Prospect of Λ-spin-flip B(M1) measurement at K1.8 beam line

Mifuyu Ukai
Dept. of Phys. Tohoku Univ.

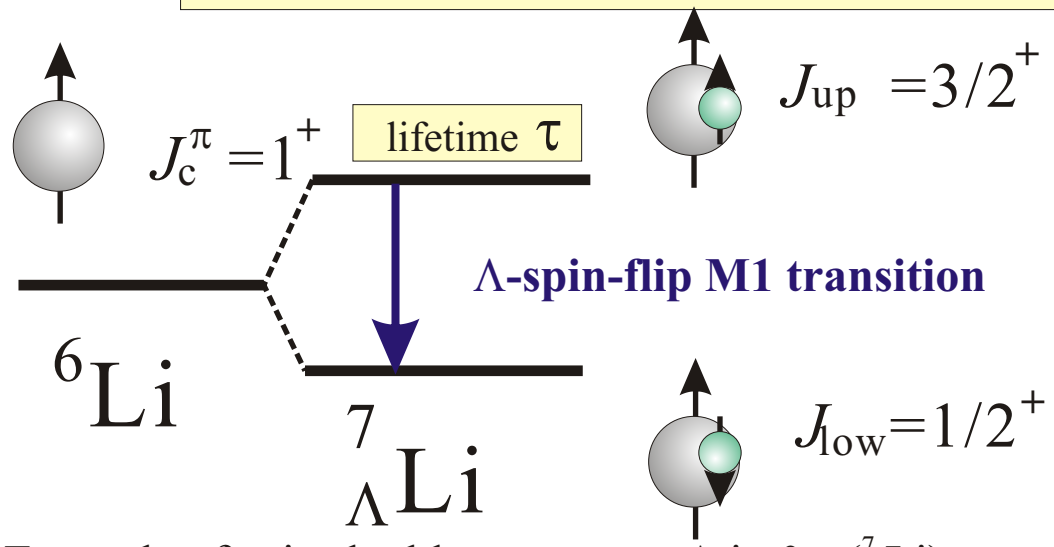
Contents

Physics Motivation

Medium effect of Baryon

Change of Baryon properties
in the nuclear medium from the free space

magnetic moment of Λ in nuleus ⇐ Λ-spin-flip B(M1) value



Example of spin-doublet structure; Λ in 0s ($^7_\Lambda$Li)

$$B(M1) = 3/8\pi\,(2J_{low}+1)/(2J_c+1)(g_c - g_\Lambda)^2$$

B(M1); reduced transition probability of M1

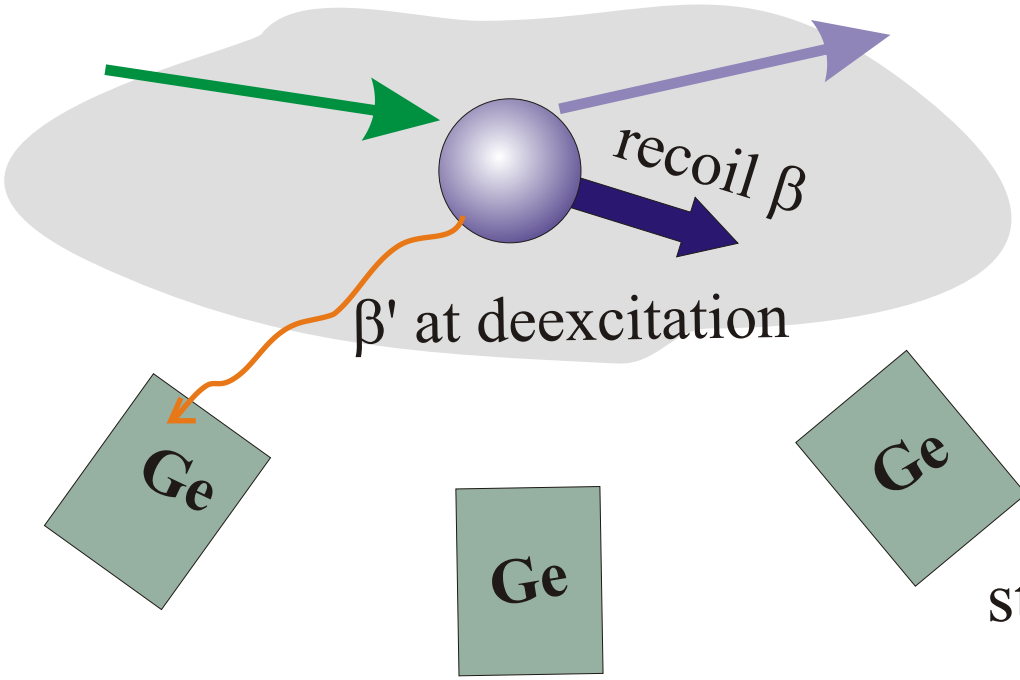
$$\Gamma = BR/\tau = 16\pi/9\; E_\gamma^3 B(M1)$$

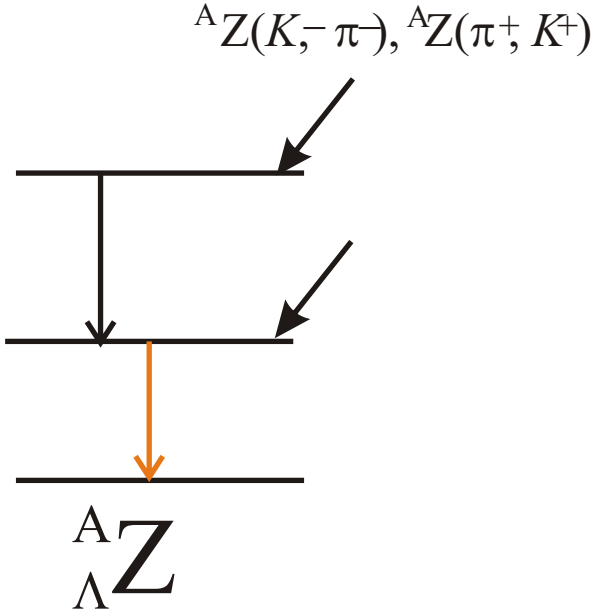
Λ-spin-flip B(M1) value ⇐ τ and Eγ of the transition

transition energy(Eγ), lifetime(τ) from peak shape analysis
Only γ-ray spectroscopy of Ge detector can measure

One of the main purpose of J-PARC E13

Doppler-shift attenuation method

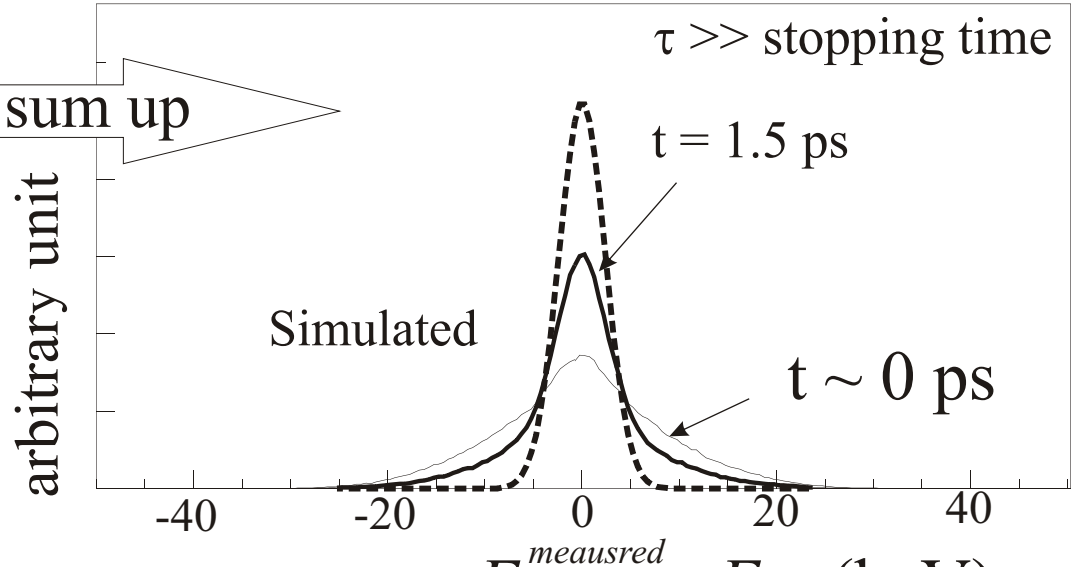




stopping time ~2 ps, initial β ~ 3%

$$E^{meausred} = E_0 / \gamma(1-\beta' \cos\theta)$$

sum up

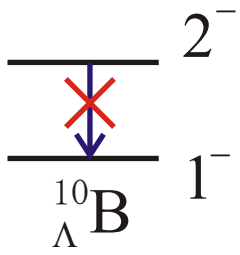


lifetime (τ) can be obtained by peak shape fitting

Privious trials of B(M1) measurement

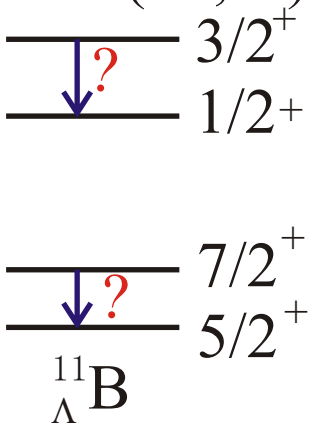
BNL-E930('01)

$^{10}B(K^-,\pi^-)$



M1 not observed

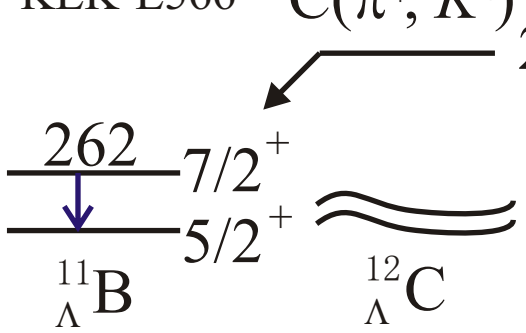
KEK-E518 $^{11}B(\pi^+,K^+)$



many γ-rays observed
can not identify the transitions

Motivated to measure B(M1)

KEK-E566 $^{12}C(\pi^+, K^+)$



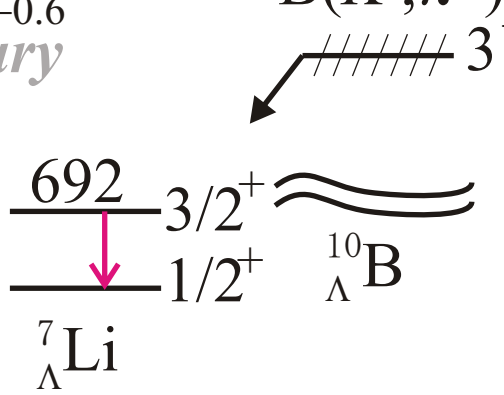
transition was identified
but spacing energy is too small
(target density too high)

g_Λ = –1.226 in free space

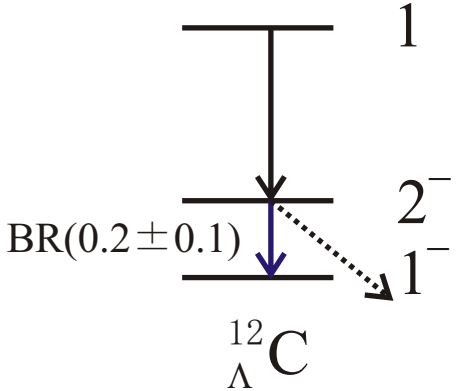
BNL-E930('01)

$g_\Lambda = -1.1\ ^{+0.4}_{-0.6}$
preliminary

$^{10}B(K^-,\pi^-)$



KEK-E566



B(M1) measured, unexpectedly

not accurate but finite value

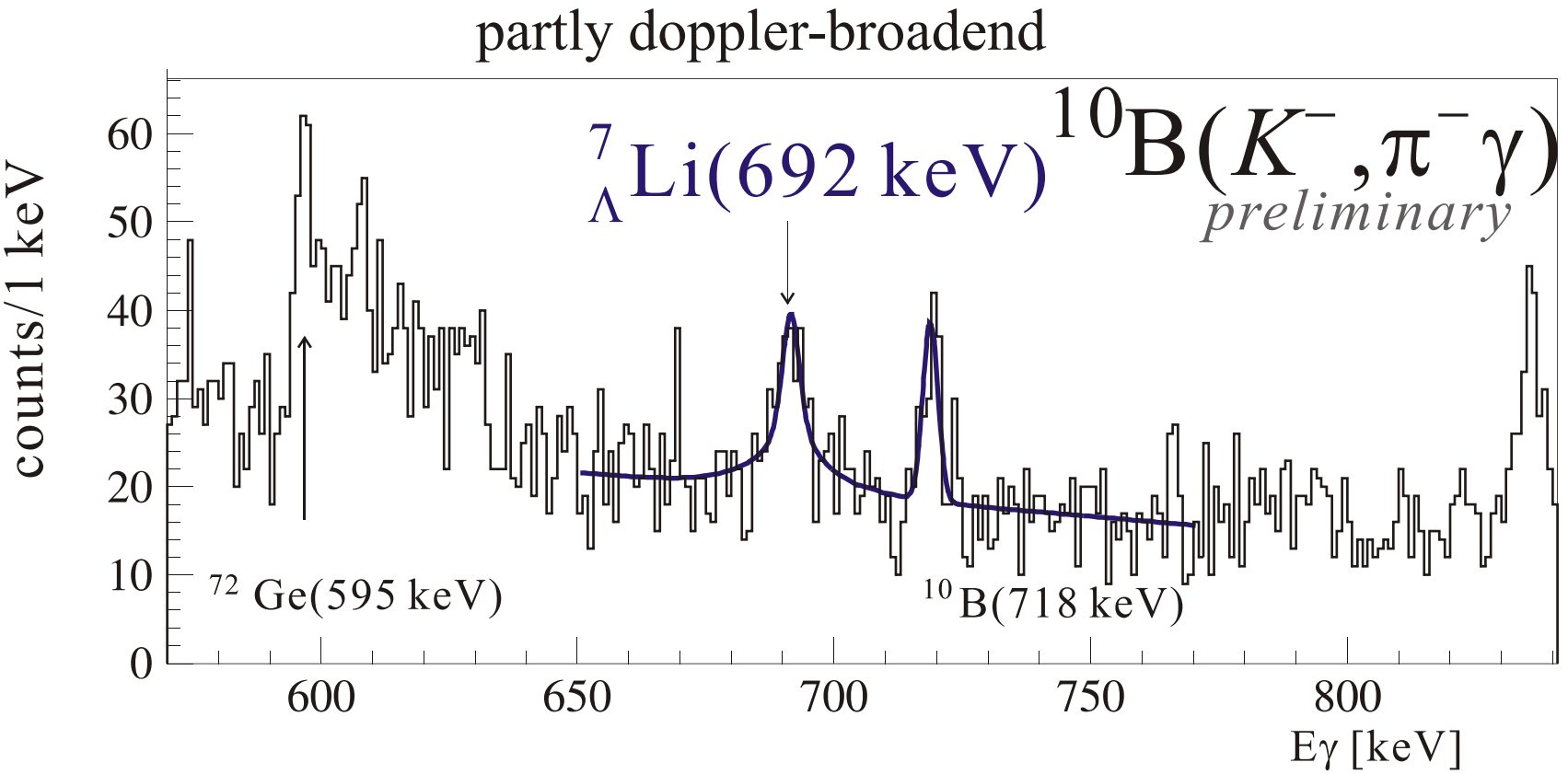
$g_\Lambda = -1.03 \pm 0.41$
preliminary

Derived from competetition with M1 and weak decay (missing yield)

$\Gamma^{weak}_{g.s.} = (228\ ps)^{-1}$

べ・・別にこんなの測りたかった実験じゃないんだからね！

Lifetime of the 3/2+ state in ${}^{7}_{\Lambda}$Li



$\tau = 0.58\ ^{+0.38}_{-0.20}$ [ps](stat. only) by DSAM

$B(M1) = 0.30\ ^{+0.12}_{-0.16}$ $[\mu_N]^2$

$g\Lambda = -1.1\ ^{+0.4}_{-0.6}$ $[\mu_N]$ ($g\Lambda$=−1.226 free space)

Unfortunately, using hot-pressed powder target density NOT uniform for traveling HN=> syst. error

B(M1) and lifetime of light hypernuclei

transition	Eγ (MeV)	g	B(M1)	1/Γ (ps)
${}^{7}_{\Lambda}$Li $(3/2^{+}\rightarrow 1/2^{+})$	0.692	0.8220	0.334	0.51
${}^{11}_{\Lambda}$B $(7/2^{+}\rightarrow 5/2^{+})$	0.262	0.6002	0.341	9.26
${}^{19}_{\Lambda}$F $(3/2^{+}\rightarrow 1/2^{+})$	0.3 ~ 0.4	(0.566)	(0.256)	8.23~3.47

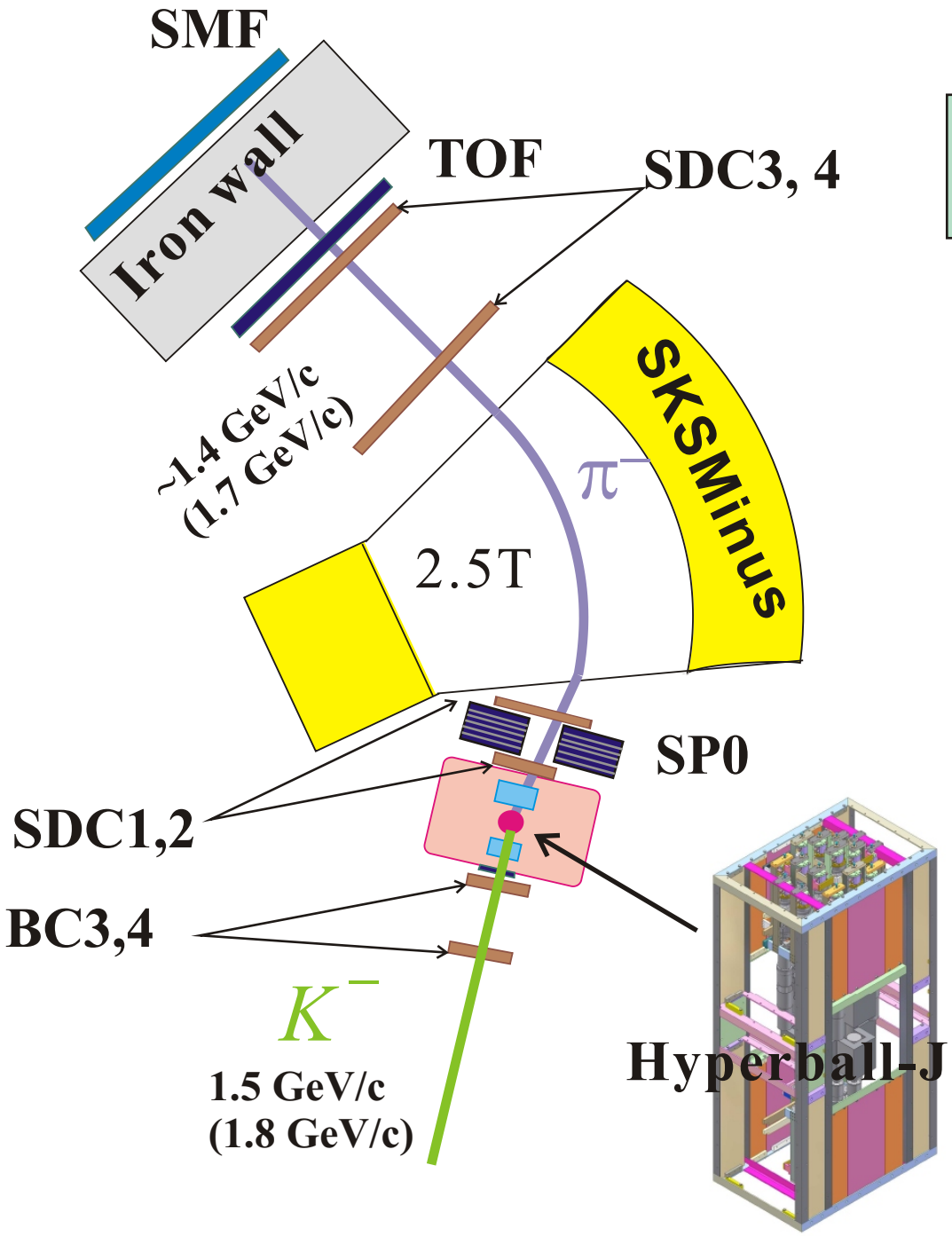
Extream rough estimation,

target material density of *p*-shell region ~ 1 ~ 2 g/cm

stopping time by (K,π), (π,K) reaction ~ 2 ps

Too fast / Too slow

Gamma-ray spectroscopy of light hypernuclei; E13



$^{4}_{\Lambda}\mathrm{He}$, $^{7}_{\Lambda}\mathrm{Li}$, $^{10}_{\Lambda}\mathrm{B}$, $^{11}_{\Lambda}\mathrm{B}$, $^{19}_{\Lambda}\mathrm{F}$

First stage of E13

$^{4}_{\Lambda}\mathrm{He}$ and $^{19}_{\Lambda}\mathrm{F}$

Motivation

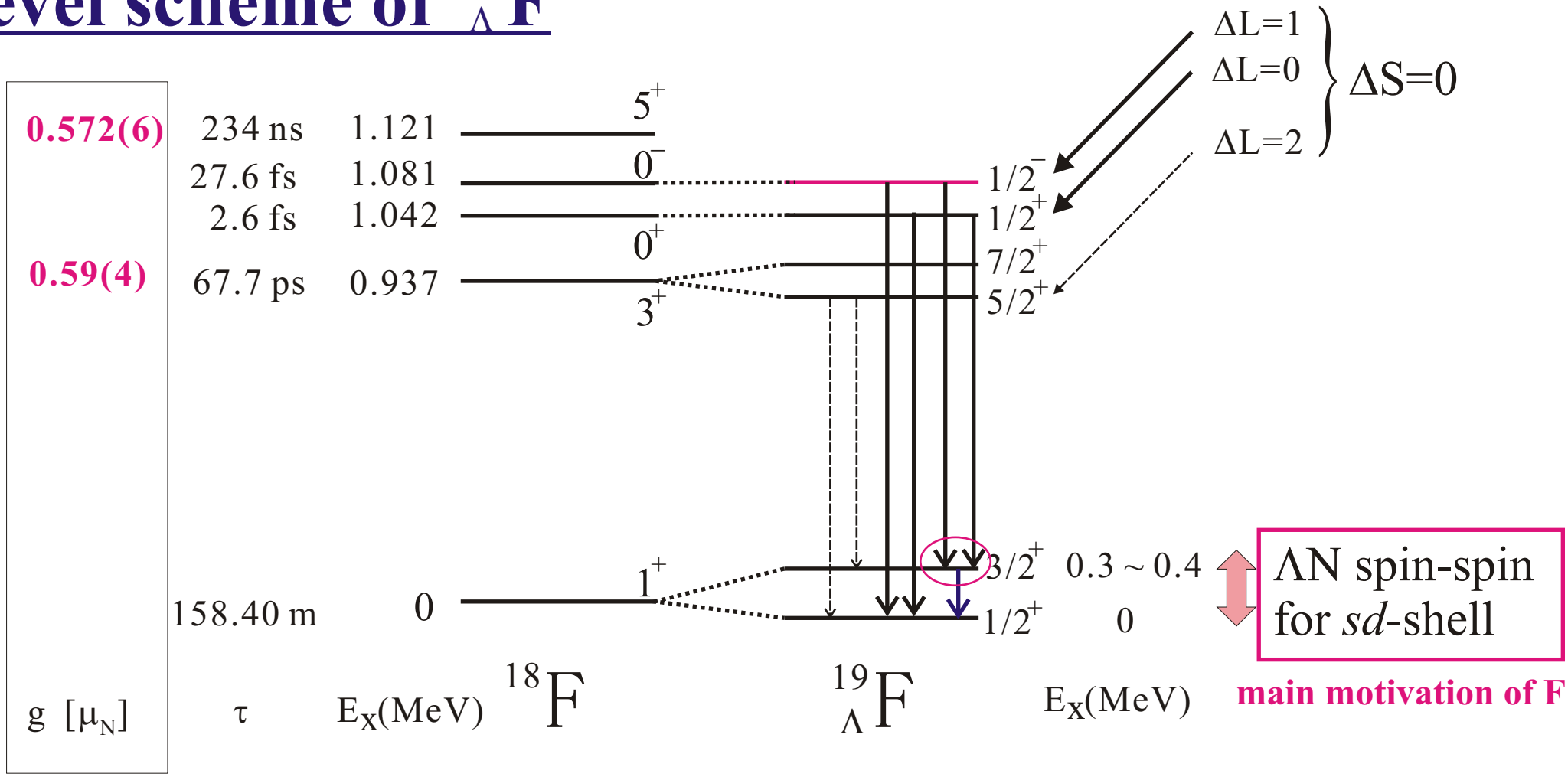
ΛN spin-spin interaction study for *sd*-shell hypernuclei

Teflon®;$(C_2F_4)_n$ as F target in proposal

(Very easy to handle)

How reliable for B(M1) measurement using low intensity target?

Level scheme of $^{19}_{\Lambda}$F



$(0d_{5/2})_p$ x $(0d_{5/2})_n$

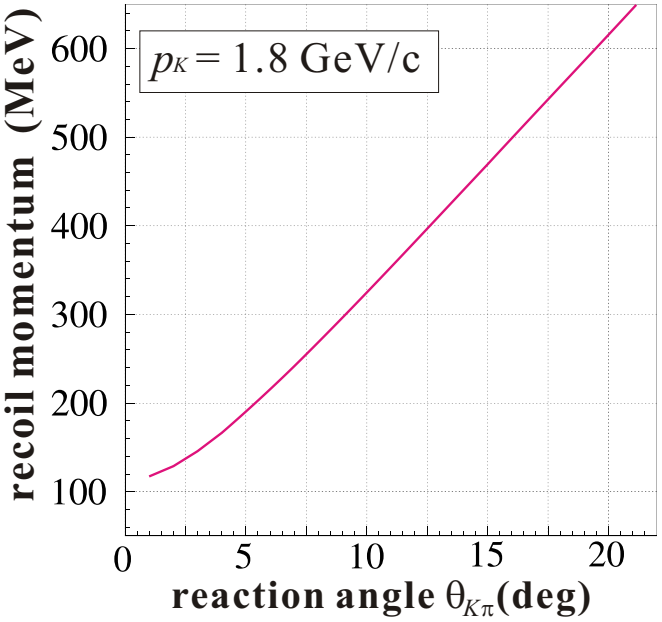
g-facotor of the g.s. of F NOT measured

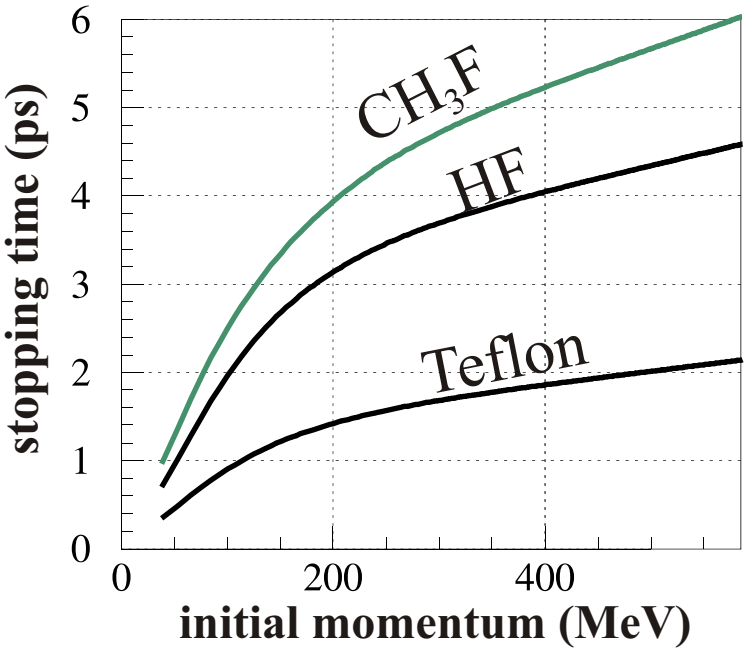
g-factor of N=Z odd-odd nucleus ($j_p = j_n$)
well reproduced by Schmit value of *jj*-coupling scheme (except for Li)

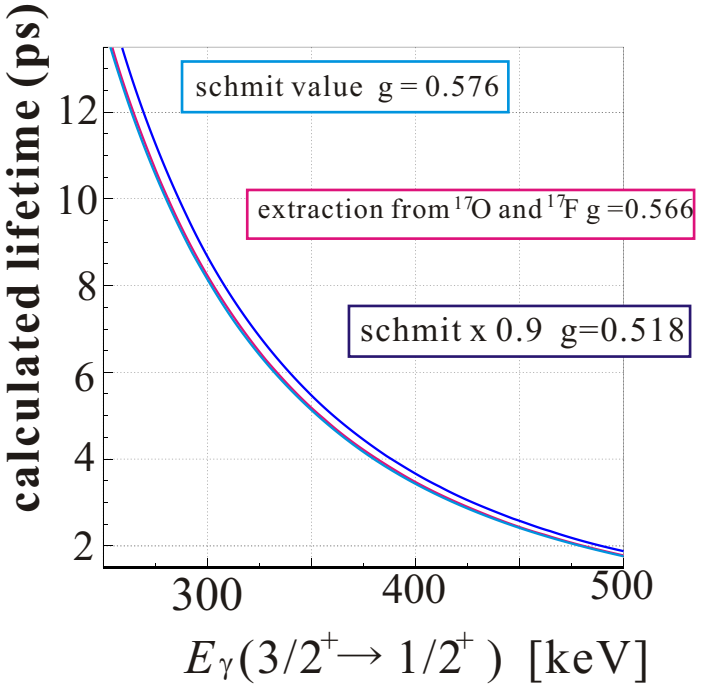
$$g = [g(0d_{5/2})_p + g(0d_{5/2})_n]/2 = 0.576 \quad \text{(Shmit value)}$$
$$= \mathbf{0.566} \quad \text{(extraporation from } ^{17}\text{O and } ^{17}\text{F)}$$

Stopping time and expected lifetime

			boiling point
Fluoromethane	CH_3F	0.557 g/cm^3	–78.2
Hydrofuloride	HF	1.002 g/cm^3	19.5
Teflon®	$(C_2F_4)_n$	2.17 g/cm^3	



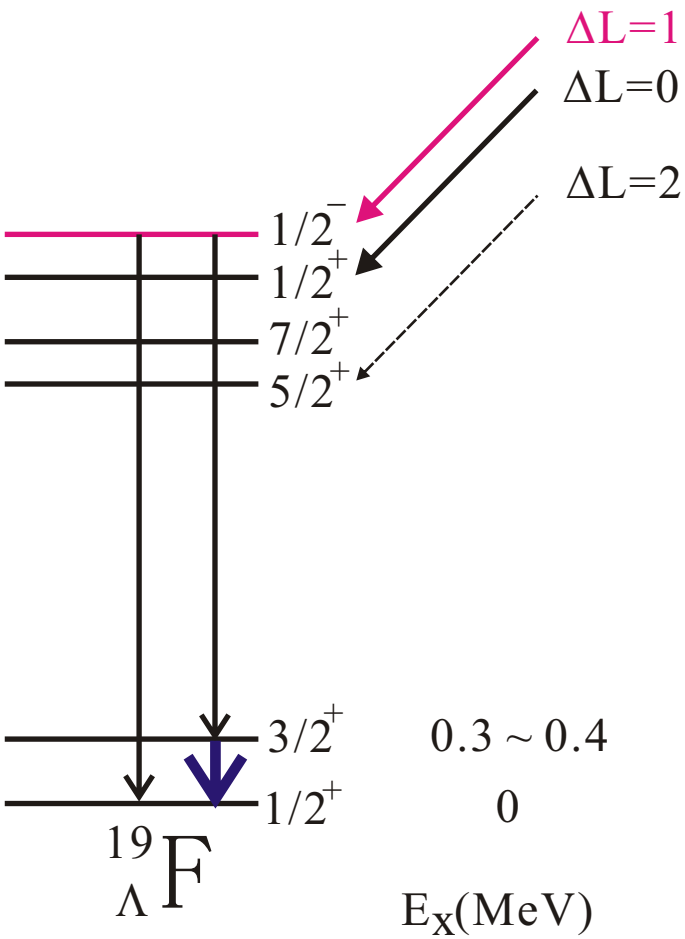




Larger momentum transfer, lower target density are feasible

Demonstrate; ^{19}F(K^- ,π^-) @ p_K = 1.8 GeV/c, CH_3F target

Yield estimation@p = 1.8 GeV/c



$$\int_{\text{SksMinus}} d\sigma/d\Omega \cdot \delta\Omega \quad \sim 7.5\ \mu b$$

(cross section ; from calculation for ^{20}Ne)

Target; CH_3F 30 cm: 17.3 g/cm^2

BR $(1/2^- \rightarrow 3/2^+)/(1/2^- \rightarrow 1/2^+, 3/2^+)$
~ 0.3 @ (3/2, 1/2) = 400 keV

$\varepsilon\gamma$ @ 400 keV ~ 10 %

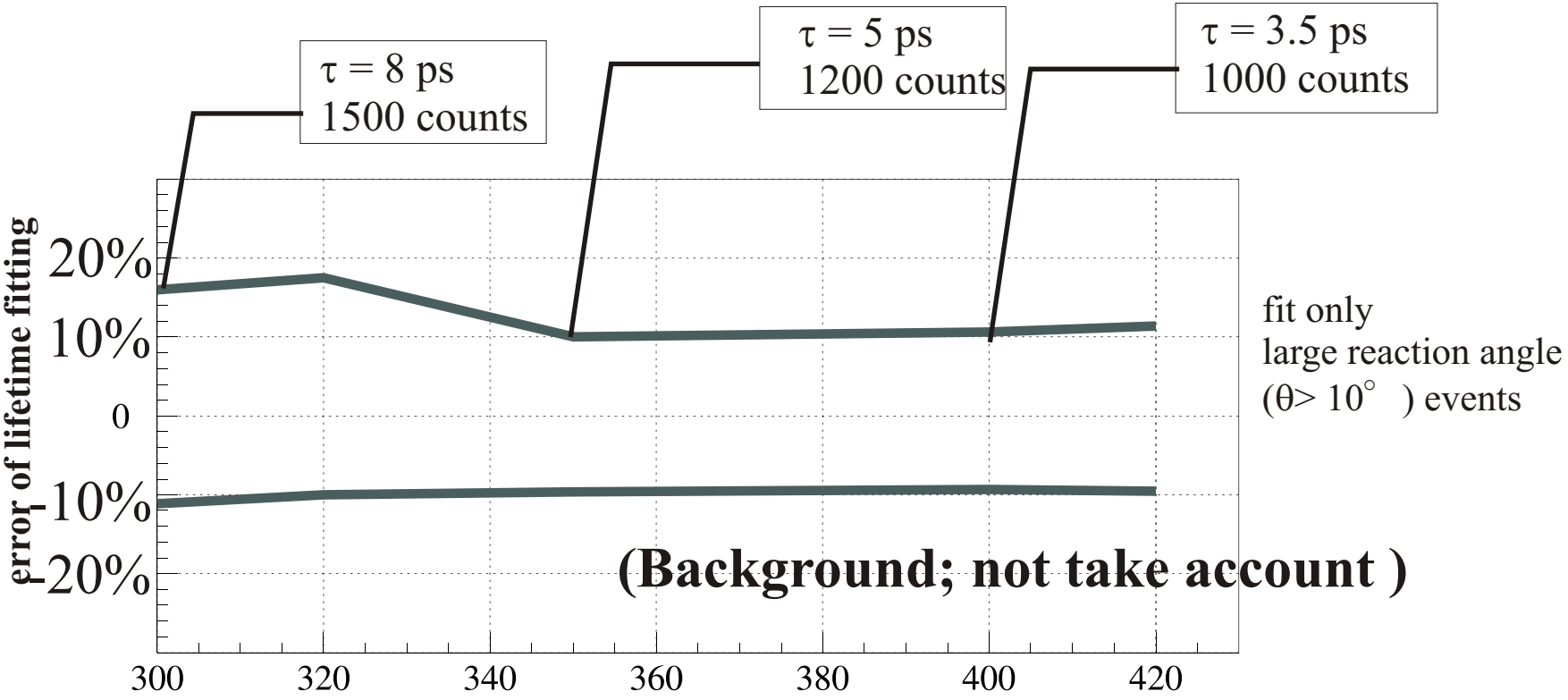
4.5 counts/ hour / (200k/spill)
(spill cycle = 6 s)

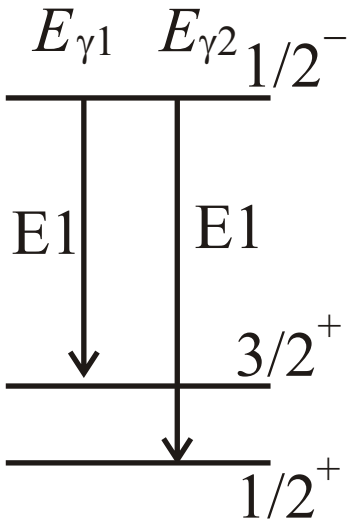
Kaon yield by rough scan
~ 45 k /spill @ 3 kW
(narrow IFV slit 2mm)
ESS1,2 = ± 200 kV

1000 counts /10 days for 200 k/spill

(direct production of 3/2+ are not included)

Sensitivity of lifetime





$BR_{\gamma 1} / BR_{\gamma 2} \propto E_{\gamma 1}^3 / E_{\gamma 2}^3$

lower $E(3/2^+)$–$E(1/2^+)$ energy:

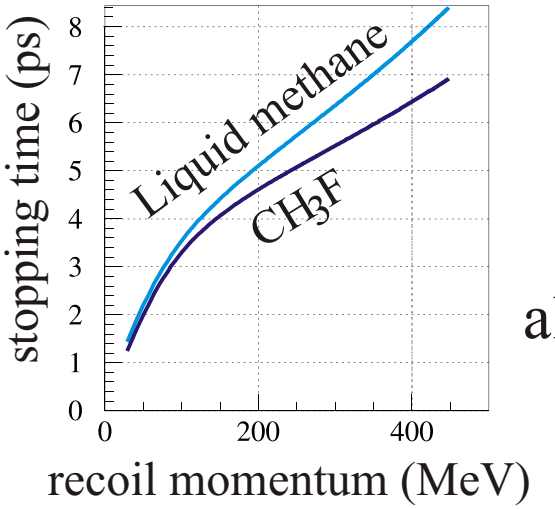
Longer lifetime↓ , Branching ratio↑ , Efficiency↑

γ-ray yield↑

lifetime~ 10 % (g ~ 7 %) accuracy acheivable

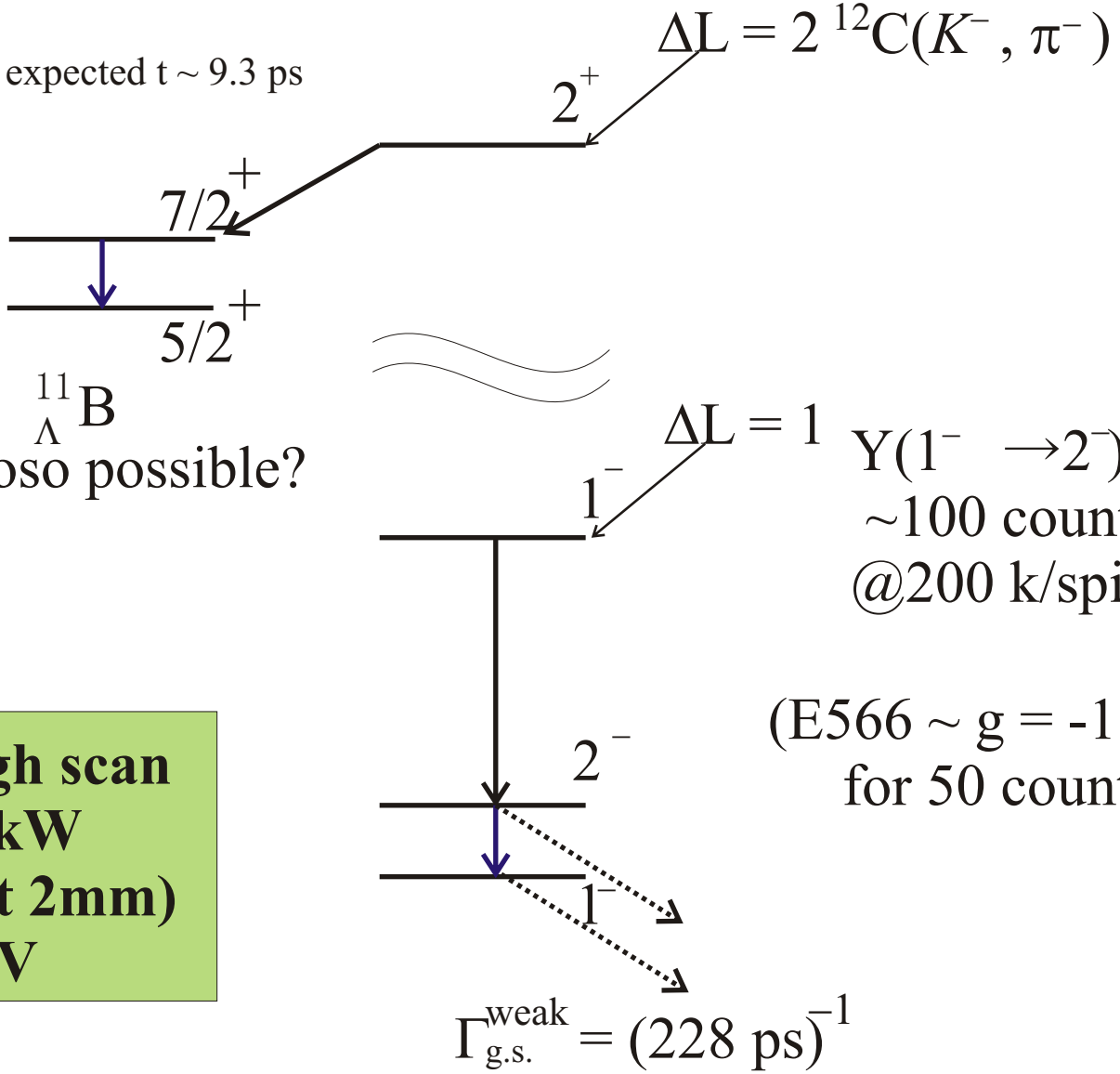
10 days beam time (if 200 k/spill)

Other B(M1) product using CH_3F target ~ low density Carbon target



$\theta > 15°$ expected t ~ 9.3 ps

$^{11}_{\Lambda}B$ aloso possible?



Y($1^- \rightarrow 2^-$)
~100 counts/ 10 days
@200 k/spill, 6 s cycle

(E566 ~ g = -1.03 ± 0.41 [μ_N]
for 50 counts/month)

Kaon yield by rough scan
~ 45 k /spill @ 3 kW
(narrow IFV slit 2mm)
ESS1,2 = ± 200 kV

Summary and Request

γ-ray spectroscopy of $^{4}_{\Lambda}$He and $^{19}_{\Lambda}$F will be perfomed at 1st stage of E13

Feasibility of Λ-spin-flip B(M1) in $^{19}_{\Lambda}$F measurement is simulated

Lifetime accuracy~ 10 % will be achiebable using 10 days (200 k/spill)

We need theoretical support!

g-factor information of F(1^{+})

Spacing energy $^{19}_{\Lambda}$F($3/2^{+}$, $1/2^{+}$)

realistic cross sections of $^{19}_{\Lambda}$F and $^{12}_{\Lambda}$C states