

A02

中性子過剰核物質中のストレレンジネス

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味村周平(RCNP)、福田共和(大阪電通大)、

鈴木隆敏(東大)

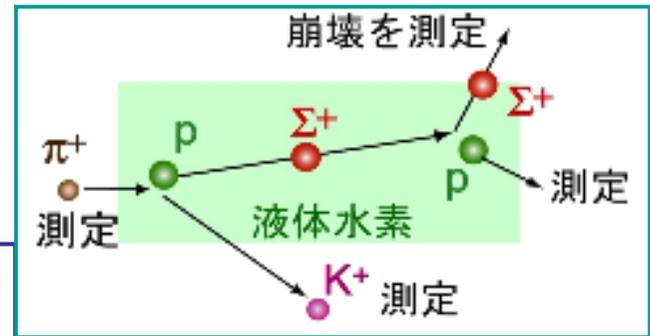
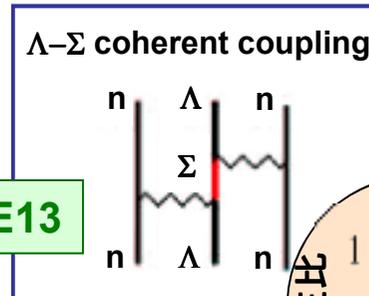
A02 中性子過剰核物質中のストレンジネス

代表者・分担者

ストレンジネスが現れだす $\rho=2\sim 3\rho_0$ 領域の
ハイペロン混合を決定する

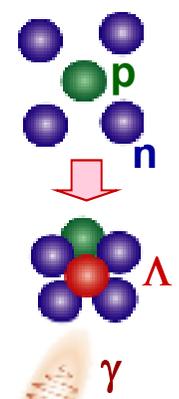
(1) Σ^+p 散乱実験 三輪、田村

-> $\Sigma^-n (= \Sigma^+p)$ 相互作用 E40
=> Σ^- が中性子星に存在するか確定



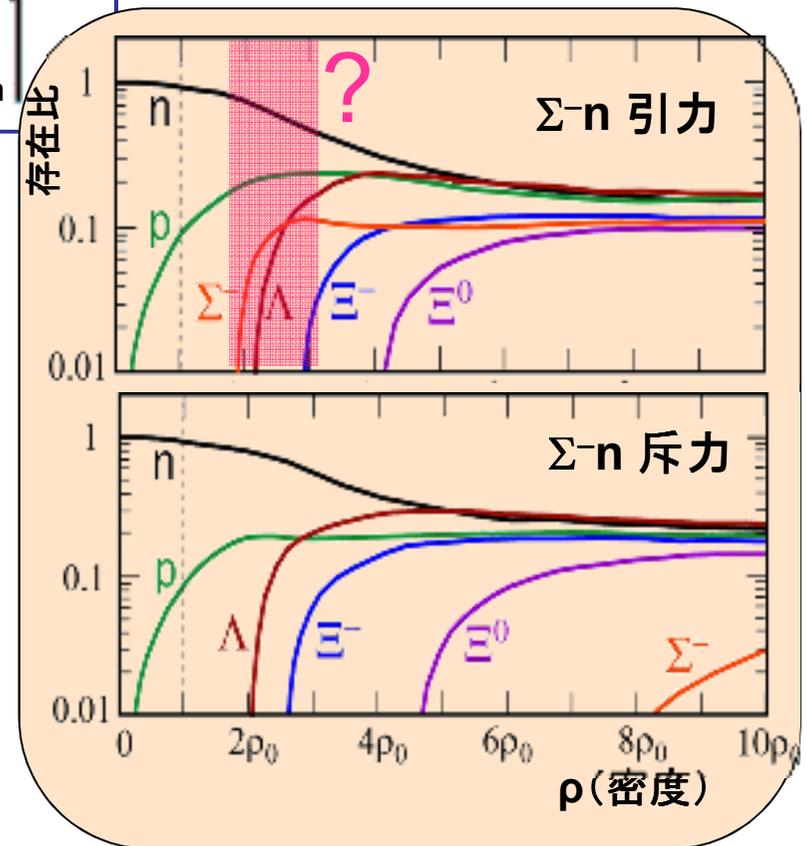
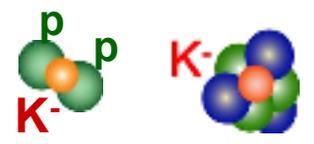
(2a) Λ ハイパー核ガンマ線分光 小池、鶴養、田村 E13

-> $\Lambda N, \Lambda NN$ 相互作用の詳細
(2b) 中性子過剰 Λ ハイパー核分光 阪口、味村、福田 E10
-> 中性子過剰環境での Λnn 相互作用
=> 中性子星中の Λ 粒子の組成比を決定



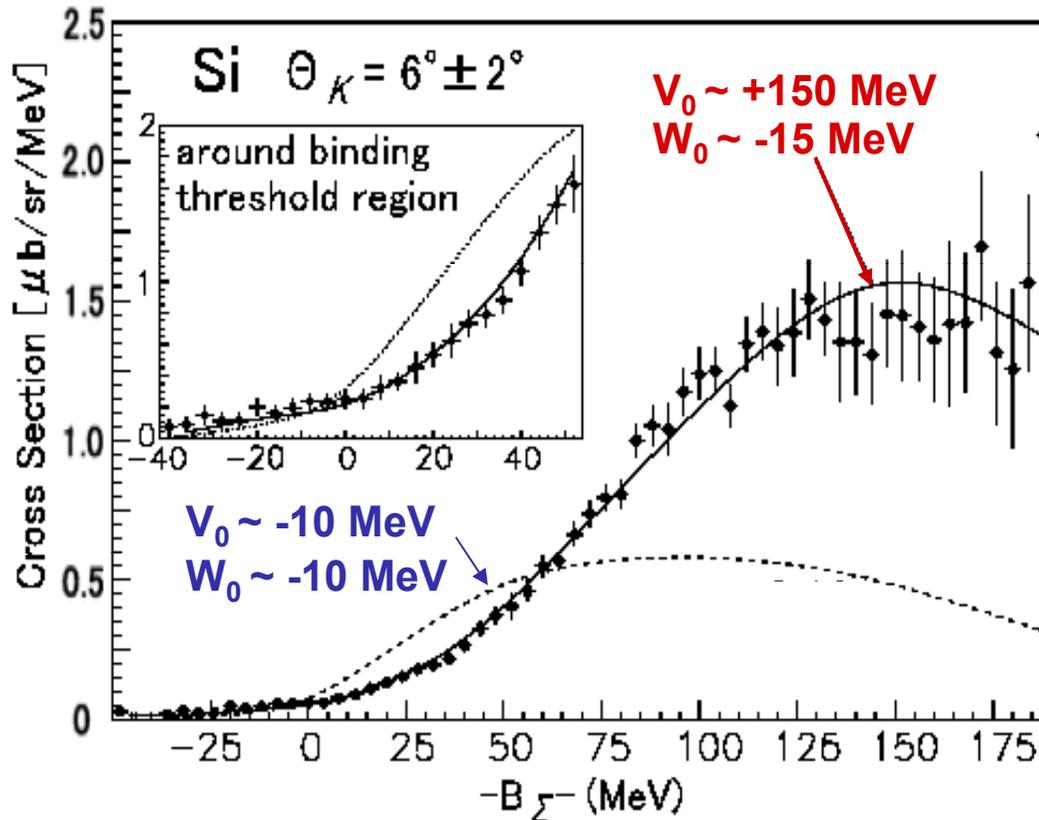
(3) K^- 原子核束縛状態 應田、鈴木
-> $K^{\text{bar}}N$ 相互作用 E15

=> K^- 中間子が中性子星に存在するかを確定



Σ^- - ^{28}Si Nuclear potential (KEK E438)

^{28}Si (π^- , K^+) at 1.2 GeV/ with SKS



Noumi et al., PRL 87(2002) 072301

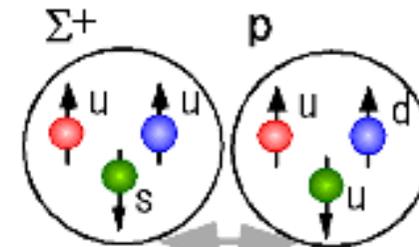
Strongly repulsive potential ($U_\Sigma \sim +30 \text{ MeV}$)

How repulsive are

$(I, S) = (3/2, 1), (1/2, 0)$ channels?

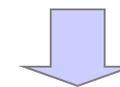
■ Strong repulsion coming from Pauli effect between quarks?

Quark Cluster Model
Lattice QCD



$$\Sigma N (I, S) = (3/2, 1)$$

■ Σ 's never appear in n-stars?



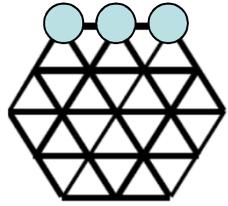
High statistics

Σ^+p / Σ^-p scattering experiment
planned at J-PARC (E40)

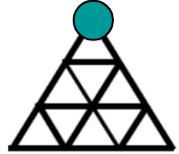
Baryon *The same behavior was already predicted by Oka-Yazaki's Quark Cluster Model*

• 6

$8 \otimes 8 =$



(27)



(10*)



(10)



(8s)



(8a)



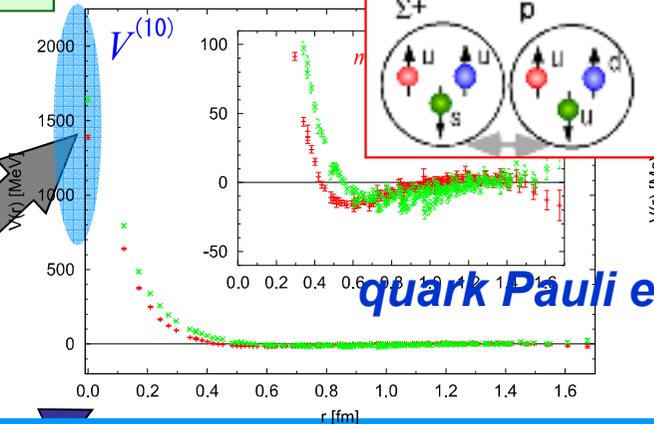
(1)

Lattice QCD,
T. Inoue et al.

Prog. Theor. Phys. 124 (2010) 4

E40

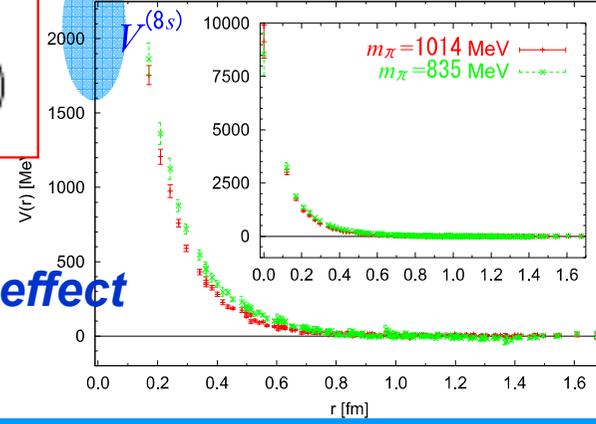
$\Sigma^+ p$ (S=1, T=3/2)



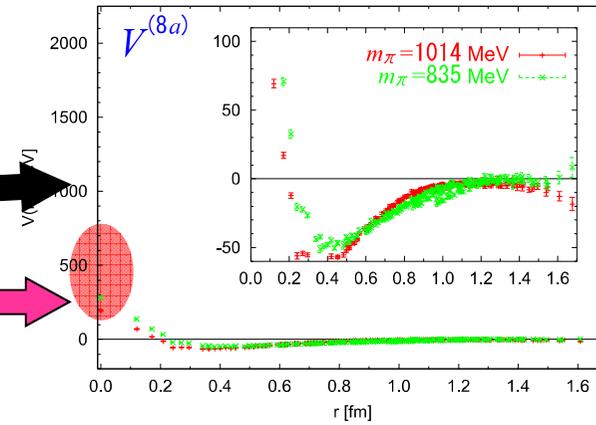
quark Pauli effect

Strong repulsive core

$\Sigma^- p$ (S=0, T=1/2)

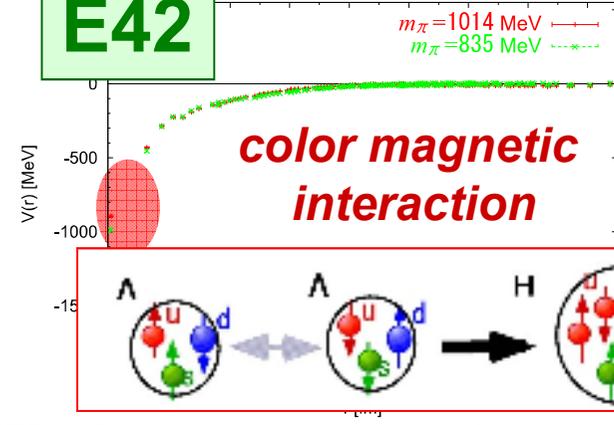


$\Xi^- p$ (T=0)



$\Xi^- p$ singlet (H-Channel)

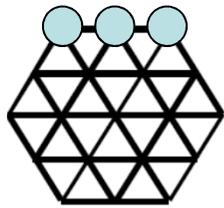
E42



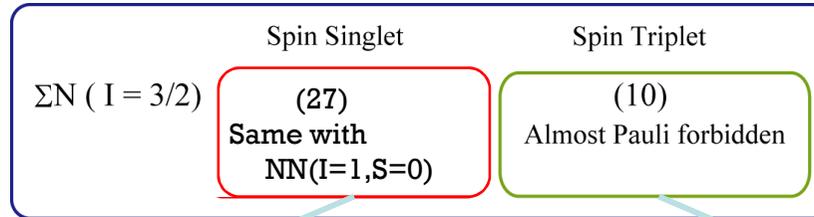
color magnetic interaction

Weak or attractive Core

Repulsive force in Σ^+p ($=\Sigma^-n$) channel



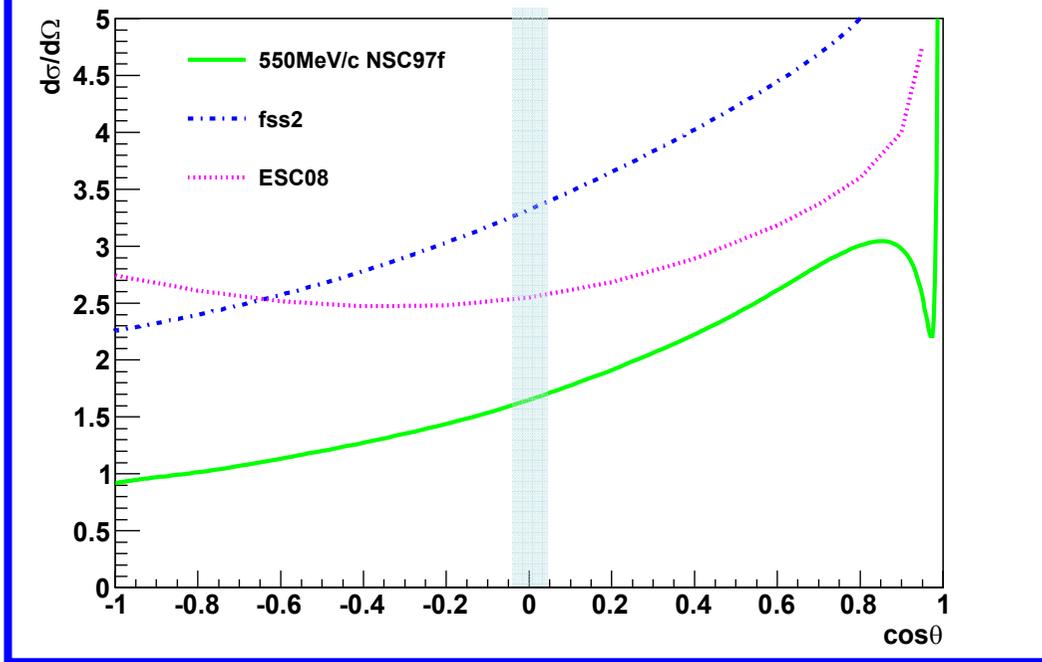
(27)



(10)

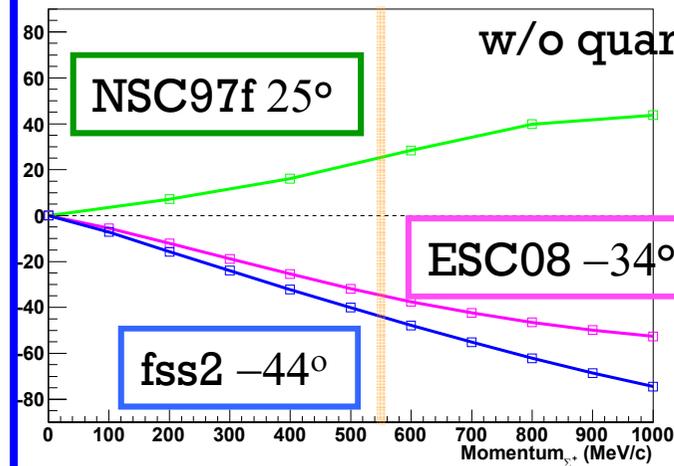
Spin weight: 3/4

Σ^+p $d\sigma/d\Omega$ ($p = 550$ MeV/c)



δ of Σ^+p scattering (Reliable !)

Phase shift of Σ^+p (3S_1 channel)



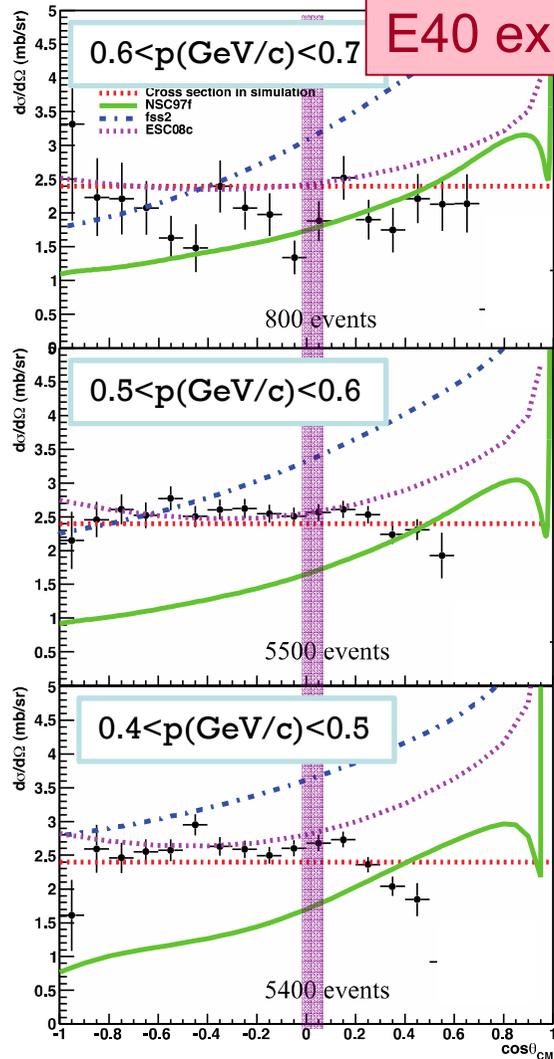
w/o quark Pauli

w/ quark Pauli

We will determine δ in 3S_1 channel.

Phase shift of 3S_1 channel

$d\sigma/d\Omega$ Σ^+p scattering



- Energy dependence of δ_{3S1} from $d\sigma/d\Omega(90^\circ)$

Negligibly small

Almost model-independent

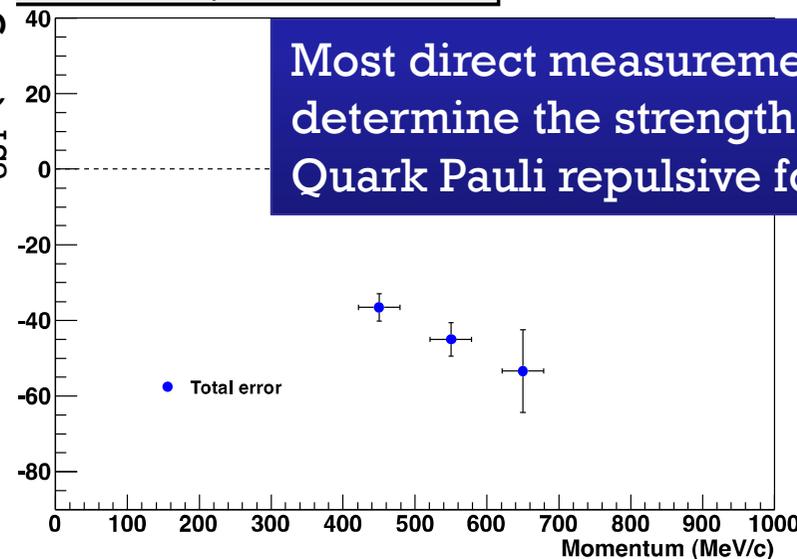
$$\frac{d\sigma}{d\Omega}(90^\circ) = \frac{1}{4} \frac{1}{k^2} \sin^2 \delta_{1S0} + \frac{3}{4} \frac{1}{k^2} \sin^2 \delta_{3S1} + (\text{higher waves, etc})$$

Phase shift δ_{3S1} (degree)

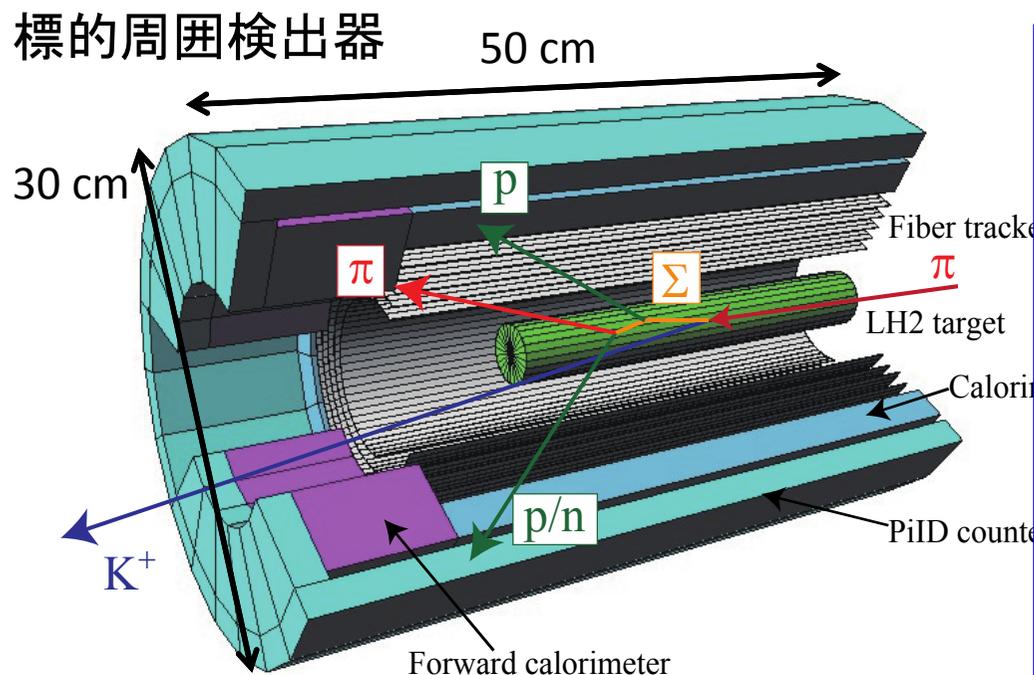
Phase shift of 3S_1 state in Σ^+p channel

E40 expected

Most direct measurement to determine the strength of Quark Pauli repulsive force

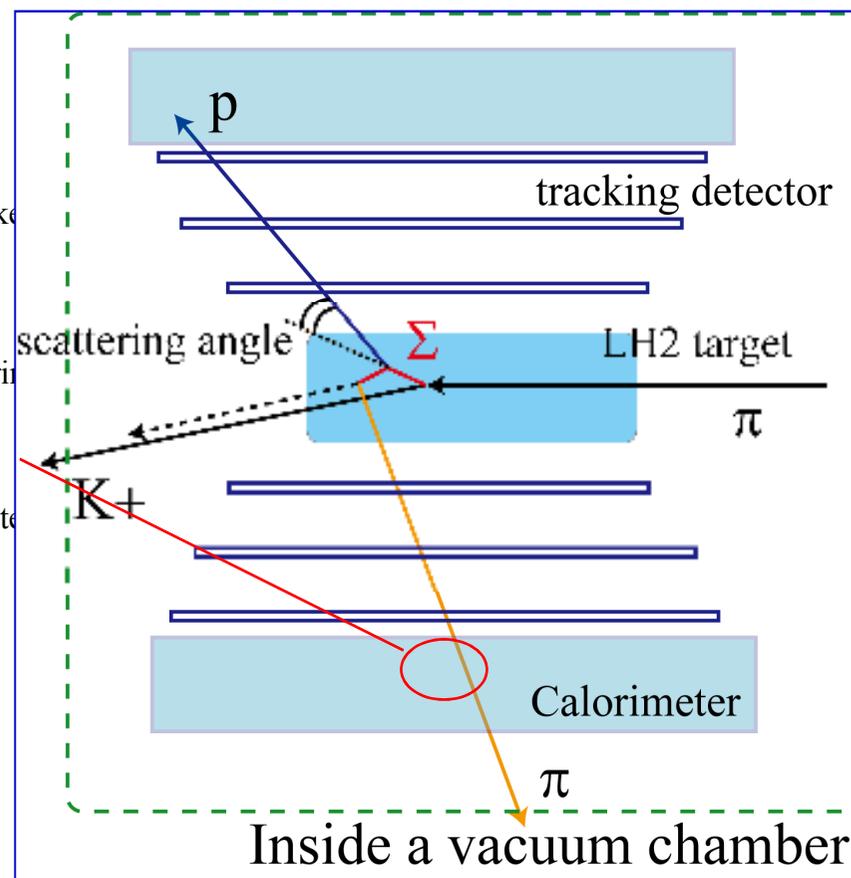


$\Sigma^\pm p$ 散乱実験 (E40)



- Fiber tracker (高速のMPPC読出し)
 - 10 layer (ϕ 方向+u,v方向のセットを5層)
- カロリメーター(BGO)
- 液体水素標的

(K^-, π^\pm)反応の測定 \rightarrow Σ の運動量ベクトル
 散乱陽子、 Σ 崩壊粒子(π/p)の角度, E, ΔE



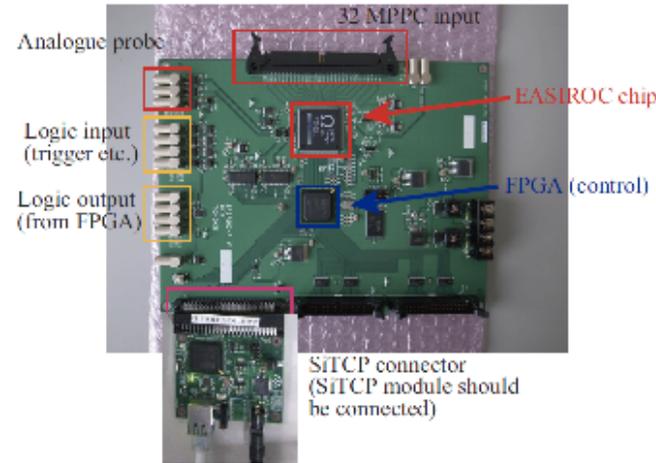
JPARC K1.8 beam line + SKS

開発した Fiber Tracker + 読出し回路系

MPPCを用いた世界初の超高速(~100倍) 飛跡検出器



K1.8ラインで使用

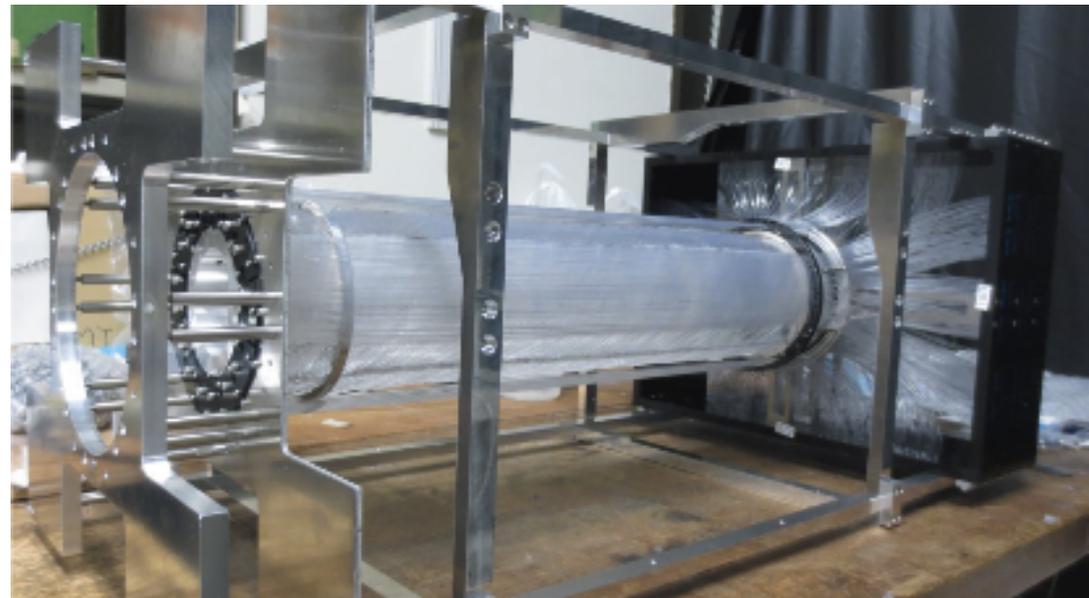


位置分解能
~ 250 μ m (FWHM)

時間分解能
< 1ns (FWHM)

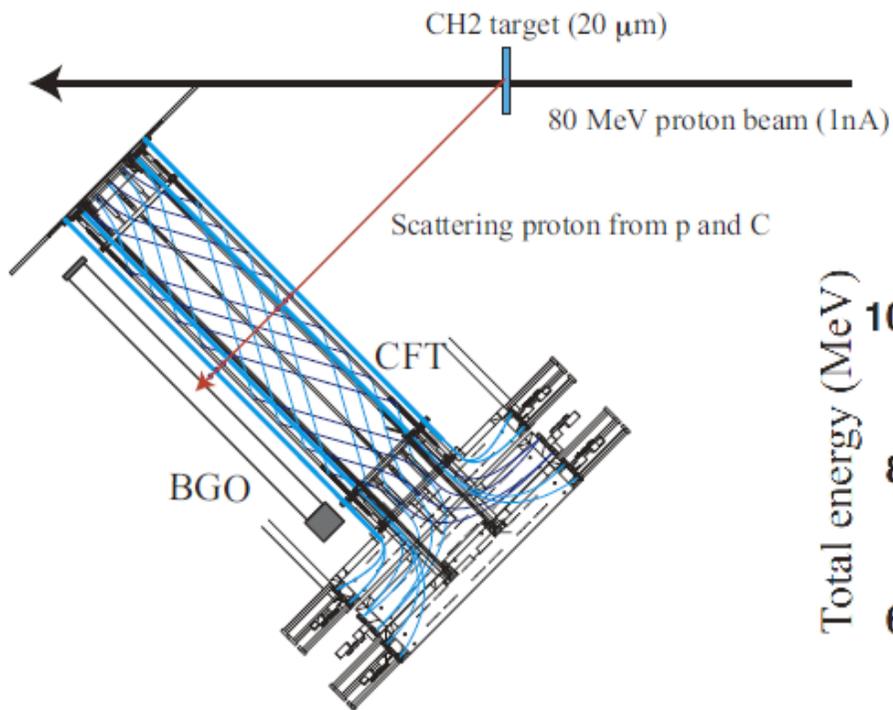
=>

使用可能なビーム強度
1x10⁶/spill -> 32x10⁶/spill

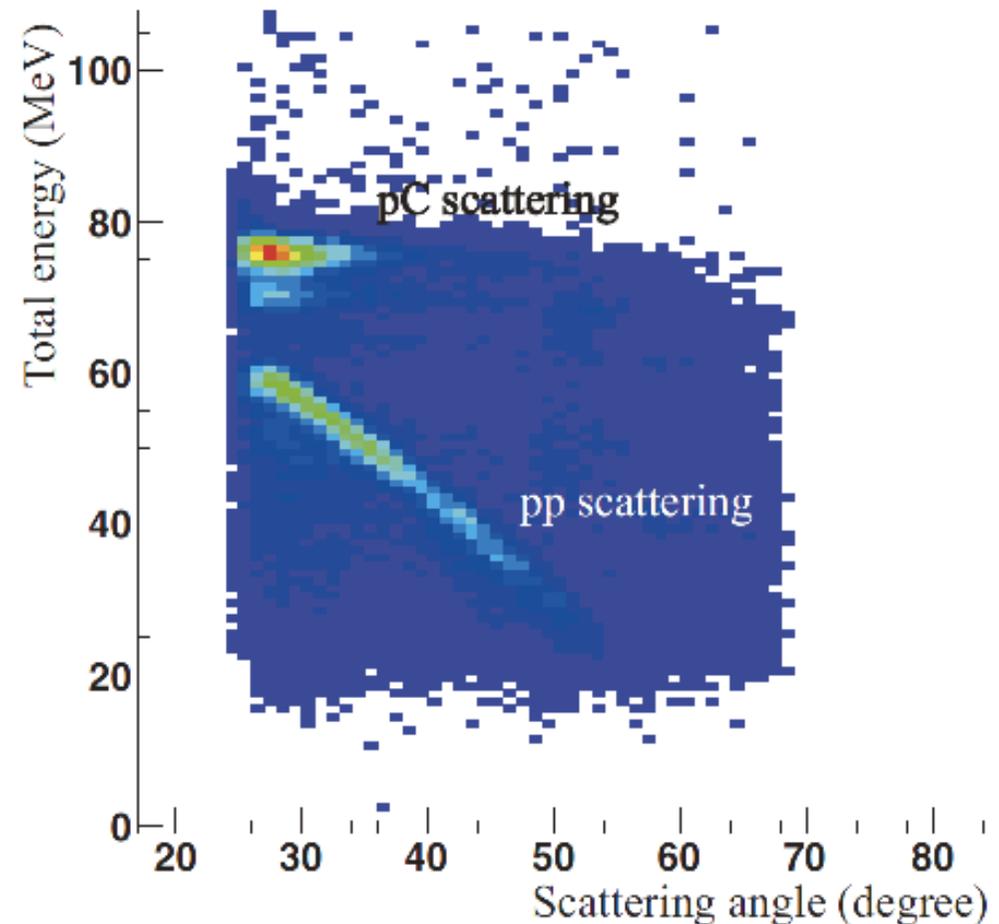
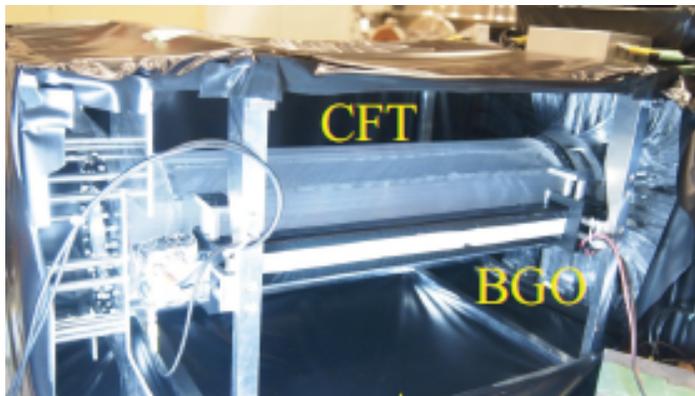


BGOカロリメータ+Fiber Trackerのテスト実験

@東北大サイクロトロン

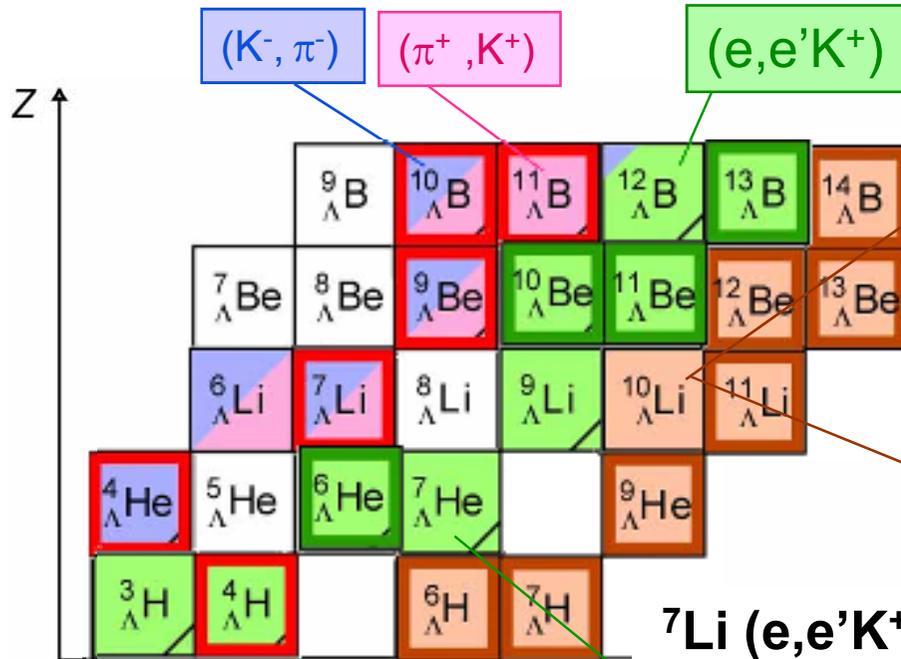


BGO E分解能 < 1.2% for 80 MeV p
CFT ΔE分解能 ~ 10% for p, 16% for π



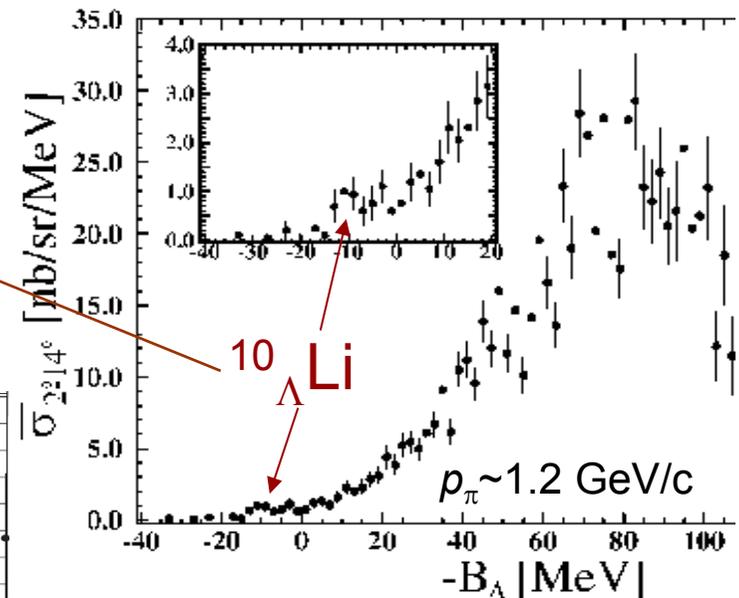
Neutron-rich Λ hypernuclei

$K^- n \rightarrow \Lambda \pi^-$ $\pi^+ n \rightarrow \Lambda K^+$ $e^- p \rightarrow e^- \Lambda K^+$ @JLab



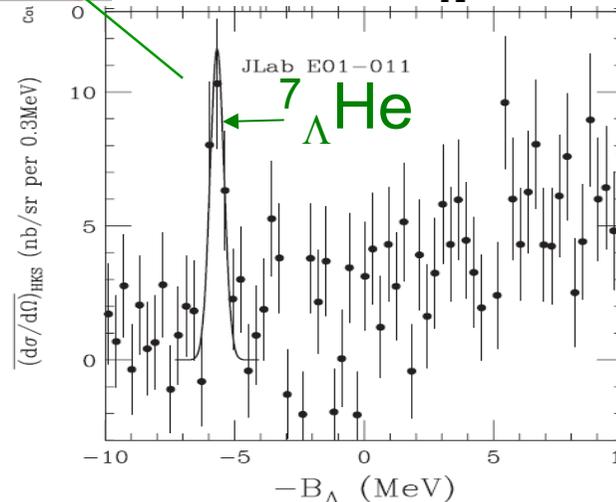
(π^-, K^+) $\pi^- p p \rightarrow \Lambda n K^+$
@KEK, J-PARC

$^{10}\text{B} (\pi^-, K^+) ^{10}_{\Lambda}\text{Li}$



Saha et al.
PRL 94 (2005) 052502

$^7\text{Li} (e, e'K^+) ^7_{\Lambda}\text{He}$



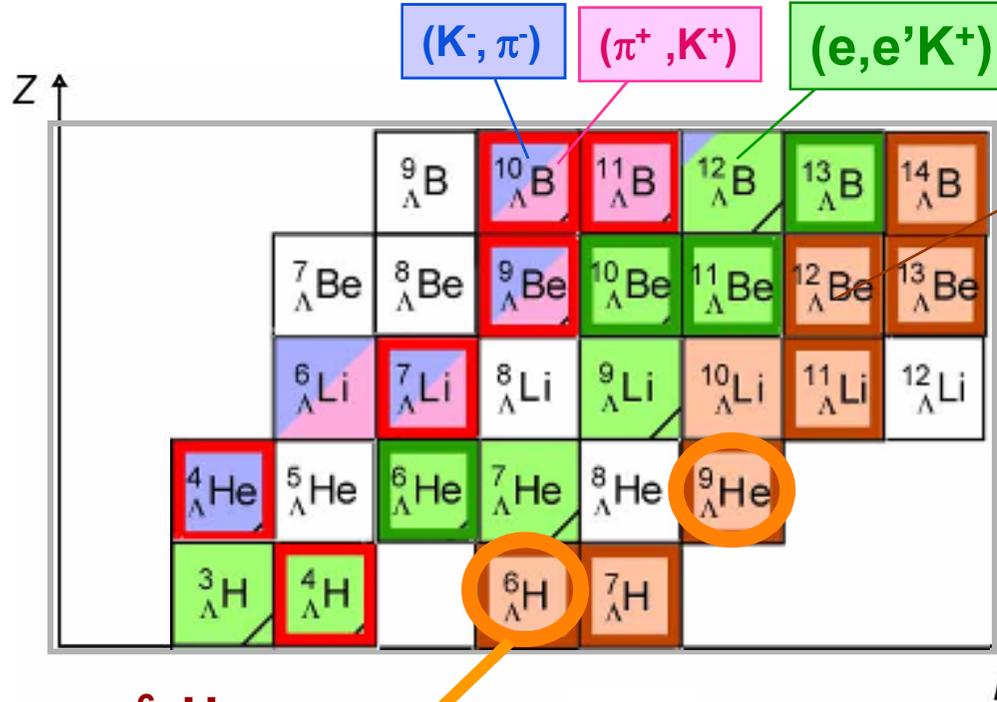
S.N. Nakamura et al.
PRL 110 (2013) 012502

J-PARC E10 (Sakaguchi)

中性子過剰 Λ ハイパー核分光

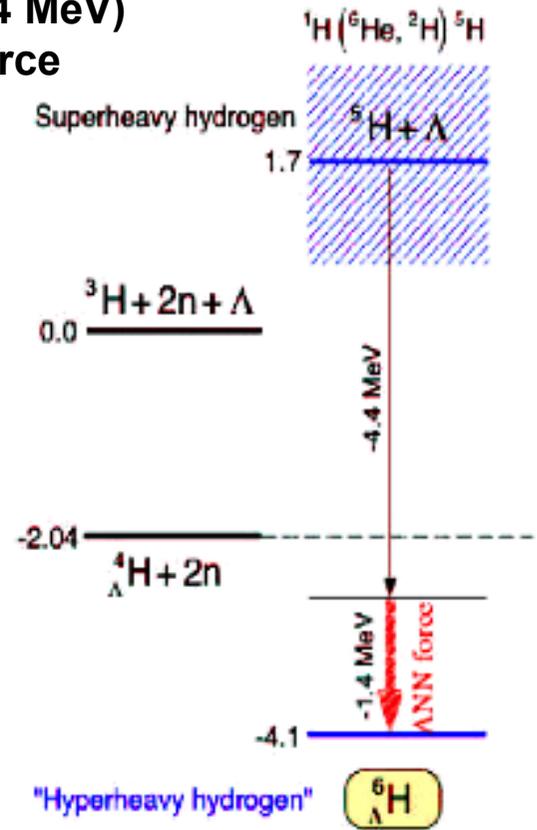
single charge exchange

double charge exchange



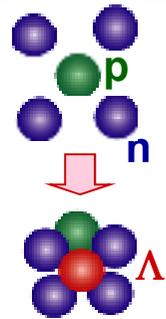
Deeply bound by additional binding (+1.4 MeV) from ΛNN force

Calc. by Akaishi

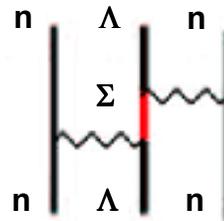


${}^6_{\Lambda}\text{H}$
“hyperheavy hydrogen”

3 events reported in
PRL 108 (2012) 042501



Λ - Σ coherent coupling

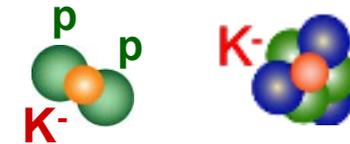


Akaishi et al.,
PRL 84 (2000) 3539

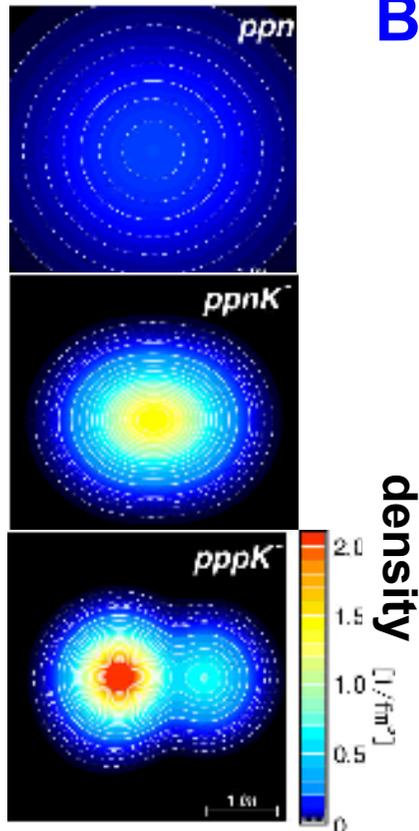
E10-1st phase 終了、データ解析中

Very dense matter? K⁻-nucleus bound states

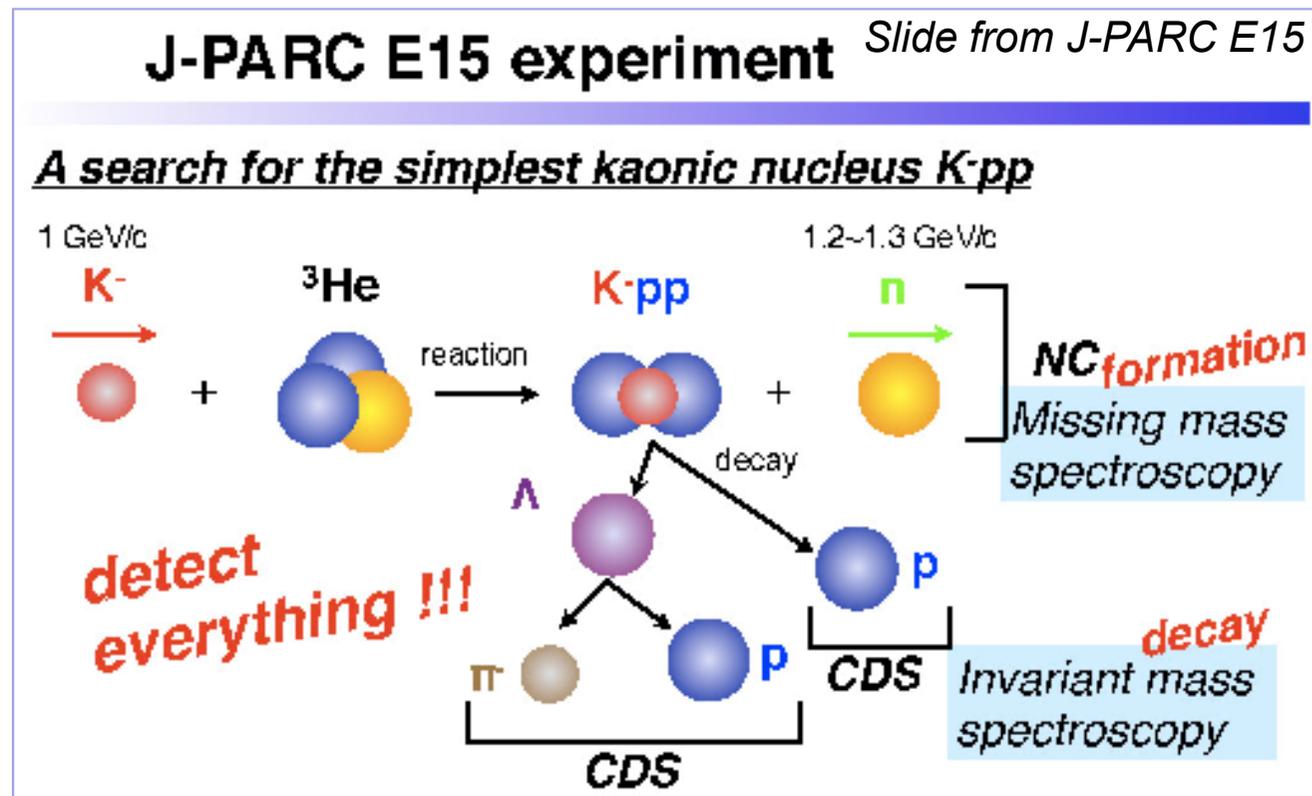
- Strong K⁻p attraction from K⁻p atomic/scattering data
- Theoretical suggestions and experimental hints of K⁻ nuclei
- K⁻ can make a nucleus extremely dense.
 - The only experimental method to produce cold and dense matter.
- K⁻ may condensate in n-star at high ρ



But not confirmed yet

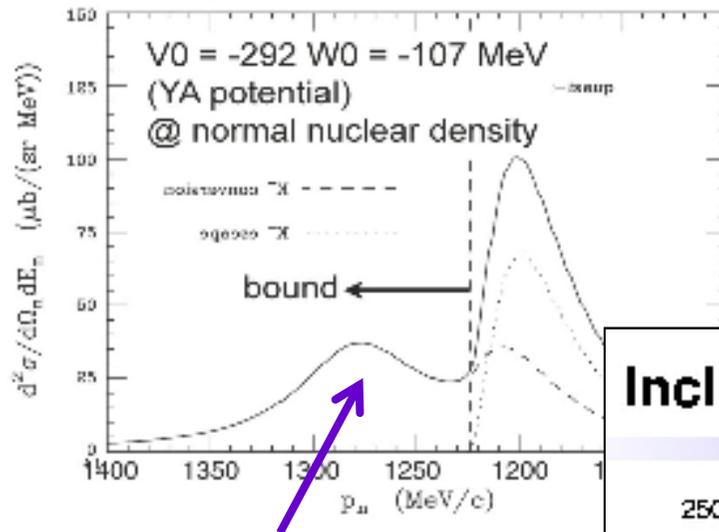


Dote et al. PLB590 (2004) 51



New J-PARC data for "K-pp"

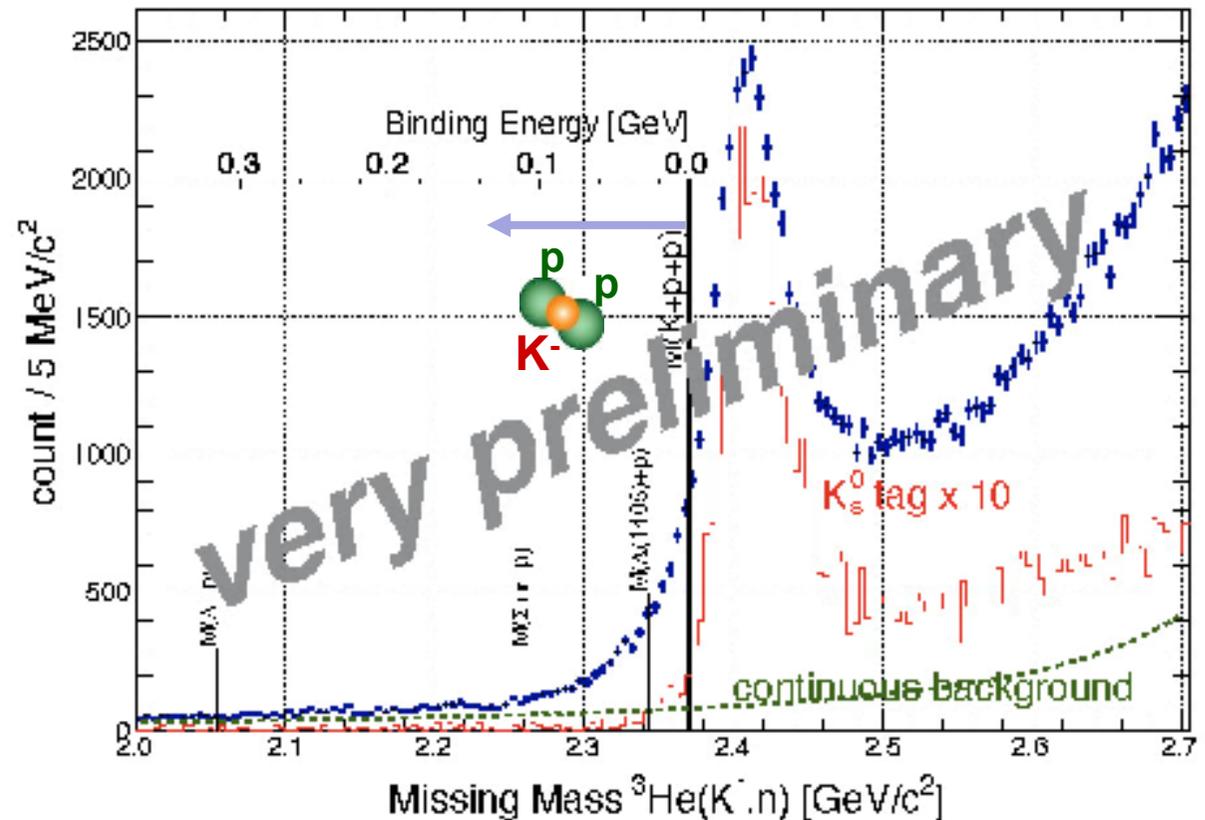
T. Hashimoto (E15) INPC2013



K-pp bound state

Theoretical estimate
for $K^- {}^3\text{He} \rightarrow \text{"K}^-\text{pp}" + n$

Inclusive neutron spectrum at forward angle



very preliminary

現状と今後の見通し

E10 (中性子過剰ハイパー核)

Phase 1 (${}^6_{\Lambda}\text{H}$)はデータ収集済、解析中。 ${}^6_{\Lambda}\text{H}$ が見えない。

Phase 2 (${}^9_{\Lambda}\text{He}$, ${}^6_{\Lambda}\text{H}$)の見通し？

E15 (K-pp)

Phase 1は半分データを収集、解析中

それ以降は1年以上遅延

E13(ガンマ線)

Phase 1のセットアップ完了もデータ収集できず、1年以上の遅延

E40 (Σp 散乱)

測定器の開発は順調だが、ビームタイムは遅延か