22pBS-1

次世代(K⁻,K⁺)反応用高分解能磁気スペクトロメータの光学設計

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2010/03/22

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Contents

Introduction -- 1

There is still a full uncertainty about *"S=-2"* world.

It's important to understand Ξ-N and Λ-Λ interaction, and also ΞN-ΛΛ coupling dynamics.

- Unified description of *B-B* int. based on $SU_f(3)$
- Strange nuclear matter in astrophysics

We will perform Ξ-hypernuclear Spectroscopy. → J-PARC E05

Beyond E05,

Direct Production of Double-Λ hypernuclei using (K^-,K^+) reaction

Introduction -- 2

Direct Production of Double-Λ Hypernuclei using (K⁻,K⁺) reaction

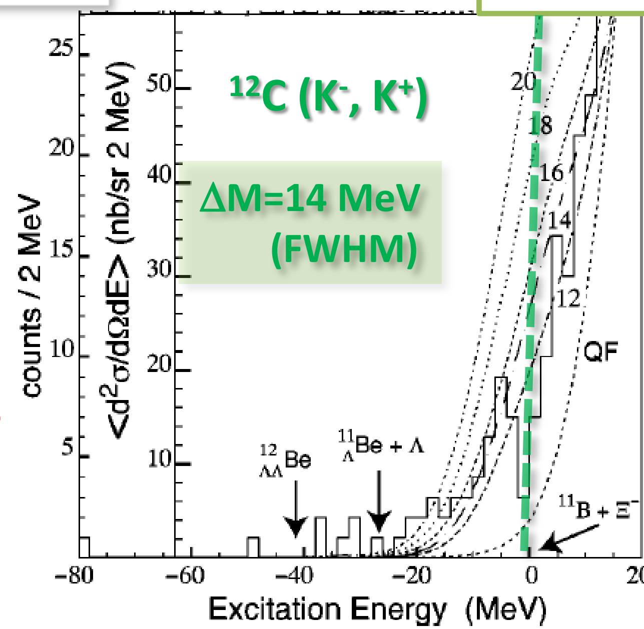
- ☐ Missing mass spectroscopy is possible.
- ☐ Statistical study is possible. c.f.) emulsion
- ☐ **can observe excited states of double-Λ hyp.**
- ☐ **sensitive to ΞN-ΛΛ coupling strength.**

But,

✓ **Cross section may be very small.**

previous exp.

BNL-E885



P.Khaustov et al., PRC61(2000)054603

No peak were observed.
Upper limit : 6~10 nb/sr

K.Yamamoto et al., PLB478(2000)401

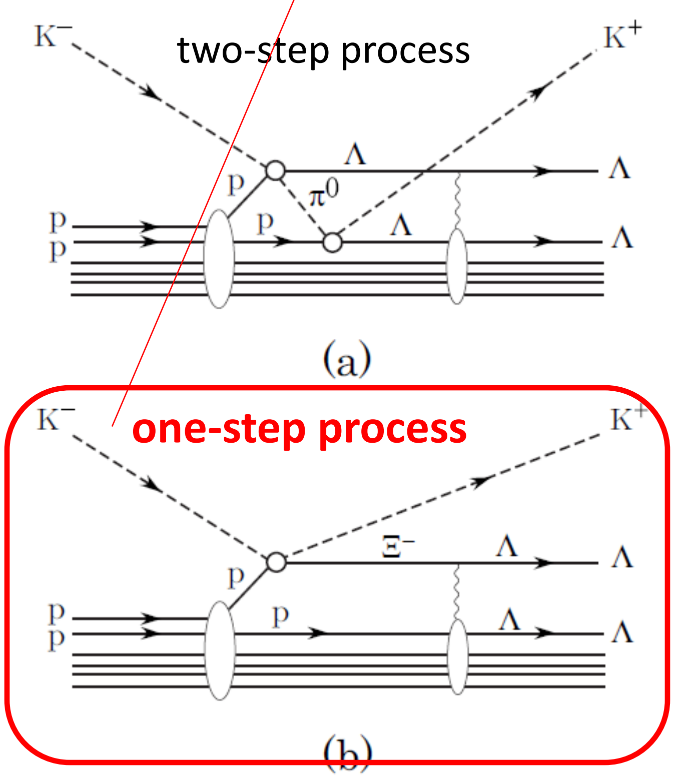
(one order of magnitude lower than Ξ-hyp.)

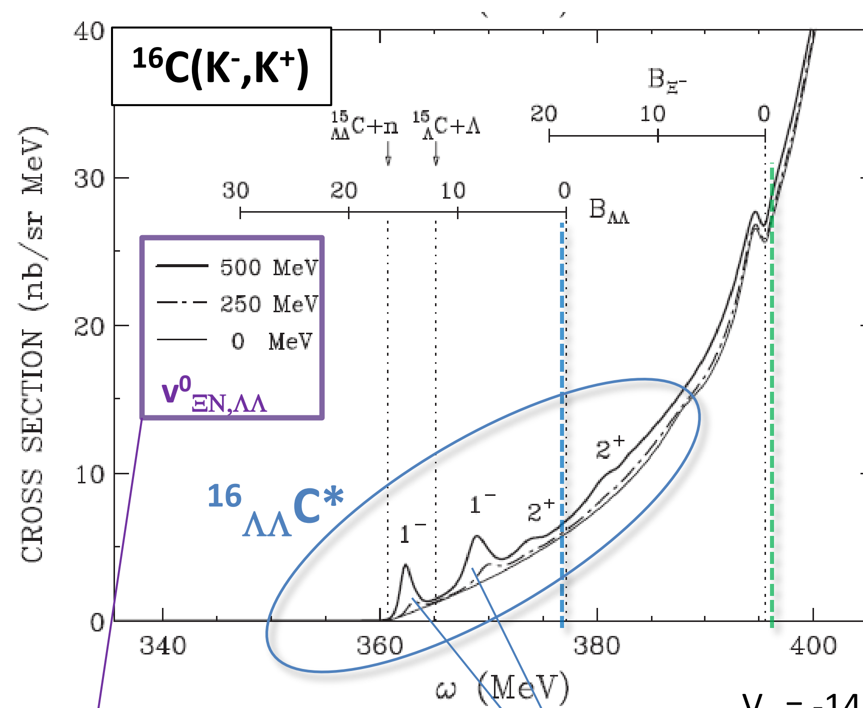
Introduction -- 3

Theoretical Prediction

20aBD-10 **T.Harada**, Y.Hirabayashi, A.Umeya

Theoretical Calculation for $^{16}_{\Lambda\Lambda}C$,
via Ξ^- doorways
in the $^{16}O(K^-,K^+)$ reaction at 1.8 GeV/c





sensitive to ΞN-ΛΛ coupling strength: $v^0_{\Xi N,\Lambda\Lambda}$

V_Ξ = -14 MeV,
$\Delta E_{EXP.}$ = 1.5 MeV
(FWHM) included

5 ~10 nb/sr

Assume 6M K^-/spill,

⇨ Yield = 30~60 events / 100 days

(3g/cm² target, 20msr, 50% K^+ decay, tracking eff.~0.5)

20aBD-10

T.Harada, Y.Hirabayashi, A.Umeya

In order to

observe peak structure precisely

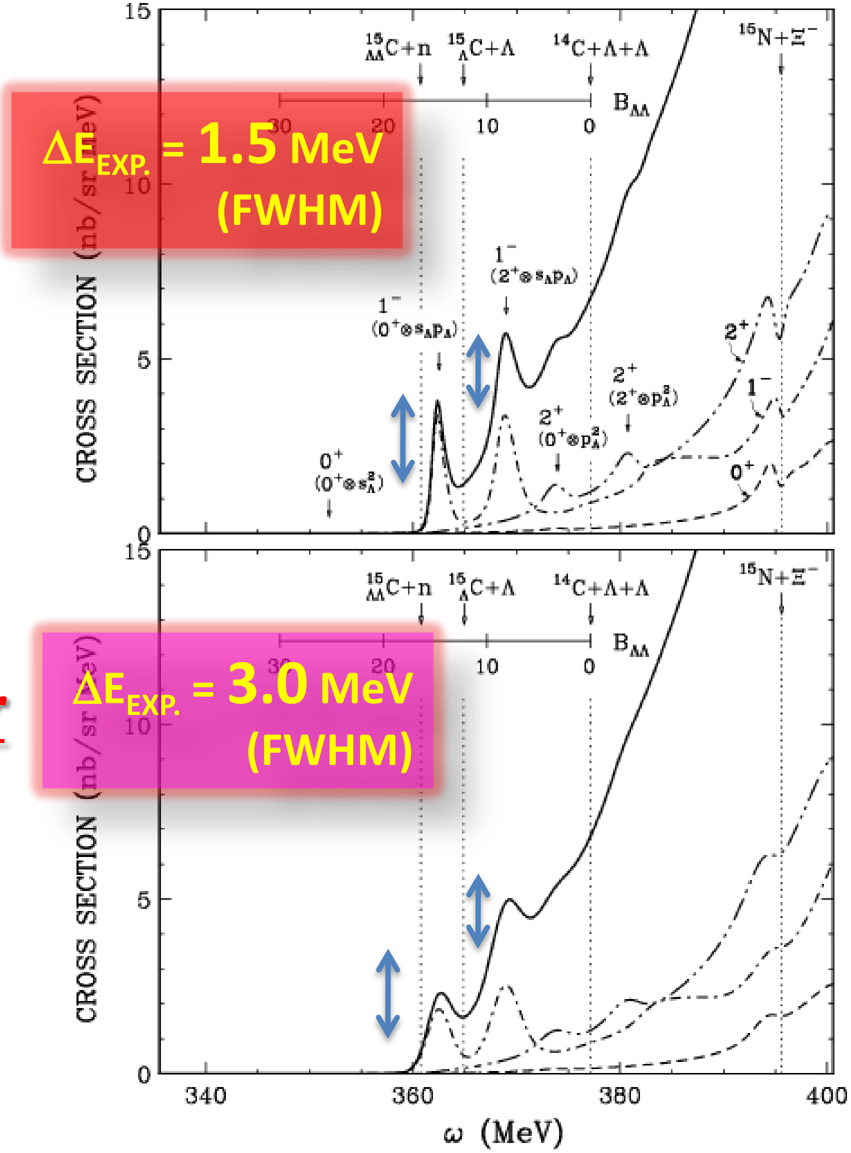
and

compensate lack of statistics,

we need a

High-Resolution Spectrometer

at J-PARC !!



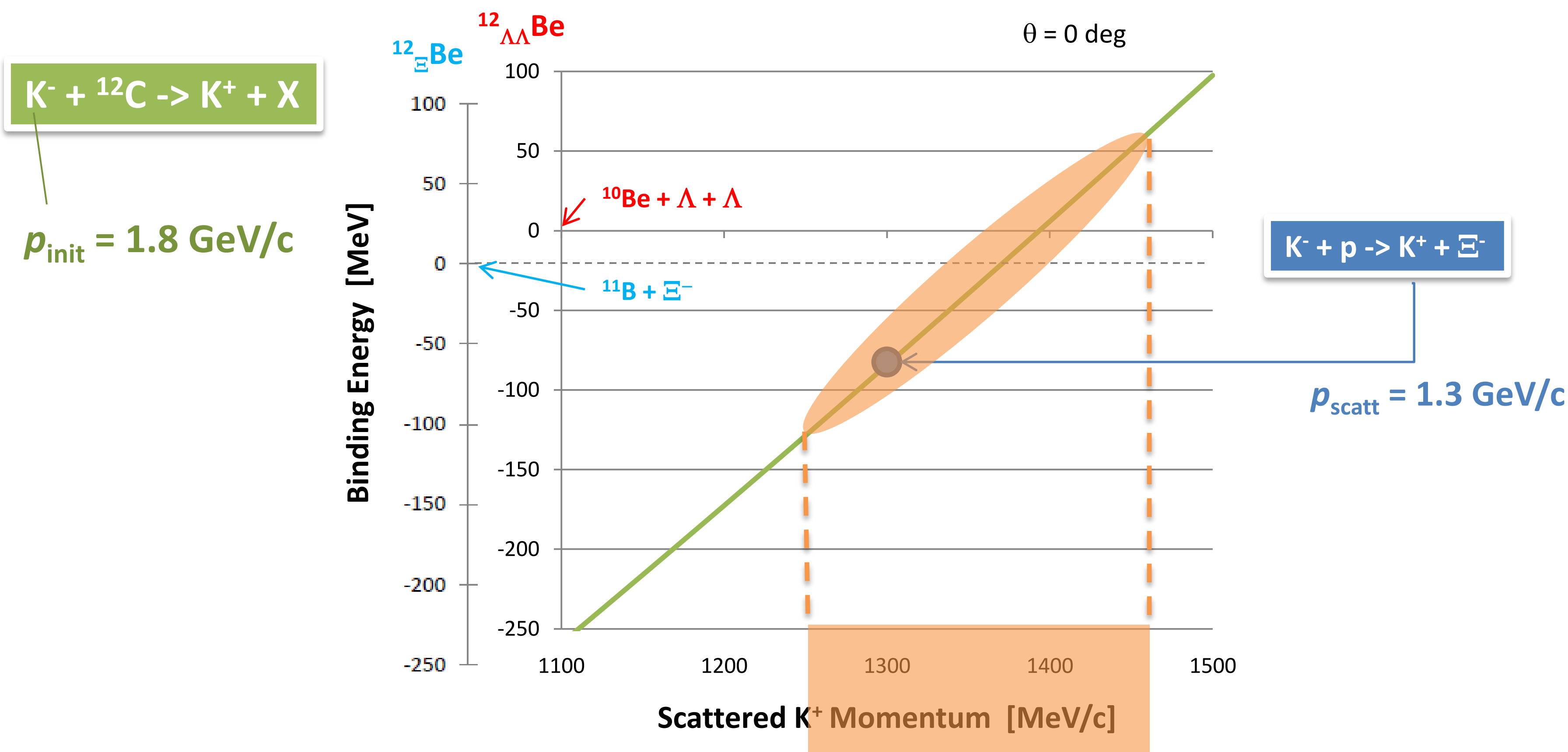
Requirements -- 1

Requirements for the Spectrometer

- Especially for (K^-, K^+) reaction @ 1.8 GeV/c
  Double-Λ hypernuclei and of course Ξ-hypernuclei
- High-Resolution : ~ 5×10^{-4} (corresponds to ΔM_{FWHM} < 1.5 MeV)
- Reasonable Acceptance : ~20 msr
- Path Length as short as possible :
  $K_{survive}$ = 50% → 6.8 m @1.3 GeV/c

Requirements -- 2

--- Central Momentum & Momentum Acceptance ---



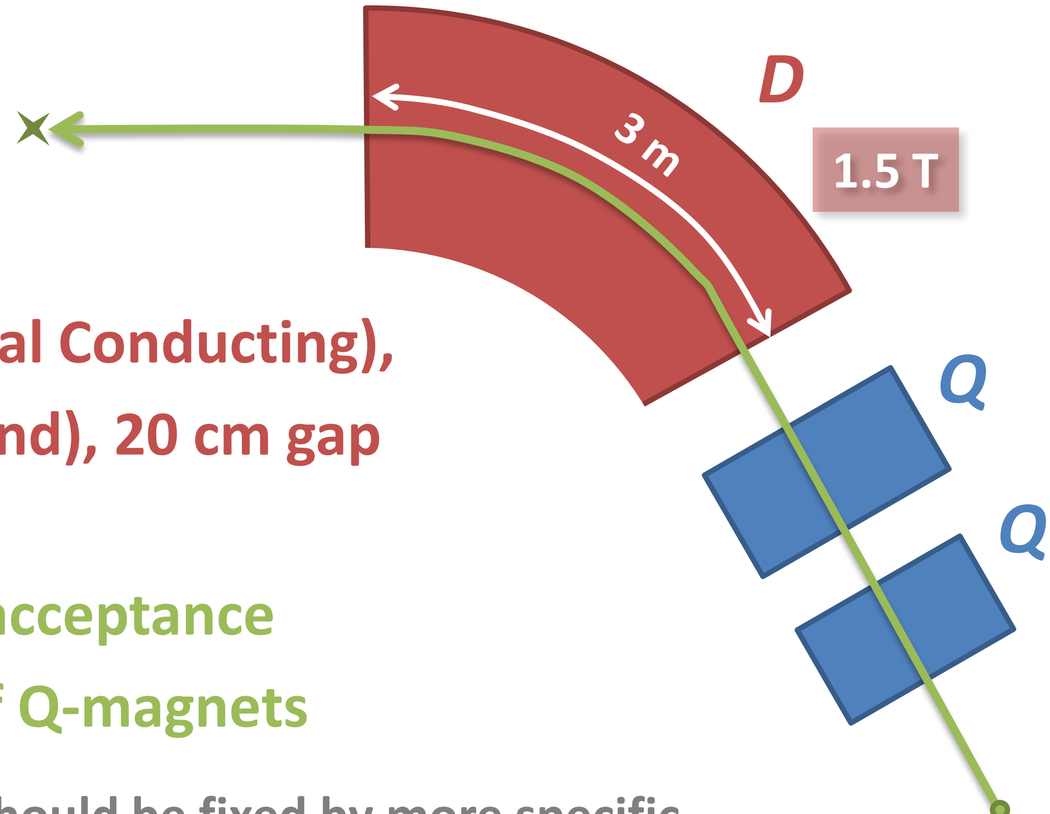
Required Momentum Acceptance = 1.25 ~ 1.45 GeV/c

Optics Design

Primary Optics Design

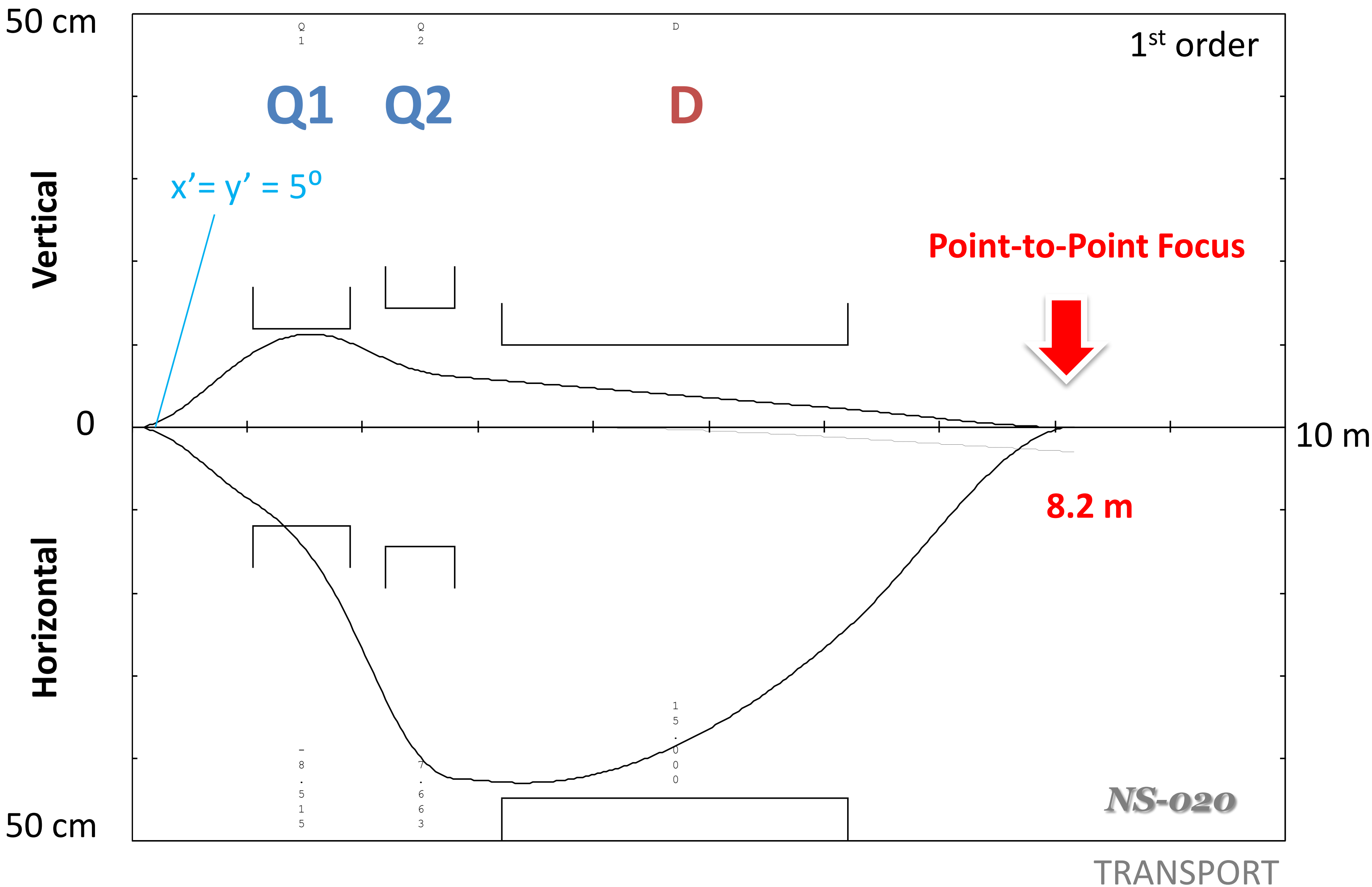
Concept

- At first, we selected standard QQD-type configuration.
  (There is existing high-resolution spectrometer : HKS@JLab)



- D-magnet : 1.5 T (Normal Conducting),
  3 m (→ 60^o bend), 20 cm gap
- Point-to-point focus
  ← For resolution & acceptance
- Adjusted by mainly *B* of Q-magnets
- Geometry of the elements should be fixed by more specific design later. → Not so concerned now.

Result of Optics Calculation -- 1



Result of Optics Calculation -- 2

Transfer Matrix (1st order)

Unit: cm, mrad, %

	x	x'	y	y'	l	δ
x	-0.70981	0.00000	0.00000	0.00000	0.00000	3.14436
x'	-8.39270	-1.40882	0.00000	0.00000	0.00000	8.61260
y	0.00000	0.00000	-7.55338	0.00000	0.00000	0.00000
y'	0.00000	0.00000	-12.91958	-0.13239	0.00000	0.00000
l	-2.02763	-0.44298	0.00000	0.00000	1.00000	-0.51019
δ	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000

Point-to-Point Focus

Magnification -0.71

Dispersion 3.14 cm/%

σ_x = 300 μm

$$\Delta\delta = \frac{\sqrt{\left(1+R_{11}^{2}\right)\sigma_x^{2} + R_{12}^{2}\sigma_\theta^{2}}}{R_{16}}$$

Δp/p = 2.8 x 10^{-4} (FWHM)

Δp = 0.36 MeV/c @ p=1.3GeV/c

$\Delta p_B/p_B$ = 3.3 x 10-4 (K1.8BS)

$\Delta\theta$ = 5 mrad

Missing Mass Resolution

$$\Delta M^2 = \Delta^2_{Beam} + \Delta^2_{Scatt} + \Delta^2_{\theta} + \Delta E^2_{strag}$$

MeV (FWHM) @ $\theta = 5^o$

	Δ_{Beam}	Δ_{Scatt}	Δ_{θ}	ΔM w/o ΔE_{strag}	ΔE_{strag}	ΔM
$K^- + {}^{12}C \rightarrow K^+ + X$	0.56	**0.45**	0.10	0.73	**1.0**	1.24

ΔM = 1.24 MeV (FWHM)

3 g/cm² Target

Sufficiently Small !!

Dominant contribution is Energy-loss Straggling !!

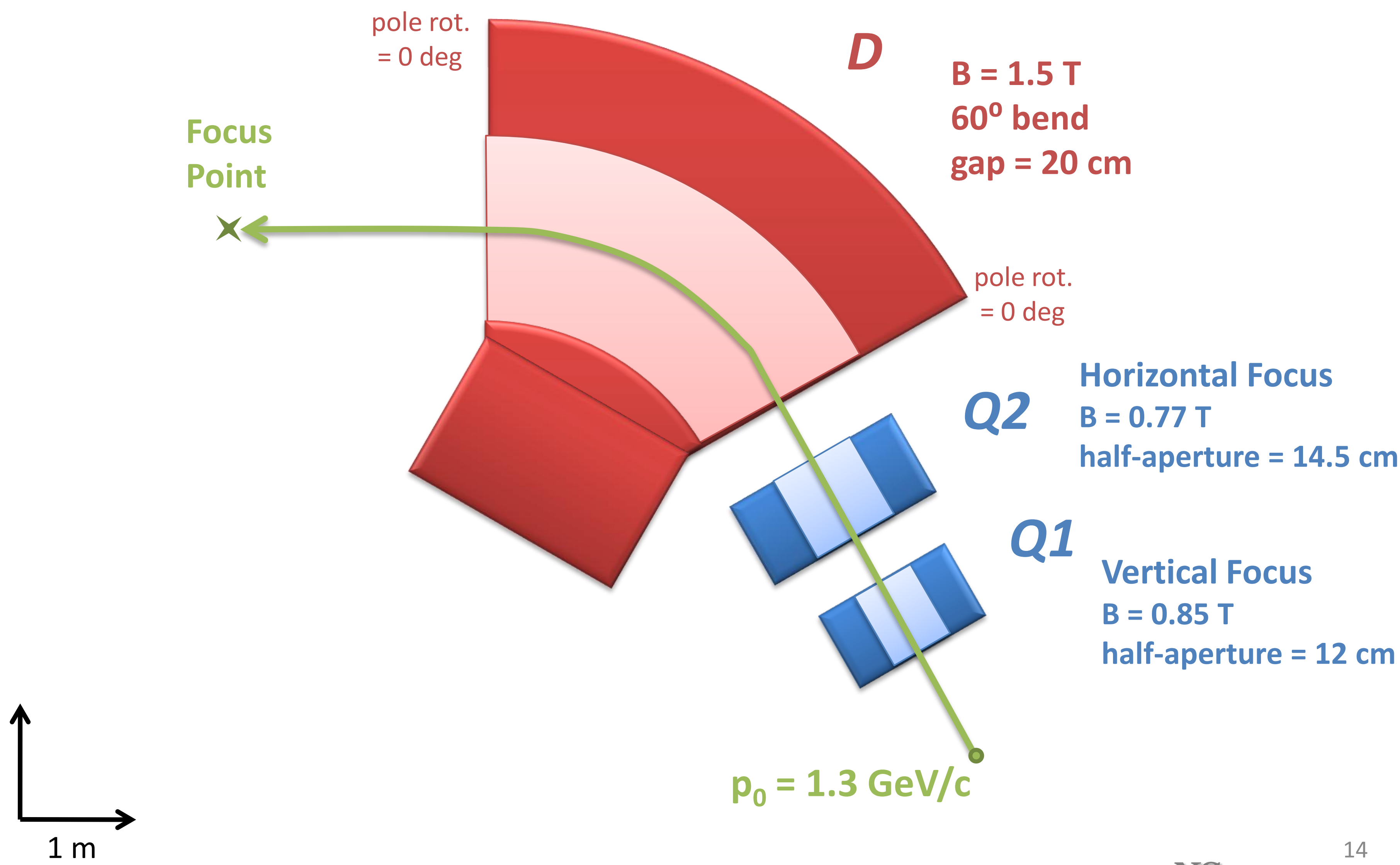
c.f.) In the case of SKS+

$K^- + {}^{12}C \rightarrow K^+ + X$	0.56	**2.27**	0.10	2.34	**2.0**	3.08

Dominant contribution is Δ_{Scatt}

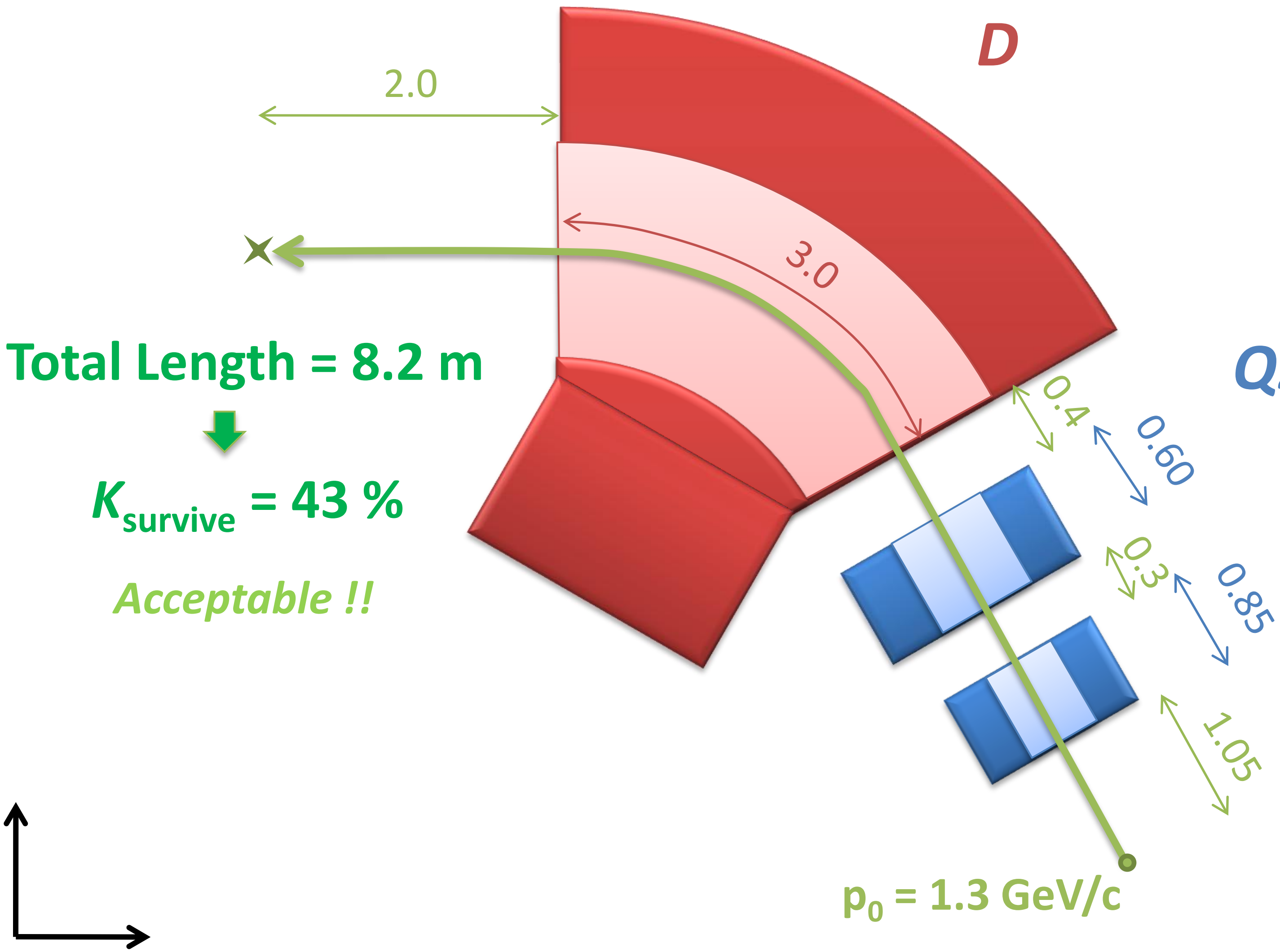
Primary Optics Design

Schematic View



Primary Optics Design

Schematic View



Total Length = 8.2 m

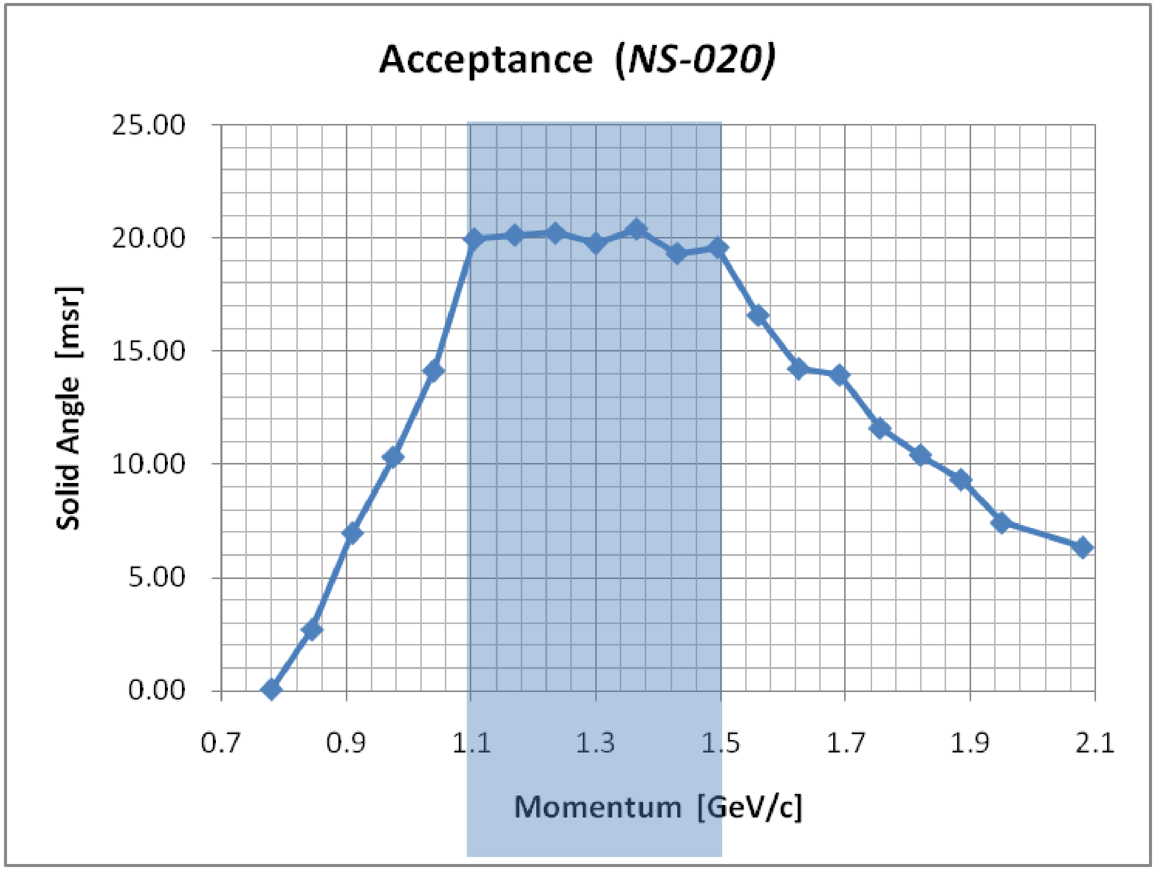
⬇

$K_{survive}$ = 43 %

Acceptable !!

Acceptance Calculation

p_0 = 1.3 GeV/c



TURTLE

20 msr @ 1.3 GeV/c±15% (1.1~1.5 GV/c)

Enough Acceptance !! **c.f.) requirement was 1.25~1.45 GeV/c**

Summary

- We attempt to make a primary optics design of the high-resolution spectrometer for the next generation (K^-,K^+) reaction.
- We could achieve the requirements.
  - Momentum Resolution ~ 3 x 10^{-4} (FWHM)
  - Acceptance ~ 20 msr @ 1.3 GeV/c ±15 %
  - $K_{survive}$ = 43 %

Prospects

- **This result is only a primary design yet. → must be improved !!**
  - ✓ Is this configuration really the best answer ?
  - ✓ How about other configurations ?
- **Need more discussion for detail design .**
  - optics design & mechanical design

    (alignment, coil, yoke, cooling, etc……)