中性子過剰ラムダ・ハイパー核実験
（J-PARC E10）

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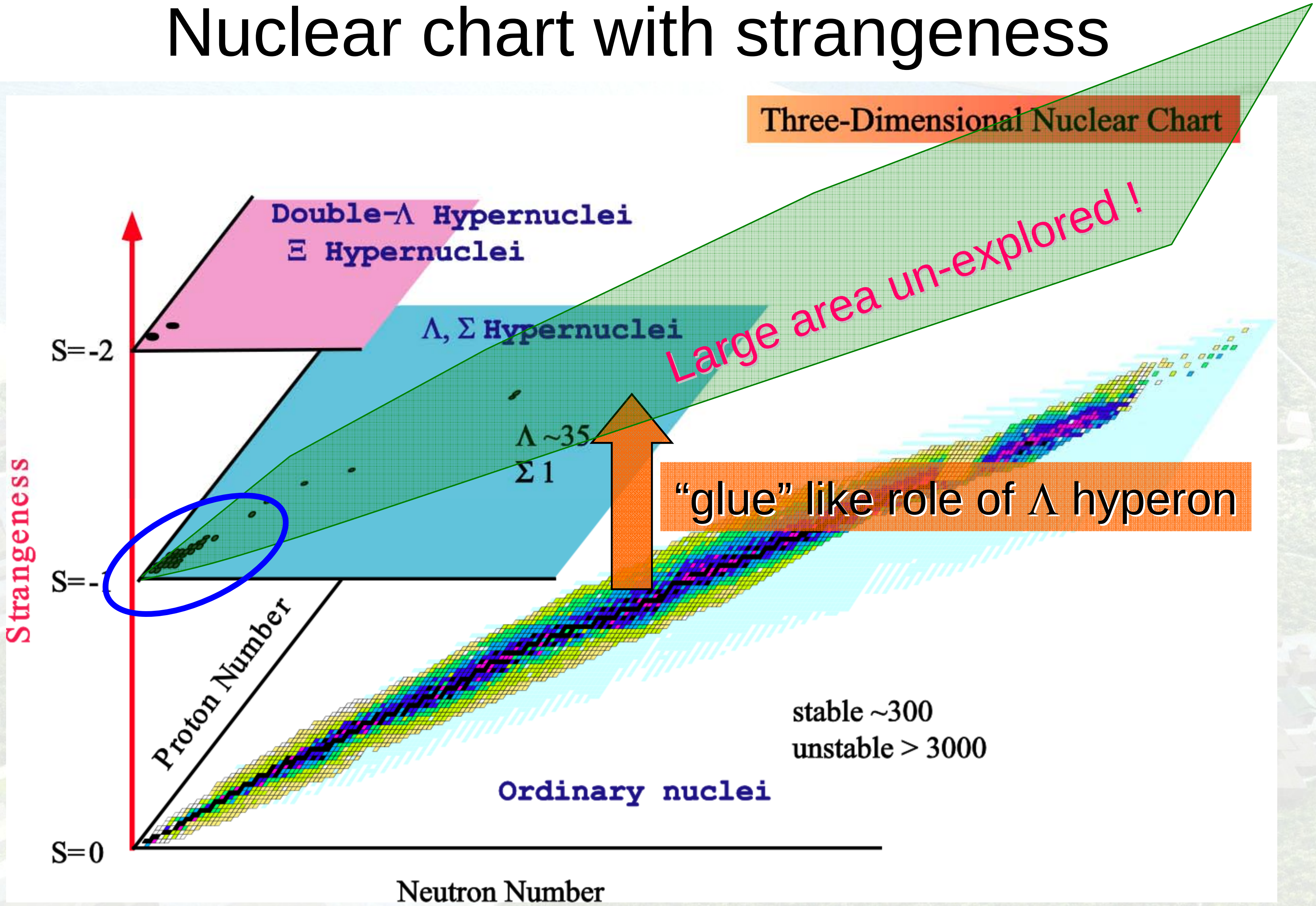
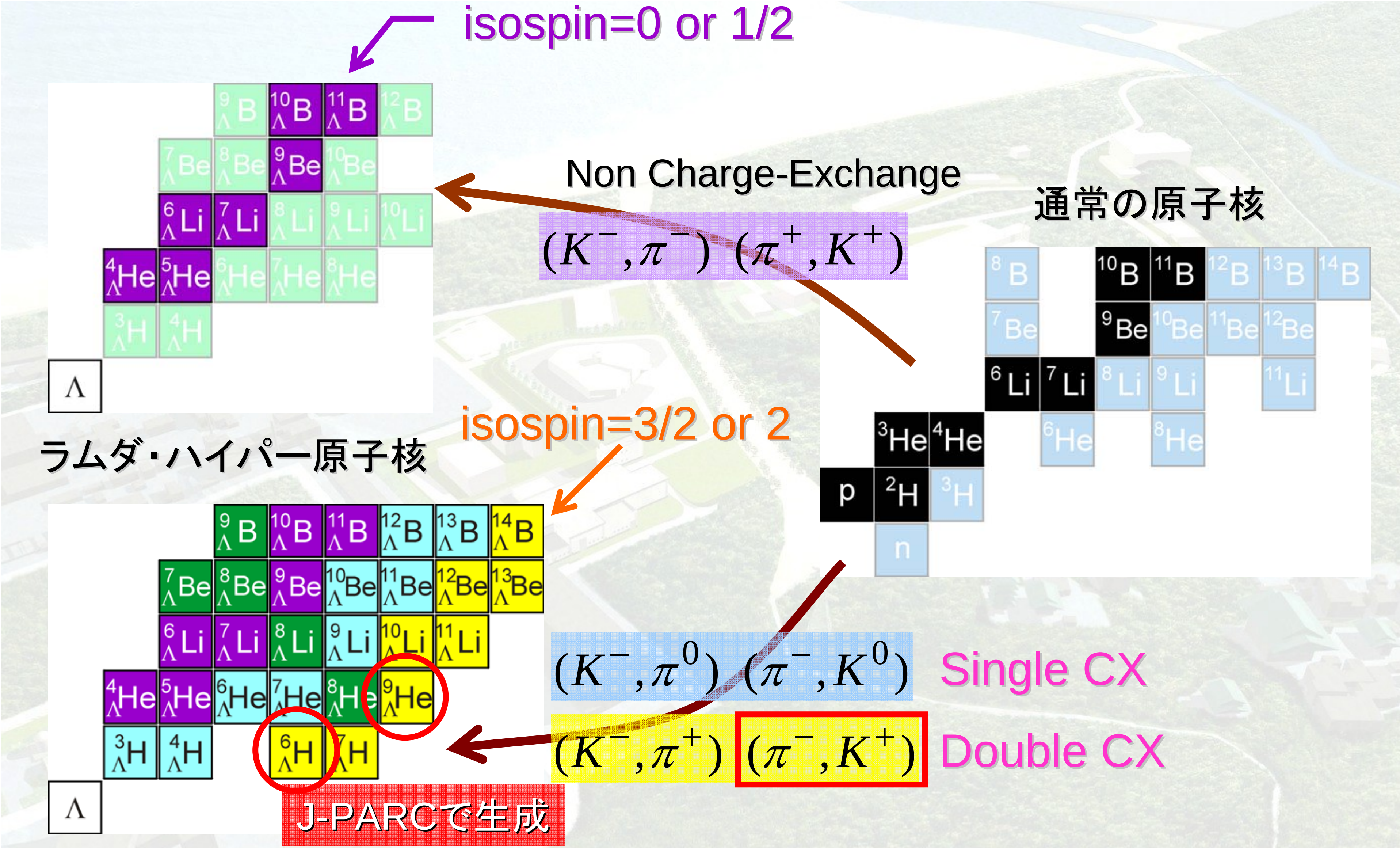
Motivation

- J-PARCで得られる大強度陽子ビーム
  - 30GeV、9 μA @ Day-1 ⇒ 50GeV、15 μA
- 大強度２次粒子ビーム
  - Kaon beams: a few × 10^6 kaons/spill (@Day-1)
  - Pion beams: kaon の 1000倍
- 大強度パイオンビームを使った実験
  - Day-1 の初期でも実施可能
  - ２重荷電交換反応による中性子過剰ハイパー核の生成
  - ハイパー核の非中間子弱崩壊の精密測定（E22 →味村）

Nuclear chart with strangeness



ハイパー核図表の拡張

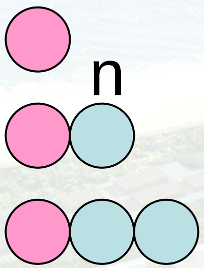


isospin=0 or 1/2
Non Charge-Exchange
(K^-,π^-) (π^+,K^+)
通常の原子核
ラムダ・ハイパー原子核
isospin=3/2 or 2
(K^-,π^0) (π^-,K^0) Single CX
(K^-,π^+) (π^-,K^+) Double CX
J-PARCで生成

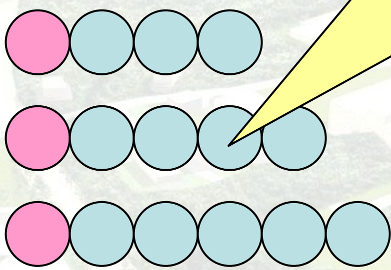
エキゾティックなラムダ・ハイパー核

- 「水素原子核」の例

A.A. Korsheninnikov, I Tanihata, *et al.*



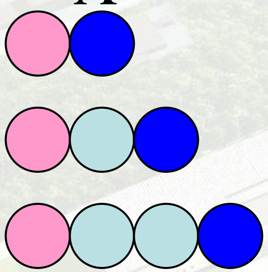
^{1}H Stable
^{2}H Stable
^{3}H Stable



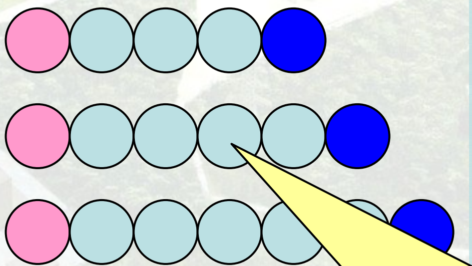
Super Heavy Hydrogen

^{4}H No evidence
^{5}H Resonance
^{6}H No evidence

Λ の接着剤的な効果



$^{2}_{\Lambda}$H Not bound
$^{3}_{\Lambda}$H Stable
$^{4}_{\Lambda}$H Stable

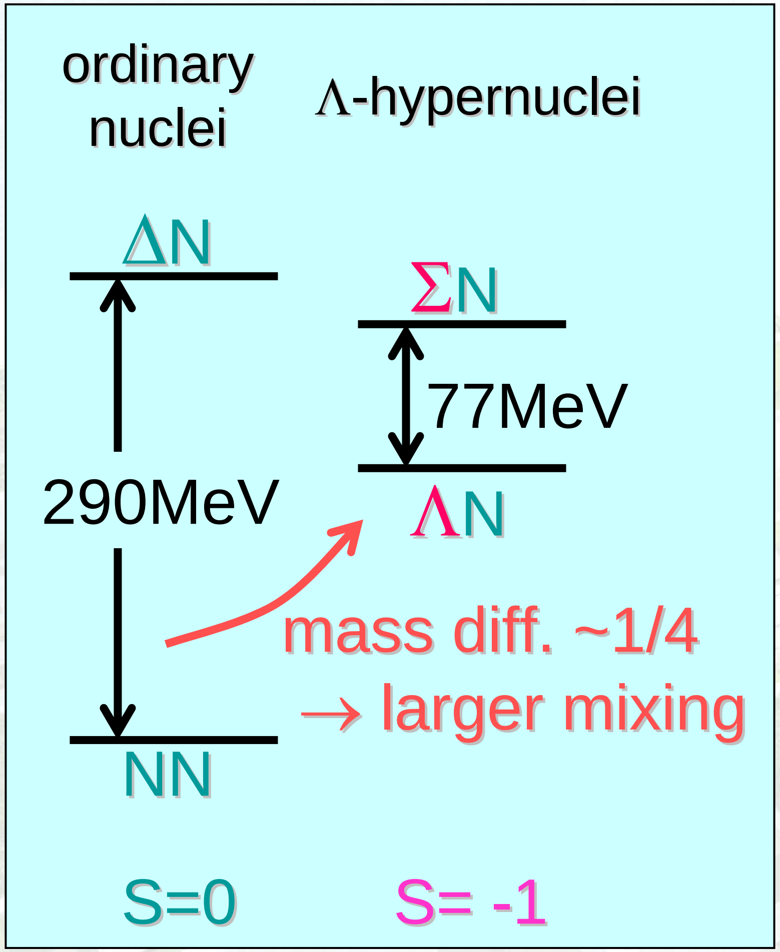


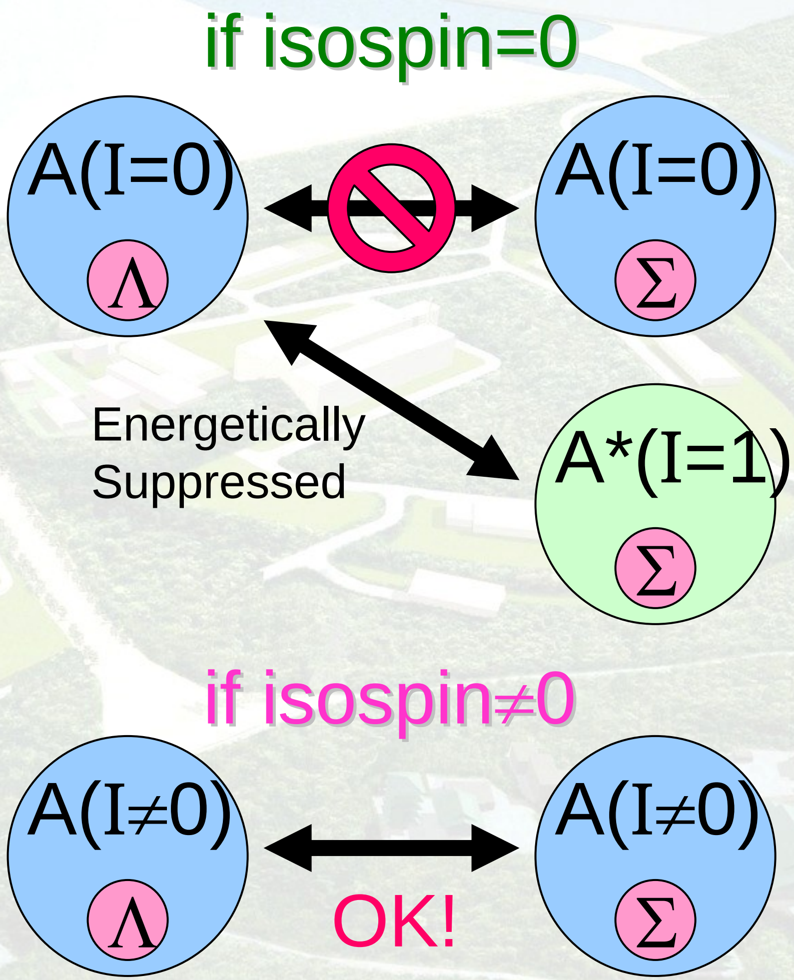
$^{5}_{\Lambda}$H No evidence
$^{6}_{\Lambda}$H Stable ?
$^{7}_{\Lambda}$H Stable ?

J-PARCで生成可能

Hyper Heavy Hydrogen

ΛN-ΣN mixing effect



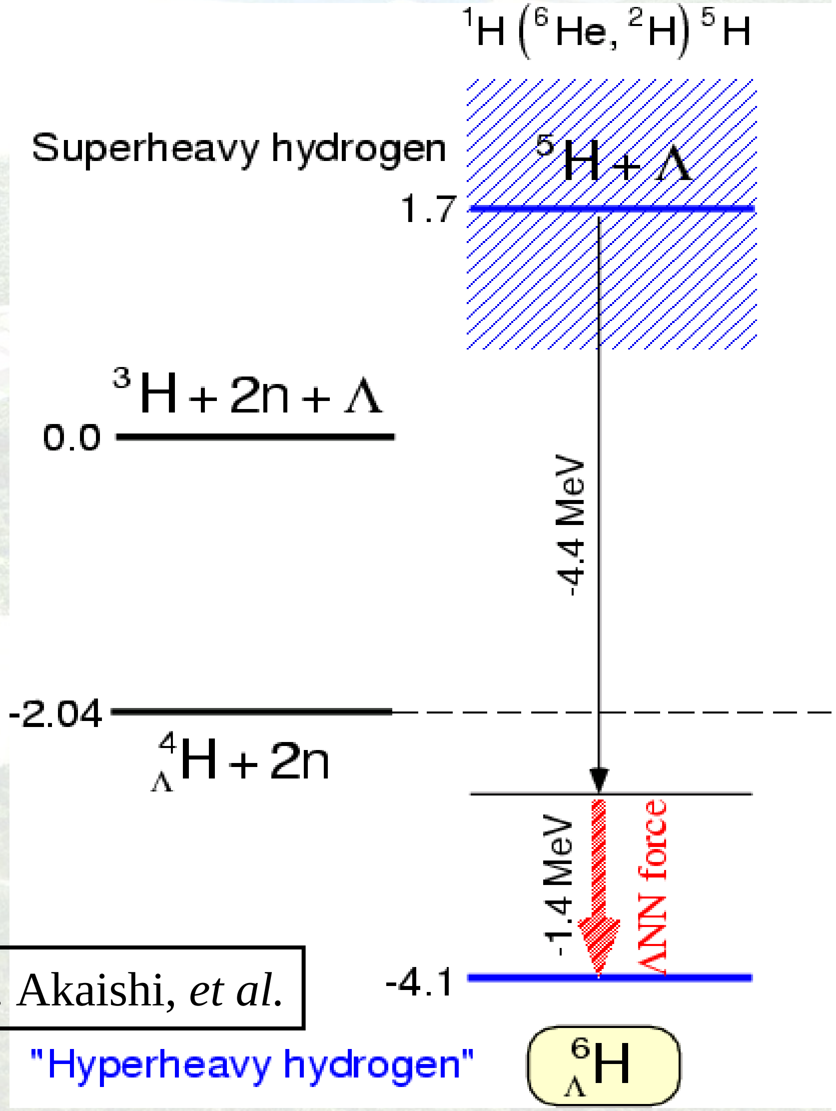


important in neutron-rich Λ-hypernuclei (large isospin)

Structure of $^{6}_{\Lambda}$H hypernucleus

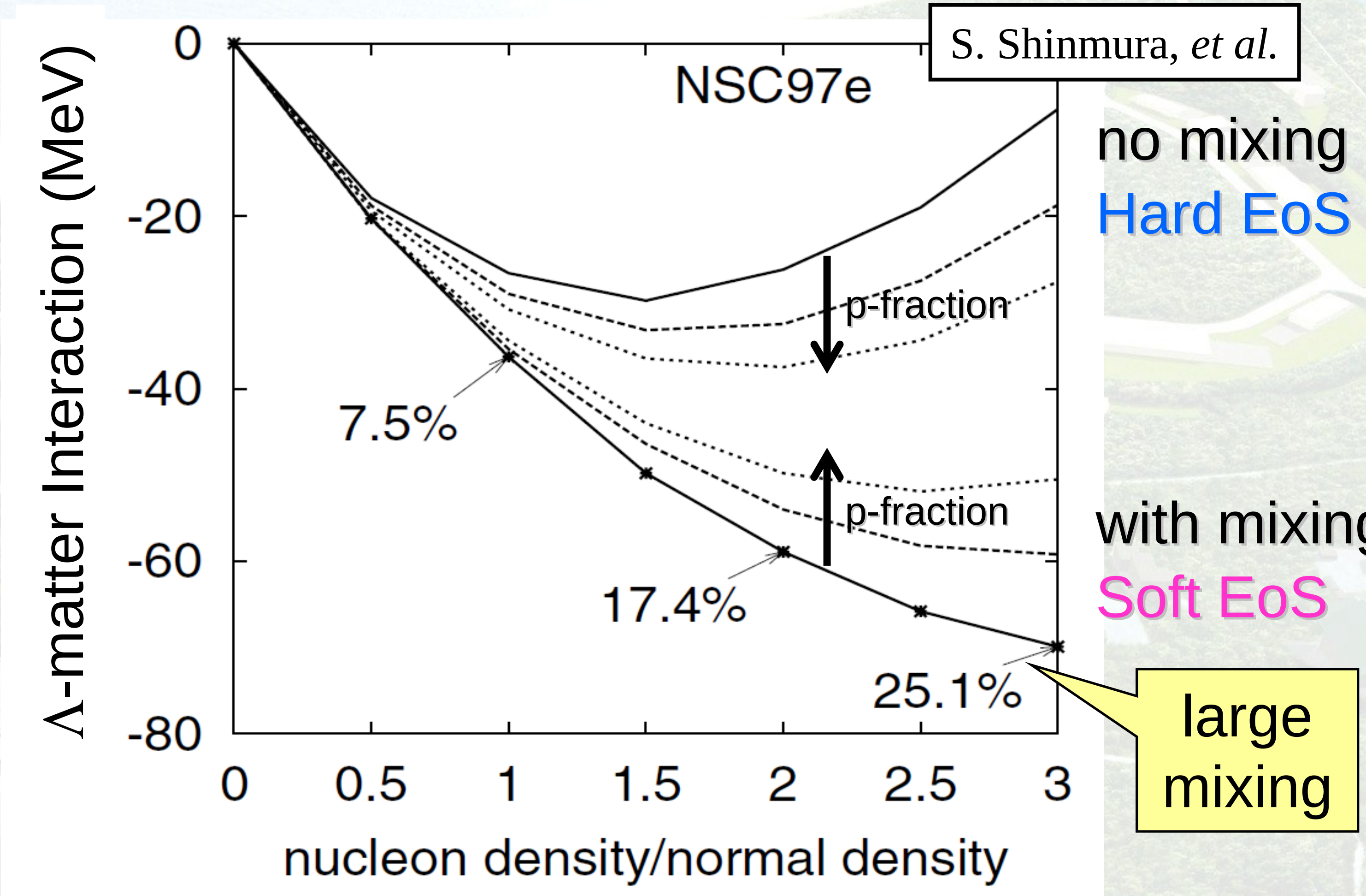
- Unbound ^{5}H
  - 1.7 MeV unbound
  - Exist as resonance
  - "Superheavy Hydrogen"

- Bound $^{6}_{\Lambda}$H ?
  - glue-like role of Λ
  - "Hyperheavy Hydrogen"
  - ΛNN force by ΛN-ΣN mixing
  - B_{Λ}= 0.5~2 MeV ?



Impact to other fields

- Degree of ΛN-Σ^0N mixing and EoS



How to produce n-rich Λ-hypernuclei

- KEK-E521 experiment established
  - $^{10}B\left(\pi^-, K^+\right)^{10}_{\Lambda}Li$ reaction
  - Clean reaction

K6 beamline @KEK-PS

SKS spectrometer

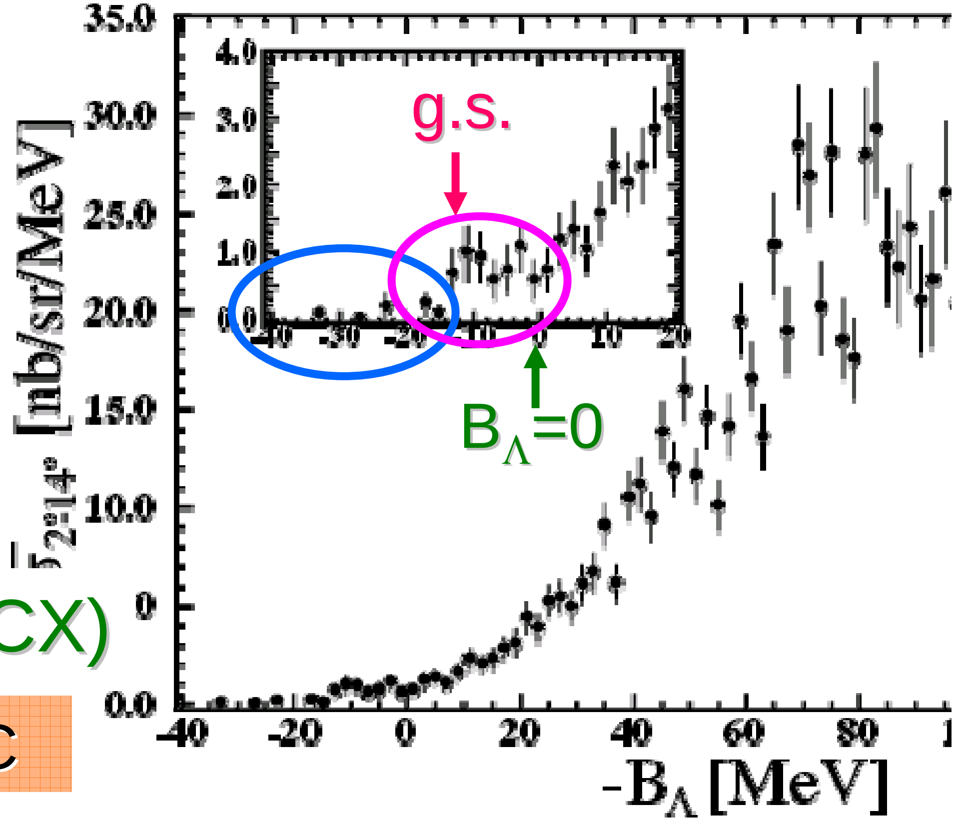
good energy resolution

ΔB_Λ = 2.5MeV (FWHM)

~45 events in bound region

dσ/dΩ~10nb/sr (1/1000 of NCX)

Increase yield ×10 at J-PARC

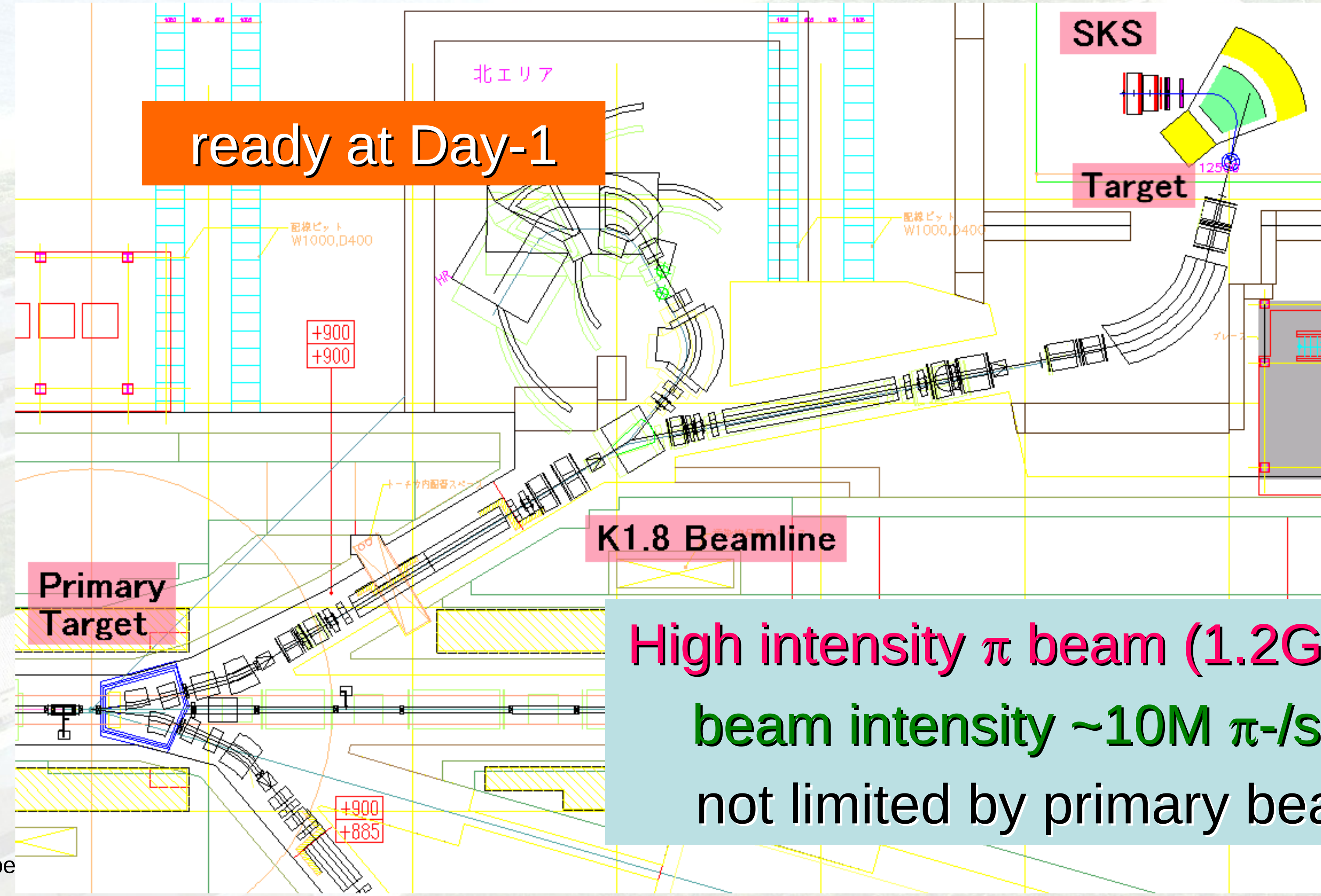


Experimental setup at J-PARC

- K1.8 beamline + SKS

Excellent resolution

Large acceptance



ready at Day-1

High intensity π beam (1.2GeV/c)

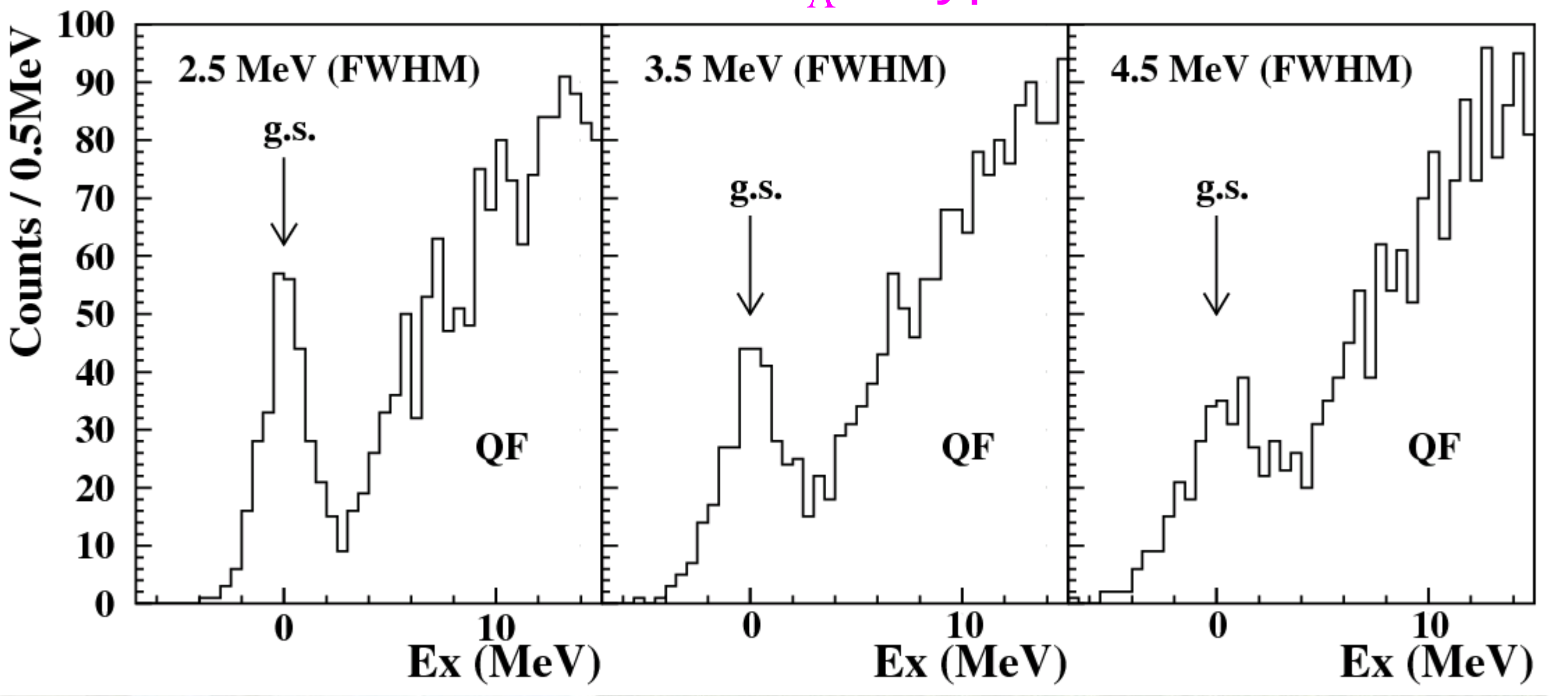
beam intensity ~10M π-/spill

not limited by primary beam

Requirement on Energy Resolution

- Clear identification of hypernuclei
  - Binding energy (guess) : $^{9}_{\Lambda}$He ~8MeV, $^{6}_{\Lambda}$H ~3MeV
  - Strong quasi-free Λ-production background

In the case of $^{6}_{\Lambda}$H hypernucleus



Yield: ${}^{9}_{\Lambda}$He production

– Particle bound → clear observation of g.s.

Parameters	Values
π^- beam momentum	1.20 GeV/c
π^- beam intensity	1×10^7 /spill
PS acceleration cycle	3.4 sec
^{9}Be target thickness	3.5 g/cm^2
Reaction cross section	10 nb/sr
Spectrometer solid angle	0.1 sr
Spectrometer efficiency	0.5
Analysis efficiency	0.5

← High beam intensity (π⁻ beam intensity)

← Large acceptance (Spectrometer solid angle)

– $d\sigma/d\Omega$=10nb/sr is assumed (same order as ${}^{10}_{\Lambda}$Li hypernucleus)

– 310 events in 3 weeks

– 7 times larger ← KEK-E521

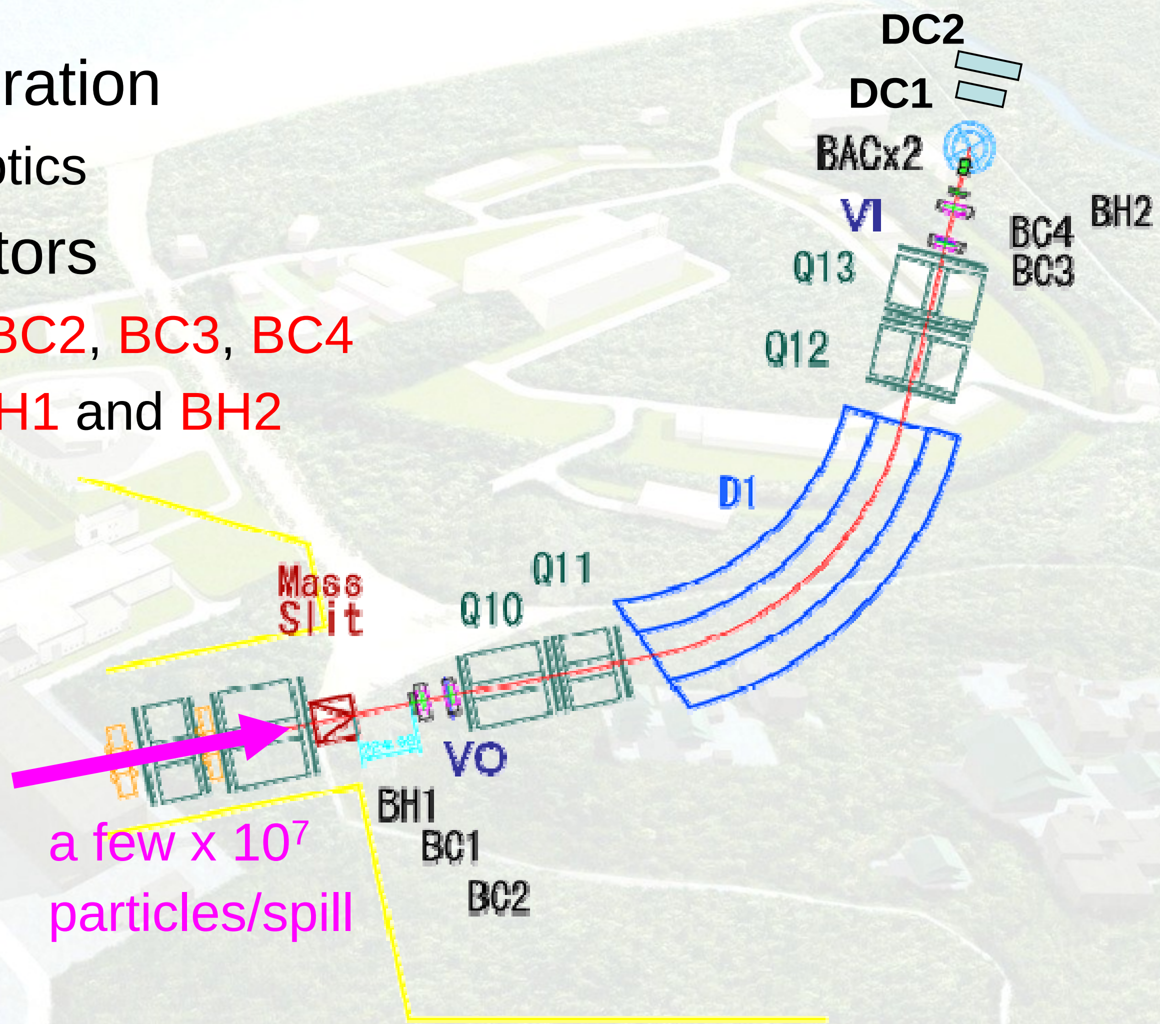
} if beam spill longer (3sec) → ×2

– Discussion on level structure possible

Beam Line Spectrometer

- Basic design
  - QQDQQ configuration
    - Point-to-point optics
  - Beam line detectors
    - Tracking: BC1, BC2, BC3, BC4
    - Time-of-flight: BH1 and BH2

E05 design	
BC1,BC2	1mm MWPC
BC3, BC4	3mm DC
DC1, DC2	3mm DC



Capability of BC operation at high rate

hit rate estimation

10^7 pions on target

→ ~400k hits/mm

(@ BC1, BC4)

to keep ~200k Hz/wire

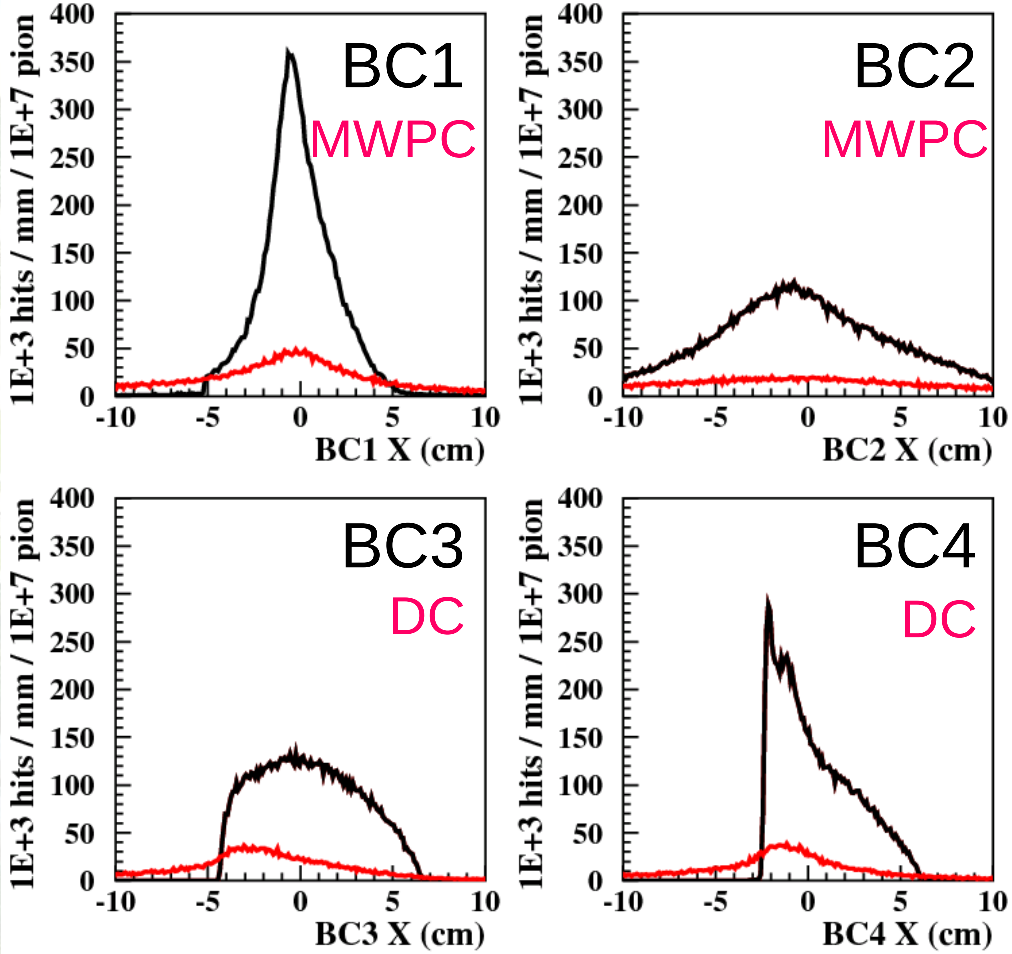
Beam spill

0.7 s → 2 s

possible at 30GeV

BC1 rate ~200k Hz/wire

pion and decay muon at BC



Space charge effect

high hit rate/wire (x wire)

narrow y size

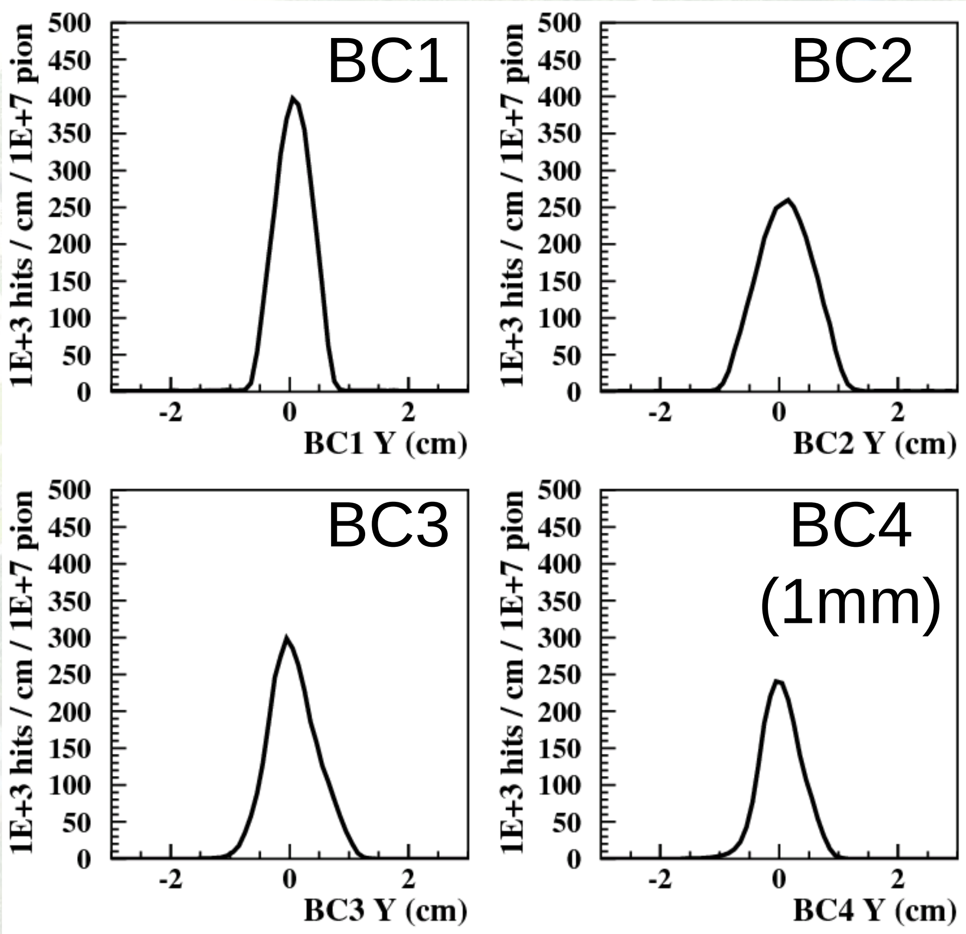
10^7 pions on target

→ ~400k hits/cm/wire (@ BC1)

spill length ~ 2s

beam ~10^7 pions/spill

→ ~200k Hz/cm/wire

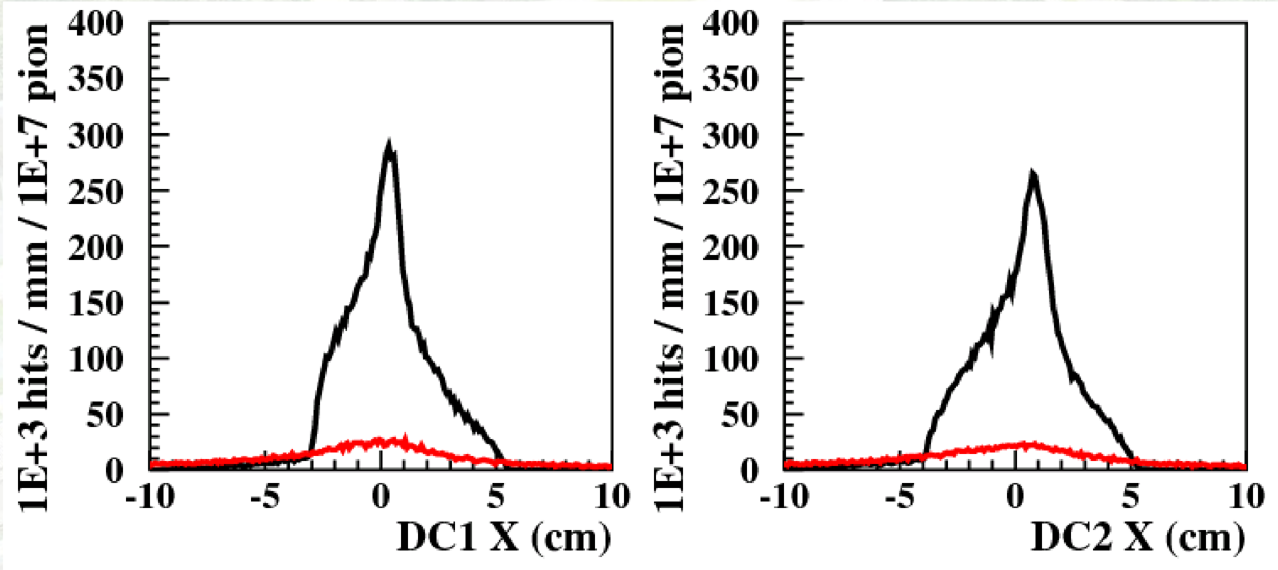


DC Hit Rate

- Consideration on beam hit rates
  - DC1 and DC2 are close to target (final focus)
  - Beam sizes at DC are small

3mm DC

1mm MWPC



  - Similar rate with BC1 and BC4
  - Need update of DC1 and DC2

Yield を増やすには？

- GEM-base chamber の開発
  - 既存方式の延長: MWPC → GEM
    - 高い rate capability
    - Ion の correction が速く space charge effect 小さい
    - 大阪電通代と共同で開発を進める
  - 欠点 : 物質量大
    - GEM foil と readout 部分
    - 物質量を減らす工夫が必要

Factor の改善

- HIHR beam line and Spectrometer
  - 新しい考え方のビームライン
    - 原理的に可能、デザインあり
  - Small cross section の実験には非常に有効

Order の改善

HIHR beam line and spectrometer

- Handle high intensity and high resolution
  - Beam line
    - Vertical dispersion on target
  - Spectrometer
    - Tracking only at exit
    - Horizontal position
    - ⇒ mom. of scattered particle
    - Vertical position
    - ⇒ beam momentum