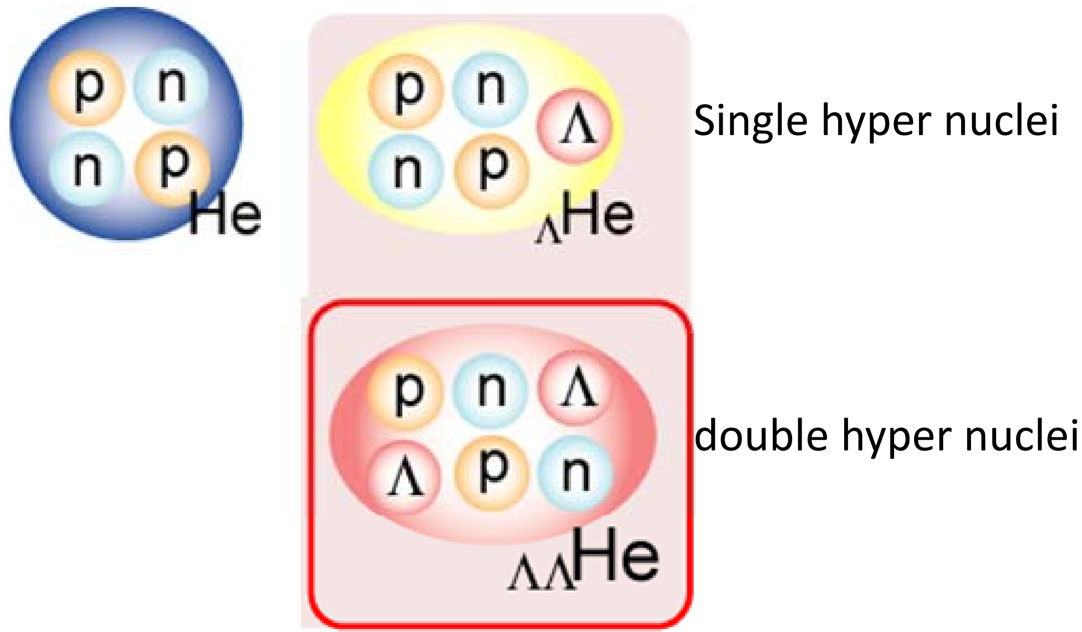
Toshinao TSUNEMI

Kyoto Univ.

1) Introduction
2) Key detector (emulsion: image processing)
3) Summary

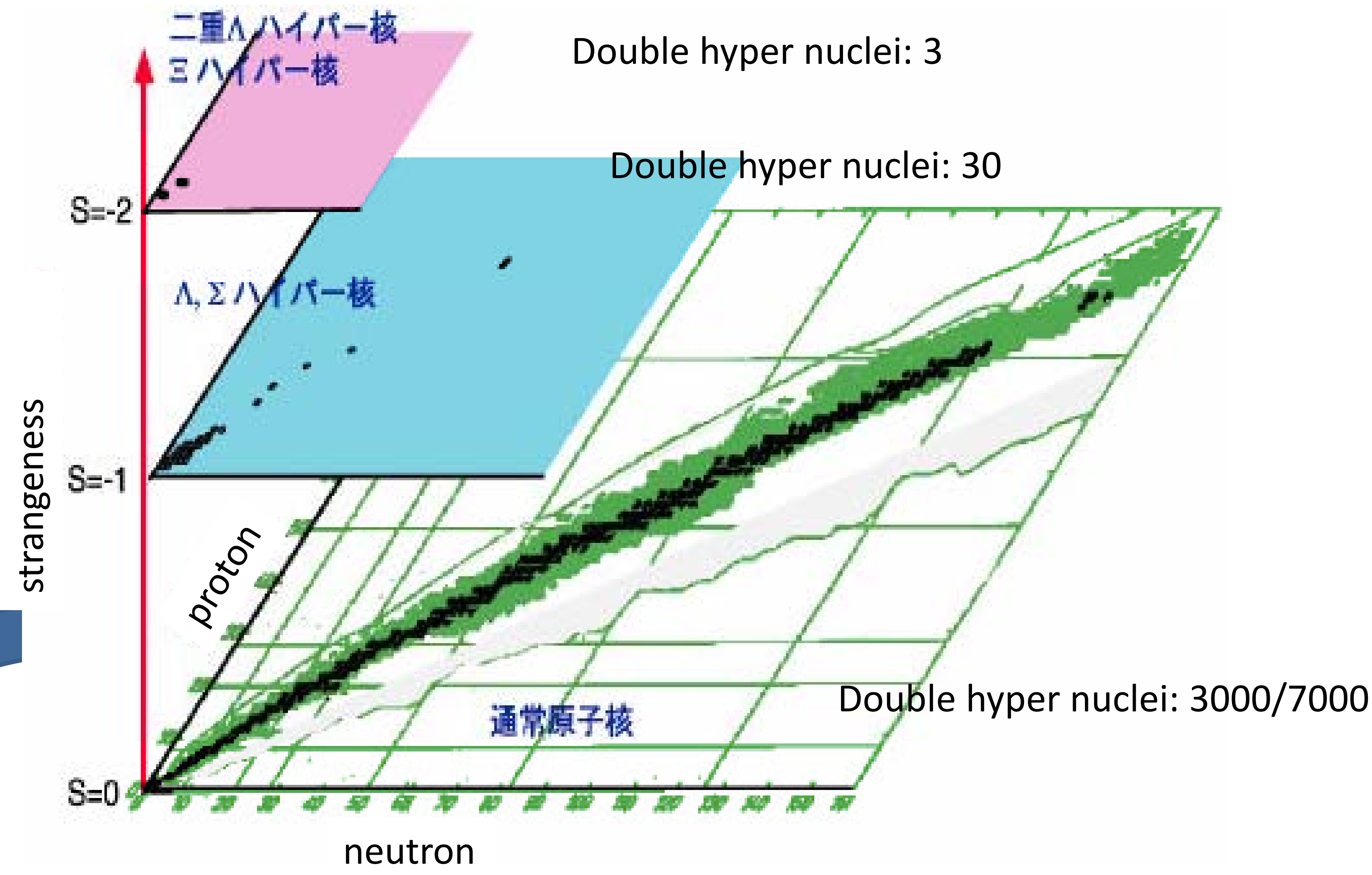
Double hyper nuclei





Nuclei and hypernuclei

Hyper nuclei(strangeness)



Charm axis

quarks

Next flavor

Charm

QUARKS

The u-, d-, and s-quark masses are estimates of so-called "current-quark masses," in a mass-independent subtraction scheme such as $\overline{MS}$ at a scale $\mu \approx 2$ GeV. The c- and b-quark masses are the "running" masses in the $\overline{MS}$ scheme. For the b-quark we also quote the 1S mass. These can be different from the heavy quark masses obtained in potential models.

u $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass m = 1.5 to 3.0 MeV [a] Charge $= \frac{2}{3}\,e$ $I_z = +\frac{1}{2}$
m_u/m_d = 0.3 to 0.6

d $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass m = 3 to 7 MeV [a] Charge $= -\frac{1}{3}\,e$ $I_z = -\frac{1}{2}$
m_s/m_d = 17 to 22
$\overline{m} = (m_u+m_d)/2$ = 2.5 to 5.5 MeV

s $I(J^P) = 0(\frac{1}{2}^+)$

Mass $m = 95 \pm 25$ MeV [a] Charge $= -\frac{1}{3}\,e$ Strangeness = −1
$(m_s - (m_u + m_d)/2)/(m_d - m_u)$ = 30 to 50

c $I(J^P) = 0(\frac{1}{2}^+)$

Mass $m = 1.25 \pm 0.09$ GeV Charge $= \frac{2}{3}\,e$ Charm = +1

b $I(J^P) = 0(\frac{1}{2}^+)$

Charge $= -\frac{1}{3}\,e$ Bottom = −1

Mass $m = 4.20 \pm 0.07$ GeV ($\overline{MS}$ mass)
Mass $m = 4.70 \pm 0.07$ GeV (1S mass)

t $I(J^P) = 0(\frac{1}{2}^+)$

Charge $= \frac{2}{3}\,e$ Top = +1

Mass $m = 174.2 \pm 3.3$ GeV [b] (direct observation of top events)
Mass $m = 172.3^{+10.2}_{-7.6}$ GeV (Standard Model electroweak fit)

DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$Wq(q = b, s, d)$			–
Wb			–
$\ell\nu_\ell$ anything	[c,d] (9.4±2.4) %		–
$\tau\nu_\tau b$			–
$\gamma q(q=u,c)$	[e] < 5.9 × 10^{-3}	95%	–
$\Delta T = 1$ weak neutral current ($T1$) modes			
$Zq(q=u,c)$ $T1$	[f] < 13.7 %	95%	–

b' (4th Generation) Quark, Searches for

Mass $m >$ 190 GeV, CL = 95% ($p\overline{p}$, quasi-stable b')
Mass $m >$ 199 GeV, CL = 95% ($p\overline{p}$, neutral-current decays)
Mass $m >$ 128 GeV, CL = 95% ($p\overline{p}$, charged-current decays)
Mass $m >$ 46.0 GeV, CL = 95% (e^+e^-, all decays)

Free Quark Searches

All searches since 1977 have had negative results.

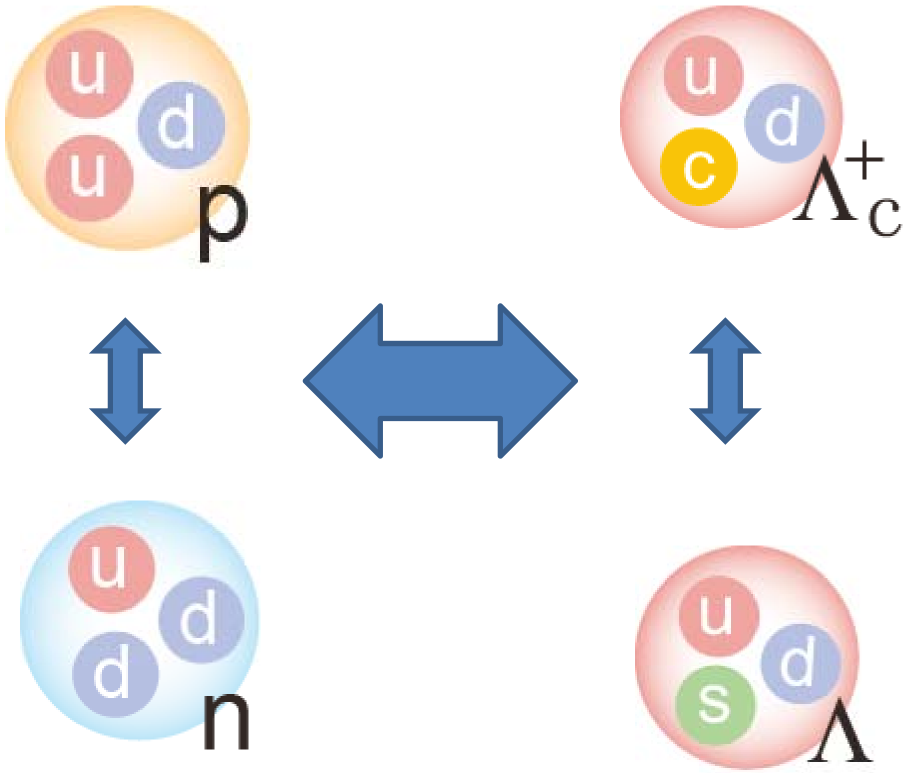
NOTES

[a] The ratios m_u/m_d and m_s/m_d are extracted from pion and kaon masses using chiral symmetry. The estimates of u and d masses are not without controversy and remain under active investigation. Within the literature there are even suggestions that the u quark could be essentially massless. The s-quark mass is estimated from SU(3) splittings in hadron masses.
[b] Based on published top mass measurements using data from Tevatron Run-I and Run-II. Including also the most recent unpublished results from Run-II, the Tevatron Electroweak Working Group reports a top mass of $172.5 \pm 1.3 \pm 1.9$ GeV. See the note "The Top Quark" in the Quark Particle Listings of this *Review*.
[c] ℓ means e or μ decay mode, not the sum over them.
[d] Assumes lepton universality and W-decay acceptance.
[e] This limit is for $\Gamma(t \to \gamma q)/\Gamma(t \to Wb)$.
[f] This limit is for $\Gamma(t \to Zq)/\Gamma(t \to Wb)$.

up 1.5 to 3.0 MeV
down 3 to 7 MeV
strange 95±25 MeV
charm 1.25±0.09 GeV
bottom 4 GeV
top 170 GeV

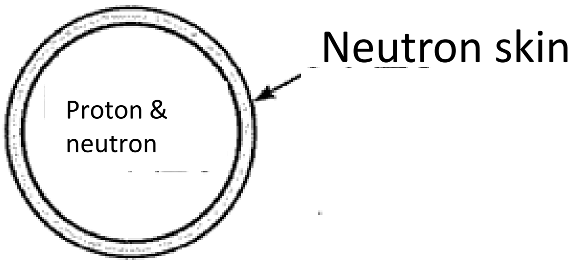
The mass of charm quark is 1.25GeV.
Mass of charm quark is 13 times as much as strange quark.
The mass of charm quark is as much as proton and neutron although it is a quark, not baryon.

“Proton and neutron” and “Λ and Λc”

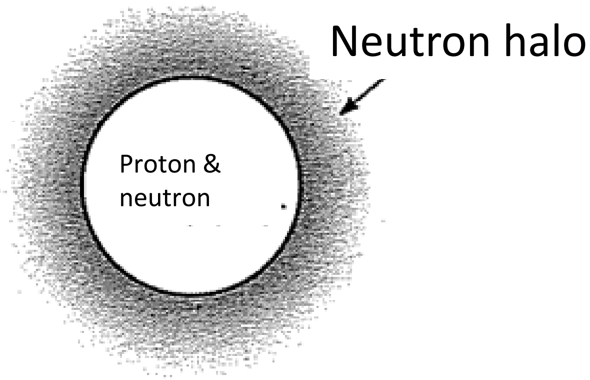


Neutron halo & neutron star

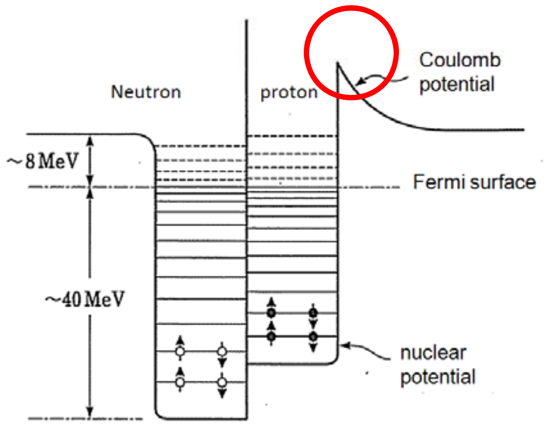
1） neutron skin & halo



Neutron skin



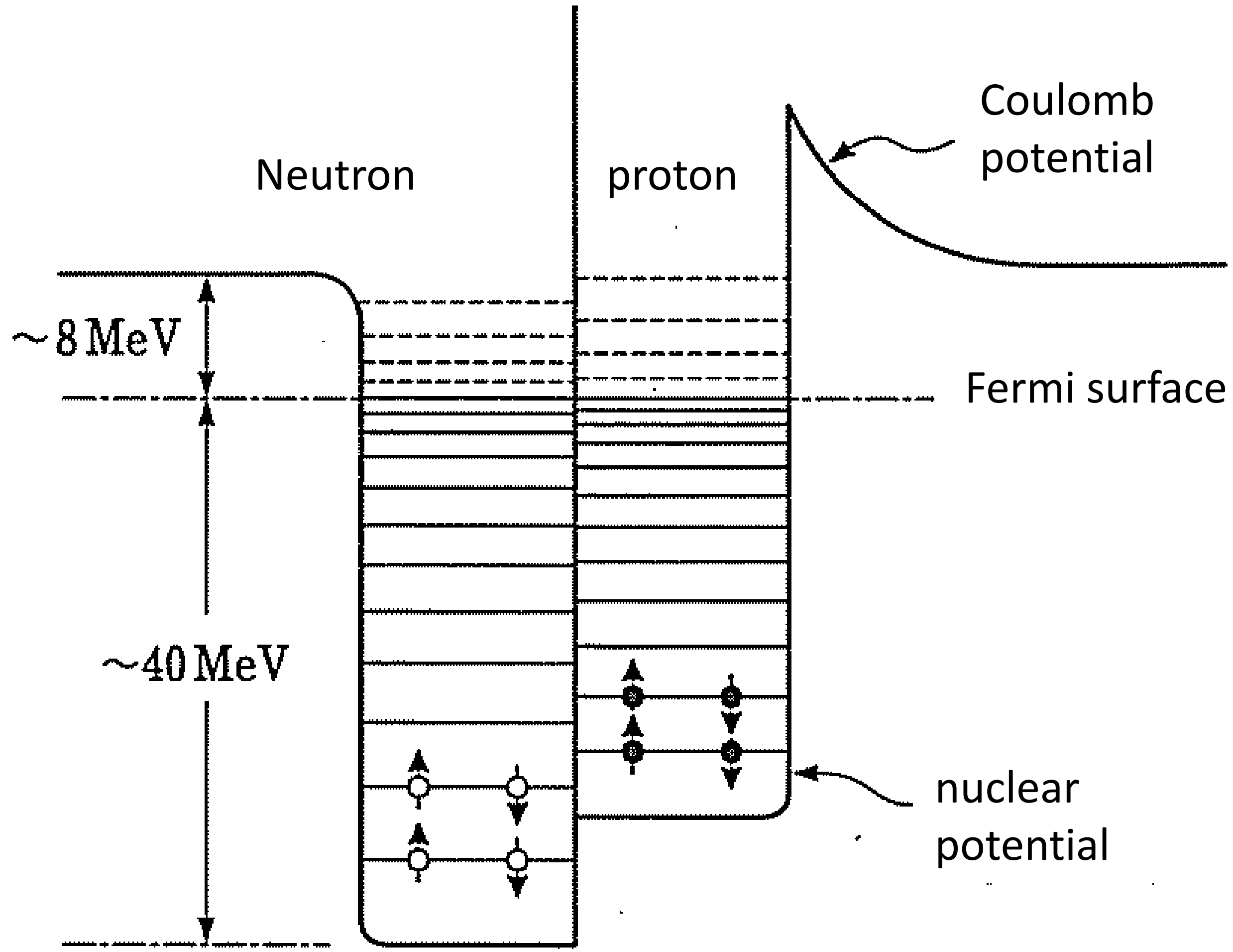
Neutron halo



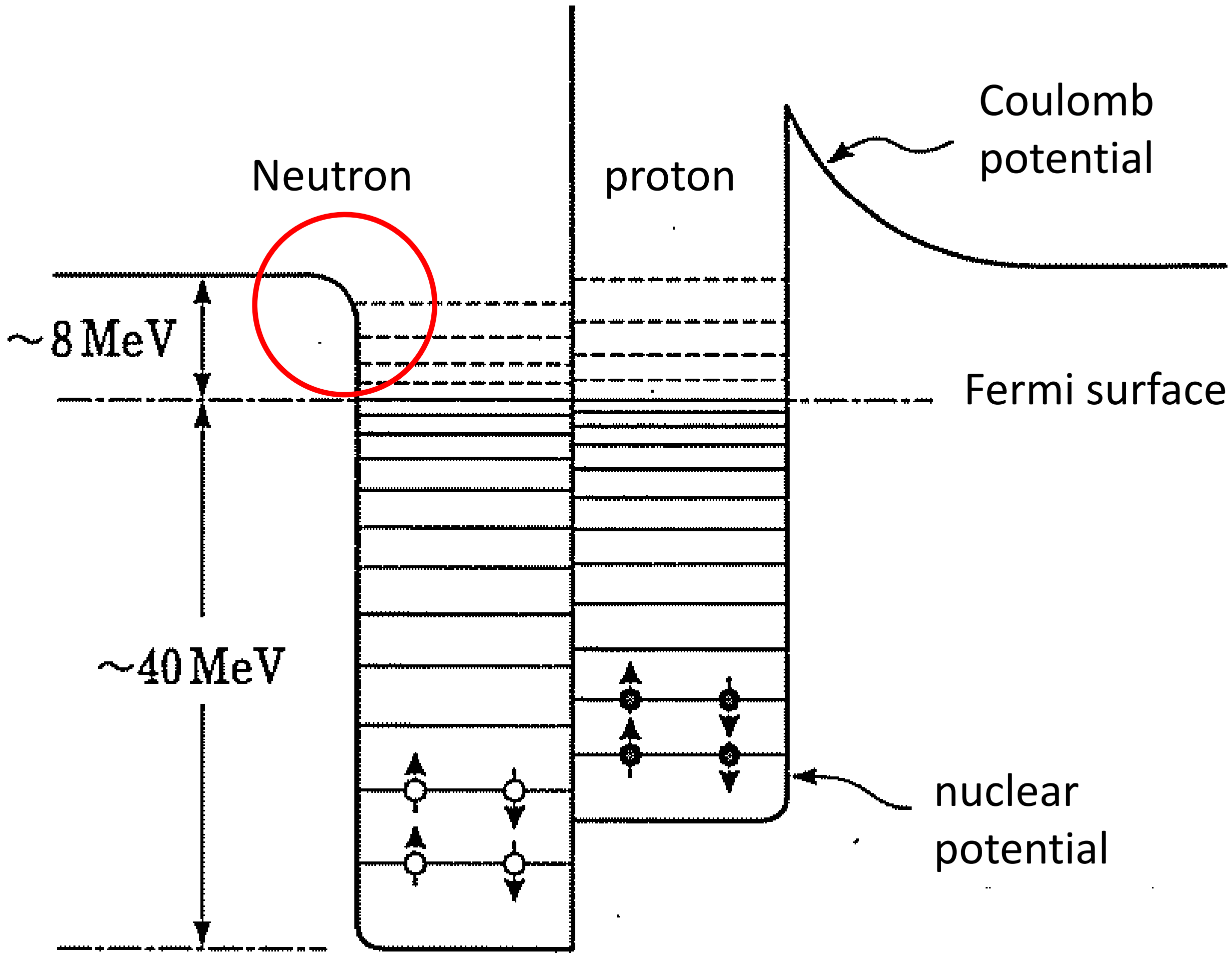
2）neutron star

A proton is different from a neutron.

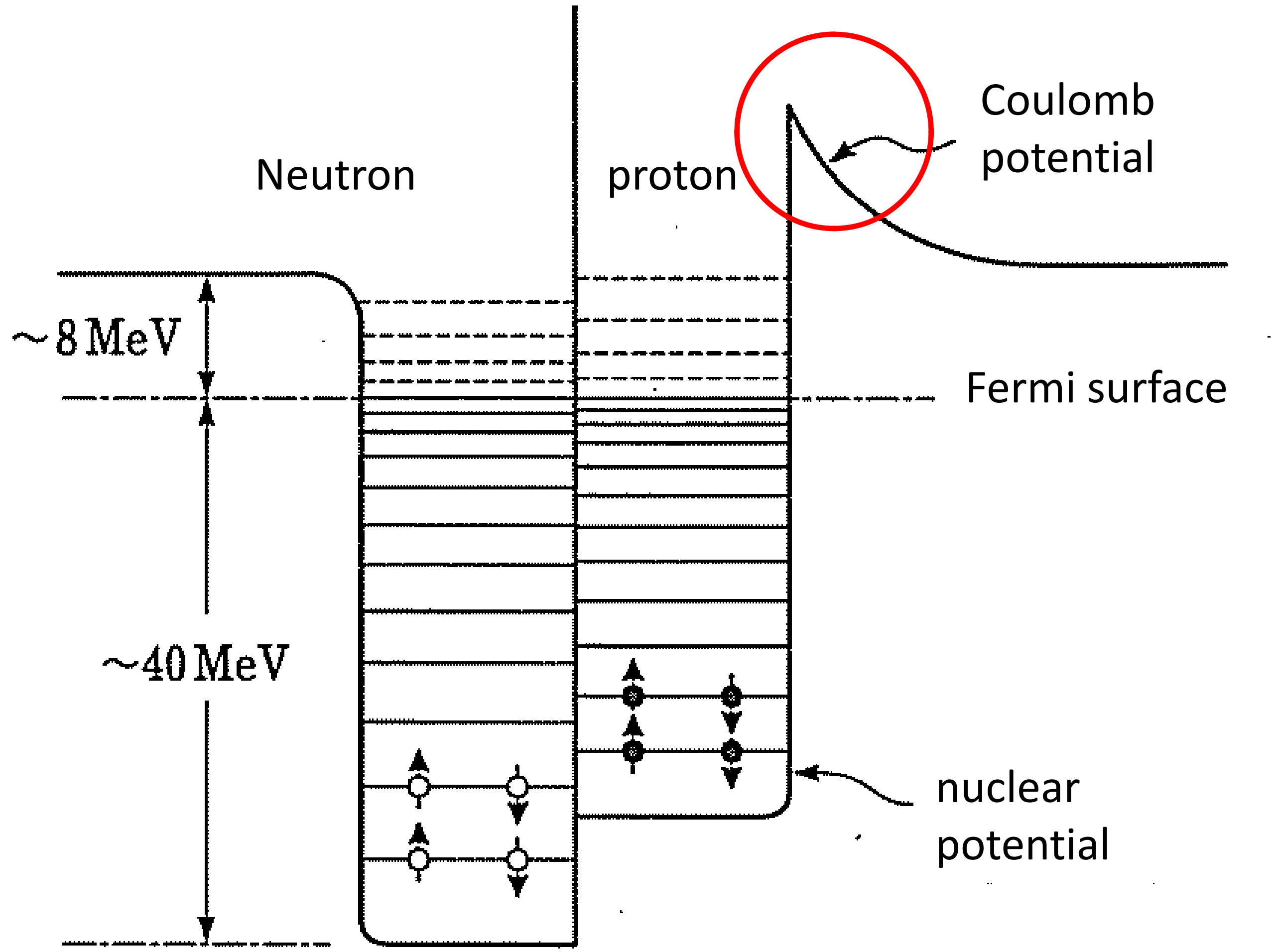
Potential energy of proton and neutron



Potential energy of proton and neutron



Potential energy of proton and neutron



Charmed Nuclei does not exist in the current Universe.

- Neutron stars contain hyperons.

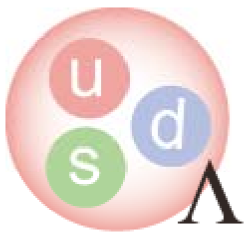
The mass of Neutron star is 1.44M(solar mass).
If hyperon does not exist in a neutron star,
A neutron star, whose mass is 2M, must exist.

But

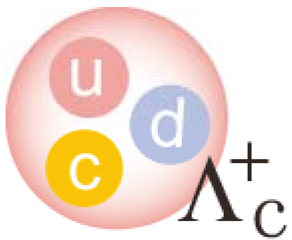
•Charmed Nuclei does not exist in the current Universe.

•The behavior of charmed nuclei is interesting.

Difference between Λ and Λc

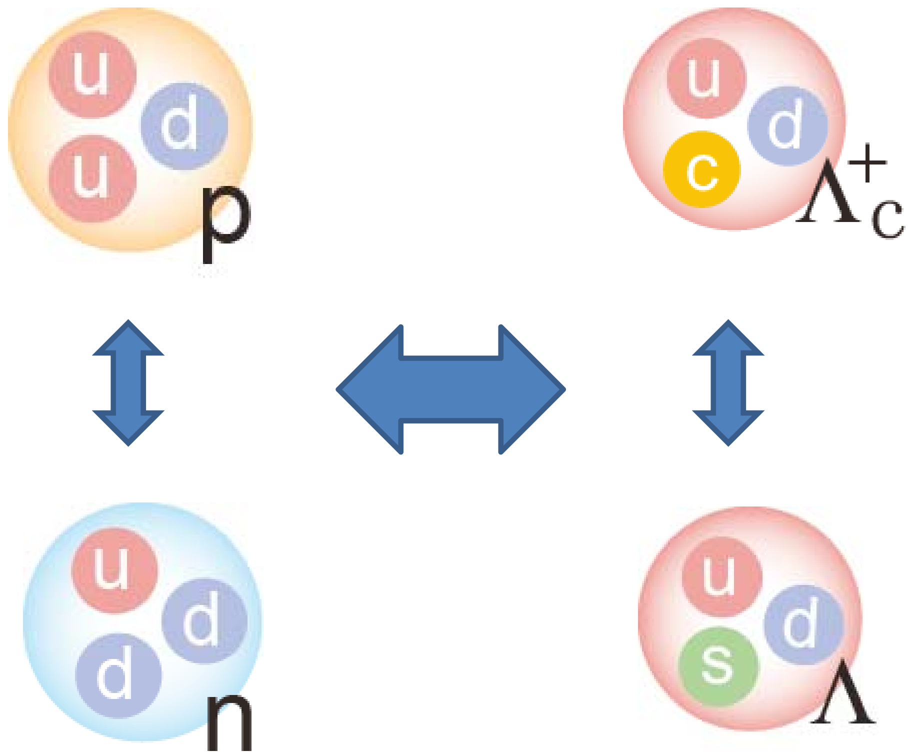


Averaged potential energy is 70% as much as usual nucleon.
LS interaction is 1/10 as small as nucleon.



?

Compare "difference between proton and neutron "
with "difference between Λc and Λ"



"the difference between proton and neutron"
must be same as "the difference between Λc and Λ"

Constraints on theory

Charmed nuclei (theories)

- C.B.Dover, S.H.Kahanna PRL 39('77) 1506
- S.Iwao. Lett. Nuov. Cim., 19('77) 647
- R.Gotto, F.Paccanoni. Nuov. Cim. A46('78) 313
- K.N.Kolesnikov et al., Yad. Fiz., 34('81) 957
- G.Bhamathi. PR C24('81) 1816
- H.Bando, M.Bando. PL B109('82) 164
- H.Bando, S.Nagata. PTP 27('83) 557;
  H.Bando. PTP Suppl. 81('85)197
- B.F.Gibson et al., PR C69('83) 2085
- Y.Yamamoto. PTP 75('86) 639

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~20 years

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- K.Tsushima, S.H.Kahanna PR C67('03) 015211; PTP Suppl 149('03) 160
- Y.-H.Tan et al., Commun. Theor. Phys. 40('03) 473; PR C70('04) 054306

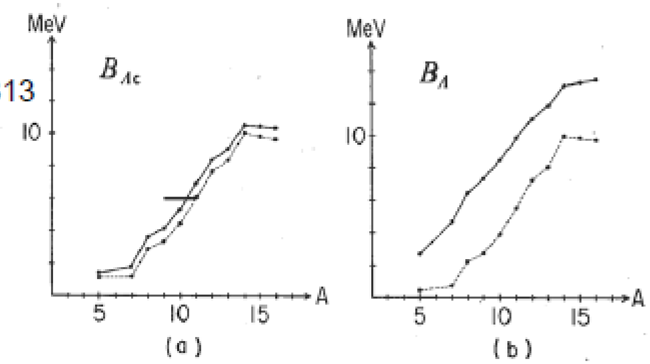


Fig. 4. In (a) part the calculated values of B_{Λ_c} are shown by solid lines. The dotted lines are obtained fixing the density-dependence of the Λ_c-nucleus potential at normal density. The horizontal line indicates the experimental value assumed $^{9-11}_{\Lambda_c}C$. In (b) part those of B_Λ are shown correspondingly for comparison.

Y.Yamamoto. PTP 75('86) 639

Dec.24,2004 Few Body Prof. Nakazawa's file

Existence of charmed nuclei

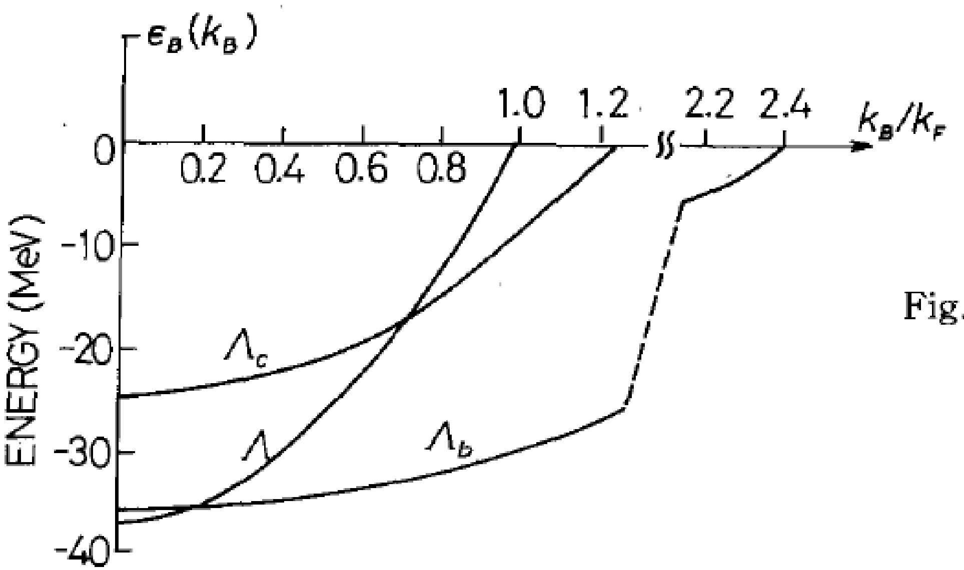
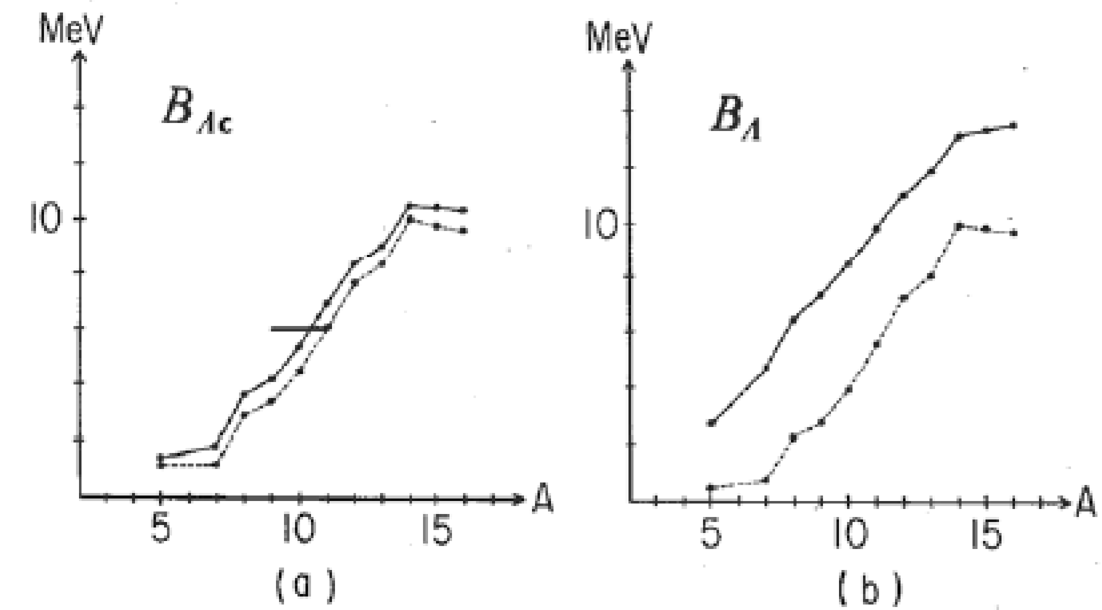


Fig. 3. Single-particle energies $\epsilon_B(k_B)$ for $B=\Lambda$, Λ_c and Λ_b drawn against the baryon momentum k_B divided by the Fermi momentum of nuclear matter ($k_F=1.35$ fm^{-1}).

Flavor Nuclei and One-Boson-Exchange Potentials
H.BANDO and S.Nagata
Progress of theoretical physics Vol.69, No.2 Feb 1983

binding energy of Λ and Λc



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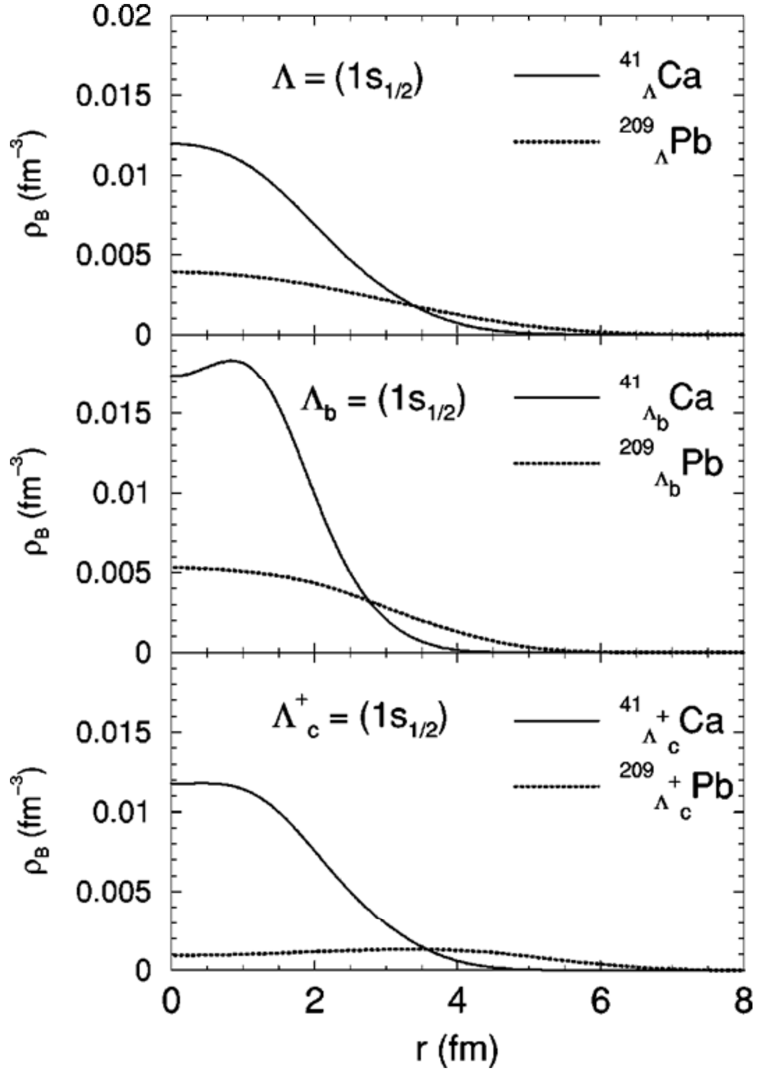
Y.Yamamoto. PTP 75('86) 639

Density



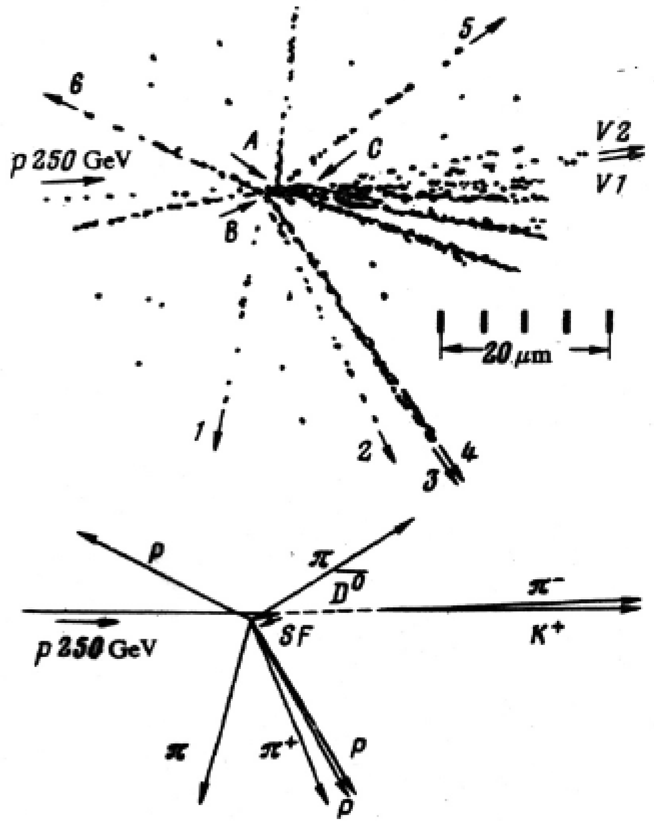
Quark-Meson Coupling(QMC) model

baryon (probability) density

Charmed nuclei (experiment)

An experimental result was reported

A.A.Tyapkin Yad.Fiz 22('75)181
250GeV/c proton ➔ emulsion
at FNAL



p + Emulsion ➔ "Charmed HY" + $\overline{D}^{0}$ + X
|➔ $K^{+}\pi^{-}$

Interpretations

① ${}^{4}_{\Lambda_c^+}$Be ➔ $\Lambda^{o}{}_{s}\,\pi^{+}\pi^{+}\pi^{-}\,p\,p\,p$

($\Lambda^{+}{}_{c}$ ➔ $\Lambda^{o}{}_{s}\,\pi^{+}\pi^{+}\pi^{-}$)

Bc = 0 ~ 10 MeV

② ${}^{4}_{\Lambda_c^+}$He ➔ $\Lambda^{o}{}_{s}\,\pi^{+}\pi^{+}\pi^{o}\,p\,p\,p$

($\Lambda^{+}{}_{c}\,n$ ➔ $\Lambda^{o}{}_{s}\,p\,\pi^{+}\pi^{+}\pi^{o}$)

⊕ $\pi^{o}n$ ➔ $\pi^{+}p$

Bc = 0 ~ 10 MeV

③ ${}^{6+k}_{\Lambda_c^+}$C ➔ $\Lambda\,s\,\pi^{+}\,\pi^{+}\,\pi^{+}\,ppp\,nn + kn\ (k>=1)$

($\Lambda^{+}{}_{c}\,p$ ➔ $\Lambda^{o}{}_{s}\,n\,\pi^{+}\pi^{+}\pi^{o}$)

⊕ $\pi^{o}\,p$ ➔ $\pi^{+}\,n$

Bc = ?

Dec.24,2004 Few Body Prof. Nakazawa's presentation

Magic momentum to produce $\Lambda^{+}{}_{c}$ at rest

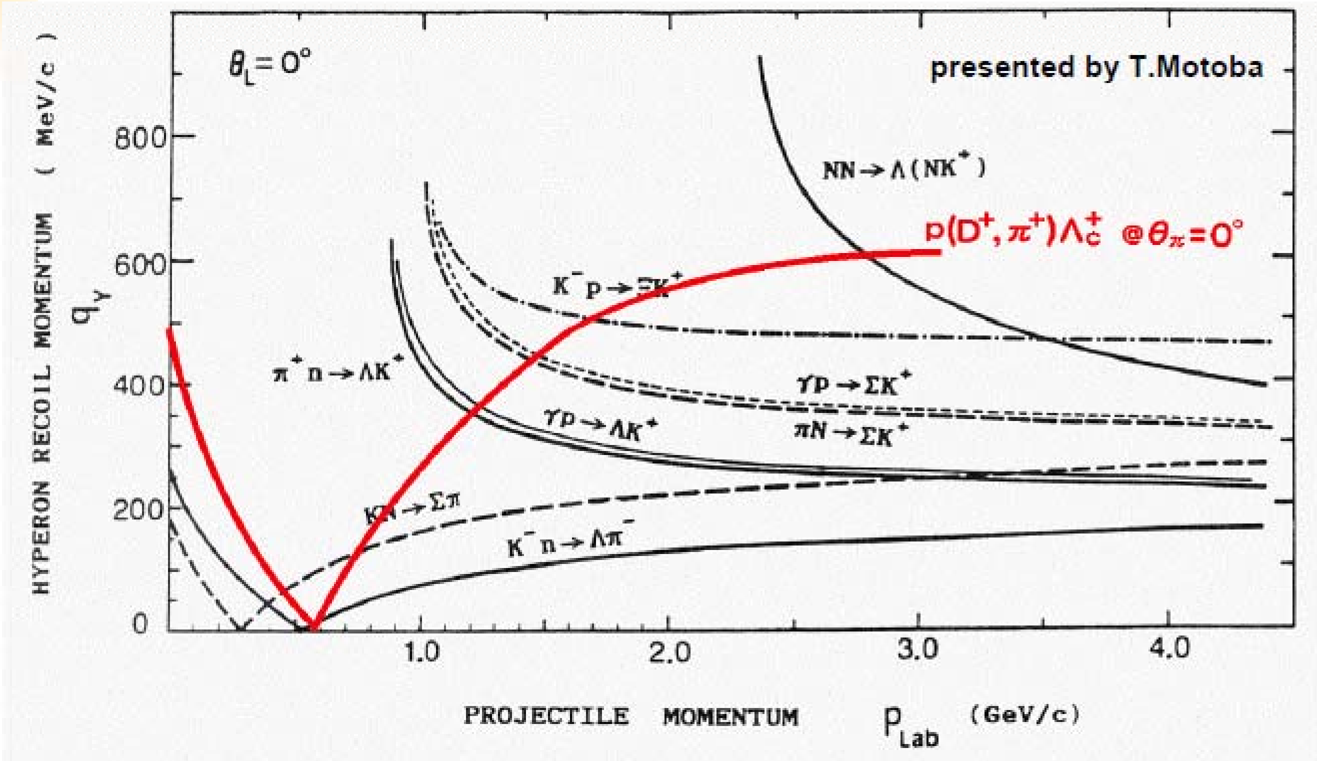
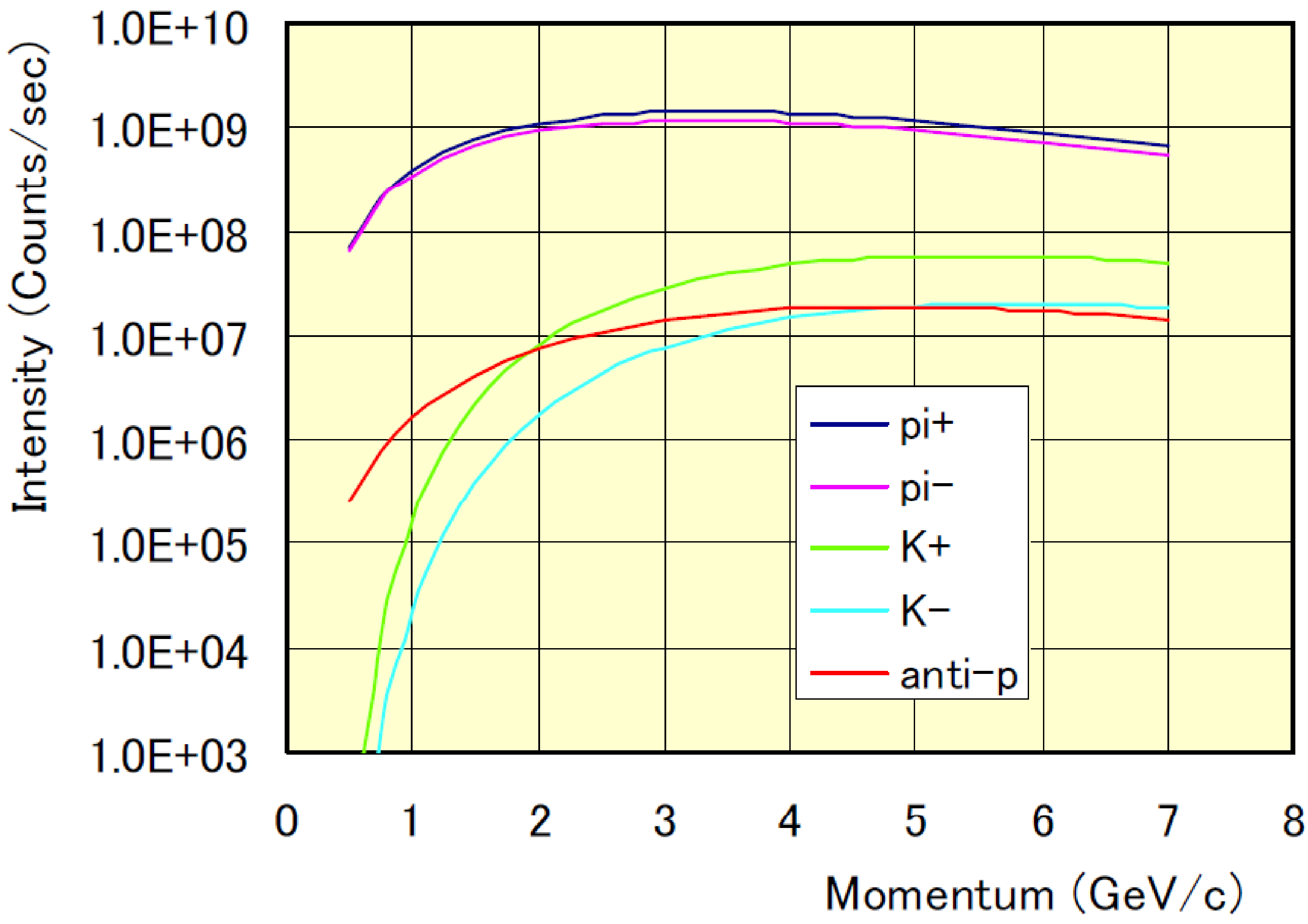


Fig. 2.3. The momentum q_Y transferred to the hyperon Y as a function of the projectile momentum $p_{\rm proj} = p_a$ in the reaction $aN \rightarrow Yb$ at $\theta_{b,L} = 0°$.

Using ν_μ beam, measure $\sigma_{\rm Int.}$ of $D^{+/-}$ to *p* & *n*.

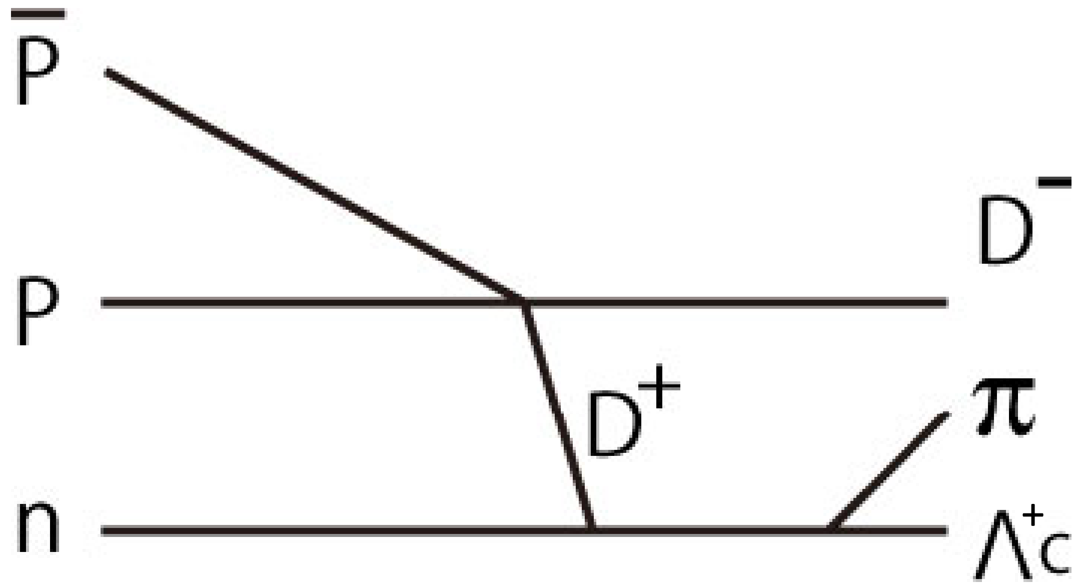
P bar beam

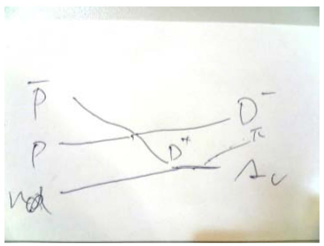


50GeV-15μA、Ni-54mm、BL-Length=50 m、Acceptance:2msr%

「ストレンジネスで探るクォーク多体系」Prof Noumi’s slide

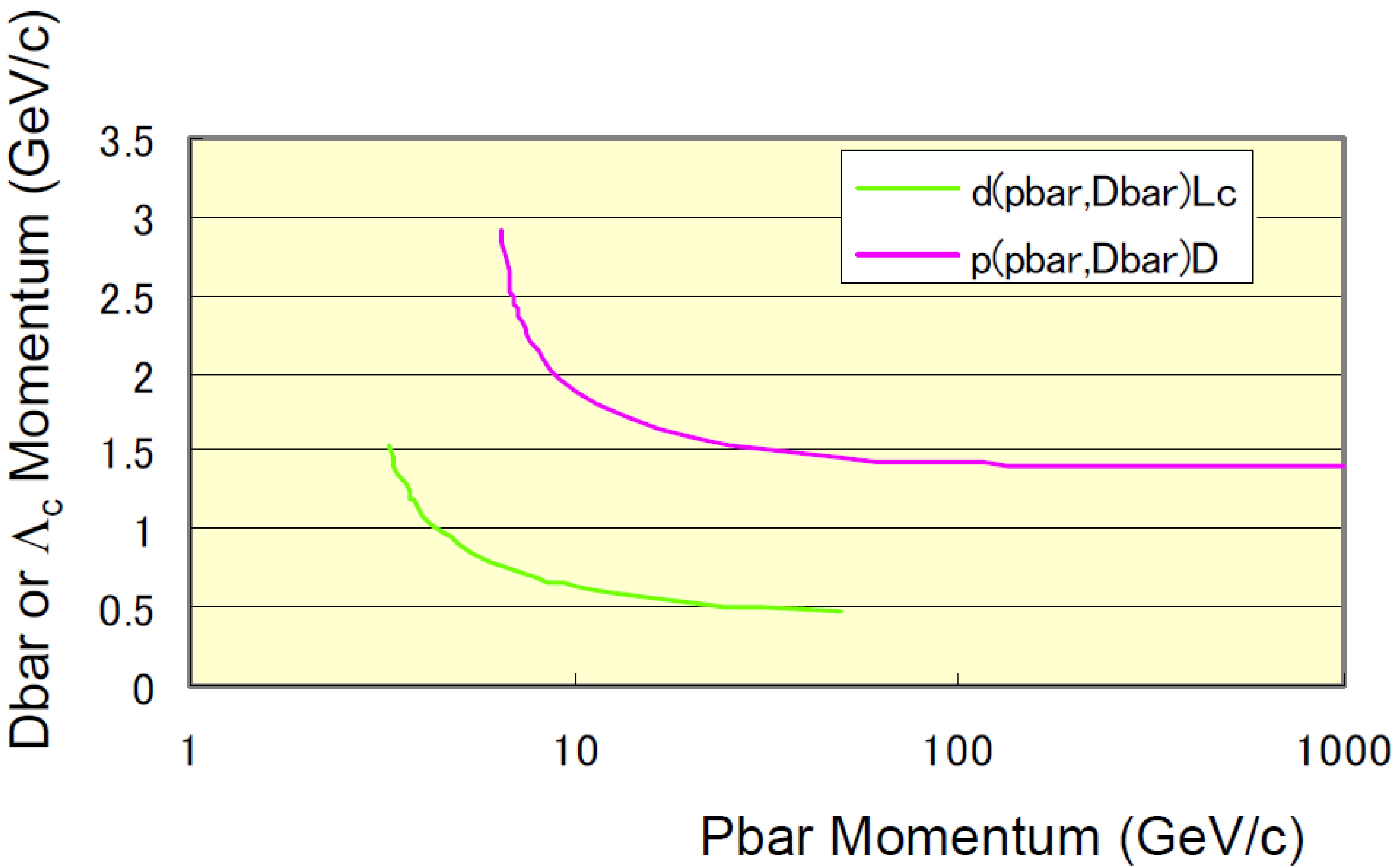
The diagram to generate Λc





Prof. Noumi's drawing
(Private communication)

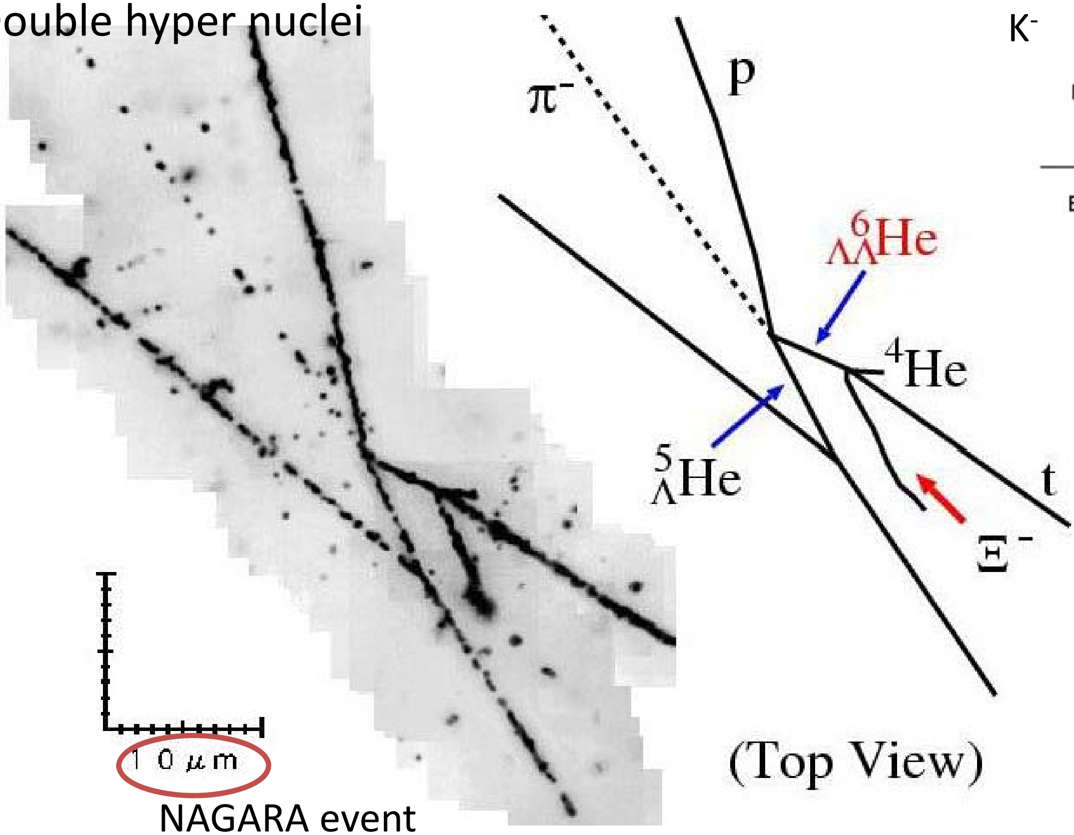
Λ_c^+ $\tau = (0.206 \pm 0.012) \times 10^{-12}$
$c\tau = 61.8\ \mu m$



「ストレンジネスで探るクォーク多体系」Prof. Noumi's Slide

detectors　KEK-PS-E373

Double hyper nuclei

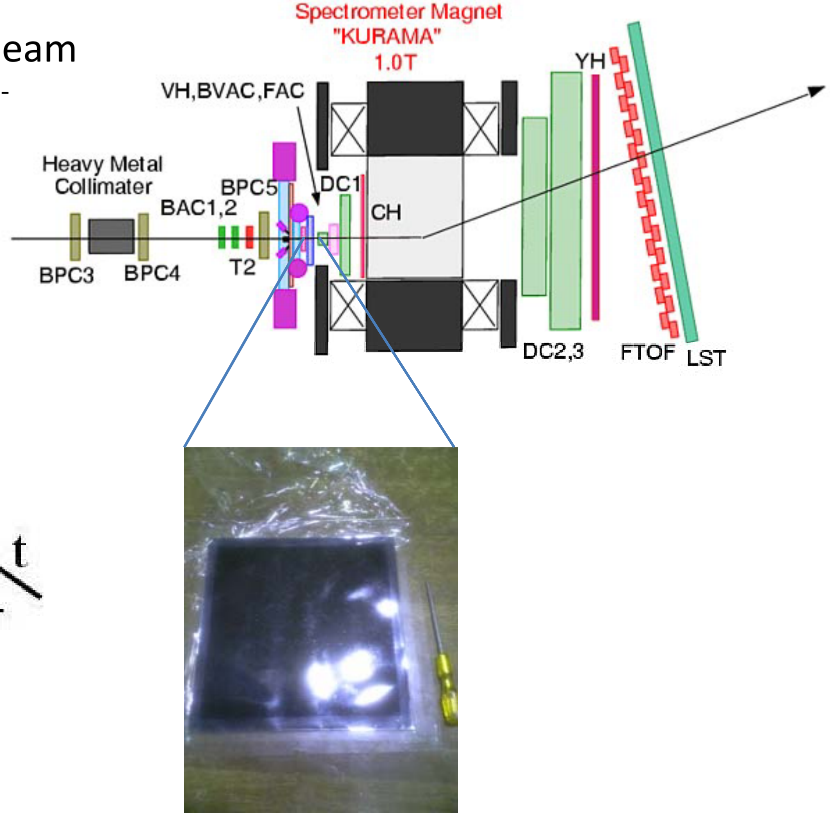


NAGARA event

Method:　hybrid scan

Beam

K⁻



General scan

1)Beam

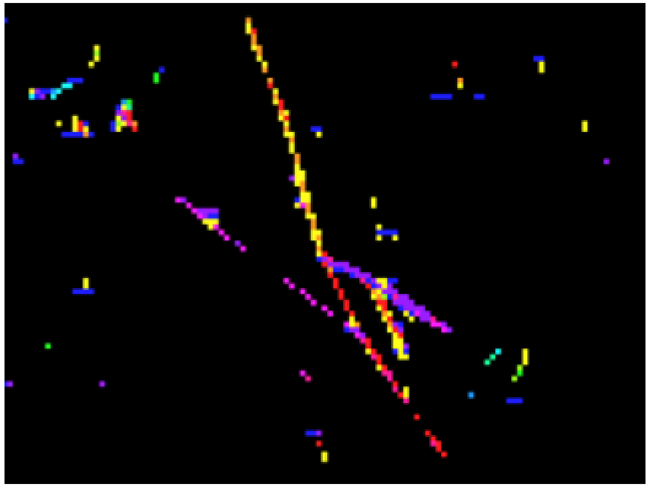
2)Target

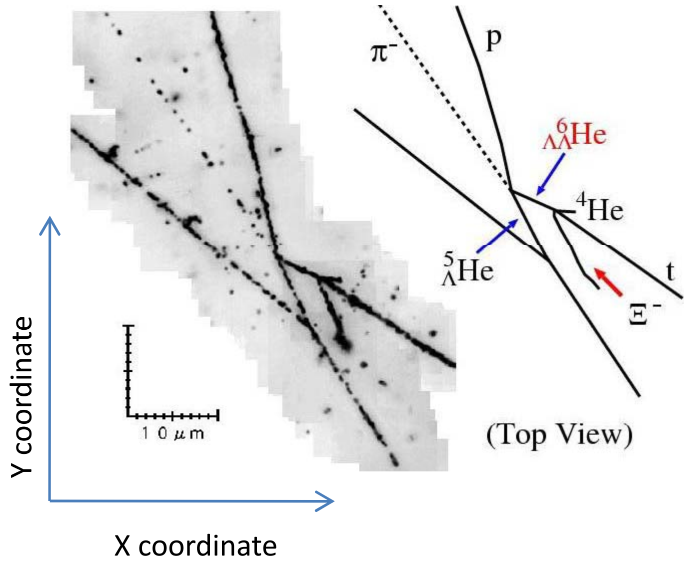
3) emulsion

The position resolution of nuclear emulsion is 1μm　Very good

Example NAGARA event

Reconstruction in 3 Dimension from tomographic image



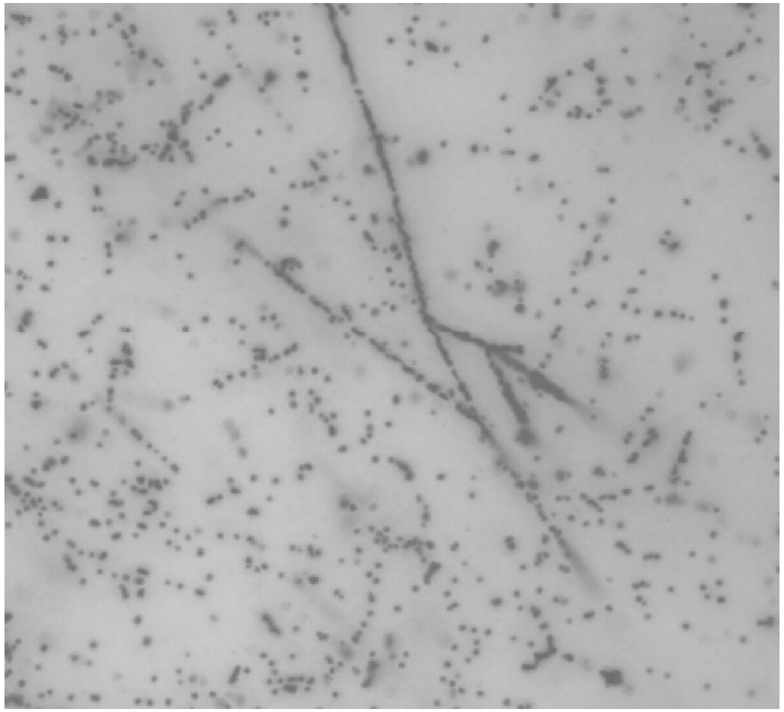


From pixel to voxel

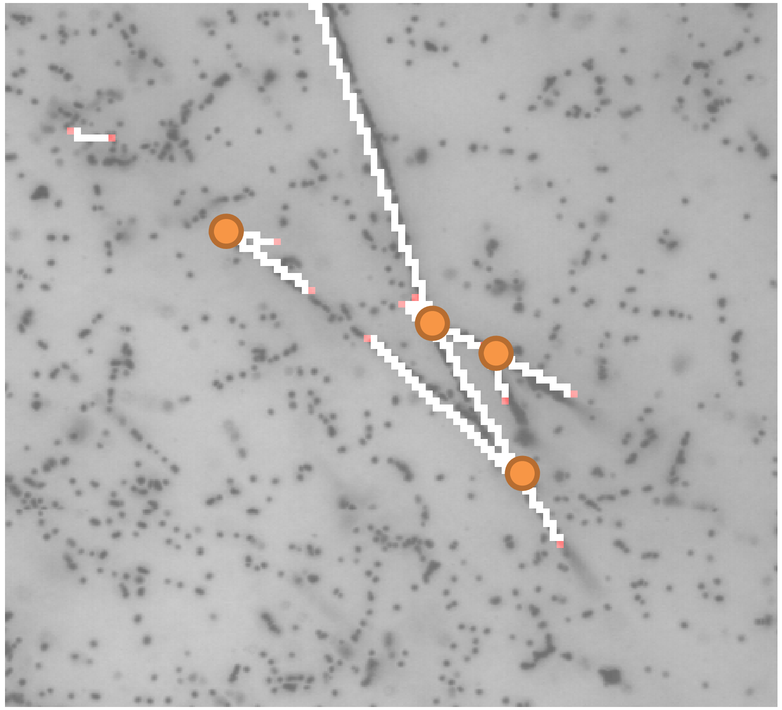
The scale of Z is different from「x・y」

Pixel is abbreviation of pictures cell
Voxel is volume pixel

Find a vertex



Three vertices

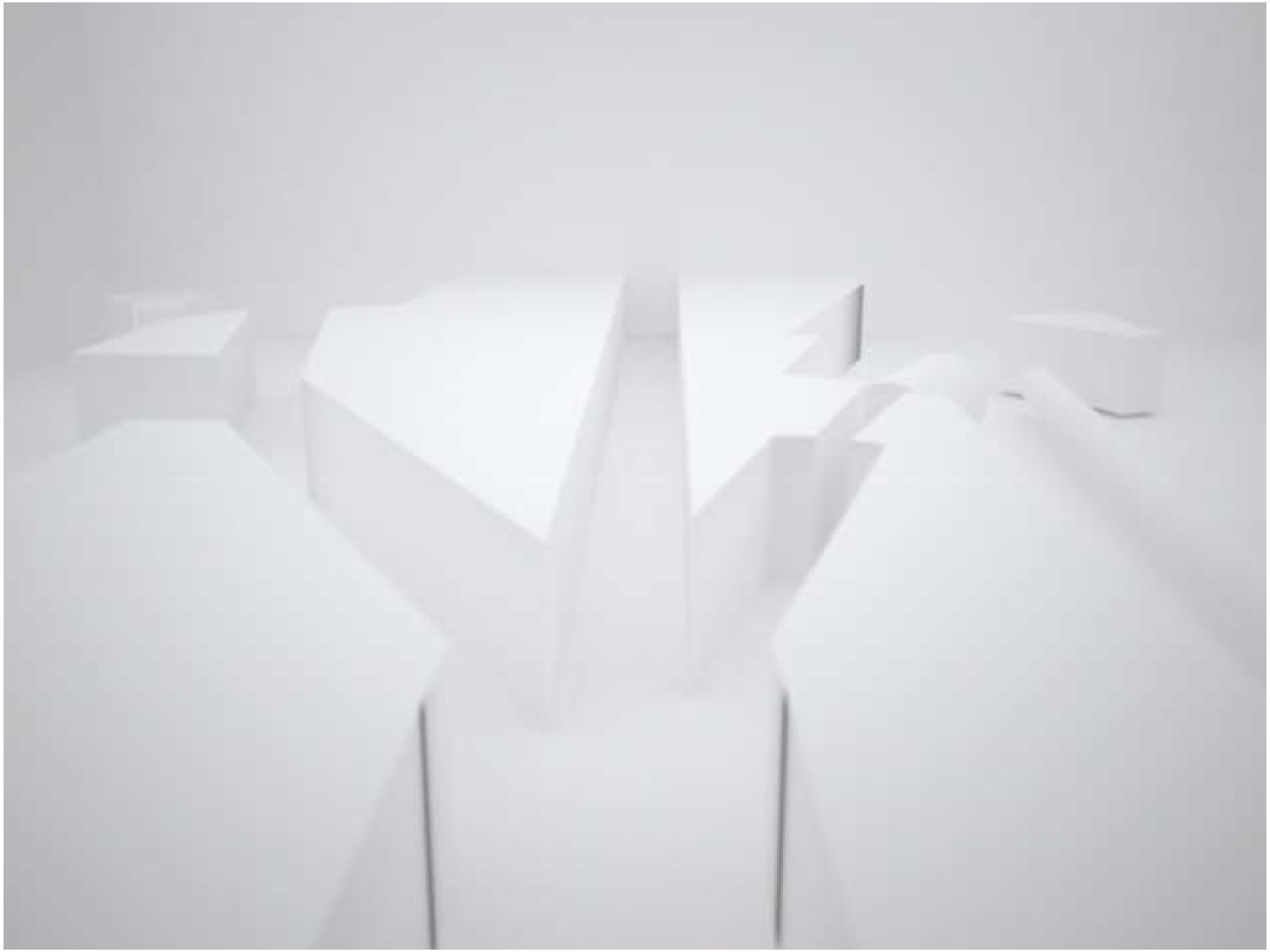


The first algorithm to find a vertex in nuclear emulsion is established.

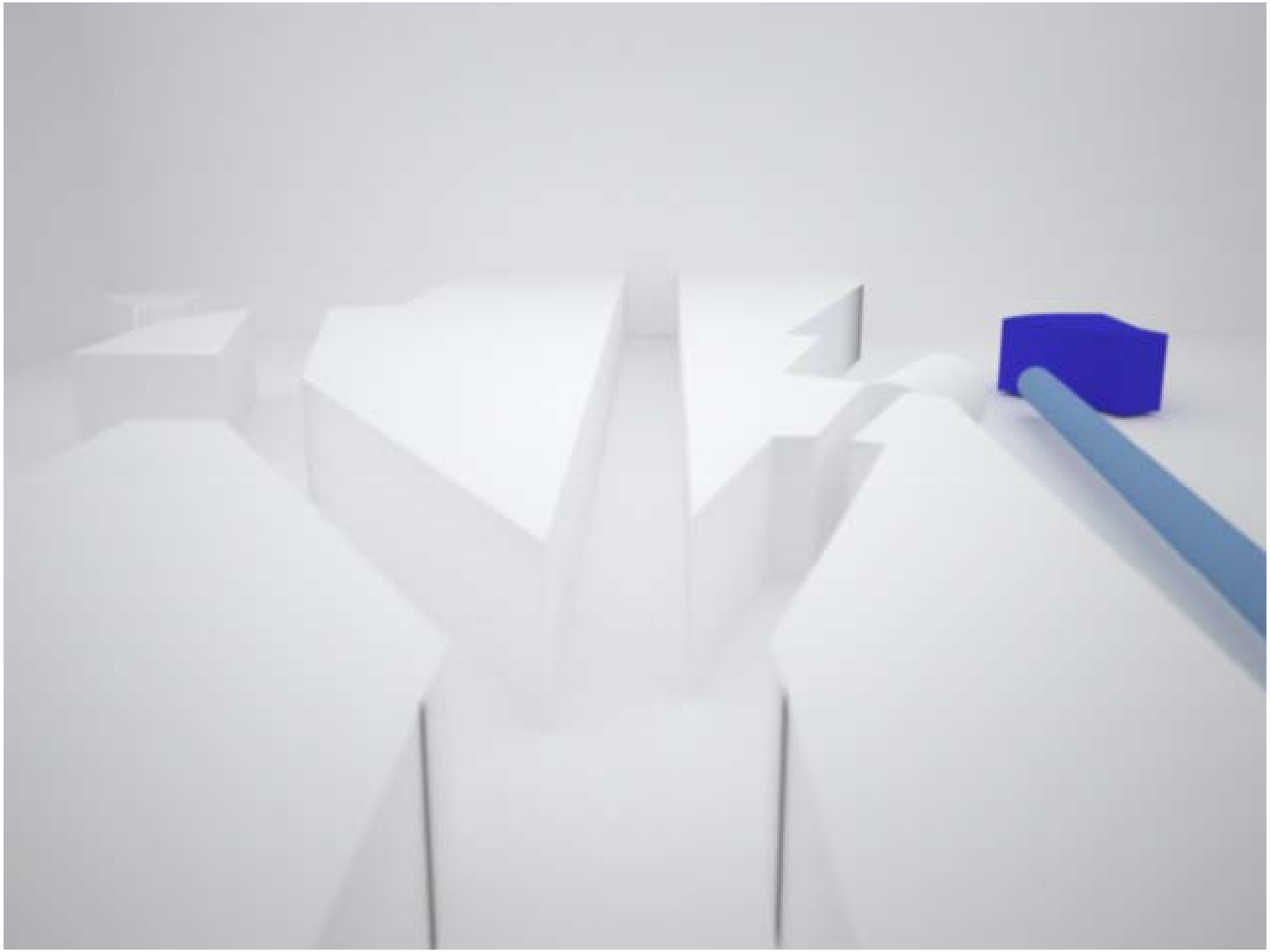
NAGARA event can be found.

J-PARC hadron hall

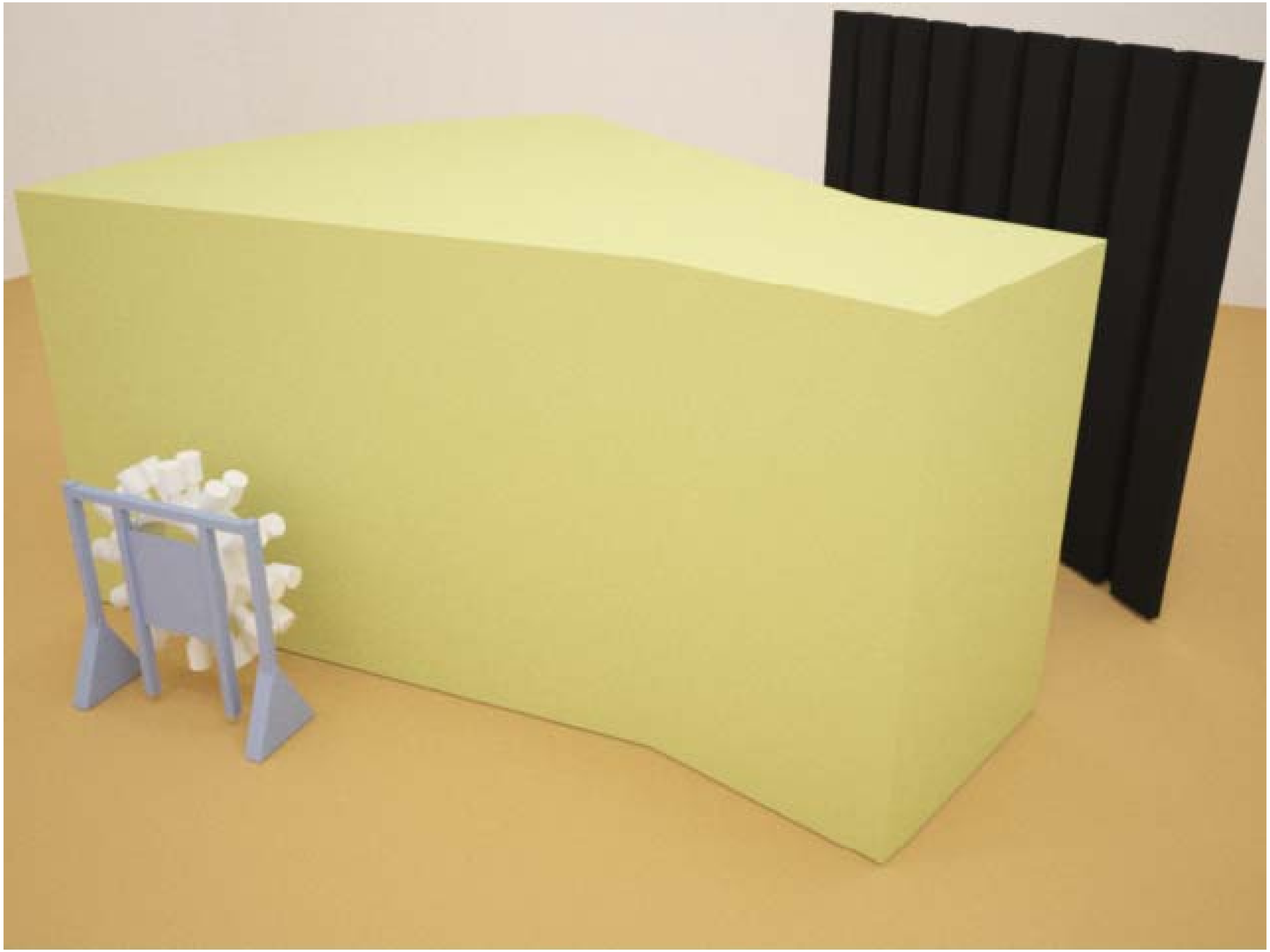
J-PARC hadron hall



J-PARC hadron hall（high momentum line）



design of detectors(very preliminary)



summary

- An experiment of searching for Super nuclei(charm) is being prepared at J-PARC experiment.
- Emulsion is a key detector.