Technical Issues for J－PARC E10 Experiment

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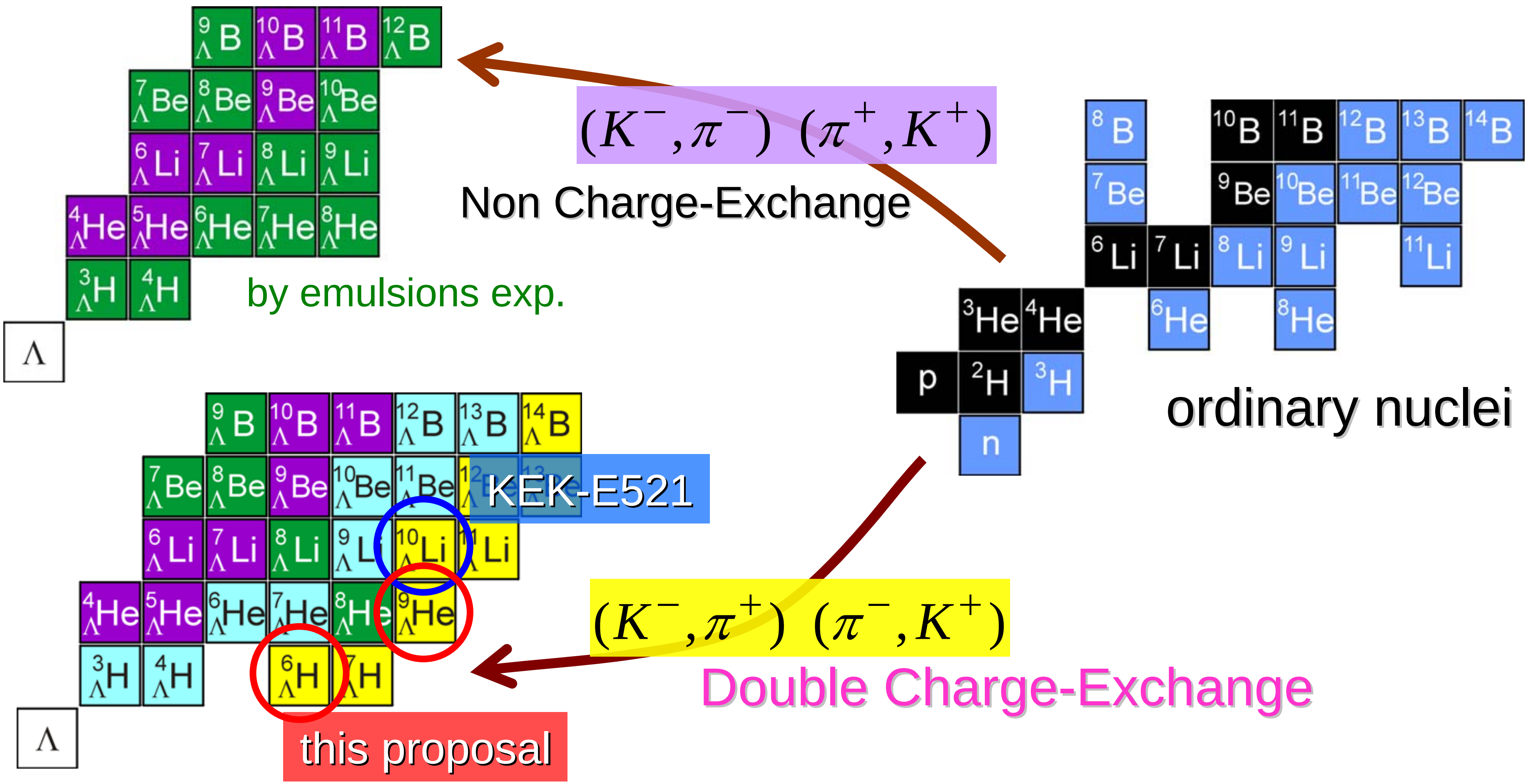
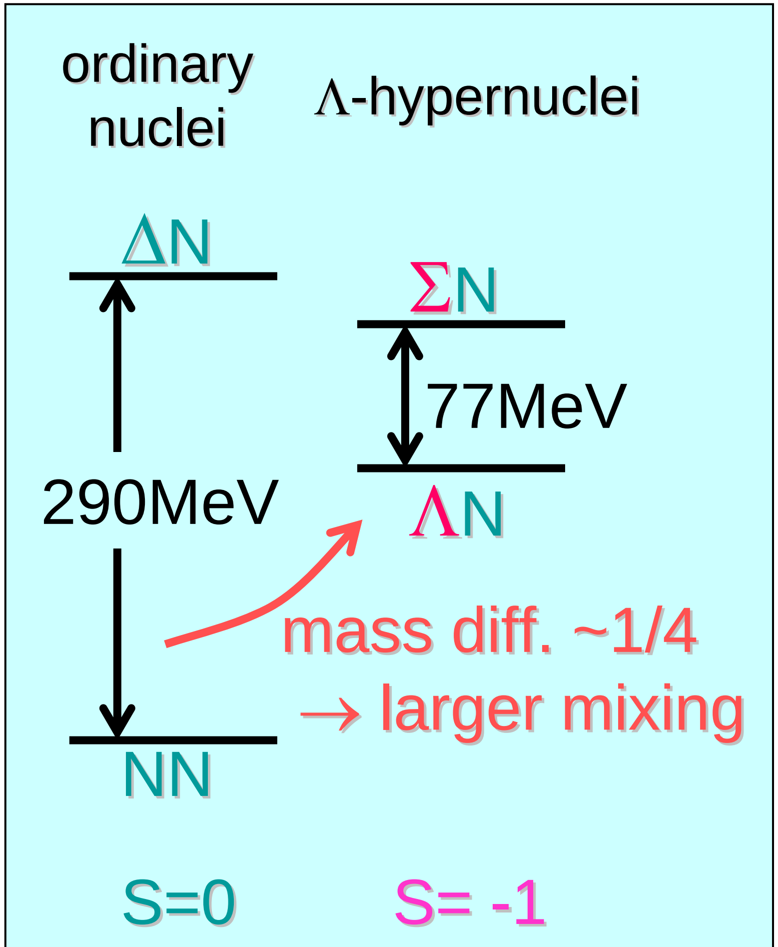
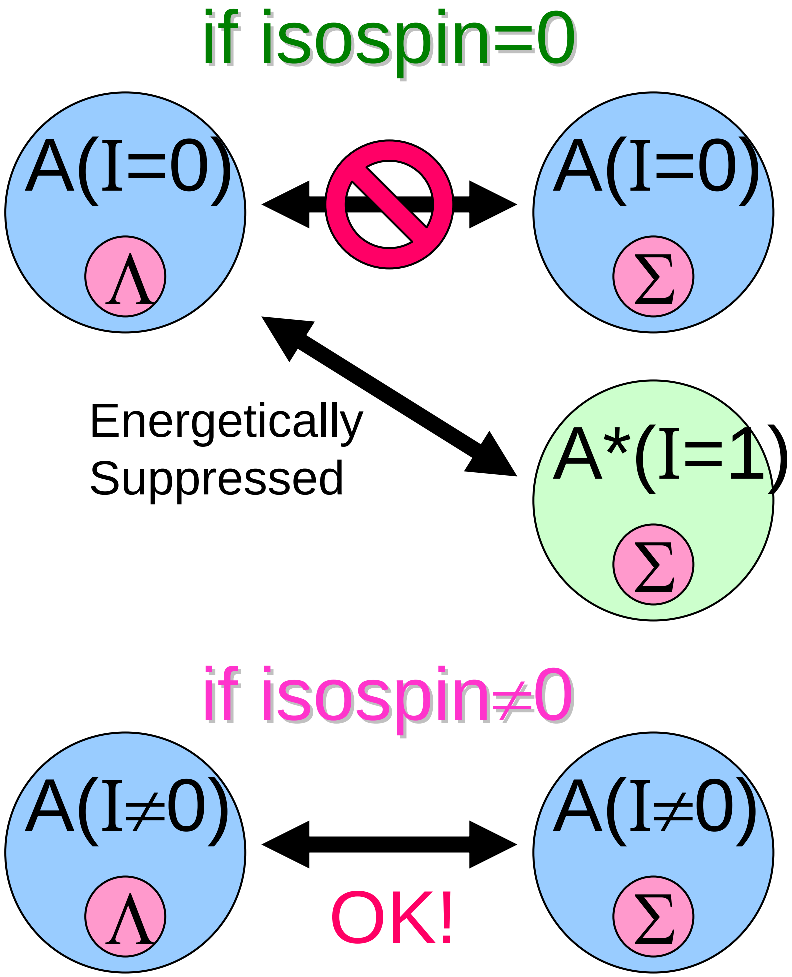
Subject of E10

- Production of neutron-rich hypernuclei
  - Hypernuclei close to neutron-drip line

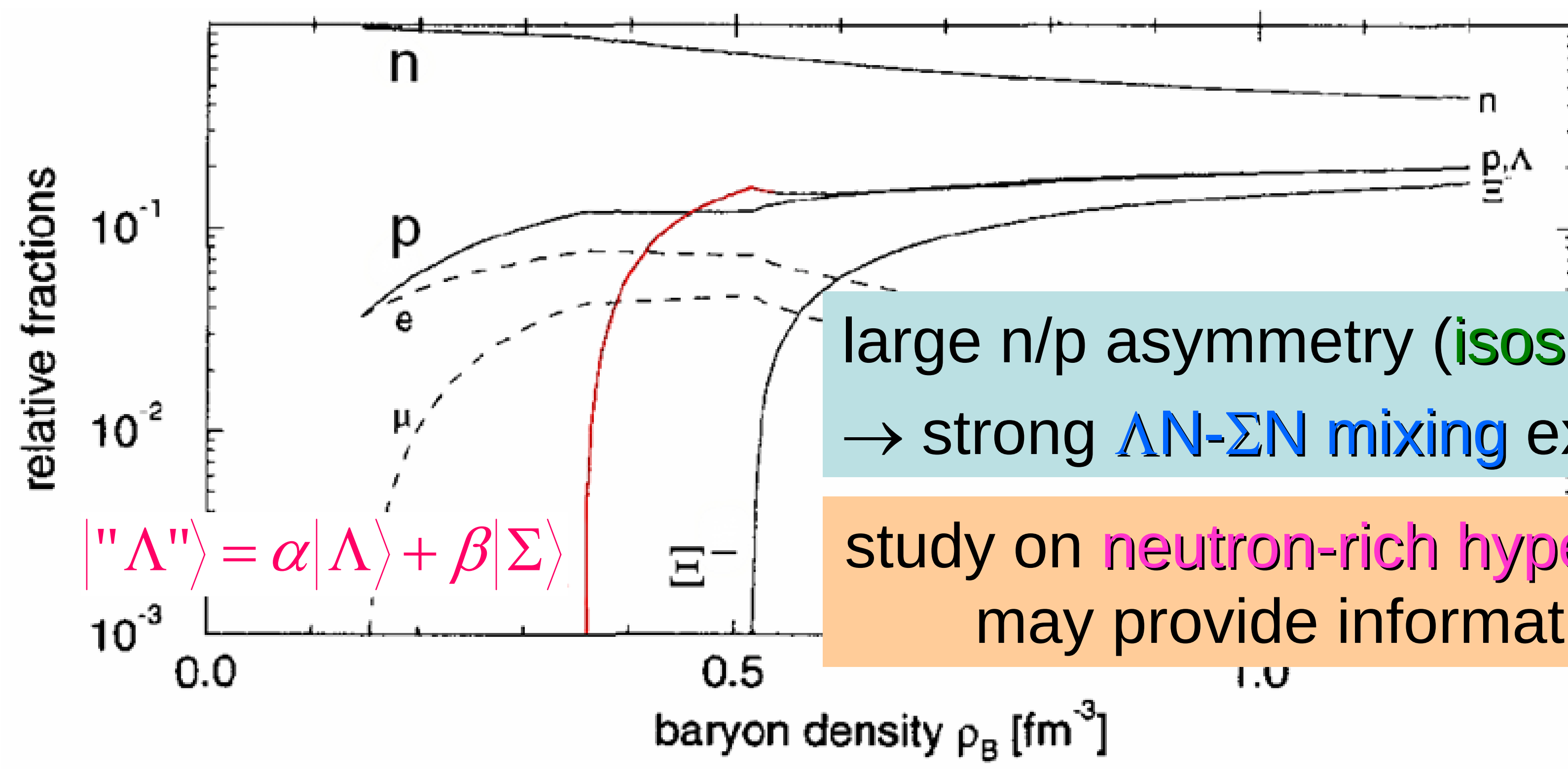


- ΛN interaction in n-rich environment
  - ΛN-ΣN mixing effect





- Impact to other field of science
  - Strangeness degree in neutron star core
  - Mass, charge, interaction, …
  - EOS of neutron stars



$$|"\Lambda"\rangle = \alpha|\Lambda\rangle + \beta|\Sigma\rangle$$

large n/p asymmetry (isospin≫1)
→ strong ΛN-ΣN mixing expected

study on neutron-rich hypernuclei may provide information

Requirement: Yield

- Yield of hypernuclei
  - Cross section of DCX is small
    - NCX ($\Delta z=0$): (K^-,π^-), (π^+,K^+) reactions
    - DCX ($\Delta z=2$): (K^-,π^+), (π^-,K^+) reactions

cross section of hypernuclei production (@ 0°)

process	typical cross section			
	(π^+, K^+)	(π^-, K^+)	(K^-, π^-)	(K^-, π^+)
production of hypernuclei	8 μb/sr	10 nb/sr	200 μb	n.a.
elementary process	0.4 mb/sr	–	4 mb/sr	–

  - About 1/1000 of NCX reaction

- Yield estimation

$$Yield\ ({}^{9}_{\Lambda}\mathrm{He}) = N_{Beam} \times \frac{N_{Target}}{9} \times N_A \times \frac{d\sigma}{d\Omega} \times \Omega_{SP} \times \varepsilon_{SP} \times \varepsilon_{Anal} \times \frac{Time}{T_{Cycle}} \quad (1)$$

Parameters	Values	Notation in Eq.(1)	
π^- beam momentum	1.20 GeV/c		
π^- beam intensity	1×10^7 /spill	N_{Beam}	← K1.8
PS acceleration cycle	3.4 sec	T_{Cycle}	
^{9}Be target thickness	3.5 g/cm^2	N_{Target}	
Reaction cross section	10 nb/sr	$d\sigma/d\Omega$	
Spectrometer solid angle	0.1 sr	Ω_{SP}	← SKS
Spectrometer efficiency	0.5	ε_{SP}	
Analysis efficiency	0.5	ε_{Anal}	

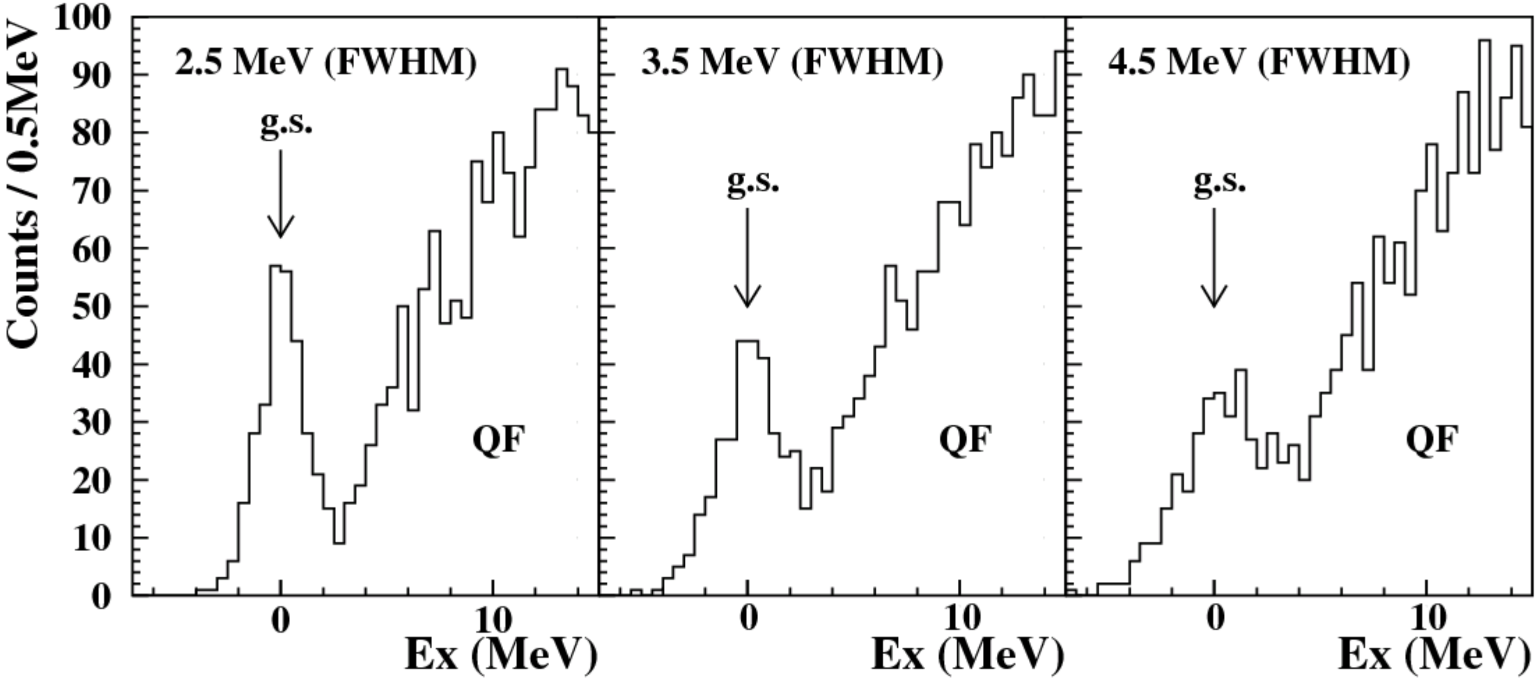
3 weeks of beamtime → ~300 events

↔ 47 events (KEK-PS E521)

Requirement: Resolution (1)

- 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



Energy resolution ≲ 2.5MeV (FWHM)

Requirement: Resolution (2)

- Precise binding energy estimation

Normal ΛN force

$B_\Lambda \sim 4.4$ MeV

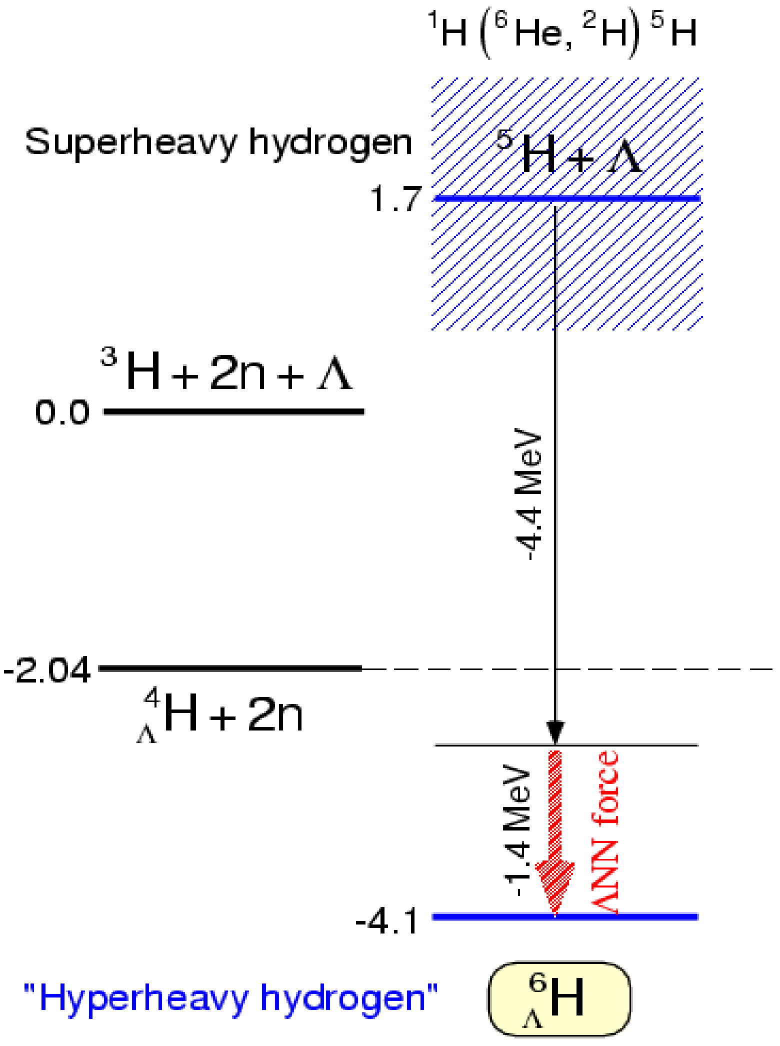
ΛN-ΣN mixing effect

$B_\Lambda \sim 4.4$ MeV + 1.4 MeV

$$\Delta BE = \frac{2.5MeV}{\sqrt{300}} \sim 0.15MeV(FWHM)$$

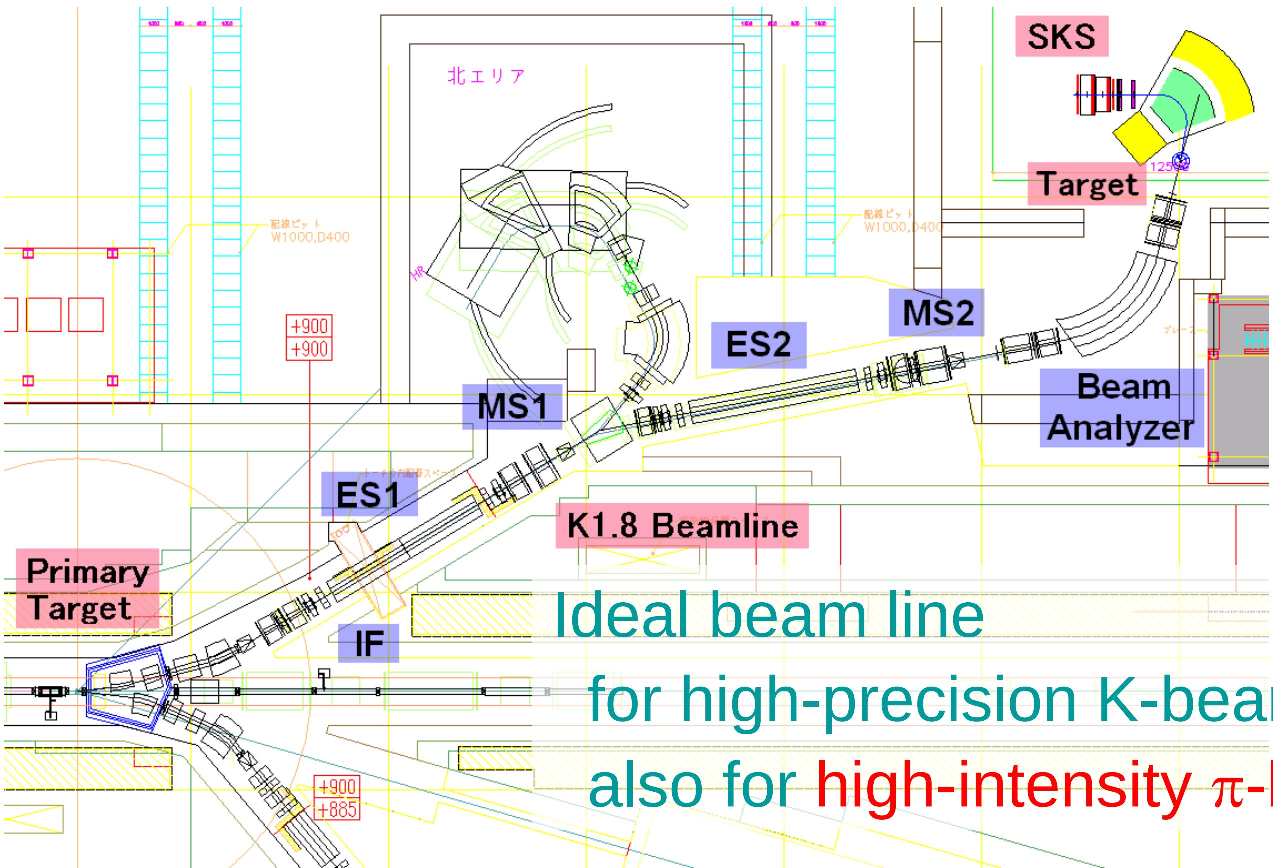
Enough resolution

if ΔE~2.5MeV and N~300



K1.8 Beam Line

- Beam line fits for hypernuclear studies
  - Particle separation is good (IF, ES1, ES2)
  - Excellent momentum resolution $\Delta p/p$=1.4/10000



Ideal beam line

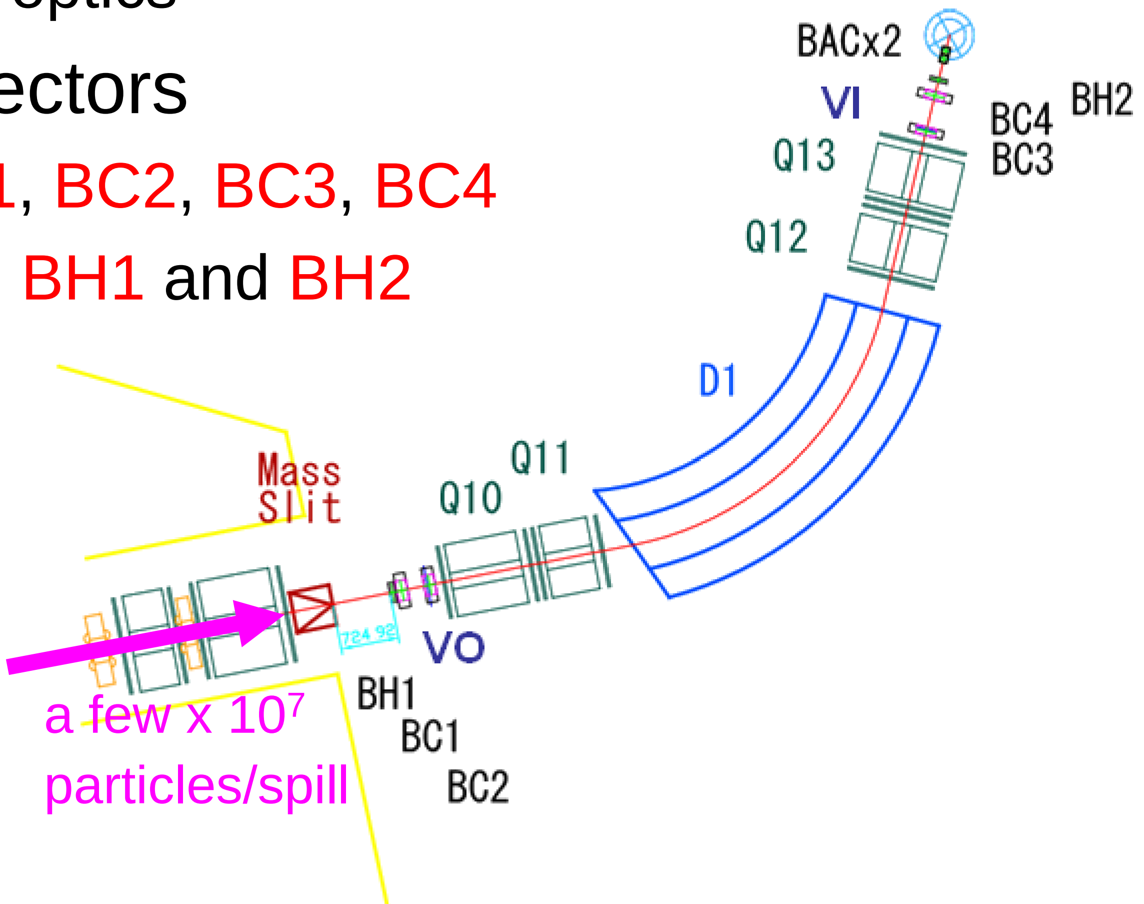
for high-precision K-beam exp.

also for high-intensity π-beam exp.

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
BH1	11 segments
BH2	5 segments



- Capability of BC operation at high rate

hit rate estimation

10^7 pions on target

→ ~400k hits/mm

(@ BC1, BC4)

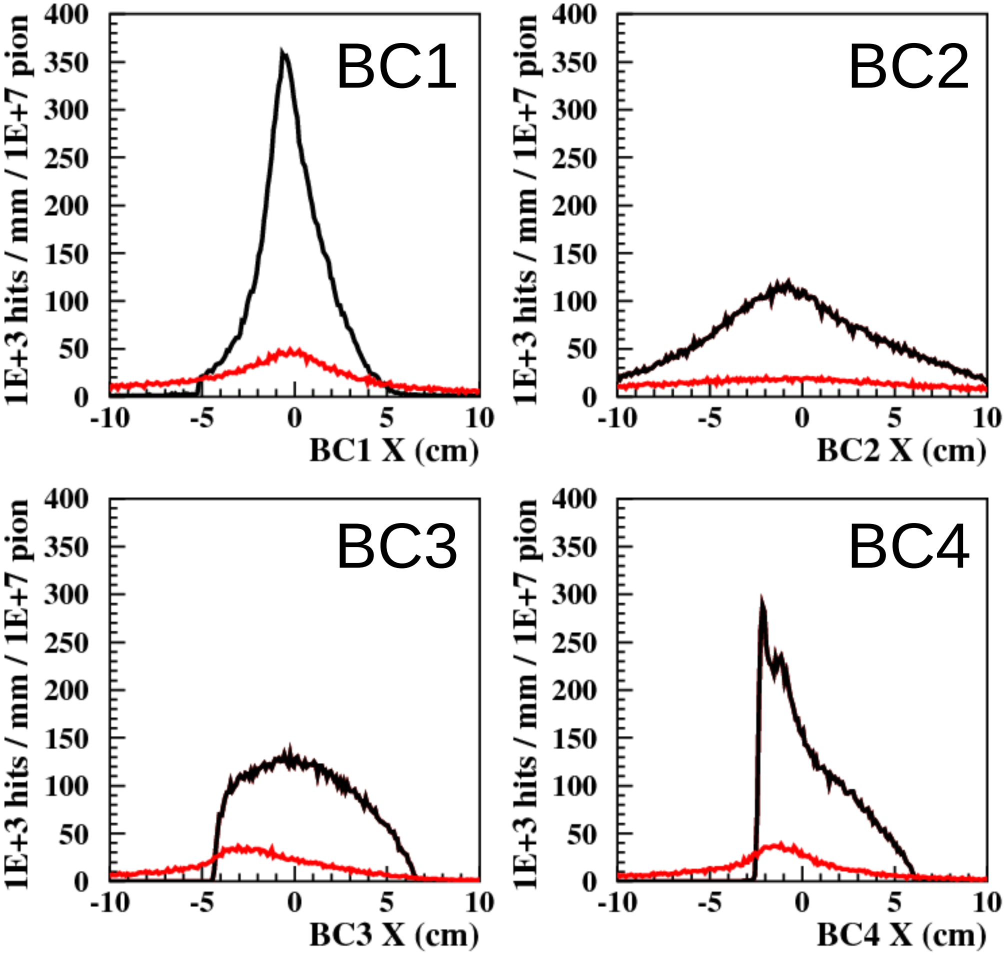
to keep ~200k Hz/wire

Beam spill

0.7 s → > 2 s

BC1 rate ~200k Hz/wire

pion and decay muon at BC



- Requirement for E10 experiment
  - Longer spill length > 2 s (max 3 s @ 30GeV)
  - BC4 replacement ~1mm wire-spacing

spill length necessary to keep BC rate < 200k Hz/wire

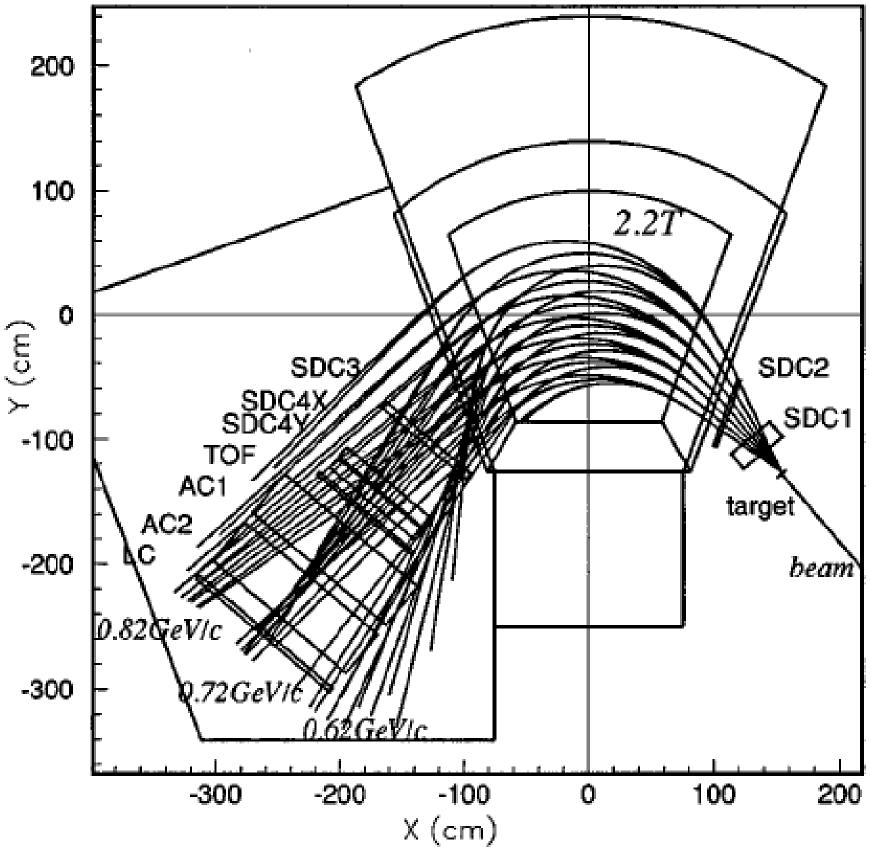
chambers	wire spacing		maximum hit rate hit/mm/$10^7\pi$	maximum hit rate hit/wire/$10^7\pi$	spill length
BC1	1 mm		400k	400k	2.00 s
BC2	1 mm		140k	140k	0.70 s
BC3	3 mm		150k	450k	2.25 s
BC4	3 mm	←E05	330k	990k	4.95 s
(BC4)	(1 mm)	←E10	330k	330k	1.65 s

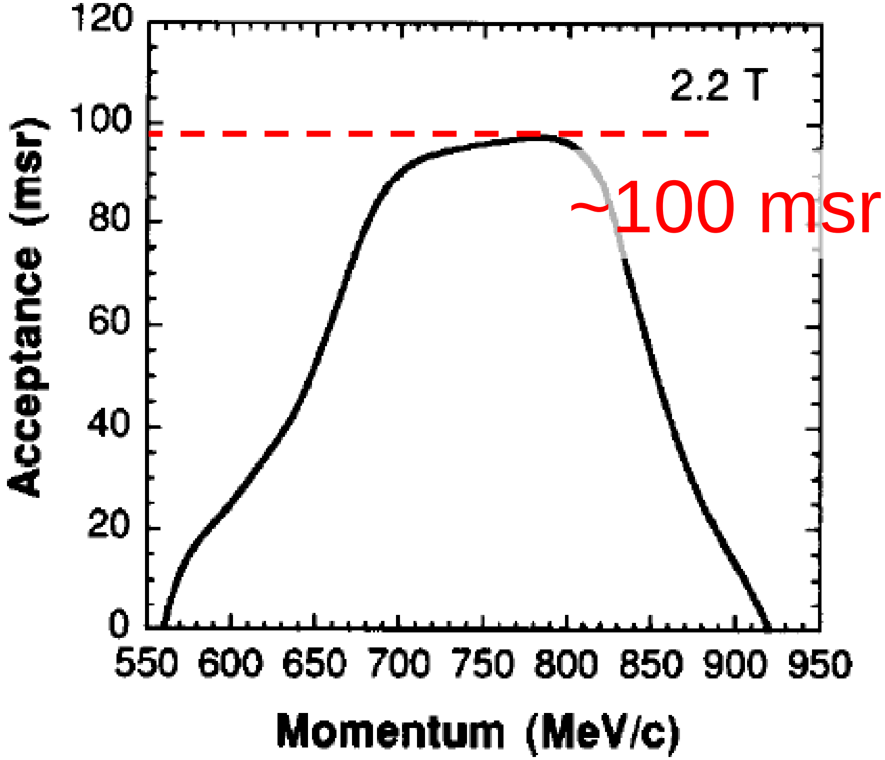
- Plans of BC4 update
  - Low cost option: exchange BC2 and BC4
    - BC2 (1mm MWPC) $\leftrightarrow$ BC4 (3mm DC)
  - Option 2: build new BC4
    - BC4 (3mm DC) $\rightarrow$ new BC4 (1mm MWPC)
  - Option 3: develop new type of detector
    - Detector for high rate operation
    - GEM-base chamber R&D at Osaka-EC Univ.
    - Sci-Fi (material, radiation damage, cost ??)

- Beam line hodoscopes (BH1, BH2)
  - E05 design (K1.8 standard ?)
    - BH1: 11 segments
    - BH2: 5 segments
  - BH module performance (study @ KEK-PS)
    - Dynode boosted PMT
    - Timing resolution ~40 ps (rms)
    - Operation up to a few x 10^6 hits/s is possible
  - Update for E10
    - BH1 is OK also for E10
    - Need BH2 update (5 $\rightarrow$ 11 segments ??)

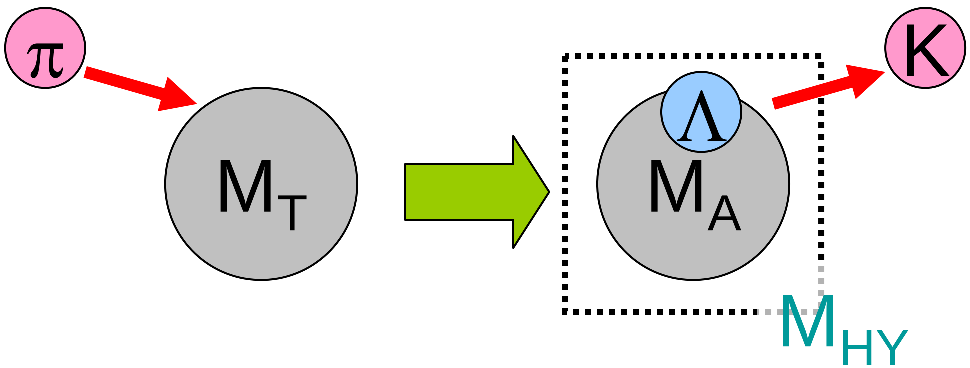
SKS Spectrometer

- spectrometer fits for hypernuclear studies
  - Large angular acceptance ~100 msr
  - Excellent momentum resolution Δp/p~1/1000





- Study by missing mass spectroscopy



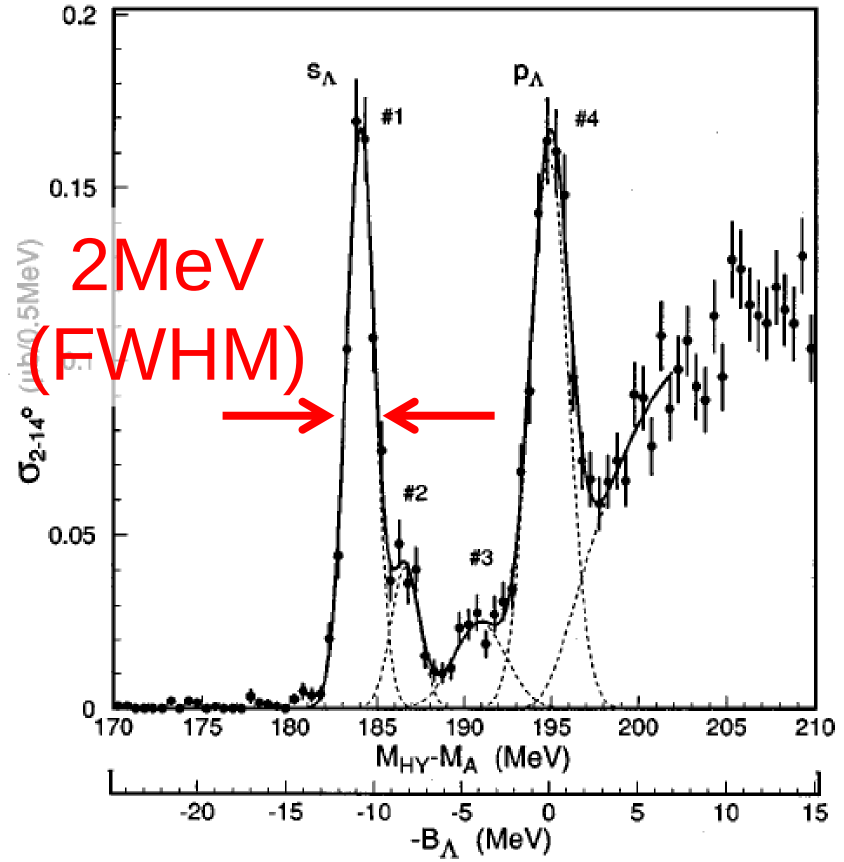
$$M_{HY} = (p_\pi + p_T - p_K)^2$$

p_π, p_T, p_K: 4-momentum

$p_T = (M_T, 0)$

$$B_\Lambda = M_{HY} - M_\Lambda - M_A$$

$^{12}C(\pi^+, K^+)^{12}_{\Lambda}C$



- Overall energy resolution
  - Determined by target thickness

dominated by

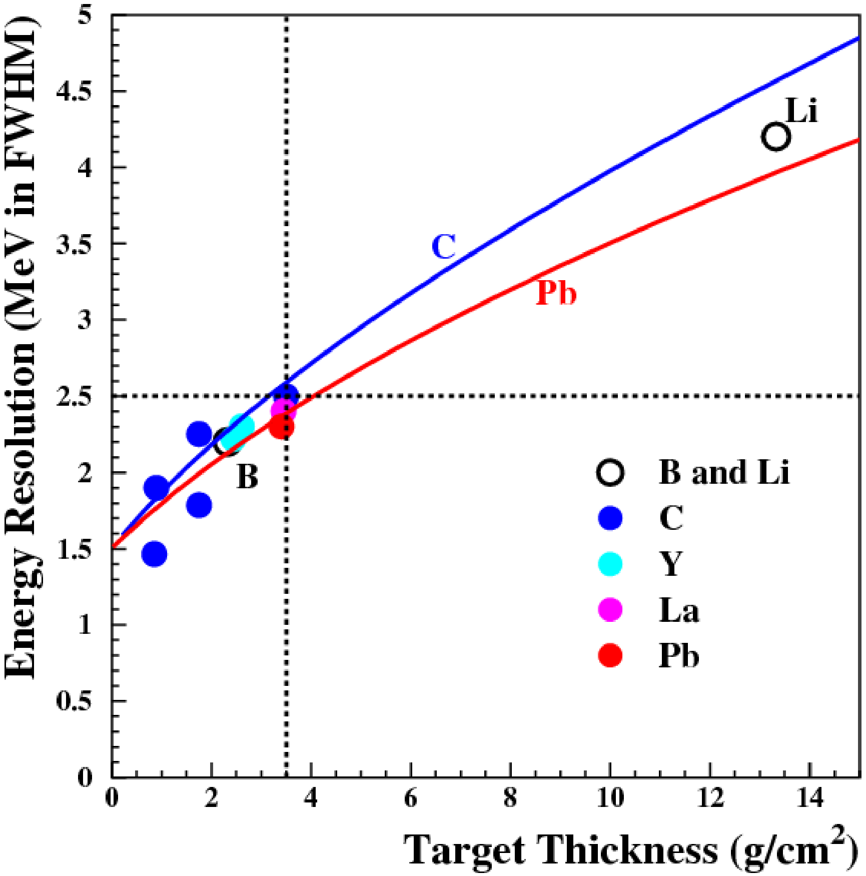
SKS mom. resolution

energy loss straggling

require 2.5MeV (FWHM)

→ 3.5 g/cm^2 target

SKS intrinsic	1.5
E-loss difference	0.4
E-loss straggling	2.0
multiple scattering	0.04

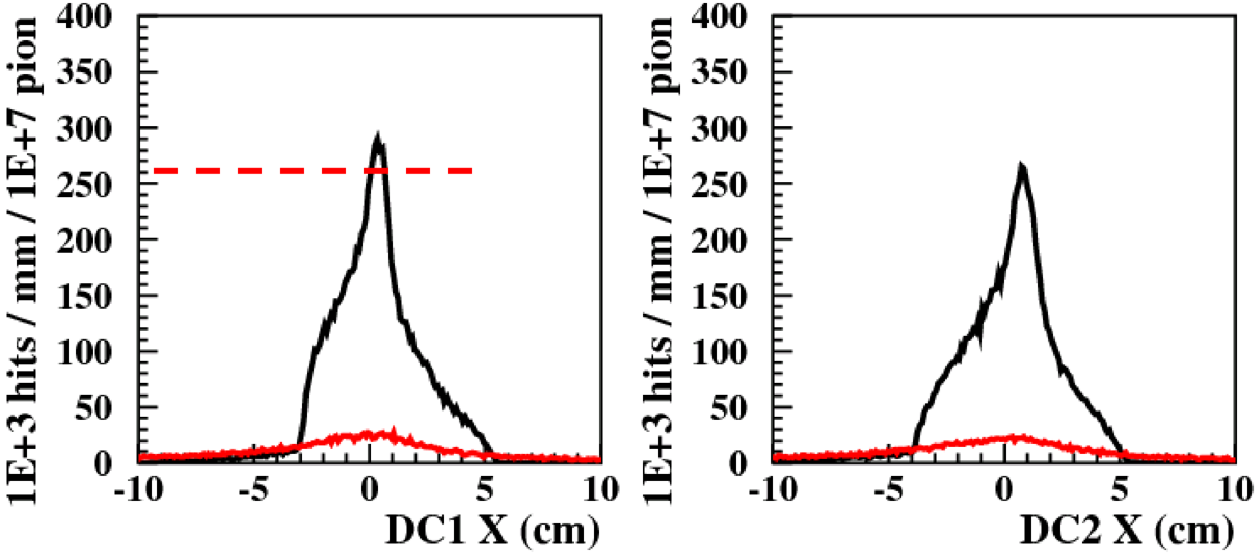


Energy Calibration

- Necessity of absolute energy calibration
  - Precise calibration necessary < 0.3MeV
- Calibration methods
  - Calibration by $^{12}C(\pi^+,K^+)^{12}{}_{\Lambda}C$ reaction
    - $B_\Lambda(^{12}{}_\Lambda C) = 10.76 \pm 0.19$ is well known
  - Polarity change of K1.8: $\pi^+ \rightarrow \pi^-$
    - Distributions of π^+ and π^- are similar
  - Estimation of polarity change effect
    - Compare $p(\pi^+,K^+)\Sigma^+$ and $p(\pi^-,K^+)\Sigma^-$
    - $m(\Sigma^-)-m(\Sigma^+) = 8.08 \pm 0.08$
  - K1.8 and SKS magnetic field monitor
    - with hole-probe and/or NMR-probe

establish during commissioning

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



– Similar rate with BC1 and BC4

– Need update of DC1 and DC2

- DC1, 2 (3mm DC) $\rightarrow$ new-DC1, 2 (1mm MWPC)

Safety Issue (1)

- Radiation protection

A few x 10^7 particles/spill

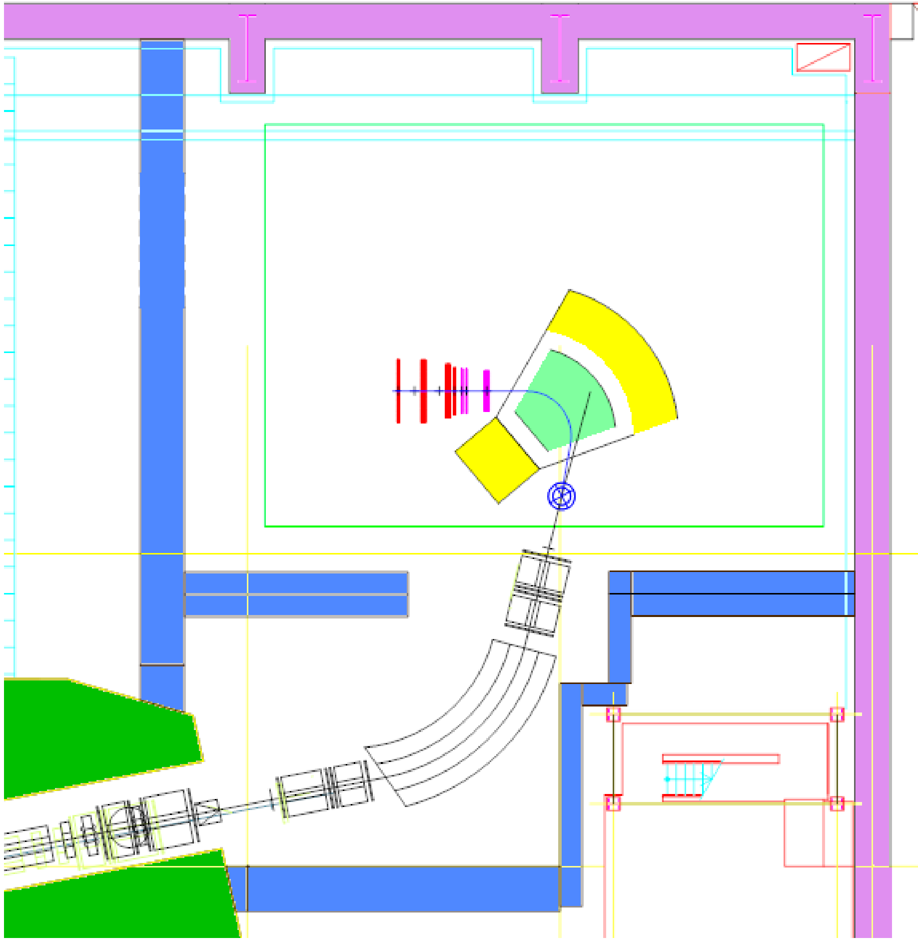
more stable than K-beam

Tochka structure

K1.8 shield

additional shield

wall of building



Safety Issue (2)

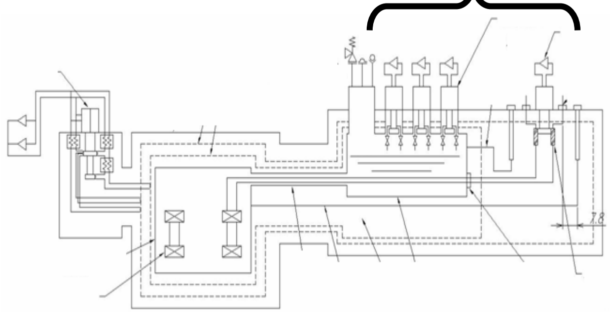
- Toxic and flammable materials
  - Be target
    - Toxic
    - Handling is not difficult (metallic Be)
  - Li target
    - Flammable
    - Careful handling (air tight seal, Ar gas flow)
    - Experience at KEK-PS K6
  - Chamber gas (ethane, iso-butane)
    - Flammable
    - Exhaust pipes to outside, gas leak detectors

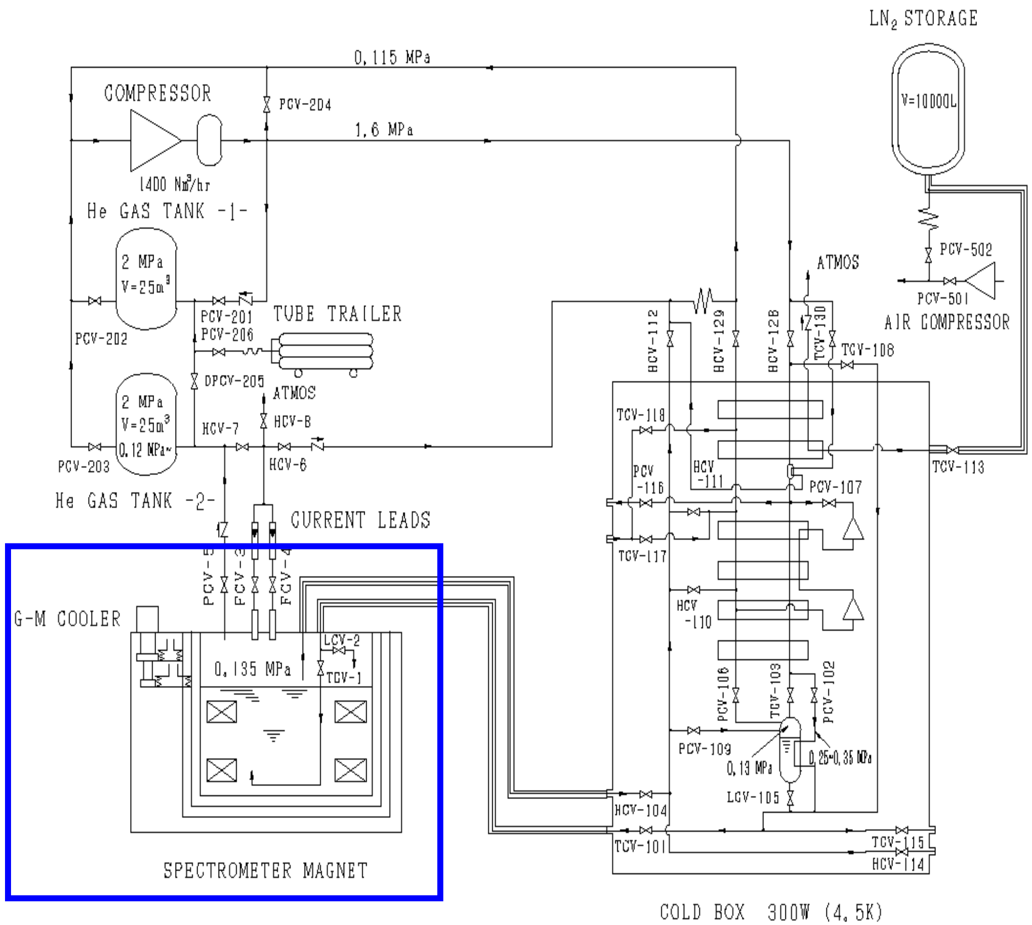
Safety Issue (3)

- Cryogenic system of SKS
  - System will be simplified

leak valve for quench
He evacuation
regular status monitoring
check by shift member
O_2 level monitoring

4K GM-JY cryocooler





Cost for Preparation

- Basic equipments will be ready
  - K1.8 beam line and SKS system
- Upgrade of several detectors for E10
  - BH2, DC1, DC2 (, BC4)

Table 6: Cost estimation for the E10 experiment.

item	unit cost (JPY)	units	total cost (JPY)
DC1, DC2 update	5,000,000	2	10,000,000
electronics for chamber	8,000,000	2	16,000,000
BH2 update	2,000,000	1	2,000,000
total			28,000,000

Status of Budget

- Basically supported by Grant-In-Aid
  - Sharing with E22 experiment necessary
  - Covers most of detector upgrades

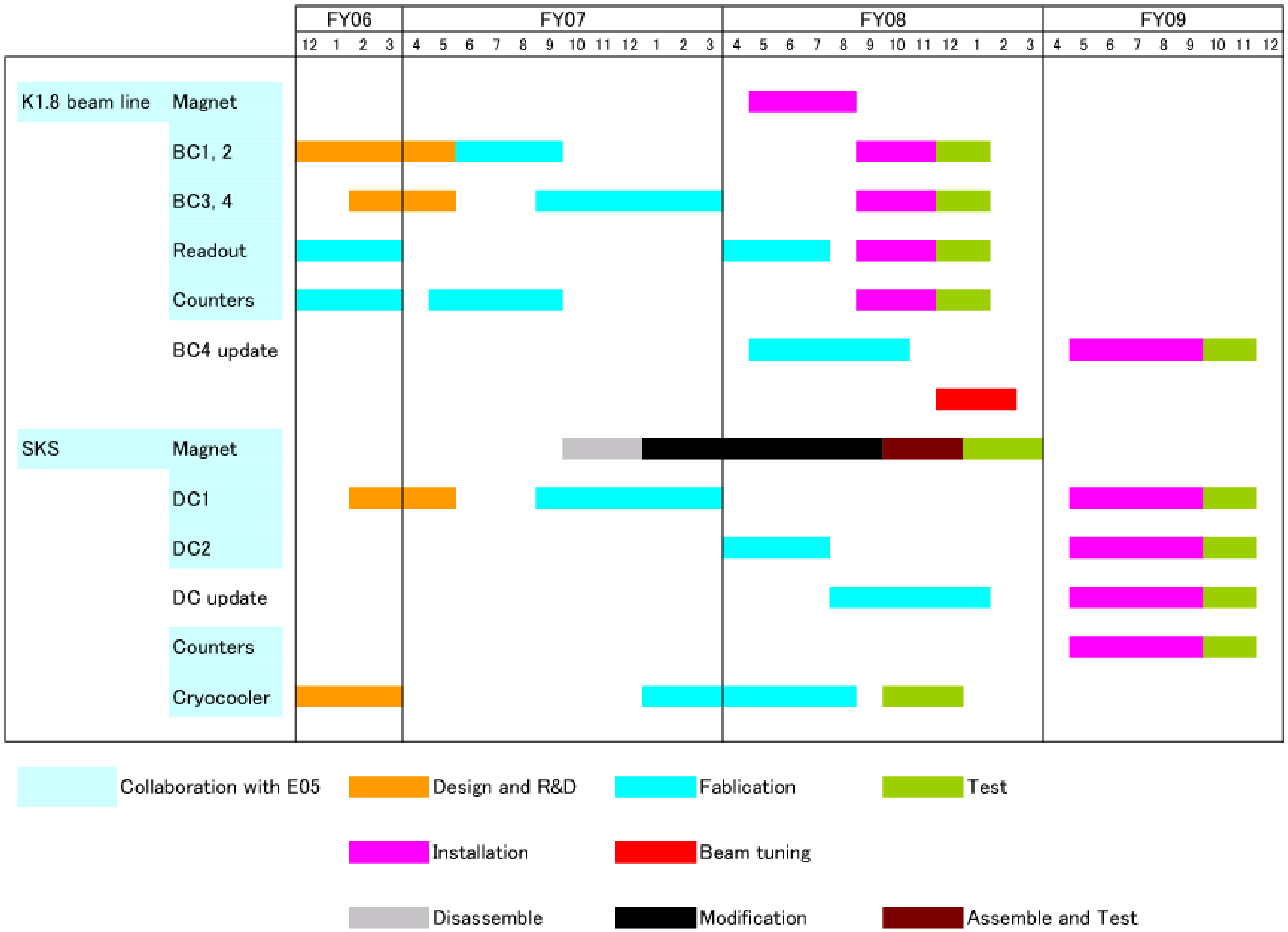
Table 7: Profile of budget from Grant-In-Aid Priority Area.

fiscal year	budget (JPY)
2005	3,600,000
2006	6,500,000
2007	47,300,000
2008	29,000,000
2009	2,700,000
total	89,100,000

79,000,000

Time Schedule

– To be ready in FY2009



Collaboration

- List of staff members only
- Collaboration with other K1.8 user groups

Table 8: List of collaboration.

Institution	Member
Osaka University	Atsushi Sakaguchi*
	Shuhei Ajimura
	Tadafumi Kishimoto
Osaka Electro-Communication University	Tomokazu Fukuda*
	Yutaka Mizoi
KEK	Toshiyuki Takahashi
	Hiroyuki Noumi
JAEA	Pranab Kumar Saha
Seoul National University, Korea	Hyoung Chan Bhang
Università di Torino, Italy	Luigi Busso
INFN, Italy	Diego Faso
INAF-IFSI, Italy	Ombretta Morra