K^-ppのスピン・パリティ測定と $\bar{K}^0nn$の探索

– Measurement of spin and parity of K^-pp and searching for $\bar{K}^0nn$–

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山我 拓巳（理化学研究所)

浅野秀光, 橋本直[A], 岩崎雅彦, 馬越, 村山理恵, 野海博之[B, C], 大西宏明[D], 佐久間史典

理研, 原研[A], 阪大RCNP[B], KEK[C], 東北大ELPH[D]

Brief introduction of $\bar{K}NN$ state

– Exotic bound state resulting strong attractive $\bar{K}N$ interaction –

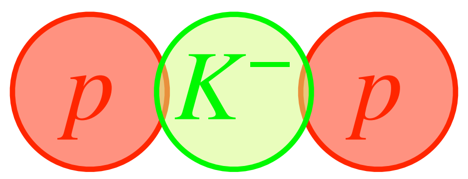
$\bar{K}NN$ bound state

The simplest kaonic nucleus system

Bound system of anti-kaon and two nucleons

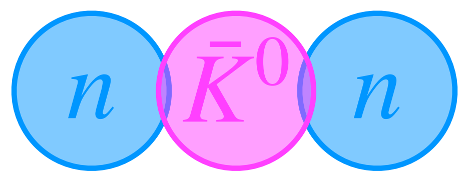
$$\left[\bar{K}_{I=\frac{1}{2}}(NN)_{I=1}\right]_{I=\frac{1}{2}}$$

K^-pp

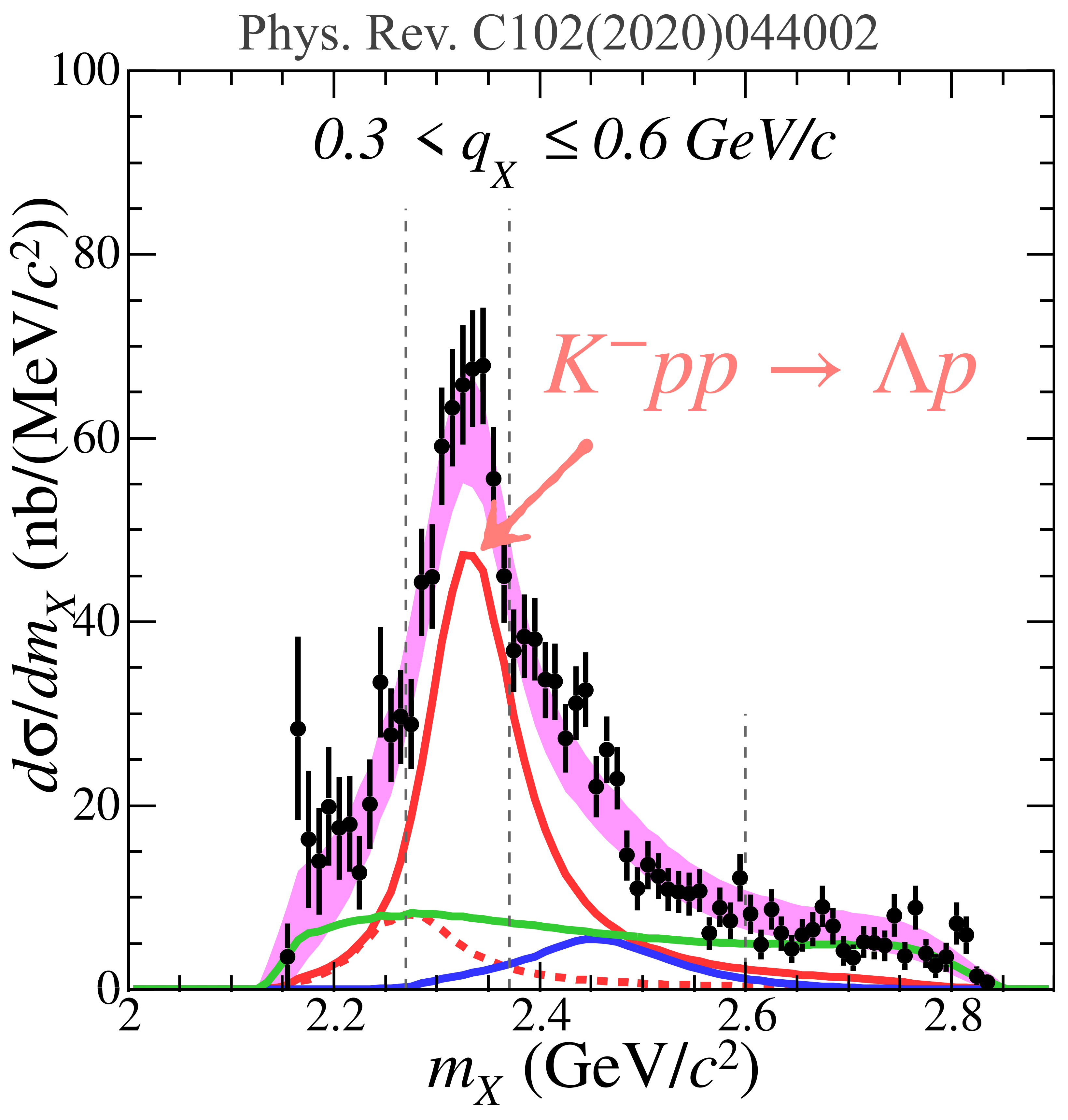


Iz = +1/2
(K^-pp - $\bar{K}^0pn$)

$\bar{K}^0nn$



Iz = -1/2
(K^-pn - $\bar{K}^0nn$)



The existence of K^-pp has been confirmed.

New programs for kaonic nuclei

– Further investigation of $\bar{K}NN$ & Searching for lighter & heavier systems –

Lighter system

$\Lambda(1405)$

$\bar{K}NN$ system

J^P determination

Search for $\bar{K}^0 nn$

Relation to Λ^*

Decay branch

Large Γ

Heavier system

P80 $\bar{K}NNN$ system

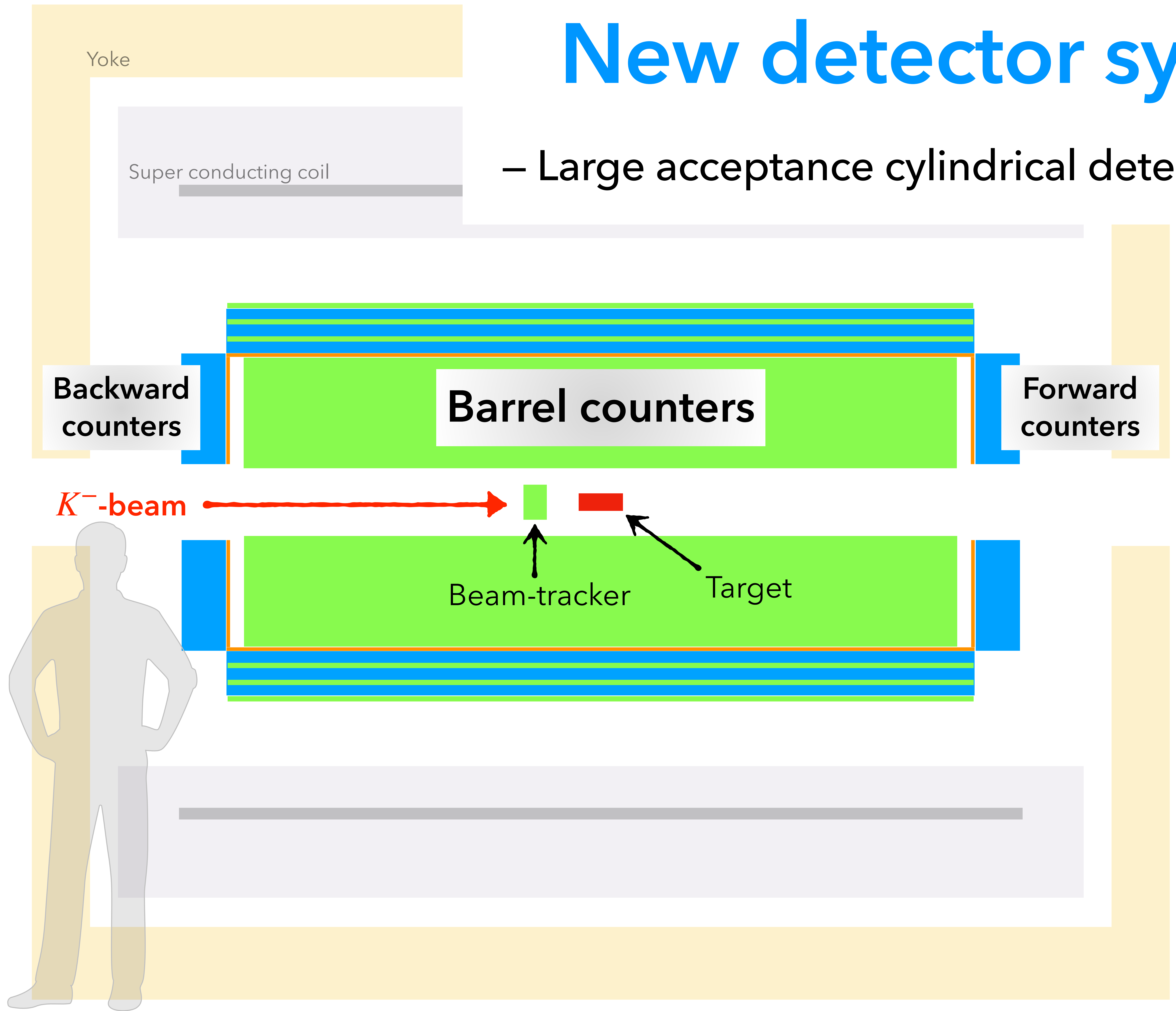
Next talk by F. Sakuma

$\bar{K}NNNN$ system

$\bar{K}\alpha\alpha$ system

New detector system

– Large acceptance cylindrical detector system –



- Barrel counters
  - Large CDC
    - Tracking of charged-particles
  - CVC + Layered-NC + Tracker
    - Charged-particles & **Neutron** detection
    - **Polarimeter**
- Forward & Backward counters
  - CVC + NC
    - Charged-particles & **Neutron** detection
- Room to install γ-detector

CDC : Cylindrical drift chamber
CVC : Charge veto counter
NC : Neutron counter

What we will measure

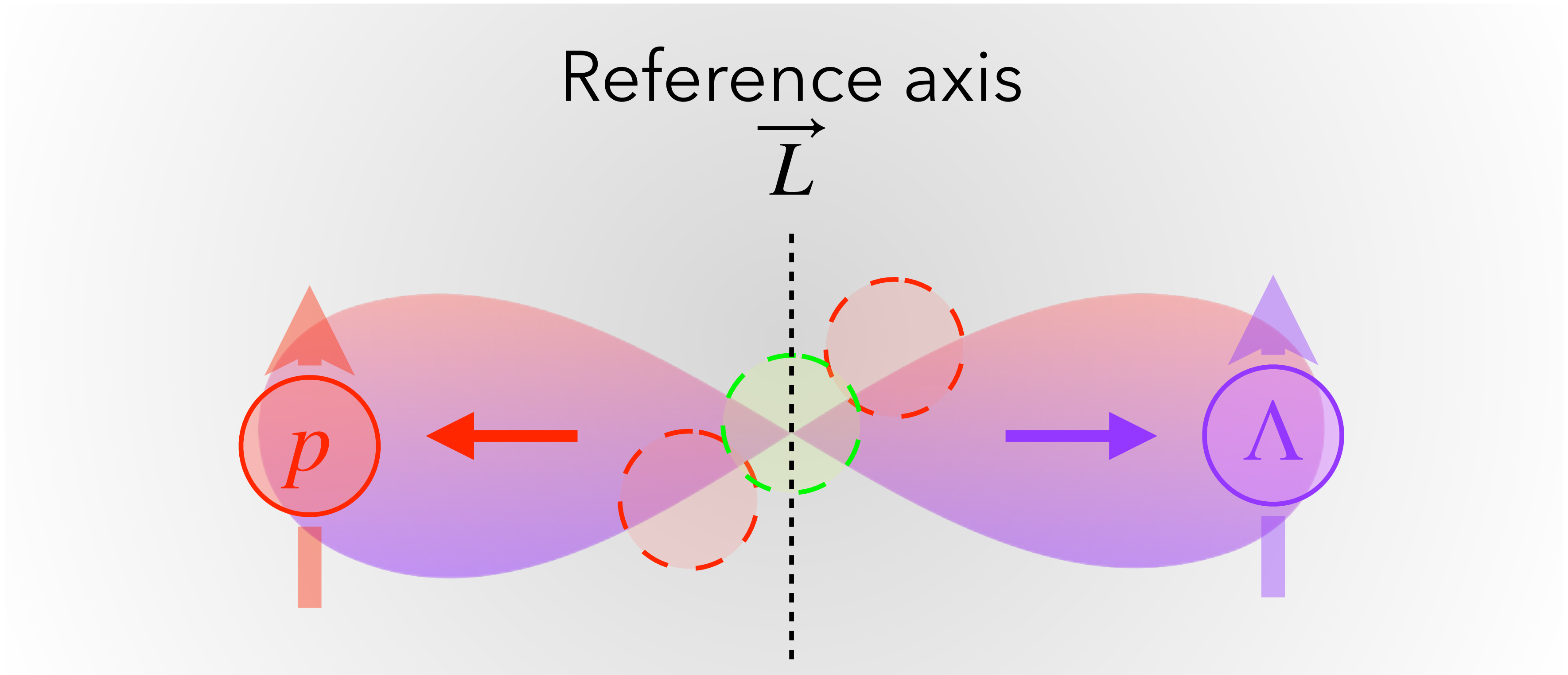
– To determine J^P of K^-pp & To search for $\bar{K}^0nn$ –

To determine J^P of K^-pp

Spin-spin correlation in $K^-pp \to \Lambda p$ decay

If K^-pp is 0^- **state**;

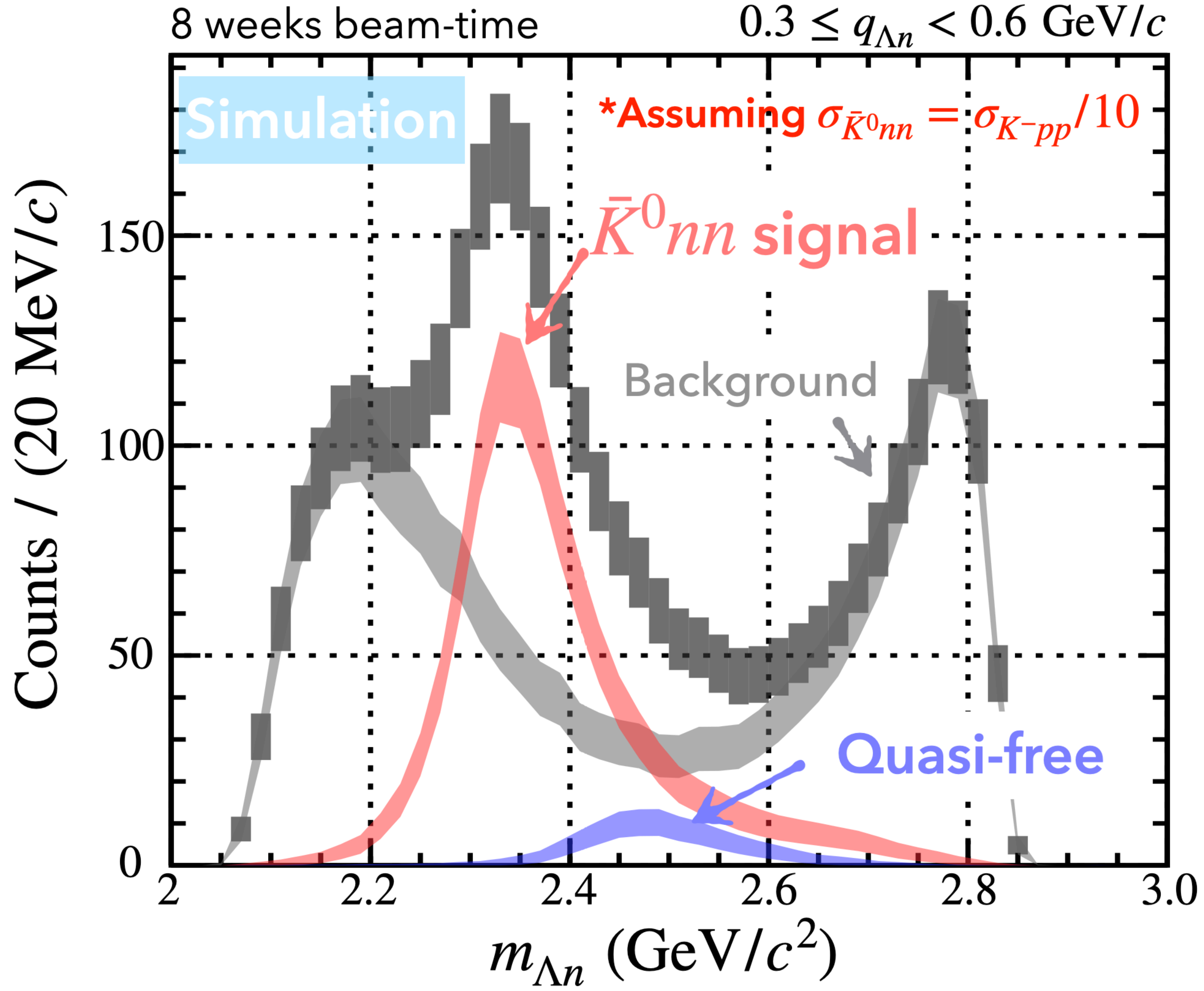
- P-wave decay
- Spins of Λ & proton to be **parallel**



To search for $\bar{K}^0nn$

Invariant-mass of Λn
& Momentum transfer to Λn

$\bar{K}^0nn$ would be observed with 8 weeks beam.



Spin-spin correlation in $K^- pp \to \Lambda p$ decay

$I_{K^-} = \frac{1}{2}, J^P_{K^-} = 0^-$

$I_{pp} = 1, J^P_{pp} = 0^+$

$$K^- pp$$

$I_{K^- pp} = \frac{1}{2}, J^P_{K^- pp}$

Strong decay $\longrightarrow$

I & J^P conserved

$$\Lambda p$$

$I_{\Lambda p} = \frac{1}{2}, J^P_{\Lambda p} = J^P_{K^- pp}$

$I_\Lambda = 0, J^P_\Lambda = \frac{1}{2}^+$

$I_p = \frac{1}{2}, J^P_p = \frac{1}{2}^+$

Λ & proton are **not polarized**,
but their spins are **correlated**.

Spin-spin correlation between Λ & proton would have J^P information.

$$\vec{S}_\Lambda \cdot \vec{S}_p \equiv \alpha_{\Lambda p}$$

Possible spin-parity of $K^- pp$

– Assuming all particles are in S-wave –

Parity of $K^- pp$ is negative. Spin of $K^- pp$ is equivalent to NN spin.

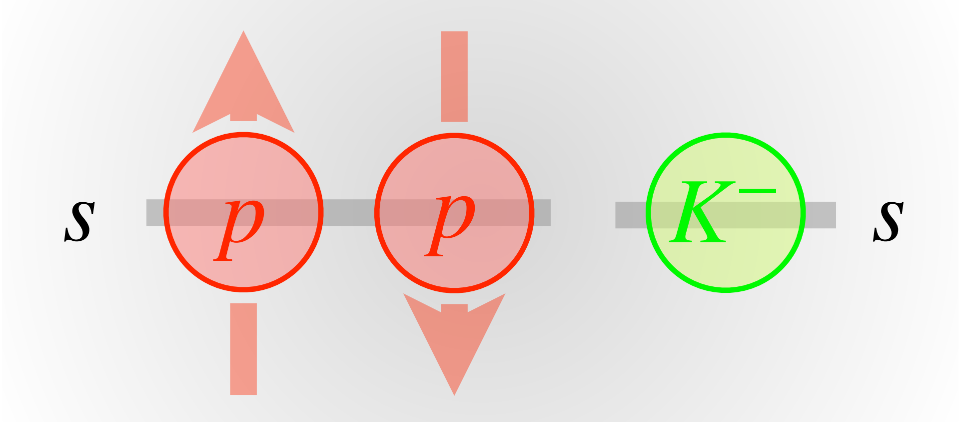
Most probable

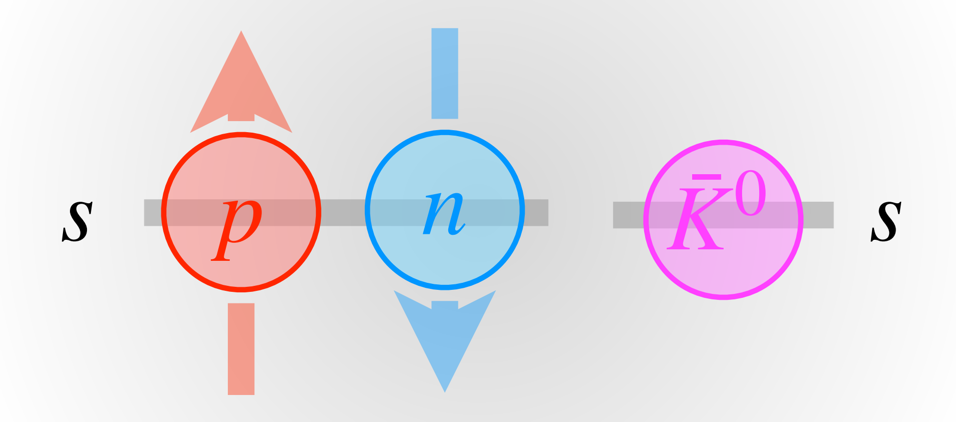
If NN is spin-singlet

$$J^P_{K^- pp} = 0^-$$

$$S_{NN} = 0, I_{NN} = 1$$

NN must be **isospin-triplet**





Expected to be **strong binding**

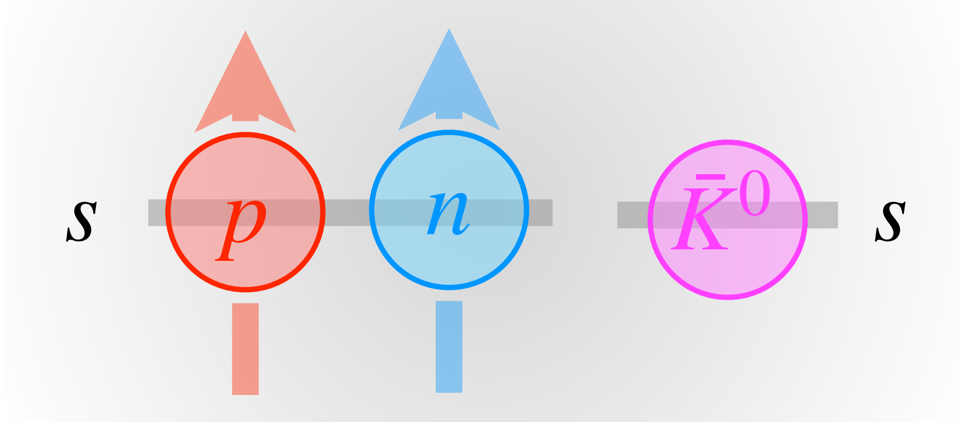
$< I_{\bar{K}N} = 0 >$: $< I_{\bar{K}N} = 1 >$ = 3 : 1

If NN is spin-triplet

$$J^P_{K^- pp} = 1^-$$

$$S_{NN} = 1, I_{NN} = 0$$

NN must be **isospin-singlet**



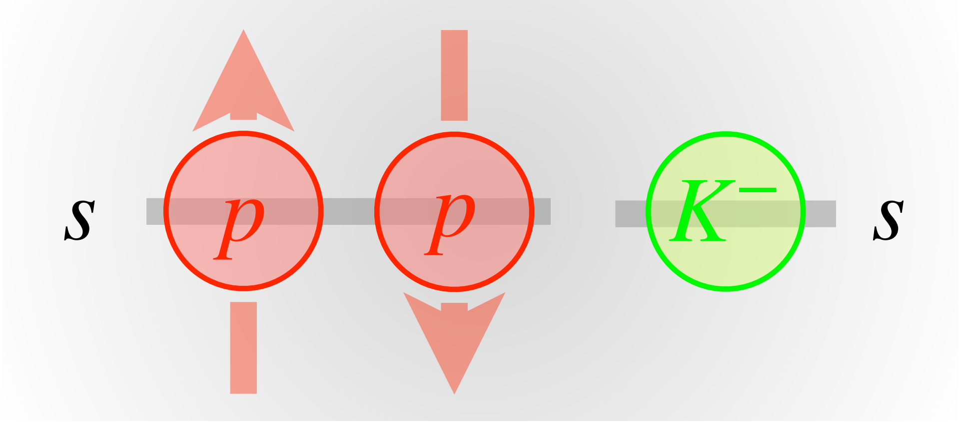
Expected to be **weak binding**

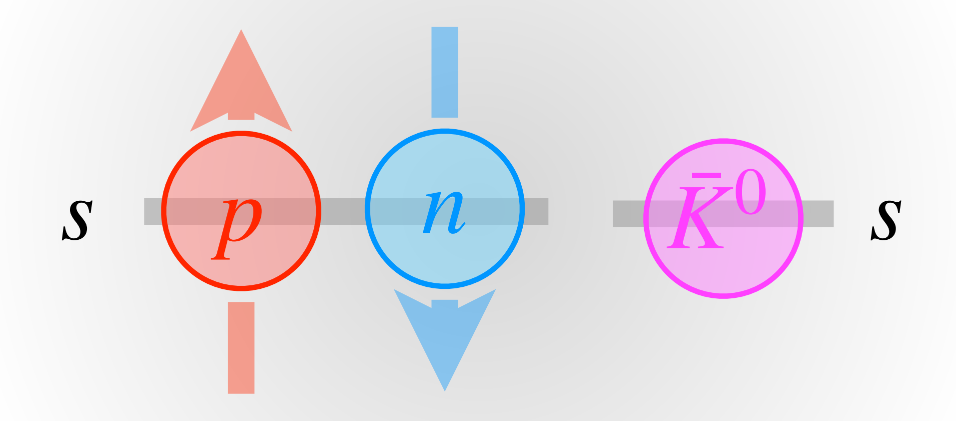
$< I_{\bar{K}N} = 0 >$: $< I_{\bar{K}N} = 1 >$ = 1 : 3

Expected spin-spin correlation

$J^P_{K^-pp} = 0^-$

NN is spin-singlet & isospin-triplet.





To make negative parity

$L_{\Lambda p} = 1$

To make total $J = 0$

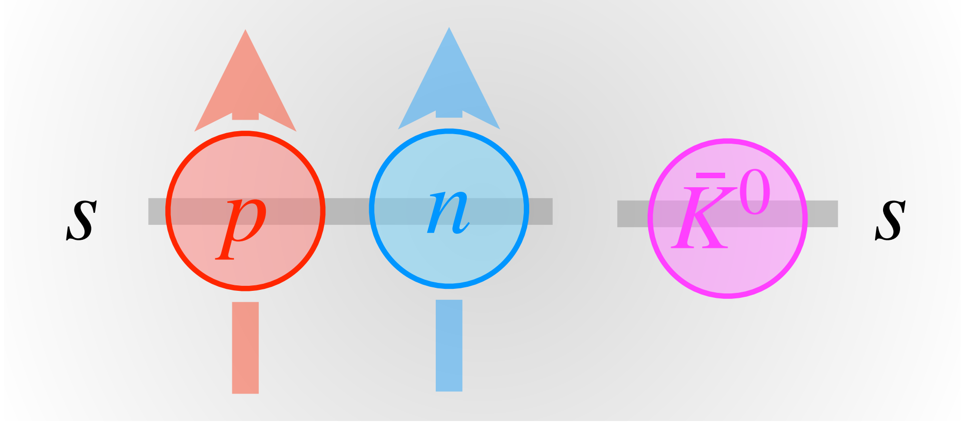
$S_{\Lambda p} = 1$

Spin flip

$\alpha_{\Lambda p} = +1$

$J^P_{K^-pp} = 1^-$

NN is spin-triplet & isospin-singlet.



To make negative parity

$L_{\Lambda p} = 1$

To make total $J = 1$

$S_{\Lambda p} = 0$ + $S_{\Lambda p} = 1$

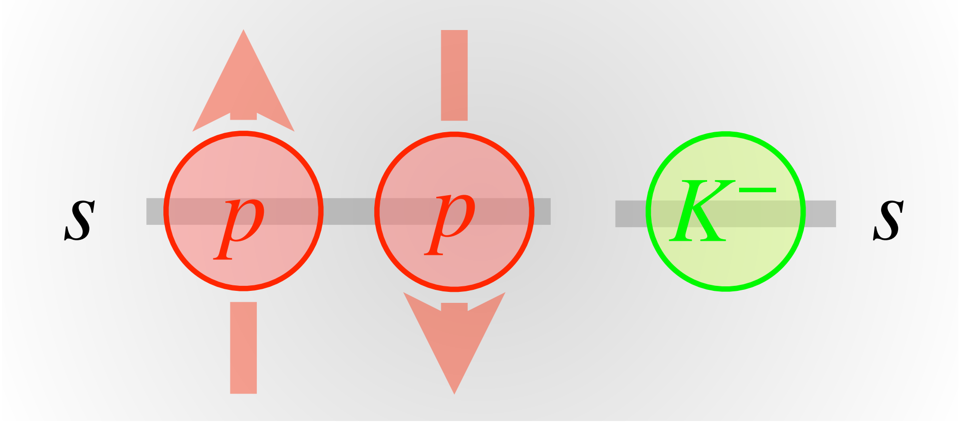
Spin flip | Spin non-flip

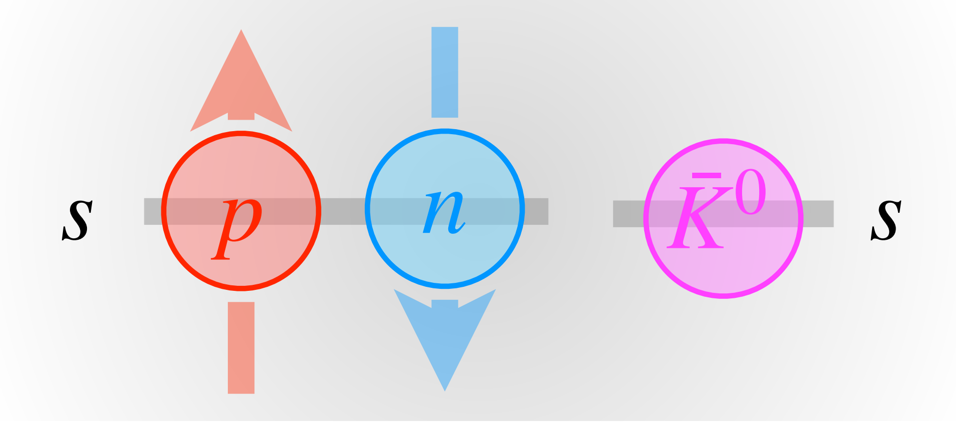
$\alpha_{\Lambda p} = -1$ + $\alpha_{\Lambda p} = +1$

Expected spin-spin correlation

$$J^P_{K^-pp} = 0^-$$

NN is spin-singlet & isospin-triplet.

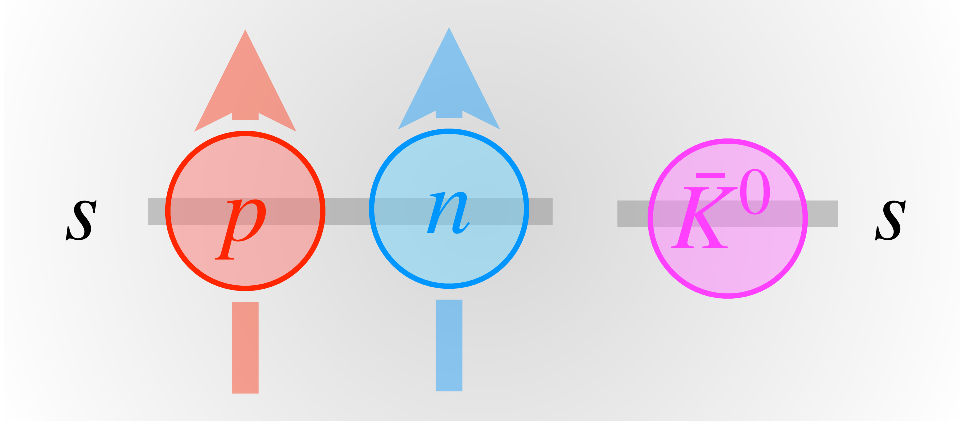




$$\alpha_{\Lambda p} = +1$$

$$J^P_{K^-pp} = 1^-$$

NN is spin-triplet & isospin-singlet.



$$\alpha_{\Lambda p} = ?$$

Under discussion with theorists

Spin flip dominant

Spin non-flip dominant

$\alpha_{\Lambda p} \to -1$

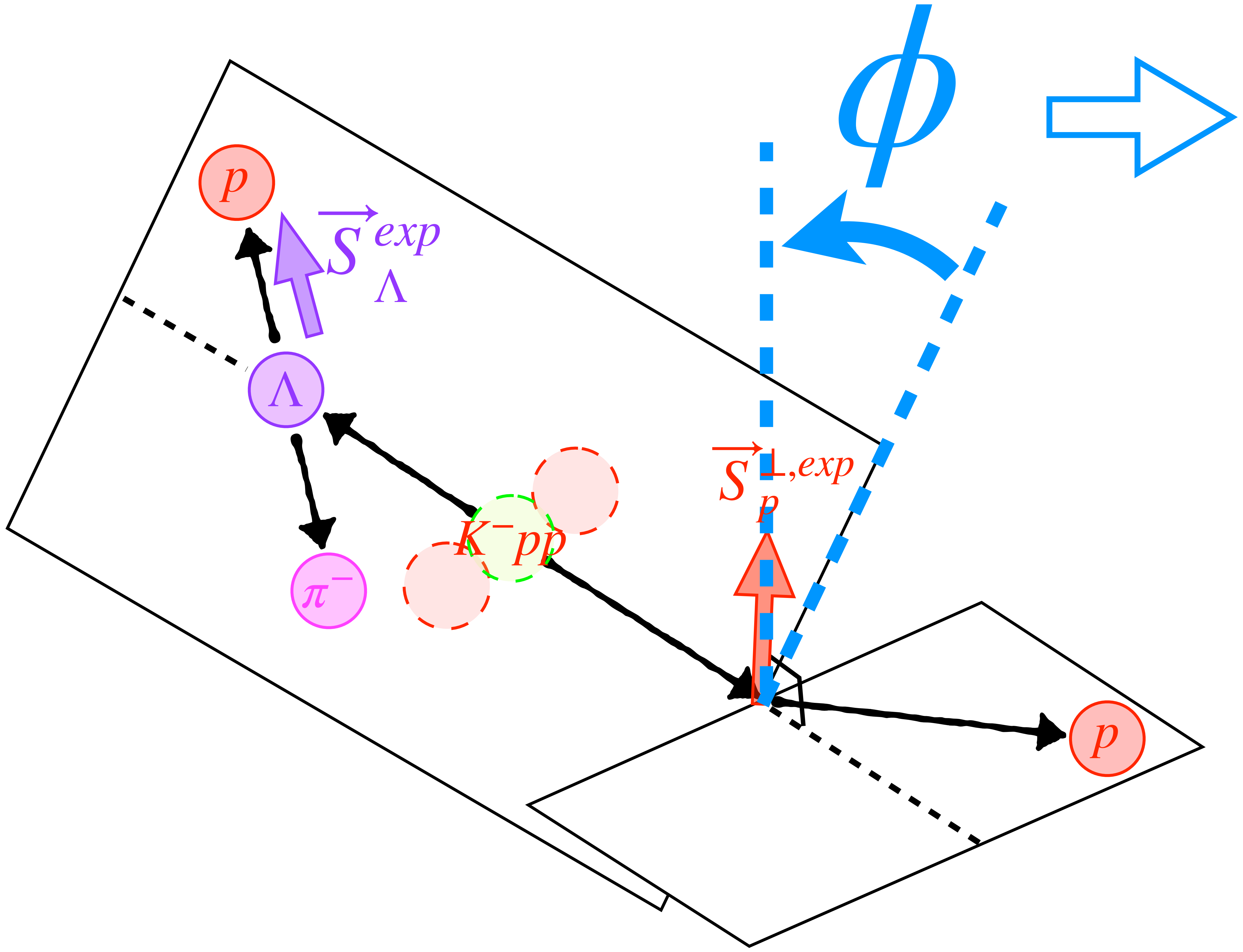
$\alpha_{\Lambda p} = -1/3$

Naive estimation

$\alpha_{\Lambda p} \to +1$

How to measure spin-spin correlation

– Measuring spin directions using asymmetries of $\Lambda \rightarrow p\pi^-$ decay & p-C scattering –



$$N(\phi) \propto 1 + r \cdot \alpha_{\Lambda p} \cdot \cos\phi$$

r ; scaling factor including α_Λ & A

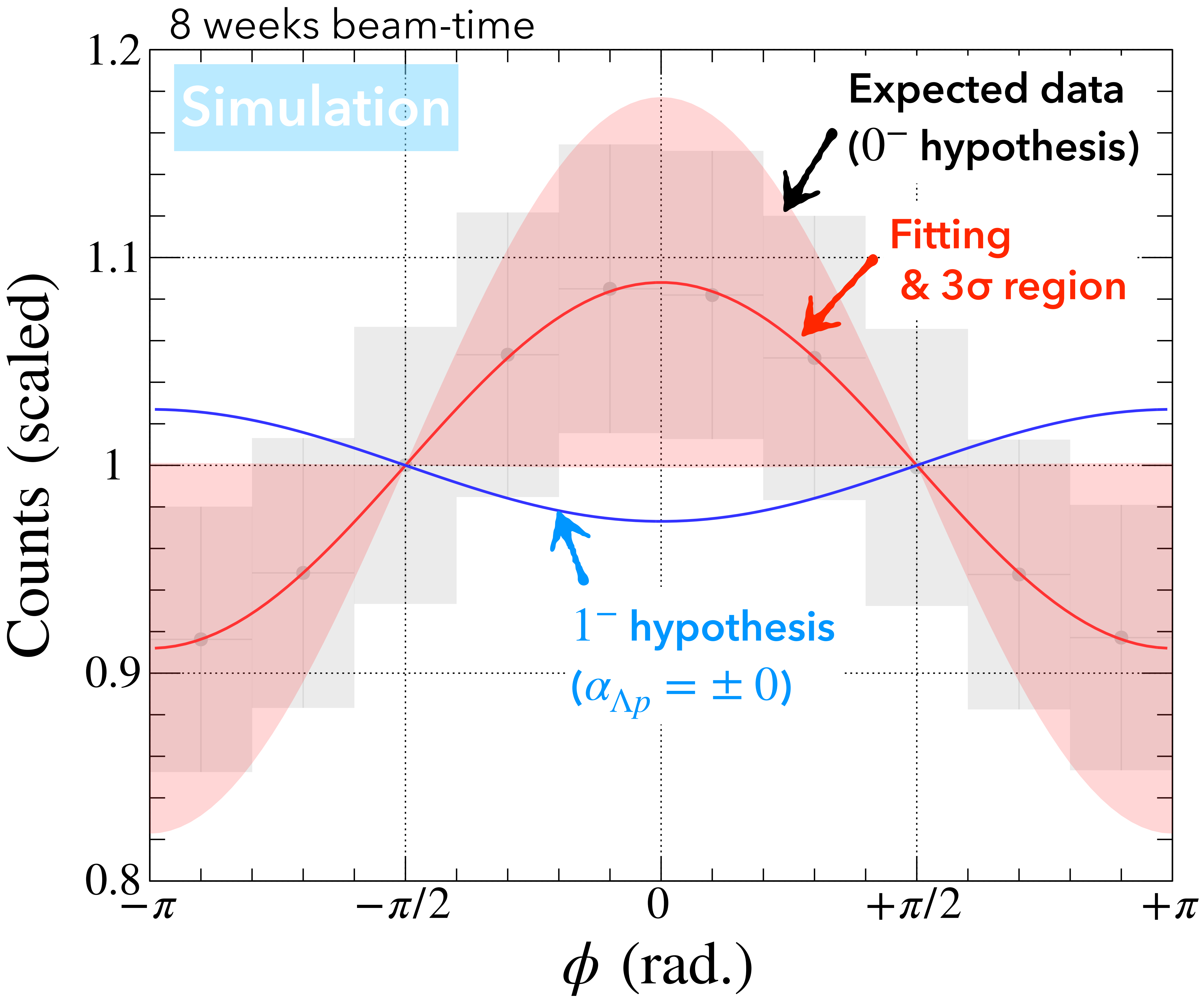
α_Λ ; Asymmetry parameter of Λ

A ; Analyzing power for proton spin

Expected result of $\alpha_{\Lambda p}$ measurement

– Estimation by Geant4 based Monte Carlo simulation –

$N(\phi) \propto 1 + r \cdot \alpha_{\Lambda p} \cdot \cos\phi$



- Expected result by Geant4 based MC simulation
  - Event generation with 0^- hypothesis
  - Number of events can be used;
    ~ 300 events / week
    - $\sigma_{K^-pp} \cdot \mathrm{BR}_{\Lambda p} = 9.3\ \mu\mathrm{b}$
      (measured value by E15)
    - $\mathscr{L} = 2.8\ \mathrm{nb}^{-1}/\mathrm{week}$
      (@ 90kW beam-power)
    - $\Omega_{CDS} \sim 15\ \%$
      (@ barrel-part of CDS including analysis efficiency)
    - $\varepsilon_{pC} \sim 10\ \%$
      (with 5cm x 3layers scintillators as a "scattering target")
    - The result with 12 weeks beam-time

1^- would be rejected with 8 weeks beam.

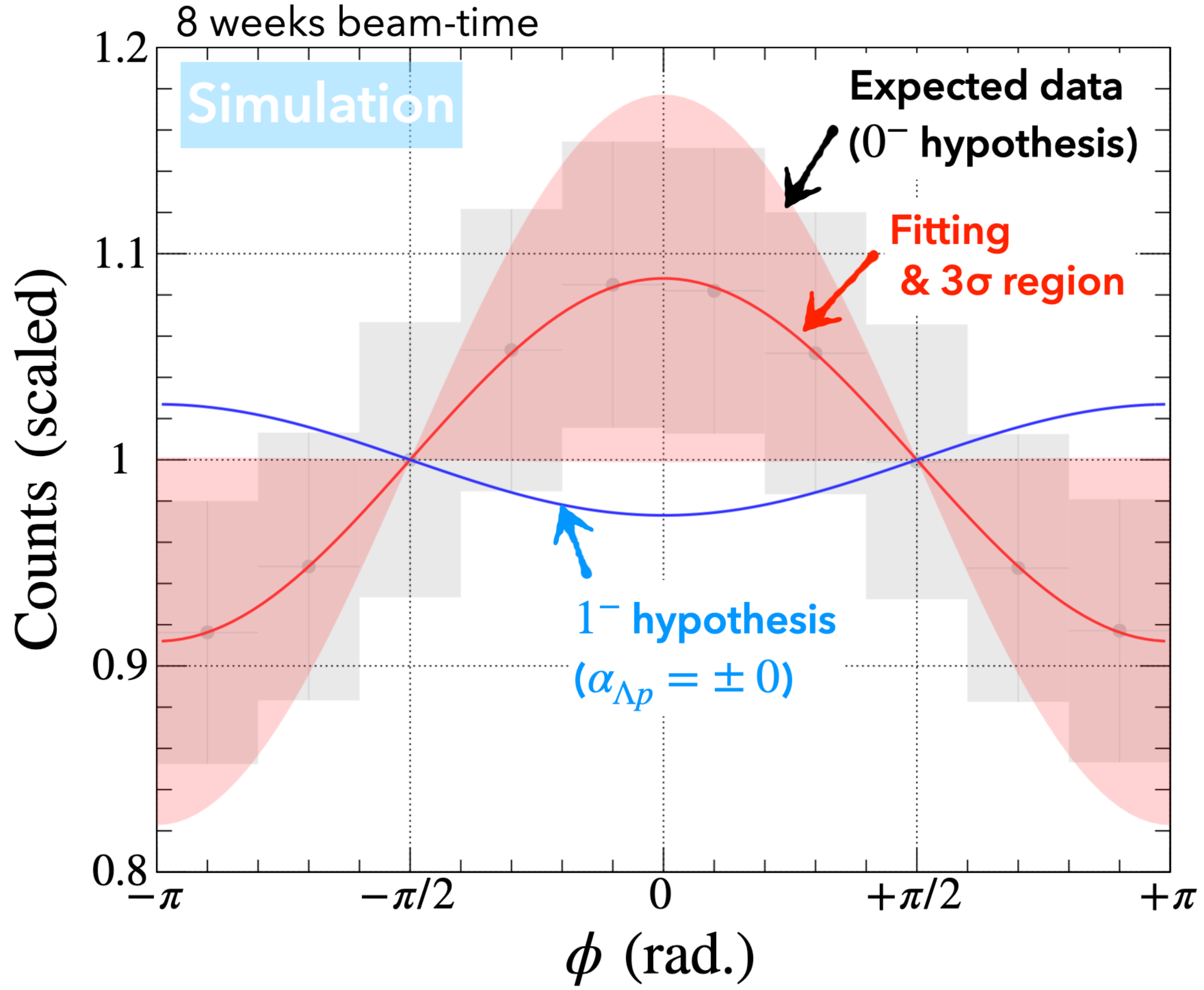
Summary

– Measurement of spin and parity of K^-pp and searching for $\bar{K}^0nn$ –

To determine J^P of K^-pp

Spin-spin correlation in $K^-pp \to \Lambda p$ decay

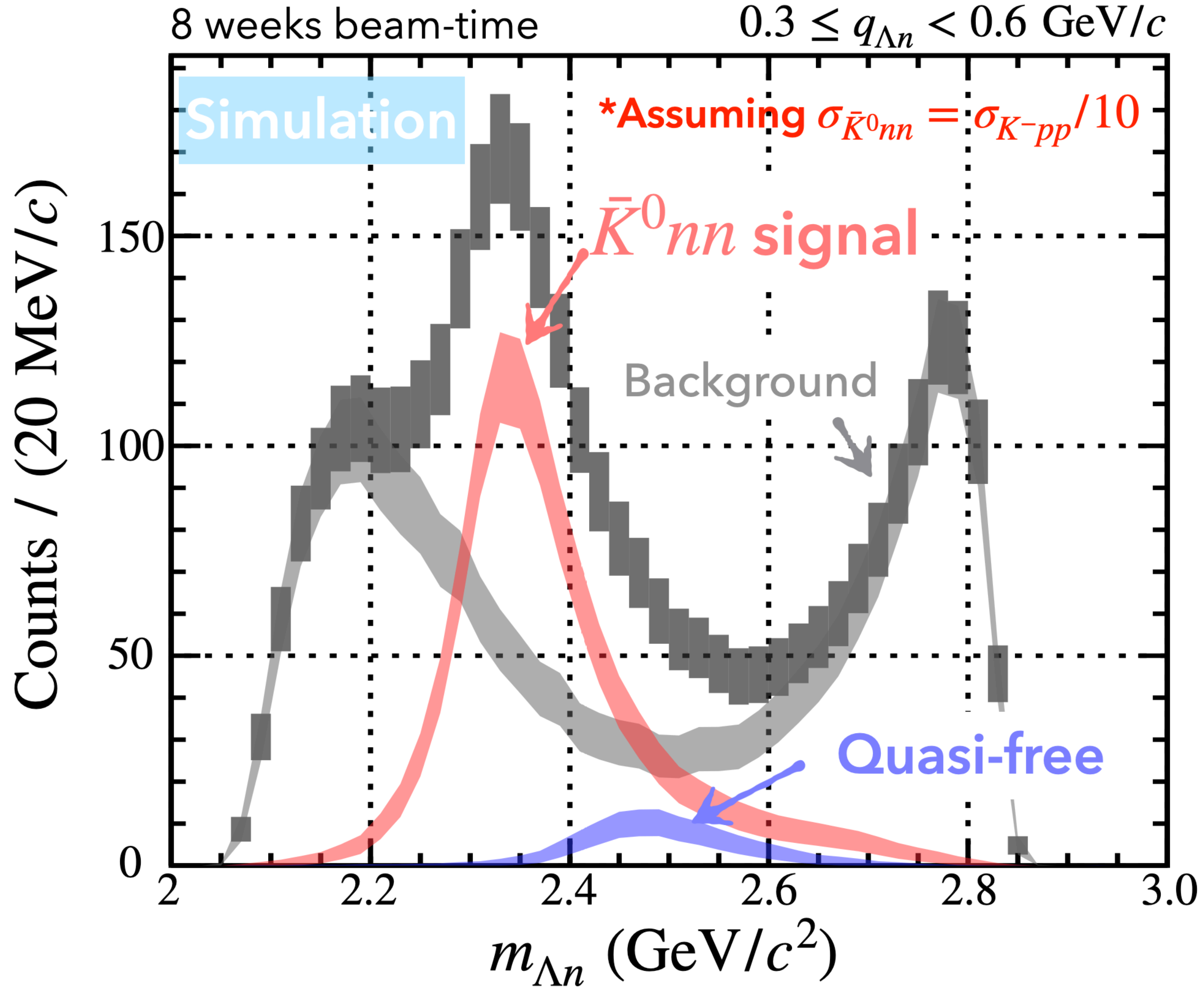
1^- **would be rejected with 8 weeks beam.**



To search for $\bar{K}^0nn$

Invariant-mass of Λn
& Momentum transfer to Λn

$\bar{K}^0nn$ **would be observed with 8 weeks beam.**



Backup

New programs for kaonic nuclei

– Further investigation of $\bar{K}NN$ & Searching for lighter & heavier systems –

Lighter system

$\Lambda(1405)$

with wider q-region

$d(K^-, n)$ reaction

$\pi^\pm\Sigma^\mp$ decay

&

$\pi^0\Sigma^0$ decay as well

$\bar{K}NN$ system

J^P determination

To confirm the existence more robustly

Measuring $d\sigma/dq$ & $\alpha_{\Lambda p}$

Search for $\bar{K}^0 nn$

Isospin-partner of K^-pp

$\bar{K}^0 nn \rightarrow \Lambda n$ decay

Relation to Λ^*

Production mechanism of $\bar{K}N$ & $\bar{K}NN$

Large Γ

Large branch to non-mesonic or substructure

Decay branch

Non-mesonic

Λp, $\Sigma^0 p$, $\Sigma^+ n$

Mesonic

$\pi\Lambda N$, $\pi\Sigma N$

Heavier system

P80 $\bar{K}NNN$ system

Door to heavier system

$^4\mathrm{He}(K^-, N)$ reaction

K^-ppn (I=0) $K^-ppp/\bar{K}^0nnn$ (I=1)

$\bar{K}NNNN$ system

Expected large B.E. & high density

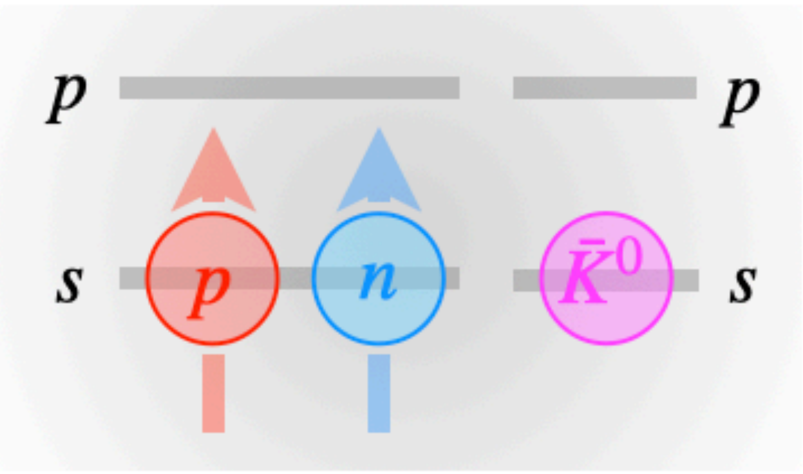
$^6\mathrm{Li}(K^-, d)$ reaction

K^--α $\bar{K}^0$-α

$\bar{K}\alpha\alpha$ system

$^9\mathrm{Be}(K^-, N)$ reaction

$J^P = 1^-$



$I_{NN} = 0,\ S_{NN} = 1,\ L_{\bar{K}} = 0$

P-wave decay

$\alpha_{\Lambda p} = ?$

To be discussed in next

spatial distribution of absorption reaction

original neutron spin

resulting Λ spin

$1 \times 1/2$

m_1	m_2	$J=3/2$, $M=+3/2$		
+1	+1/2	1		

m_1	m_2	$J=3/2$, $M=+1/2$	$J=1/2$, $M=+1/2$
+1	−1/2	1/3	2/3
0	+1/2	2/3	−1/3

m_1	m_2	$J=3/2$, $M=-1/2$	$J=1/2$, $M=-1/2$
0	−1/2	2/3	1/3
−1	+1/2	1/3	−2/3

m_1	m_2	$J=3/2$, $M=-3/2$
−1	−1/2	1

$Y_1^{\pm 0}$ $\quad Y_1^{-1}$

original neutron spin

$$(S_{pn} = |1,+1\rangle)\bar{K}^0 = \frac{1}{\sqrt{2}}(p\Uparrow n\Uparrow - n\Uparrow p\Uparrow)\,\bar{K}^0$$

$\bar{K}^0 n \to \Lambda$ P-wave absorption

$$-\sqrt{\frac{2}{3}}\sqrt{\frac{3}{4\pi}}\frac{\sin\theta}{\sqrt{2}}e^{-i\phi}\frac{(p\Uparrow \Lambda\Downarrow - \Lambda\Downarrow p\Uparrow)}{\sqrt{2}} - \sqrt{\frac{1}{3}}\sqrt{\frac{3}{4\pi}}\cos\theta\frac{(p\Uparrow \Lambda\Uparrow - \Lambda\Uparrow p\Uparrow)}{\sqrt{2}}$$

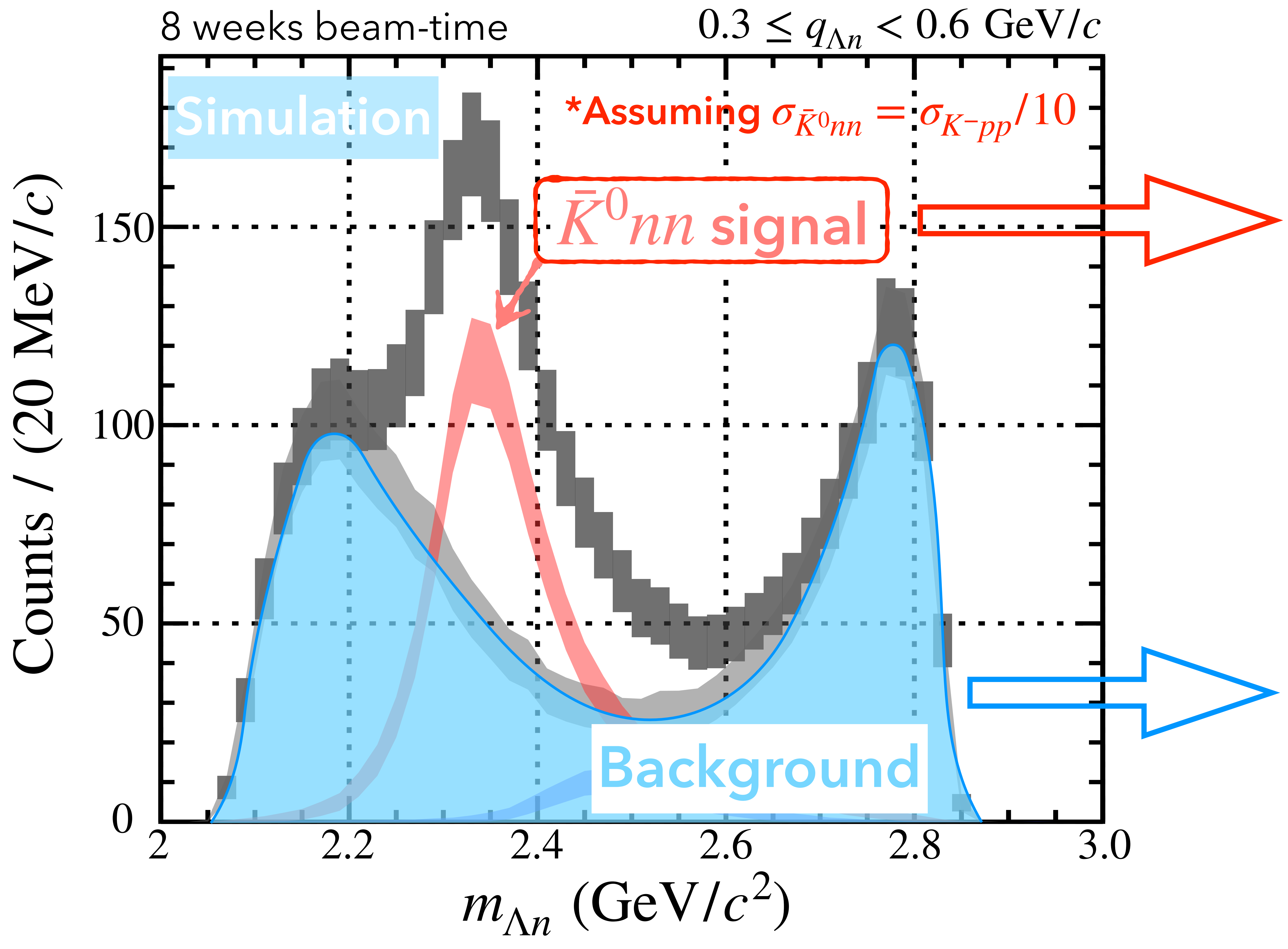
probability: $\dfrac{2}{3}\cdot 1^2 \cdot |S_{\Lambda p} = |0,0\rangle|^2 + \dfrac{1}{3}\cdot 1^2 \cdot |S_{\Lambda p} = |1,+1\rangle|^2$

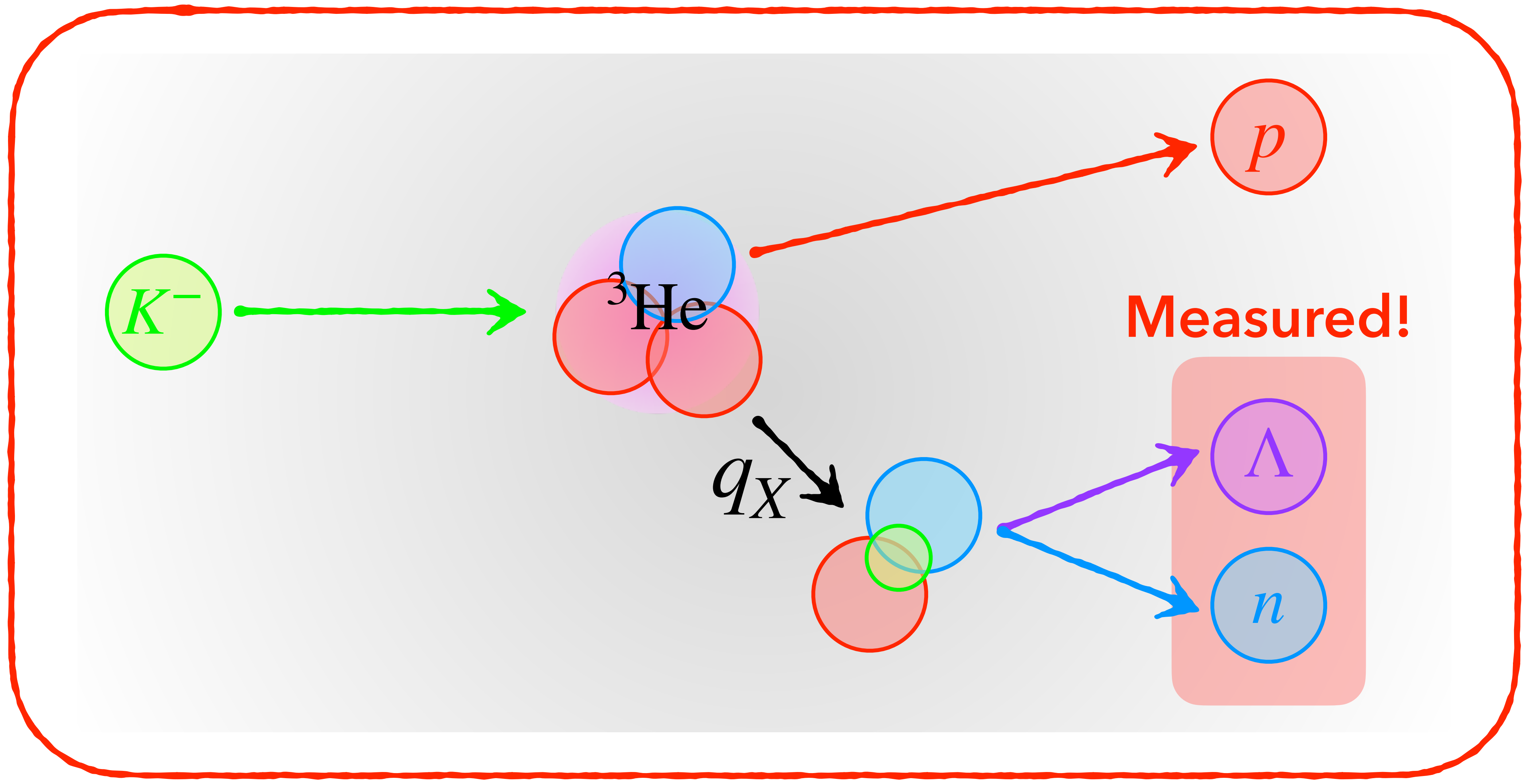
anti-parallel $\qquad$ *parallel*

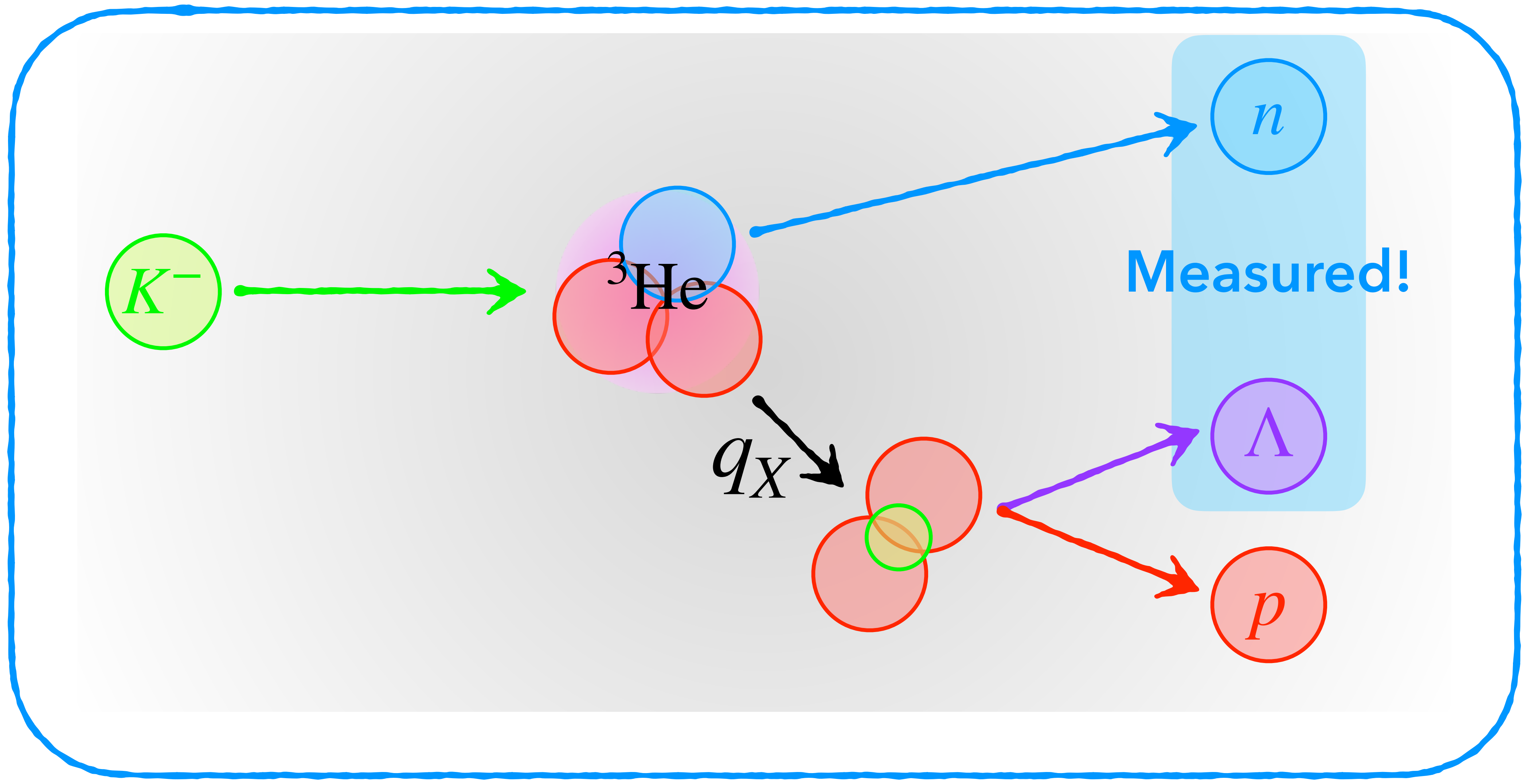
spin • spin correlation: $\alpha_{\Lambda p} = -\dfrac{2}{3} + \dfrac{1}{3} = -\dfrac{1}{3}$

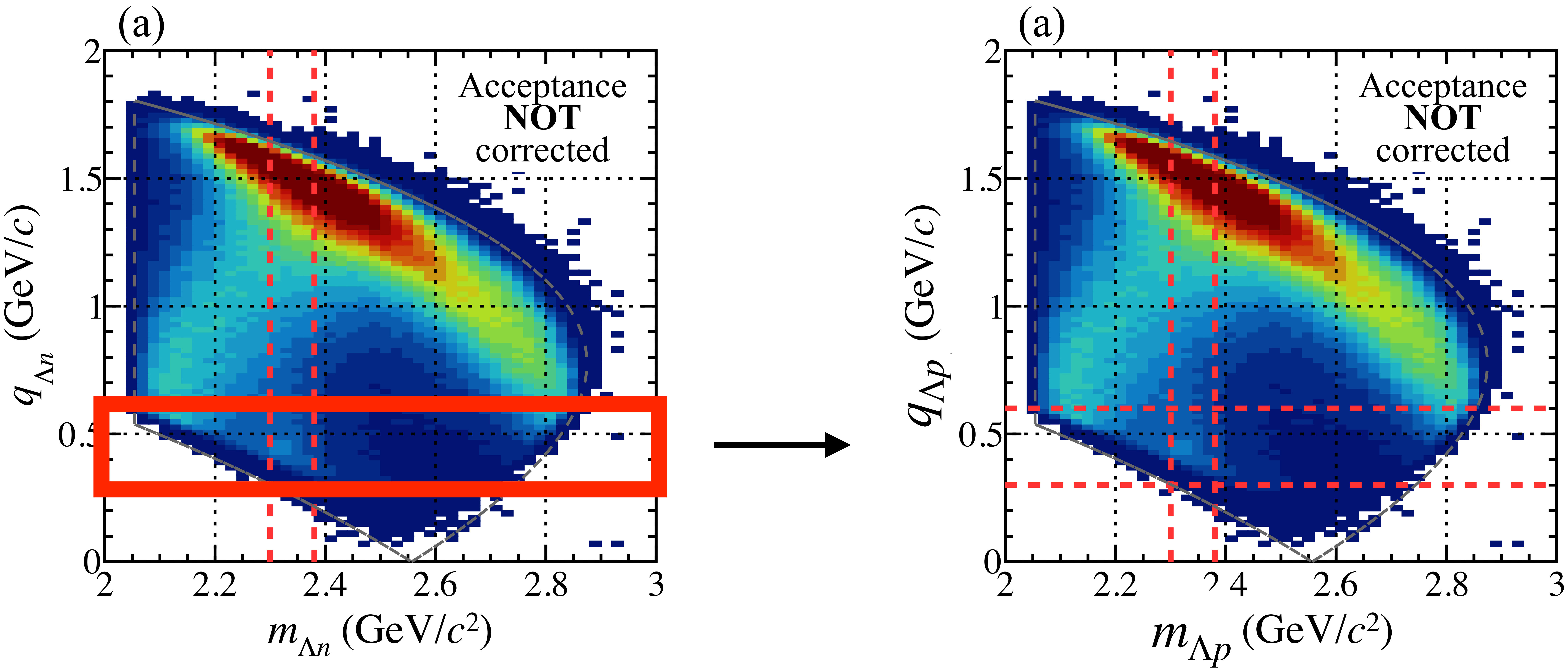
same for other S_{pn} *direction*

Background for $\bar{K}^0 nn$ searching









(a)
Acceptance
NOT
corrected
$q_{\Lambda n}$ (GeV/c)
$m_{\Lambda n}$ (GeV/c^2)
(a)
Acceptance
NOT
corrected
$q_{\Lambda p}$ (GeV/c)
$m_{\Lambda p}$ (GeV/c^2)

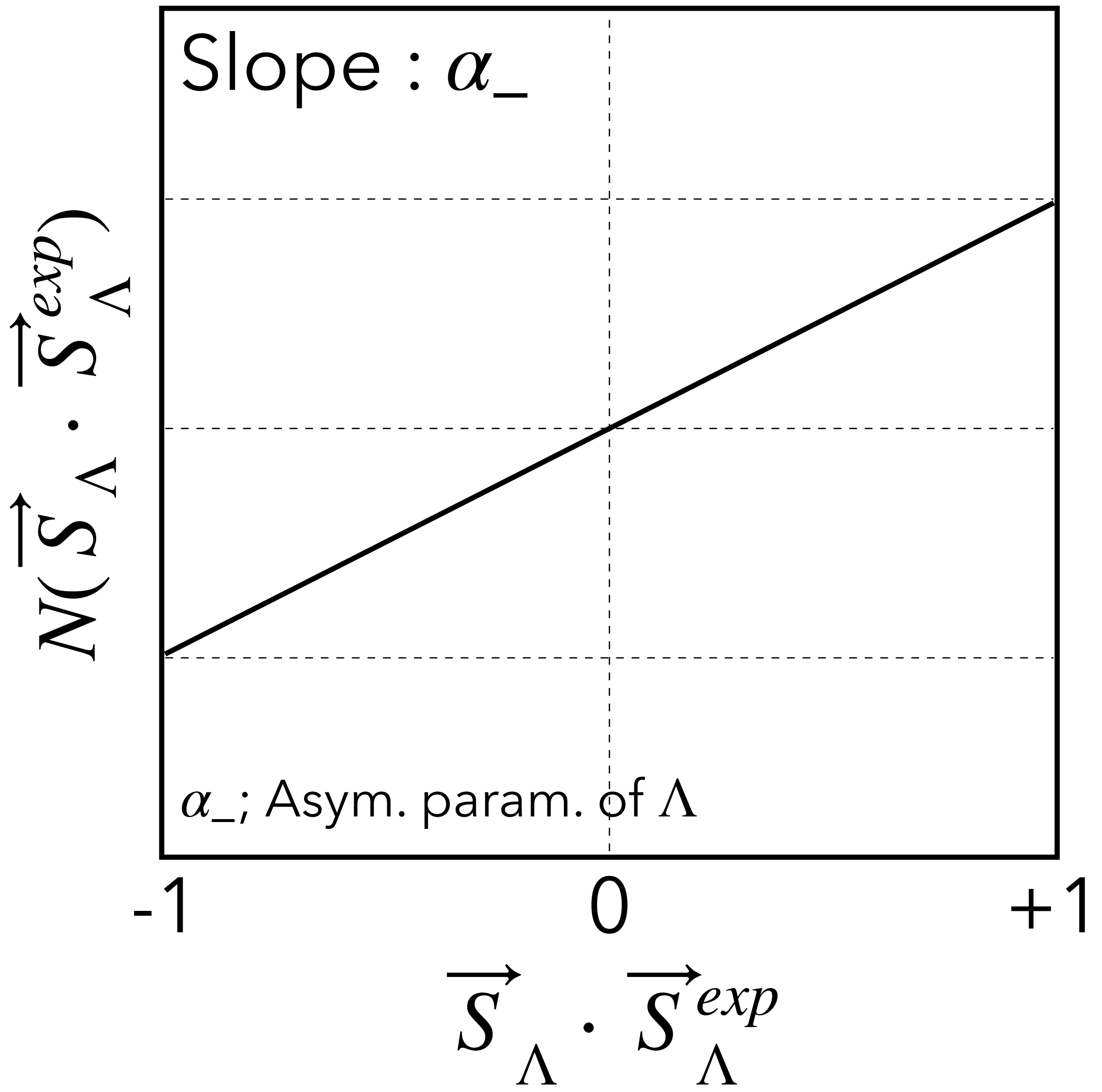
How to measure spin-spin correlation

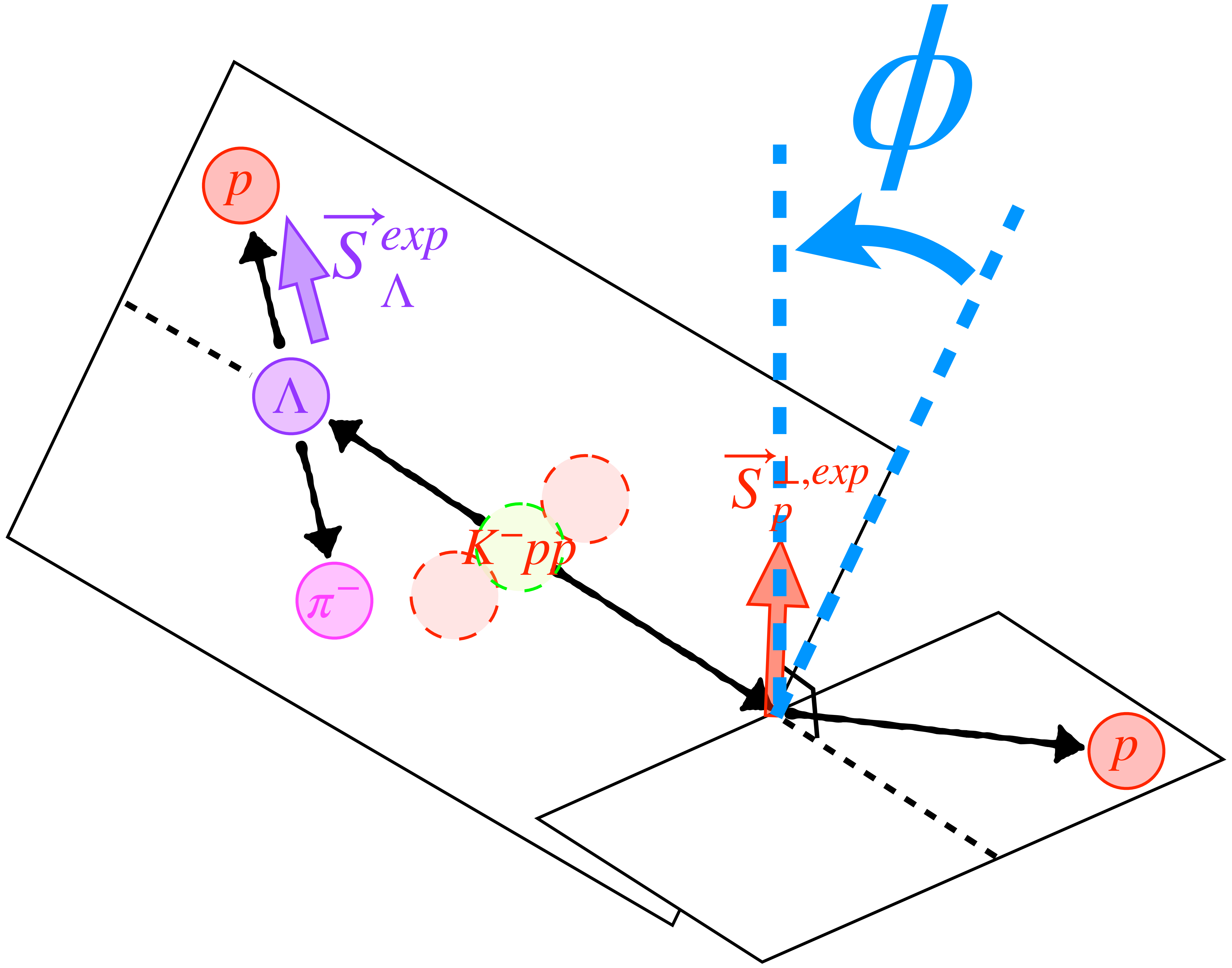
– Measuring spin directions using asymmetries of $\Lambda \to p\pi^-$ decay & p-C scattering –

Λ-spin

Asymmetry of $\Lambda \to p\pi^-$ decay

$$\vec{S}_\Lambda^{exp} = \frac{\vec{p}_{p\ \mathrm{from}\ \Lambda}}{|\vec{p}_{p\ \mathrm{from}\ \Lambda}|}$$





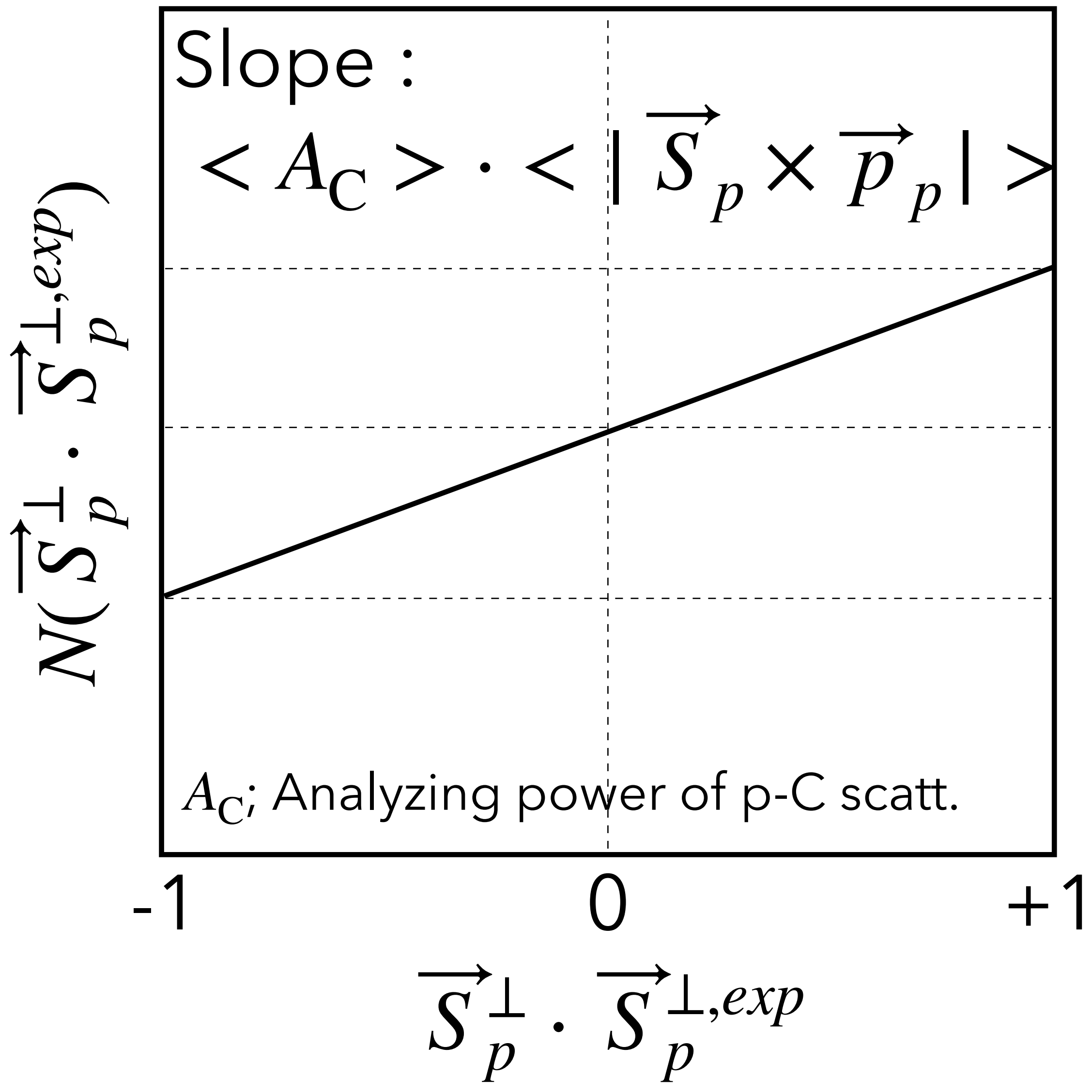
$$N(\phi) \propto 1 + r \cdot \alpha_{\Lambda p} \cdot \cos\phi$$

r ; scaling factor including α_-, A_C etc.

Proton spin

Asymmetry of p-C scattering

$$\vec{S}_p^{\perp,exp} = \frac{\vec{p}_p \times \vec{p}_{p'}}{|\vec{p}_p \times \vec{p}_{p'}|}$$



What we will measure

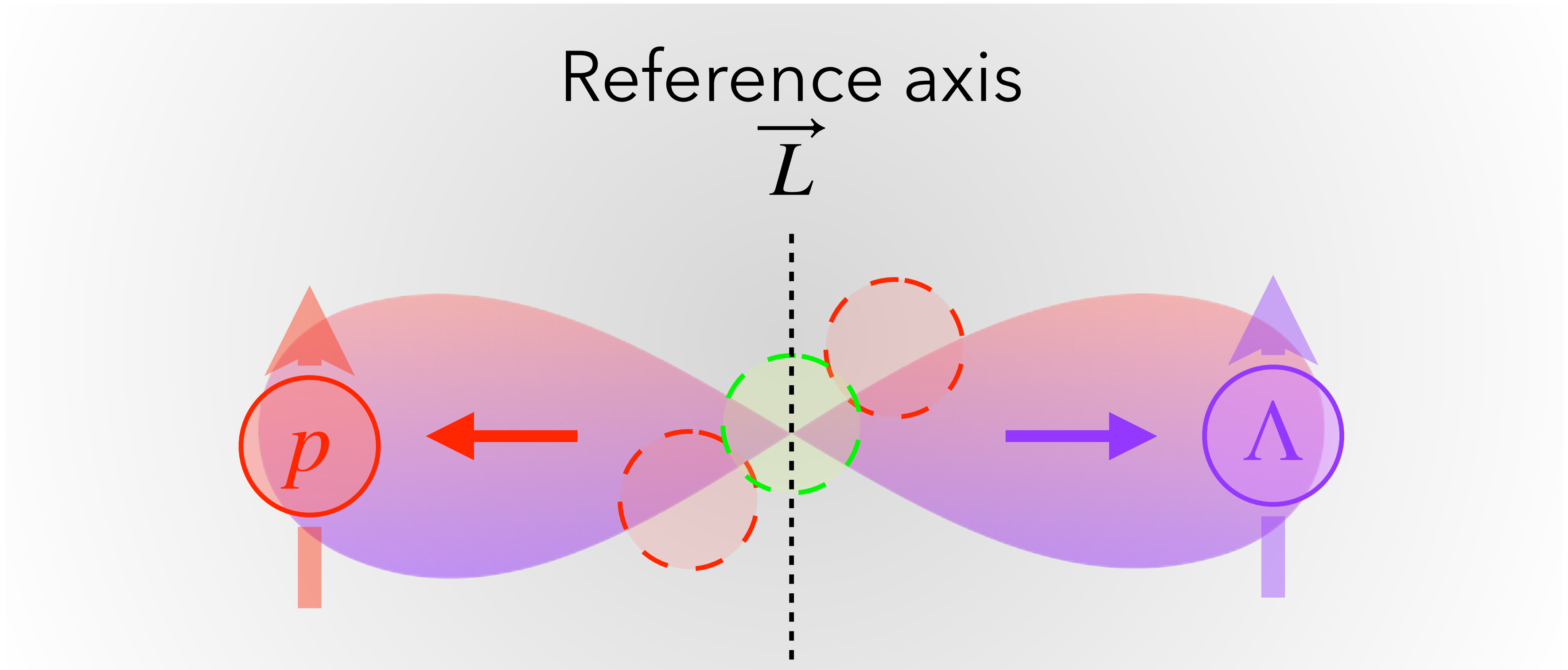
– To determine J^P of $K^{-}pp$ & To search for $\bar{K}^0nn$ –

To determine J^P of $K^{-}pp$

Spin-spin correlation in $K^{-}pp \rightarrow \Lambda p$ decay

If $K^{-}pp$ is **0^{-} state**;

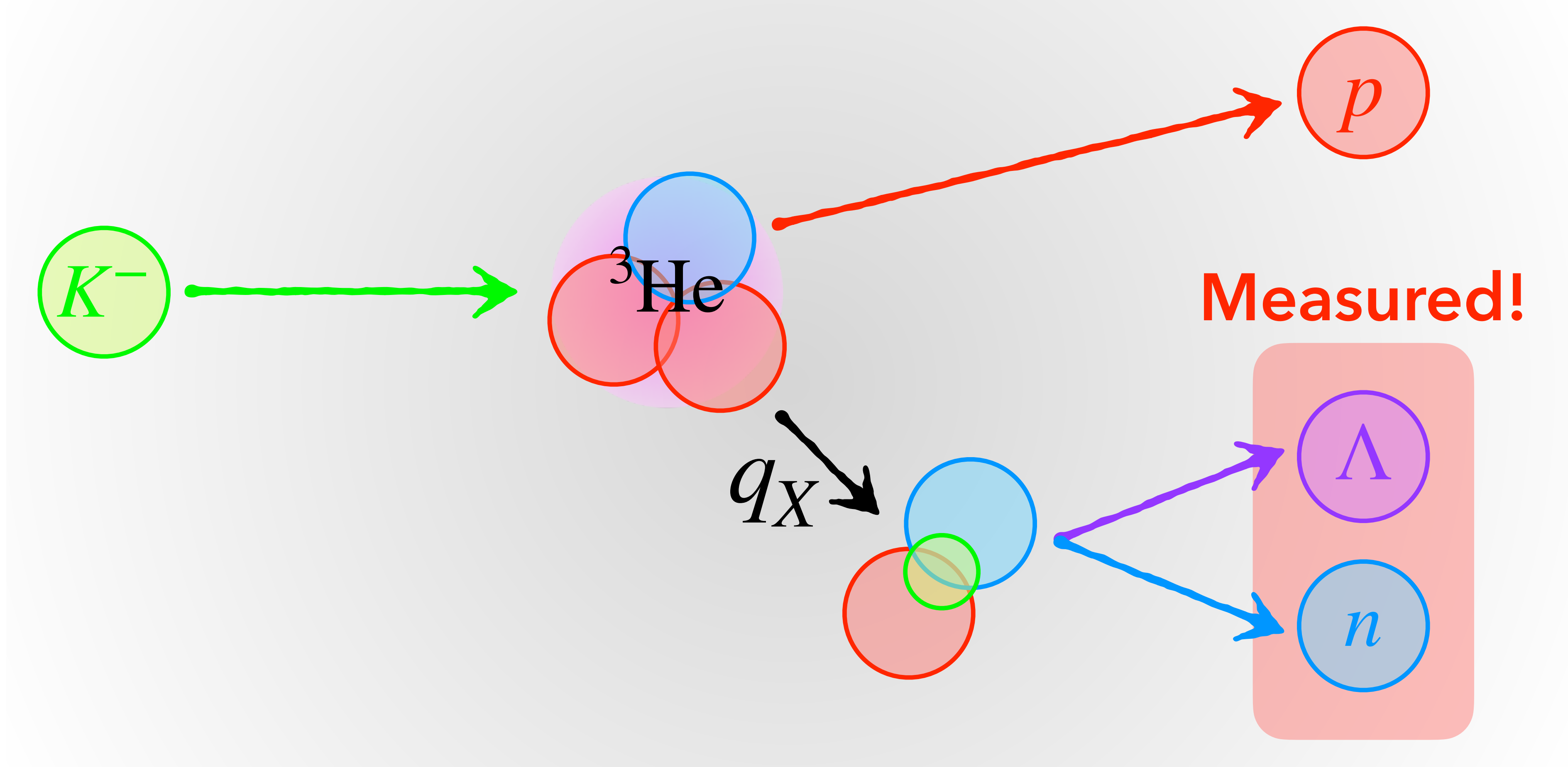
- **P-wave** decay
- Spins of Λ & proton to be **parallel**



To search for $\bar{K}^0nn$

Invariant-mass of Λn
& Momentum transfer to Λn

$$K^{-} + {}^{3}\mathrm{He} \rightarrow \bar{K}^0nn + p$$
$$\hookrightarrow \Lambda n$$



Production ratio between $\bar{K}^0nn$ & K^-pp

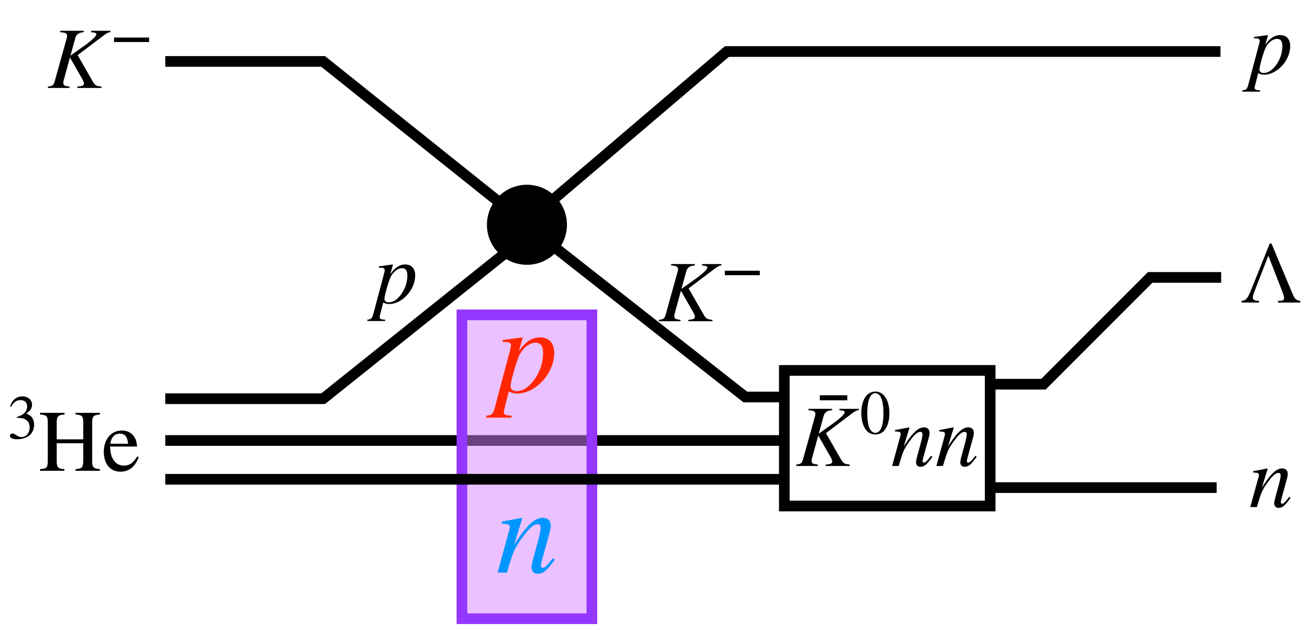
– To estimate production cross section of $\bar{K}^0nn$ –

Assuming $\sigma_{\bar{K}NN} \propto A\sigma_{\bar{K}N} \times C_{NN}^2 \times C_{\bar{K}NN}^2$

(A ; Effective nucleon number, $\sigma_{\bar{K}N}$; Elementary cross-section, C_{NN} & $C_{\bar{K}NN}$; Clebsch-Gordan coeffic.)

$\bar{K}^0nn$ production by $K^-p \to K^-p$

($\sigma_{K^-p} \sim 1.8$ mb/sr @ $\theta_p = 0°$)



If $|I_{pn}> = |1, 0>$;

$\bar{K}^0nn \to 0^-$

$\sigma_{\bar{K}^0nn} \propto A_p\sigma_{K^-p} \times \frac{1}{2} \times \frac{1}{3}$

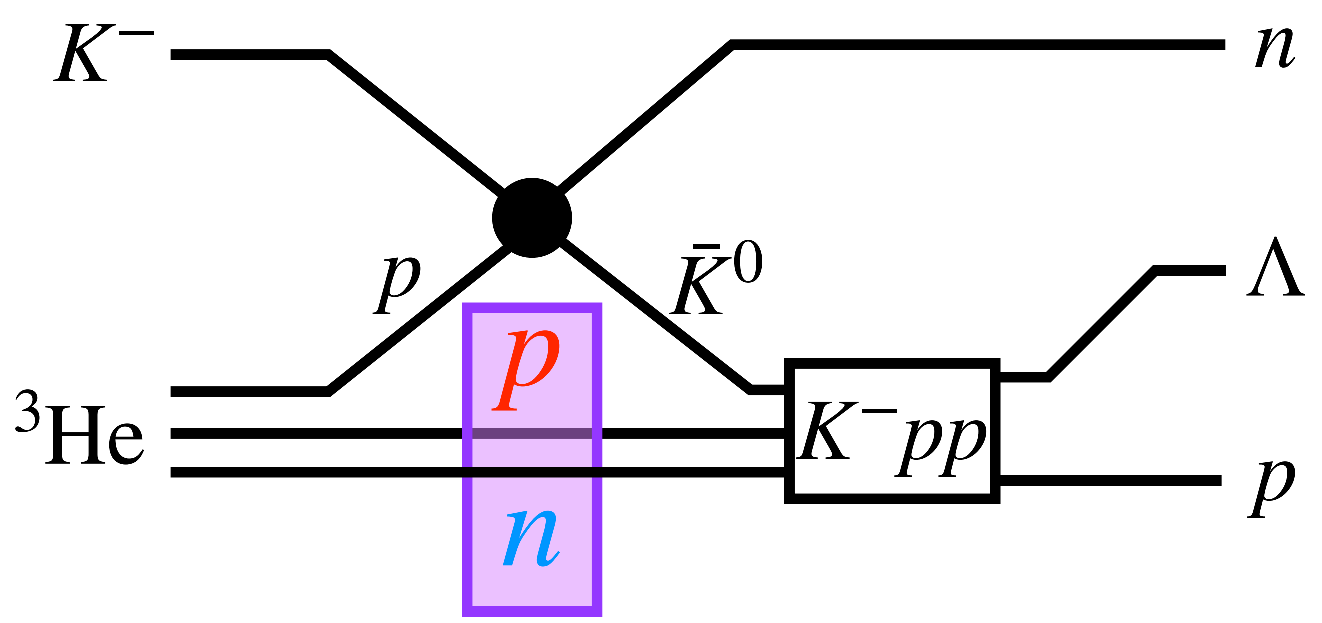
If $|I_{pn}> = |0, 0>$;

$\bar{K}^0nn \to 1^-$

$\sigma_{\bar{K}^0nn} \propto A_p\sigma_{K^-p} \times \frac{1}{2} \times 1$

K^-pp production by $K^-p \to \bar{K}^0n$

($\sigma_{\bar{K}^0n} \sim 2.4$ mb/sr @ $\theta_n = 0°$)



If $|I_{pn}> = |1, 0>$;

$K^-pp \to 0^-$

$\sigma_{K^-pp} \propto A_p\sigma_{\bar{K}^0n} \times \frac{1}{2} \times \frac{1}{3}$

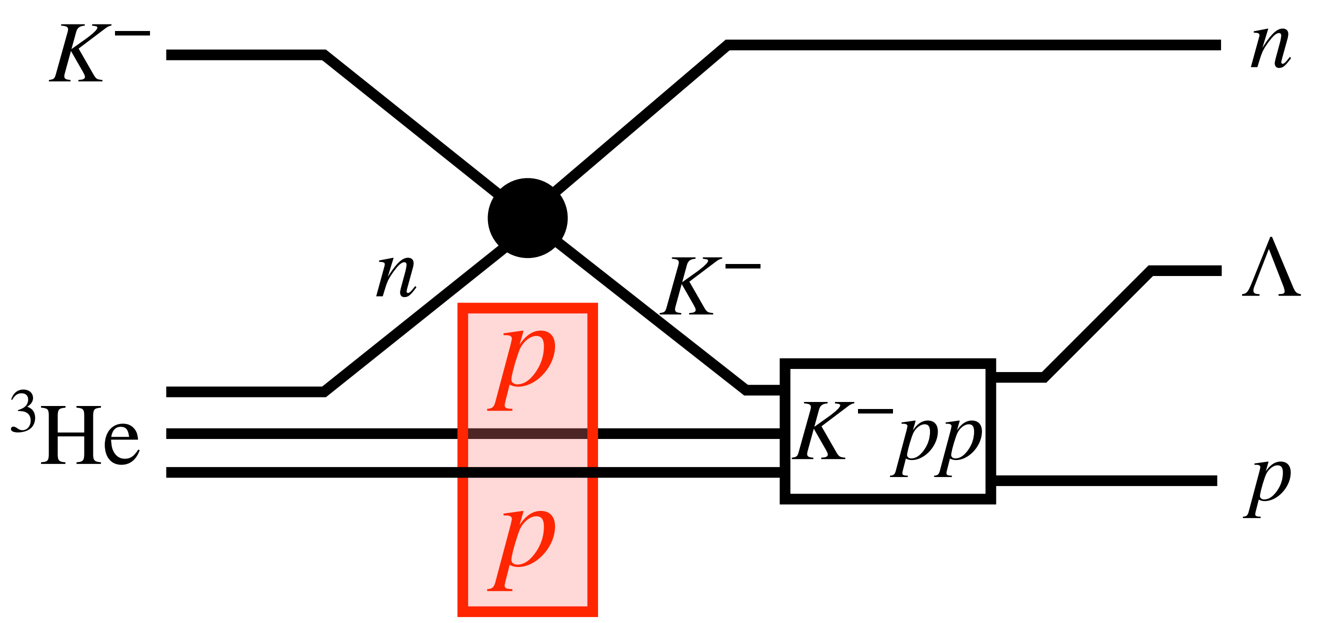
If $|I_{pn}> = |0, 0>$;

$\bar{K}^0nn \to 1^-$

$\sigma_{K^-pp} \propto A_p\sigma_{\bar{K}^0n} \times \frac{1}{2} \times 1$

K^-pp production by $K^-n \to K^-n$

($\sigma_{K^-n} \sim 4.7$ mb/sr @ $\theta_n = 0°$)



$|I_{pp}> = |1, +1>$;

$K^-pp \to 0^-$

$\sigma_{K^-pp} \propto \sigma_{K^-n} \times 1 \times \frac{2}{3}$

Measurement of spin-spin correlation of Λ & proton

Decay of $K^{-}pp$

– Assuming $J^P = 0^-$ –

P-wave decay; $L_{\Lambda p} = 1$

$S_{\Lambda p} = 1$ to make $J = 0$

$I_{K^-} = \frac{1}{2}, J^P_{K^-} = 0^-$

$I_{pp} = 1, J^P_{pp} = 0^+$

$$K^{-}pp$$

$I_{K^-pp} = \frac{1}{2}, J^P_{K^-pp} = 0^-$

Strong decay

I & J^P conserved

$$\Lambda p$$

$I_{\Lambda p} = \frac{1}{2}, J^P_{\Lambda p} = 0^-$

$I_\Lambda = 0, J^P_\Lambda = \frac{1}{2}^+$

$I_p = \frac{1}{2}, J^P_p = \frac{1}{2}^+$

Λ & proton are **not polarized**, but their spins are **correlated**.

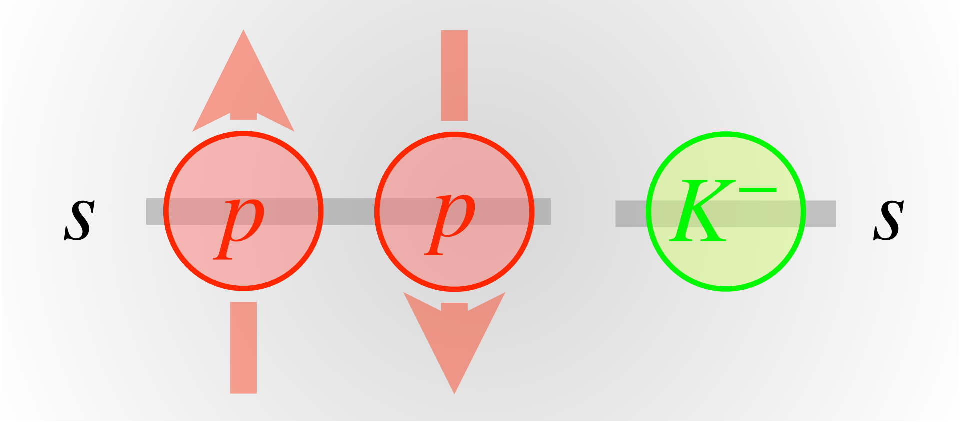
We consider spin-spin correlation between Λ & proton.

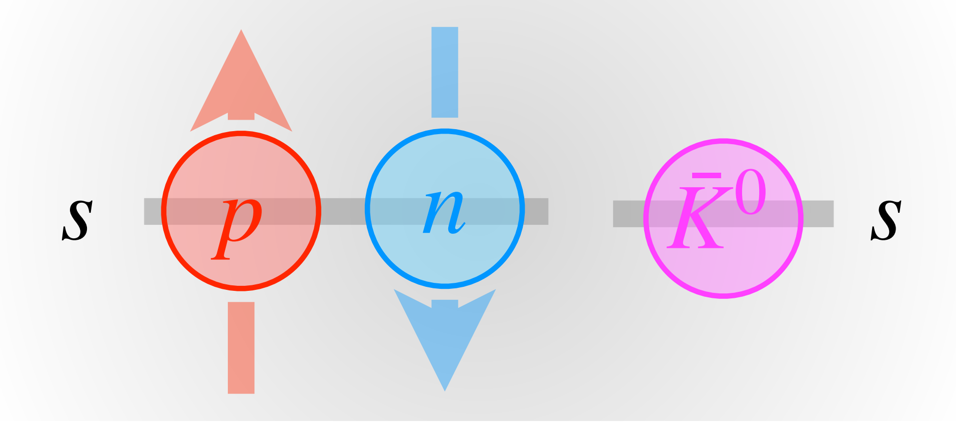
$$\vec{S}_\Lambda \cdot \vec{S}_p \equiv \alpha_{\Lambda p}$$

Expected spin-spin correlation

$J^P_{K^-pp} = 0^-$

NN is spin-singlet & isospin-triplet.





To make negative parity

$L_{\Lambda p} = 1$

To make total $J = 0$

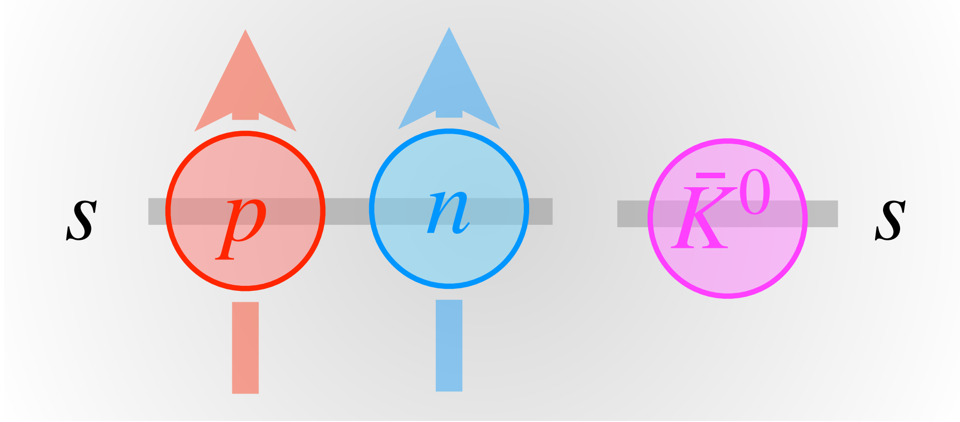
$S_{\Lambda p} = 1$

Spin flip

$\alpha_{\Lambda p} = +1$

$J^P_{K^-pp} = 1^-$

NN is spin-triplet & isospin-singlet.



To make negative parity

$L_{\Lambda p} = 1$

Both are possible.

$S_{\Lambda p} = 0$ + $S_{\Lambda p} = 1$

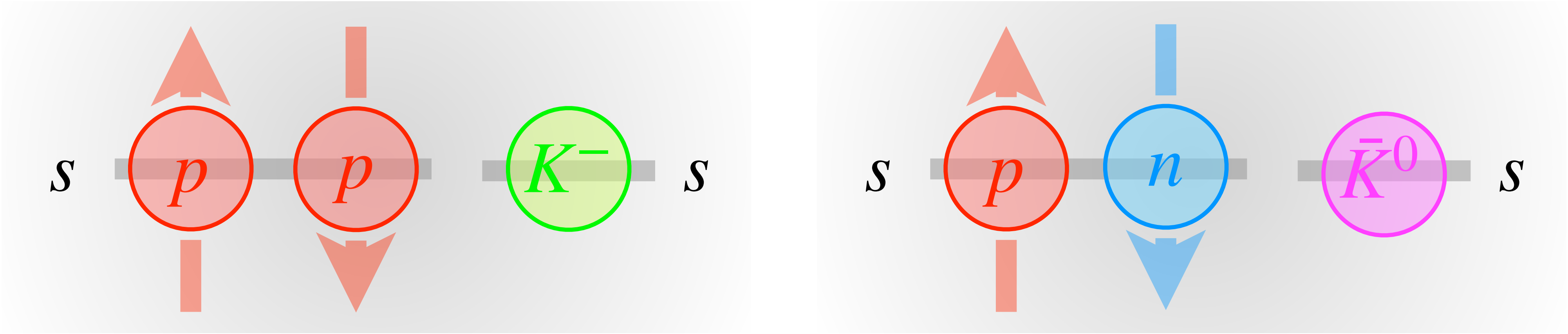
Spin flip | Spin non-flip

$\alpha_{\Lambda p} = -1$ + $\alpha_{\Lambda p} = +1$

Expected spin-spin correlation

$J^P_{K^-pp} = 0^-$

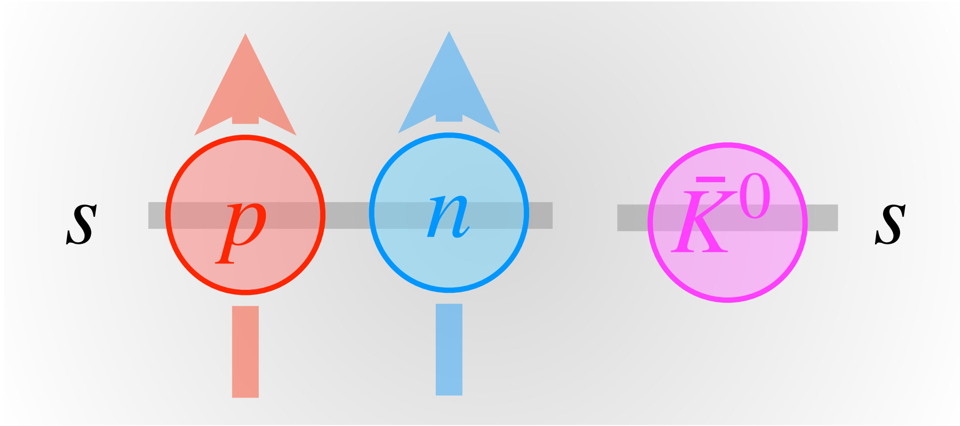
NN is spin-singlet & isospin-triplet.



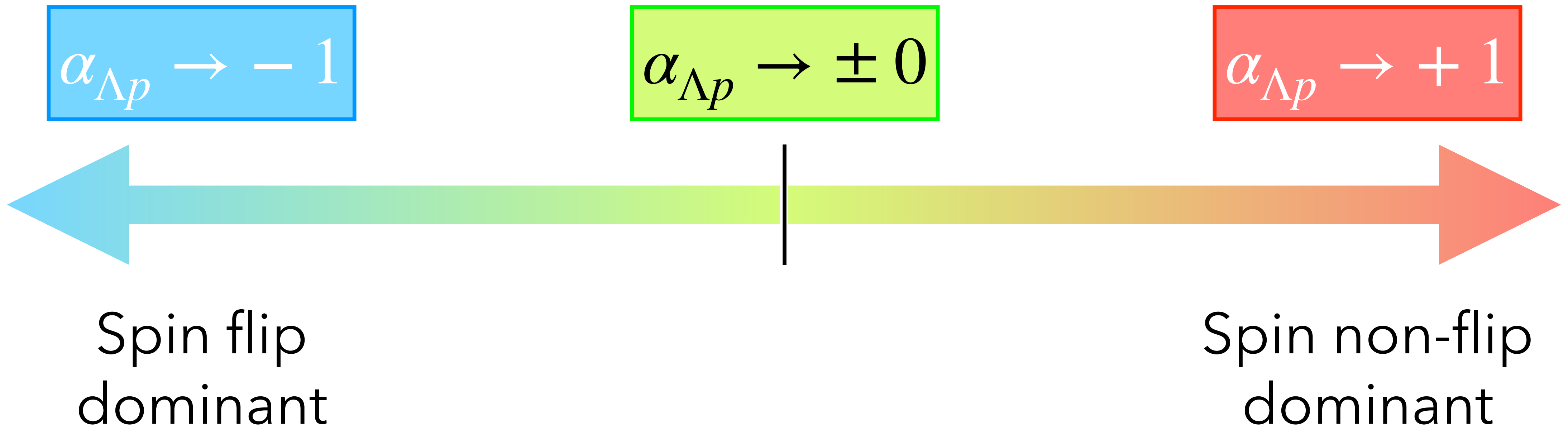
$\alpha_{\Lambda p} = +1$

$J^P_{K^-pp} = 1^-$

NN is spin-triplet & isospin-singlet.



$\alpha_{\Lambda p} = ?$



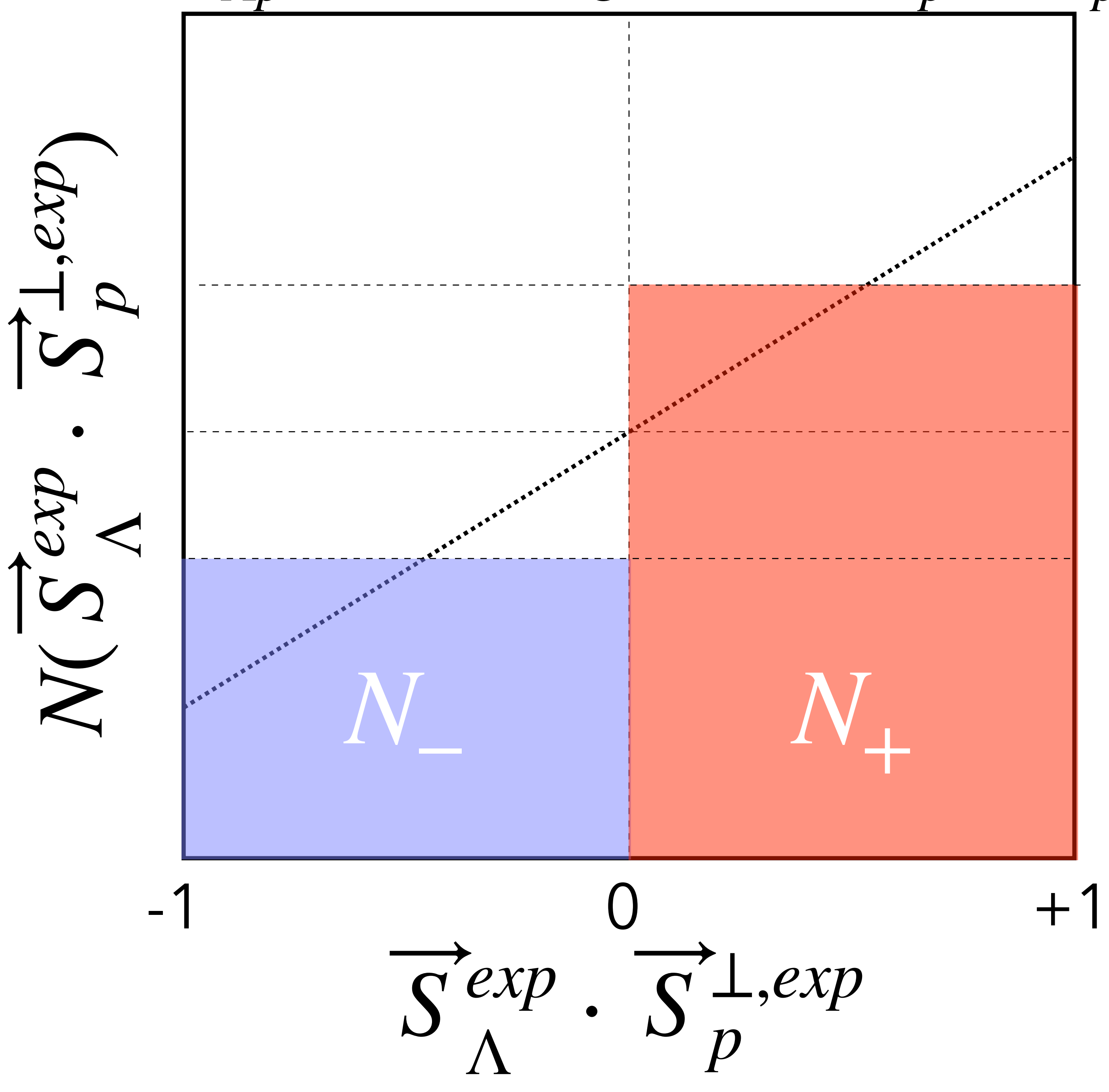
Estimation of the accuracy

– Overview –

Spin-spin correlation; $\alpha_{\Lambda p}$

$$\alpha_{\Lambda p} = \frac{N_+ - N_-}{N_+ + N_-} \cdot \frac{2}{r} \qquad r \equiv \alpha_- \cdot < A_C > \cdot < | \vec{S}_p \times \vec{p}_p | >$$

Slope : $\alpha_{\Lambda p} \cdot \alpha_- \cdot < A_C > \cdot < | \vec{S}_p \times \vec{p}_p | >$



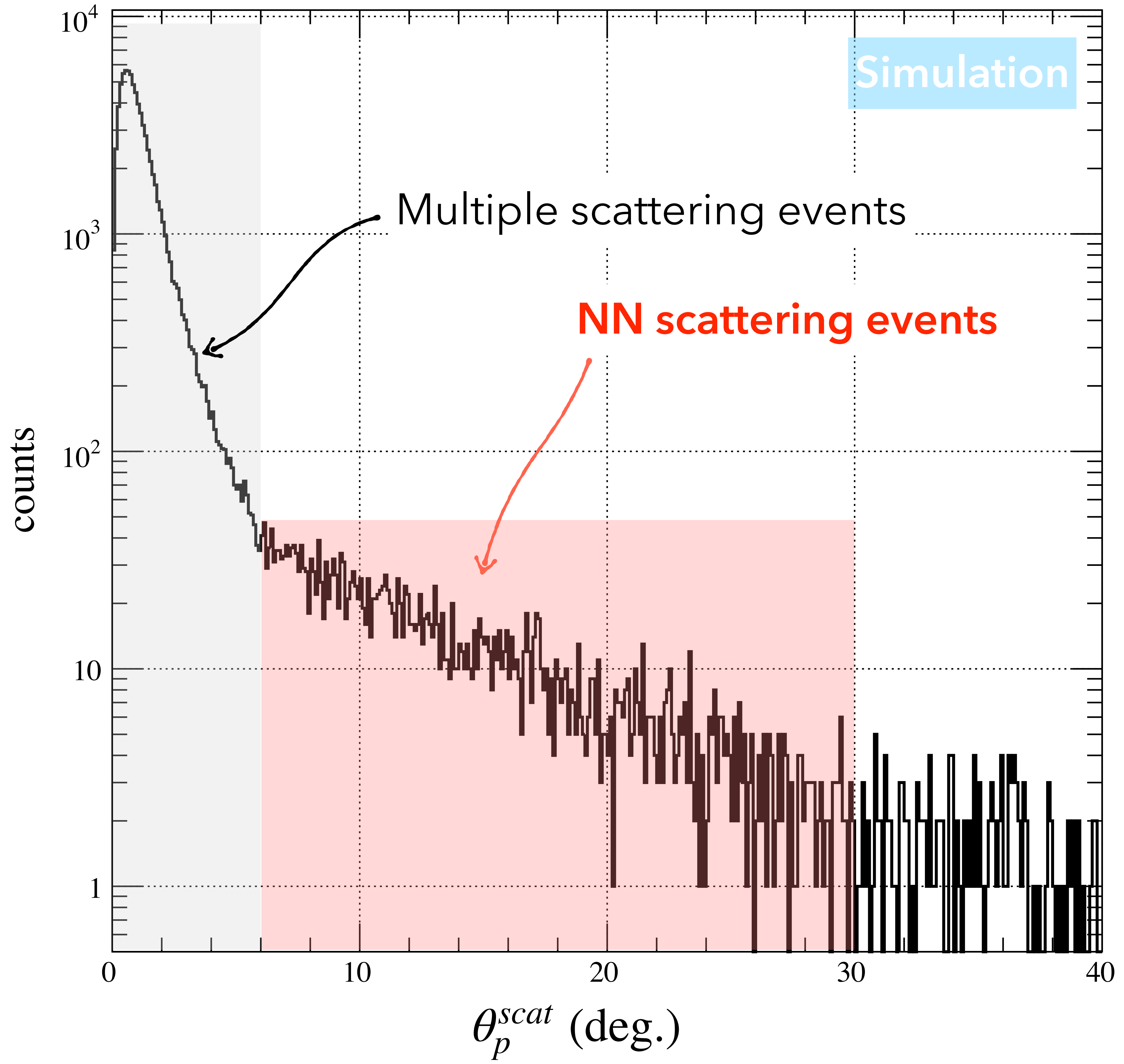
- Statistical error;

$$\Delta\alpha_{\Lambda p} = \frac{2}{\alpha_- \cdot < A_C > \cdot < | \vec{S}_p \times \vec{p}_p | >} \cdot \frac{1}{\sqrt{N_+ + N_-}}$$

  - $\alpha_- \sim 0.7$ (well known)
  - $< A_C >$, $< | \vec{S}_p \times \vec{p}_p | >$, and number of scattering events should be studied.
- Systematic error;
  - Good reference to evaluate systematic
    - Proton polarization in $\Lambda \to p\pi^-$ decay
    - To be discussed later

Estimation of the accuracy

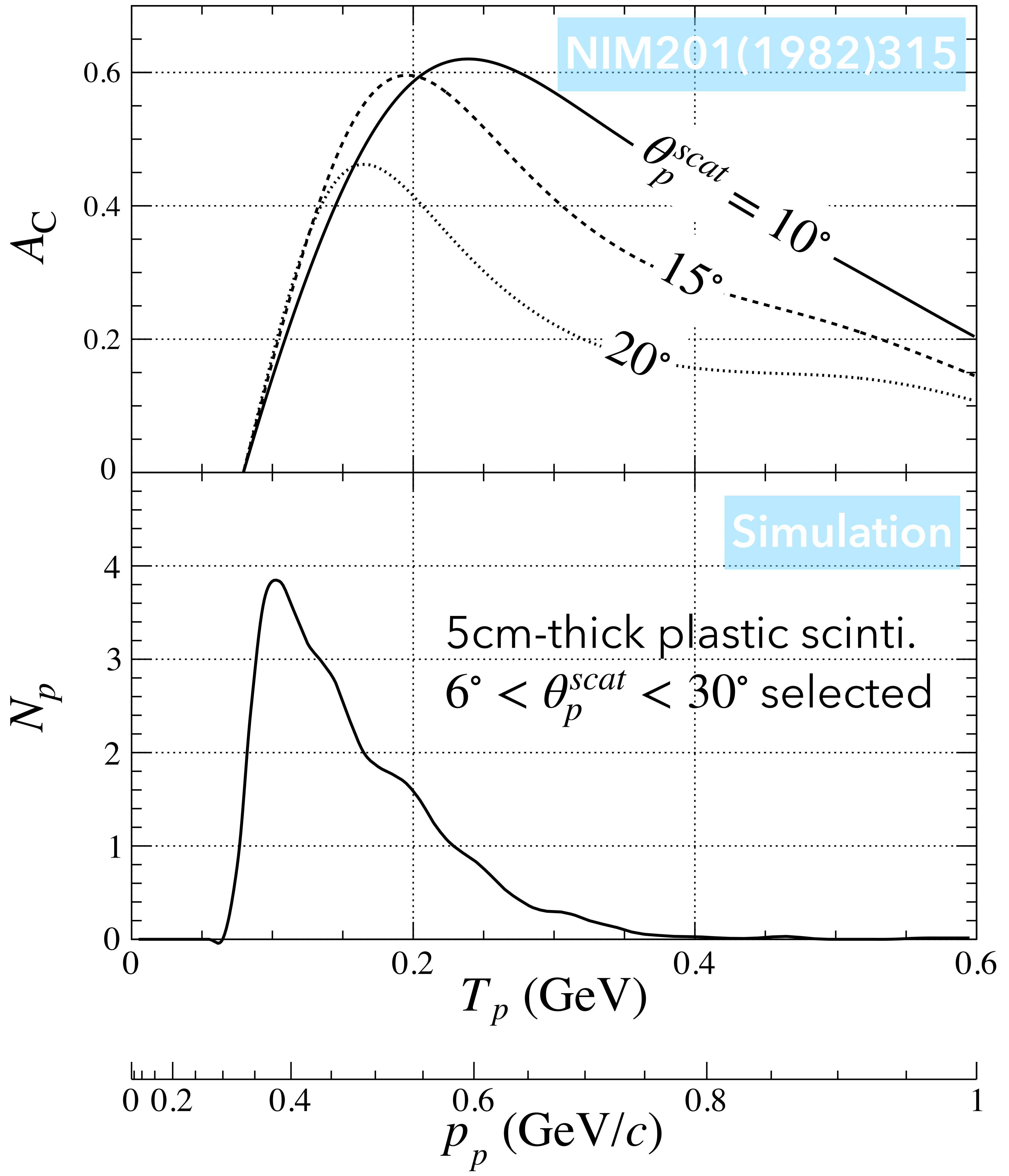
– Numbers of $K^{-}pp \to \Lambda p$ & p-C scattering –



- Number of $K^{-}pp \to \Lambda p$ to be detected
  - $N^{det}_{K^{-}pp} \sim 3000/\mathrm{week}$
    - Cross section of $K^{-}pp$:
      $\sigma_{K^{-}pp} \cdot \mathrm{BR}_{\Lambda p} = 9.3\ \mu\mathrm{b}$ (measured value)
    - Expected luminosity :
      $\mathscr{L}_{week} = 2.8\ \mathrm{nb}^{-1}/\mathrm{week}$
      (estimation with 90kW beam-power)
    - Acceptance including analysis efficiency : $\sim 15\,\%$
      (proton detected by barrel-part of new CDS)
- **Number of p-C scattering**
  - $N_{total} = N_{+} + N_{-} \sim 300\ \mathrm{events/week}$
    - 5 cm x 3 layers plastic-scintillators used as “scattering target”
    - Reaction rate : $\sim 3\,\%$ of all incident proton per one 5cm-plastic-scintillator
      (Estimated by Geant4 based MC simulation)

Estimation of the accuracy

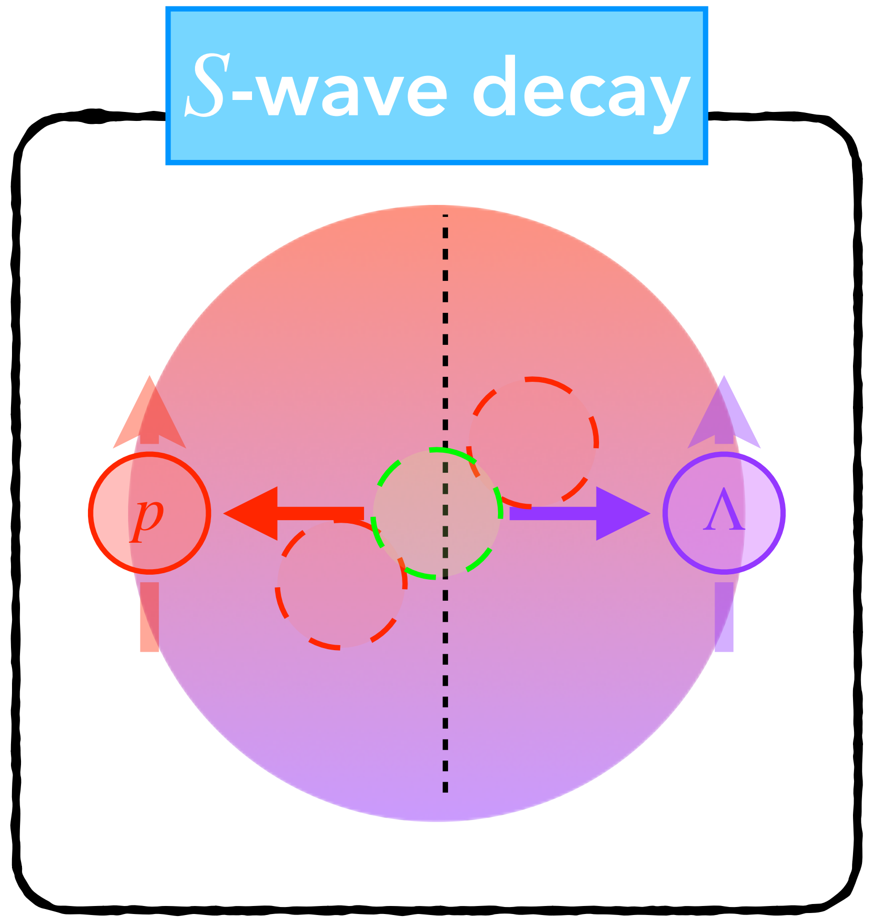
– Analyzing power –

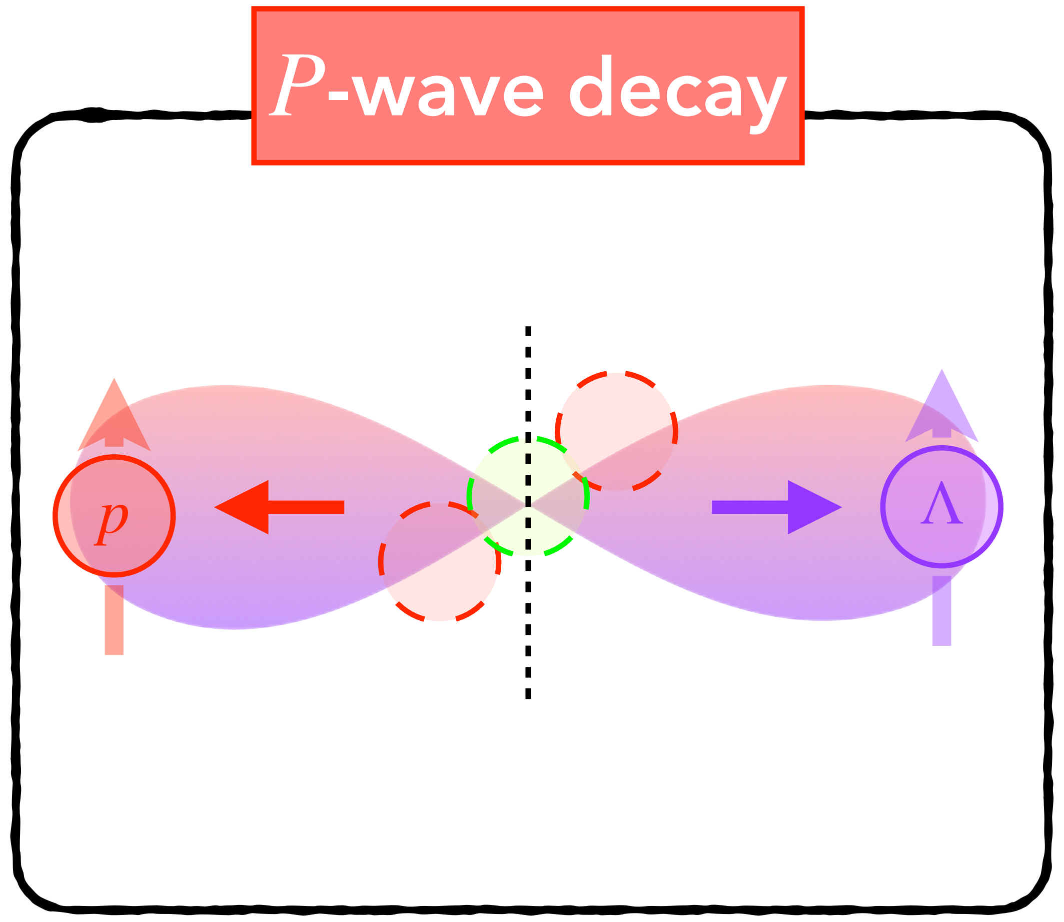


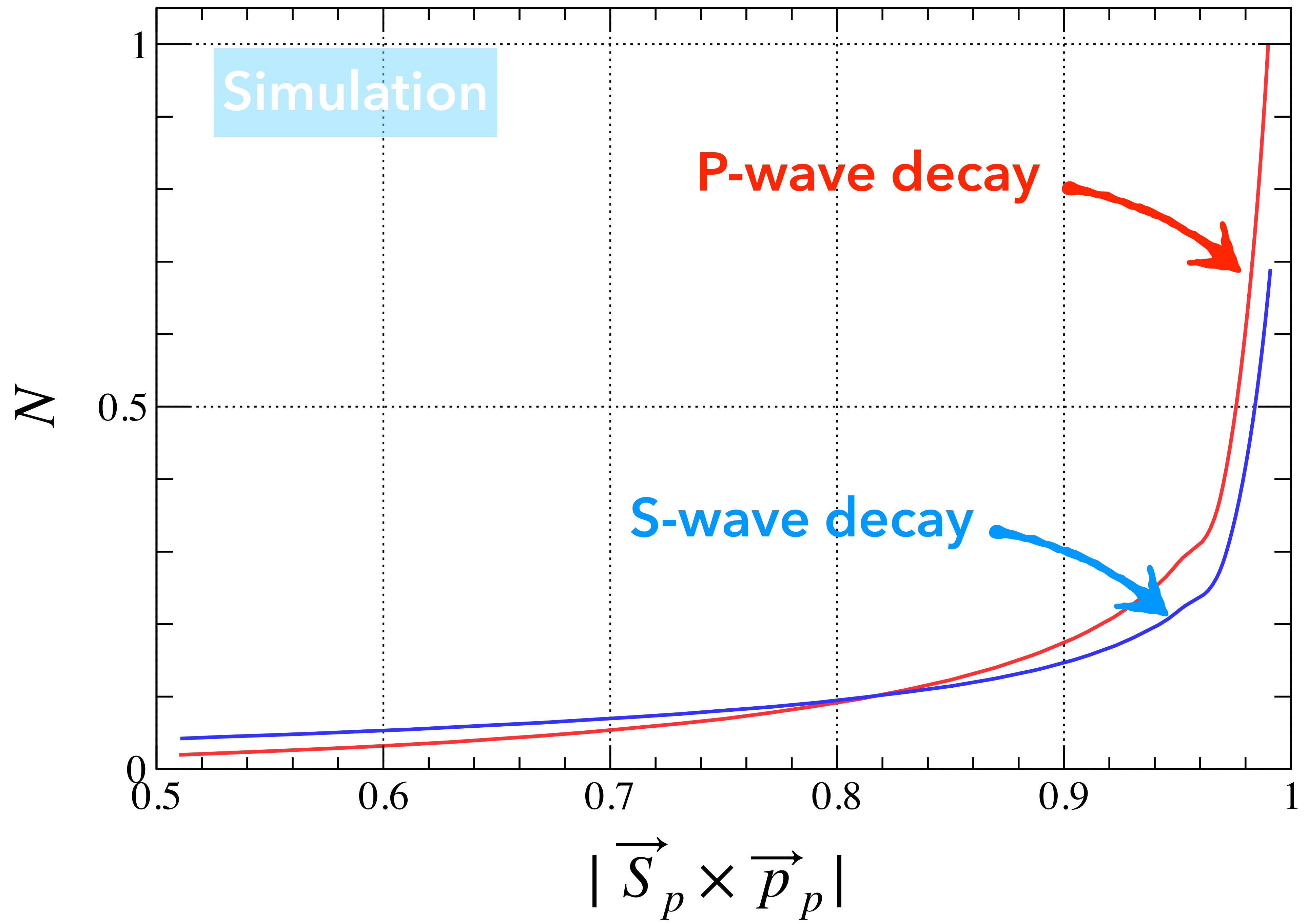
- Analyzing power of carbon taken from Ref.
  - Peak around $T_P = 0.2$ GeV
- Momentum distribution of proton
  - Simulated by MC
    - with 5cm thickness plastic scintillator
    - $6° < \theta_p^{scat} < 30°$ selected
  - Similar to A_C shape
- **Average : $< A_C > \sim 0.4$**

Estimation of the accuracy

– Transverse component of proton spin –



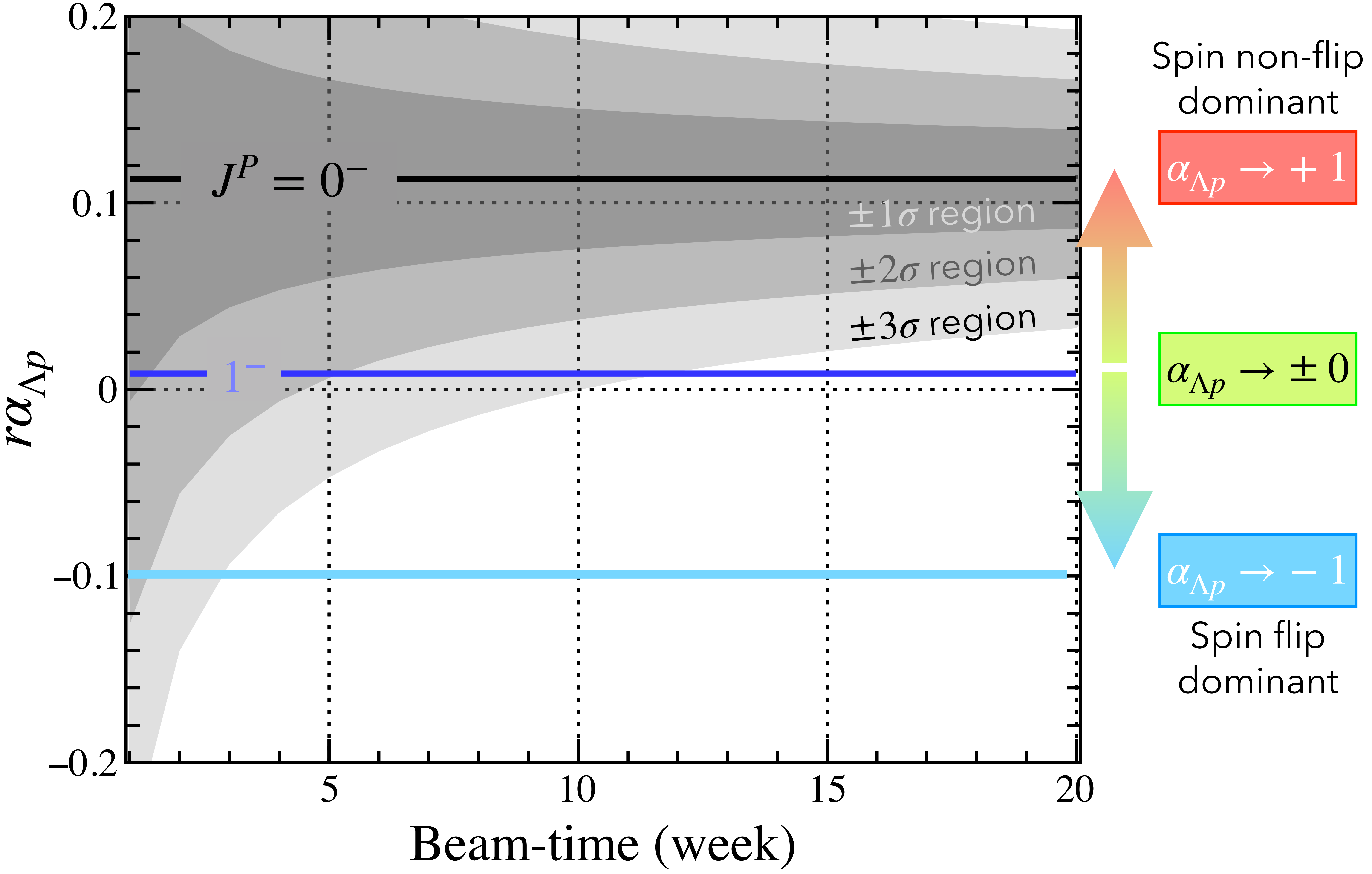




- Large transverse component is expected.
  - better to measure
- Small difference between S & P wave decay
  - $<|\vec{S}_p \times \vec{p}_p|> \sim 0.8$ (S-wave decay)
  - $<|\vec{S}_p \times \vec{p}_p|> \sim 0.9$ (P-wave decay)

Estimation of the accuracy

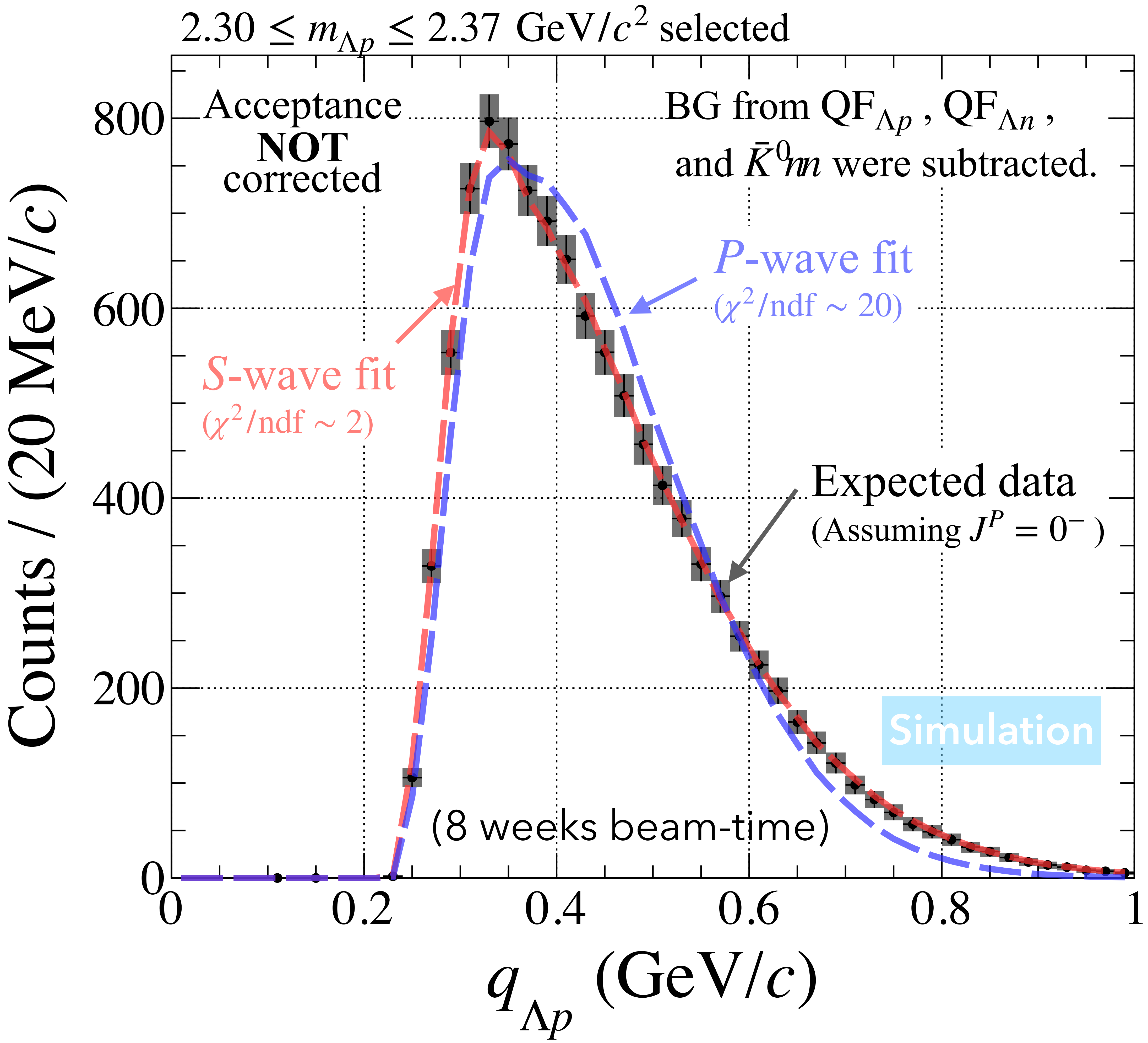
– The accuracy & Necessary beam-time to determine J^P –



- If we assume $\alpha_{\Lambda p} = \pm 0$;
  - J^P would be determined with **~13 weeks**
    - Proton detected by barrel part of the new CDS
    - With 90kW beam power & 5 cm x 3 layers plastic scintillator
- If $\alpha_{\Lambda p} \to -1$;
  - J^P determination becomes easy.
    - within a month beam-time
- If $\alpha_{\Lambda p} \to +1$;
  - Need other way…

Distinguish between 0^- & 1^+

– Momentum transfer dependence of S & P -wave states –

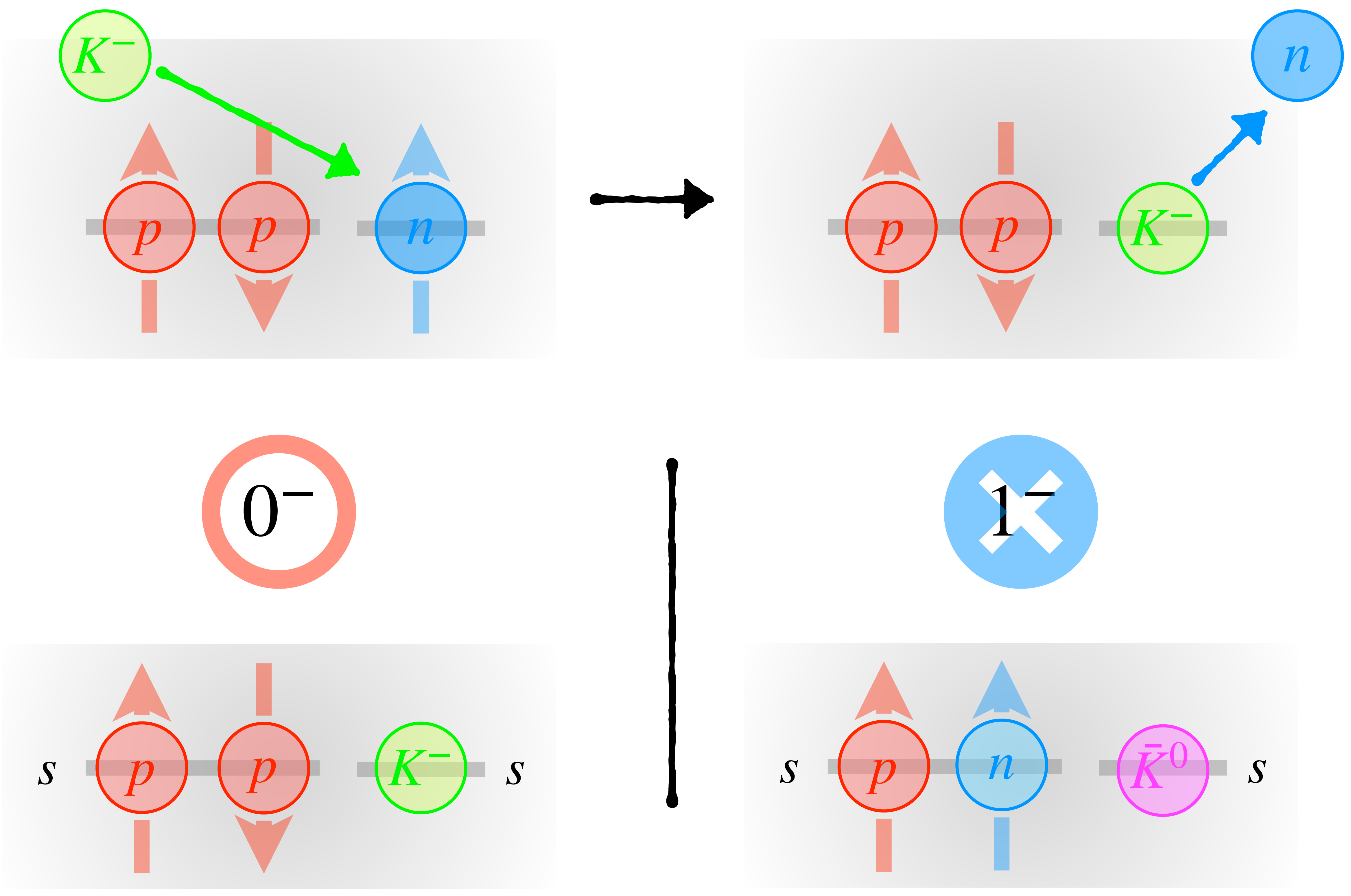


- Differential cross section should be different:
  - $\propto \exp\left(-\frac{q^2}{Q^2}\right)$ for S-wave state
  - $\propto \frac{q^2}{Q^2} \exp\left(-\frac{q^2}{Q^2}\right)$ for P-wave state
- We need to subtract BG from other reaction.
  - Especially, higher q region has large BG contamination.
  - Systematic uncertainty should be considered carefully.
- CS dependence must be considered more carefully.
  - Simple PWIA may be invalid.
  - We need to discuss with theoretician to derive the realistic CS dependence.

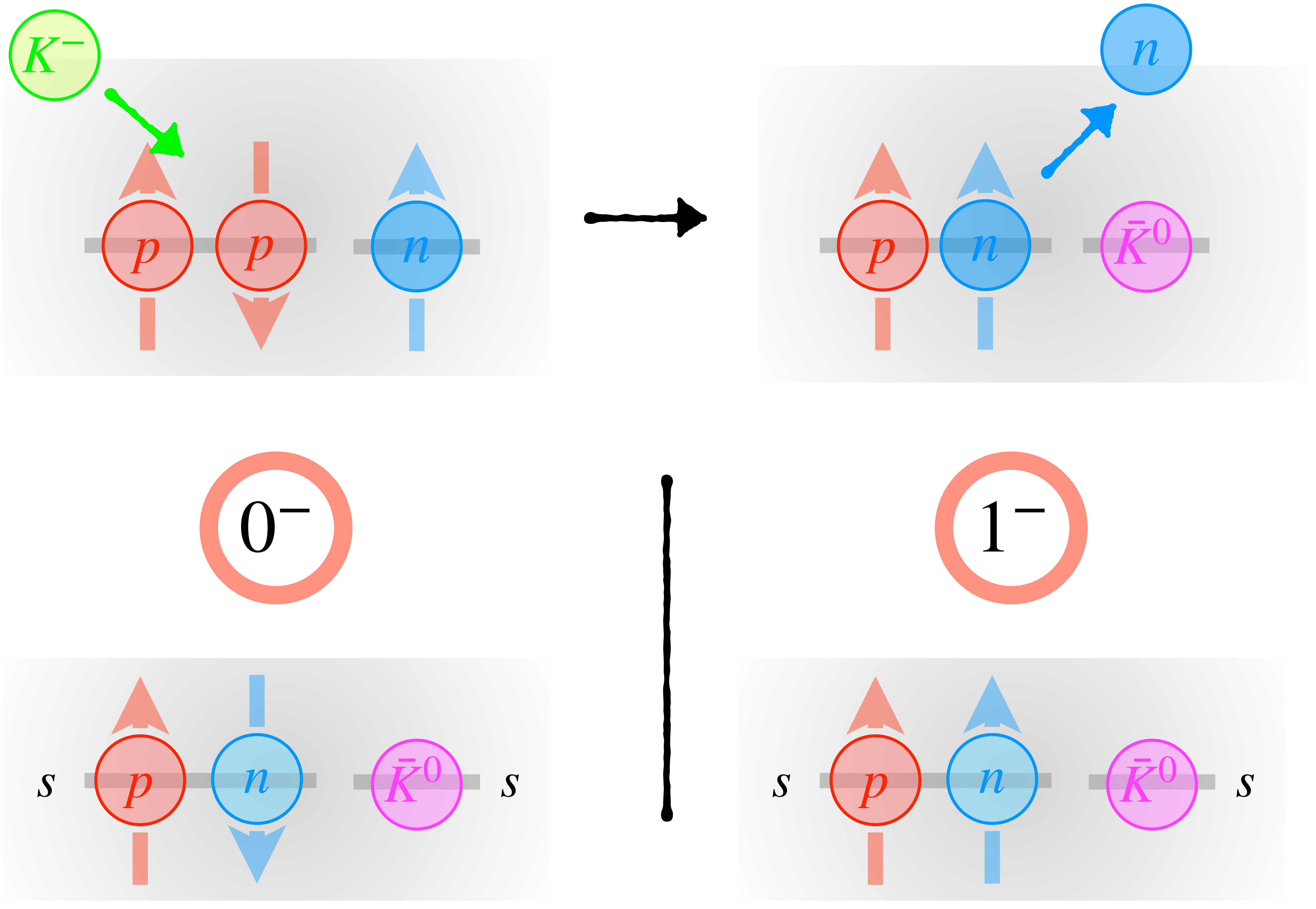
Production cross-sections of K^-pp & $\bar{K}^0nn$

Production of $K^{-}pp$

Involved by
elastic $K^{-}n \to K^{-}n$ reaction



Involved by
charge-exchange $K^{-}p \to \bar{K}^{0}n$ reaction



Production of K^-pp

Involved by
elastic $K^-n \to K^-n$ reaction

$$\sigma_{K^-n\to K^-n} \sim 4.7 \text{ mb/sr}$$
at $\theta_n = 0^\circ$

0^-

$$\sigma \propto 4.7 \times \frac{2}{3} \sim 3.2$$

To make $I_{\bar{K}NN} = |1/2, +1/2>$
from $|1, +1> \otimes |1/2, -1/2>$

1^-

$$\sigma = 0$$

Involved by
charge-exchange $K^-p \to \bar{K}^0 n$ reaction

$$\sigma_{K^-p\to \bar{K}^0 n} \sim 2.4 \text{ mb/sr}$$
at $\theta_n = 0^\circ$

0^-

$$\sigma \propto 2.4 \times \frac{1}{2} \times \frac{1}{3} \sim 0.4$$

To make $I_{NN} = |1,0>$
from $|1/2, +1/2> \otimes |1/2, -1/2>$

To make $I_{\bar{K}NN} = |1/2, +1/2>$
from $|1,0> \otimes |1/2, +1/2>$

1^-

$$\sigma \propto 2.4 \times \frac{1}{2} \sim 1.2$$

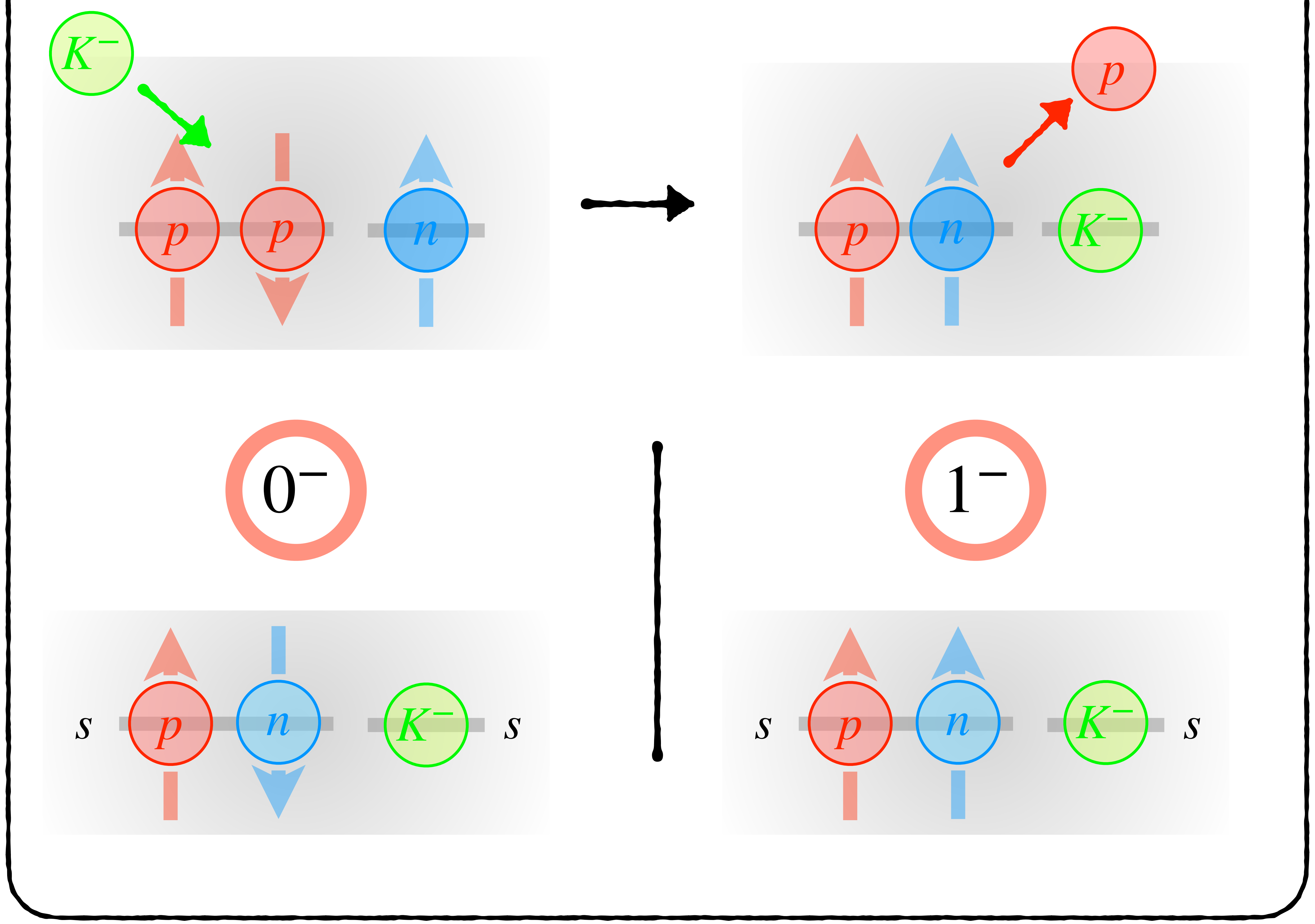
To make $I_{NN} = |0>$
from $|1/2, +1/2> \otimes |1/2, -1/2>$

*Assuming effective proton number = 1

Production of $\bar{K}^0 nn$

Involved by

elastic $K^- p \to K^- p$ reaction



Production of $\bar{K}^0 nn$

Involved by
elastic $K^-p \to K^-p$ reaction

$$\sigma_{K^-p \to K^-p} \sim 1.8 \text{ mb/sr}$$

at $\theta_p = 0^\circ$

0^-

$$\sigma \propto 1.8 \times \frac{1}{2} \times \frac{1}{3} \sim 0.3$$

1^-

$$\sigma \propto 1.8 \times \frac{1}{2} \sim 0.9$$

To make $I_{NN} = |1{,}0>$
from $|1/2, +1/2> \otimes |1/2, -1/2>$

To make $I_{\bar{K}NN} = |1/2, -1/2>$
from $|1{,}0> \otimes |1/2, -1/2>$

To make $I_{NN} = |0>$
from $|1/2, +1/2> \otimes |1/2, -1/2>$

*Assuming effective proton number = 1

Production ratio between $K^- pp$ & $\bar{K}^0 nn$

	$K^- pp$	$\bar{K}^0 nn$
$J^P = 0^-$	**12** (3.2+0.4=3.6)	**1** (0.3)
$J^P = 1^-$	**4** (1.2)	**3** (0.9)

*Assuming effective proton number = 1

Production ratio between $K^- pp$ & $\bar{K}^0 nn$

	$K^- pp$	$\bar{K}^0 nn$
$J^P = 0^-$	**7** (3.2+0.4x2=4.0)	**1** (0.3x2=0.6)
$J^P = 1^-$	**4** (1.2x2=2.4)	**3** (0.9x2=1.8)

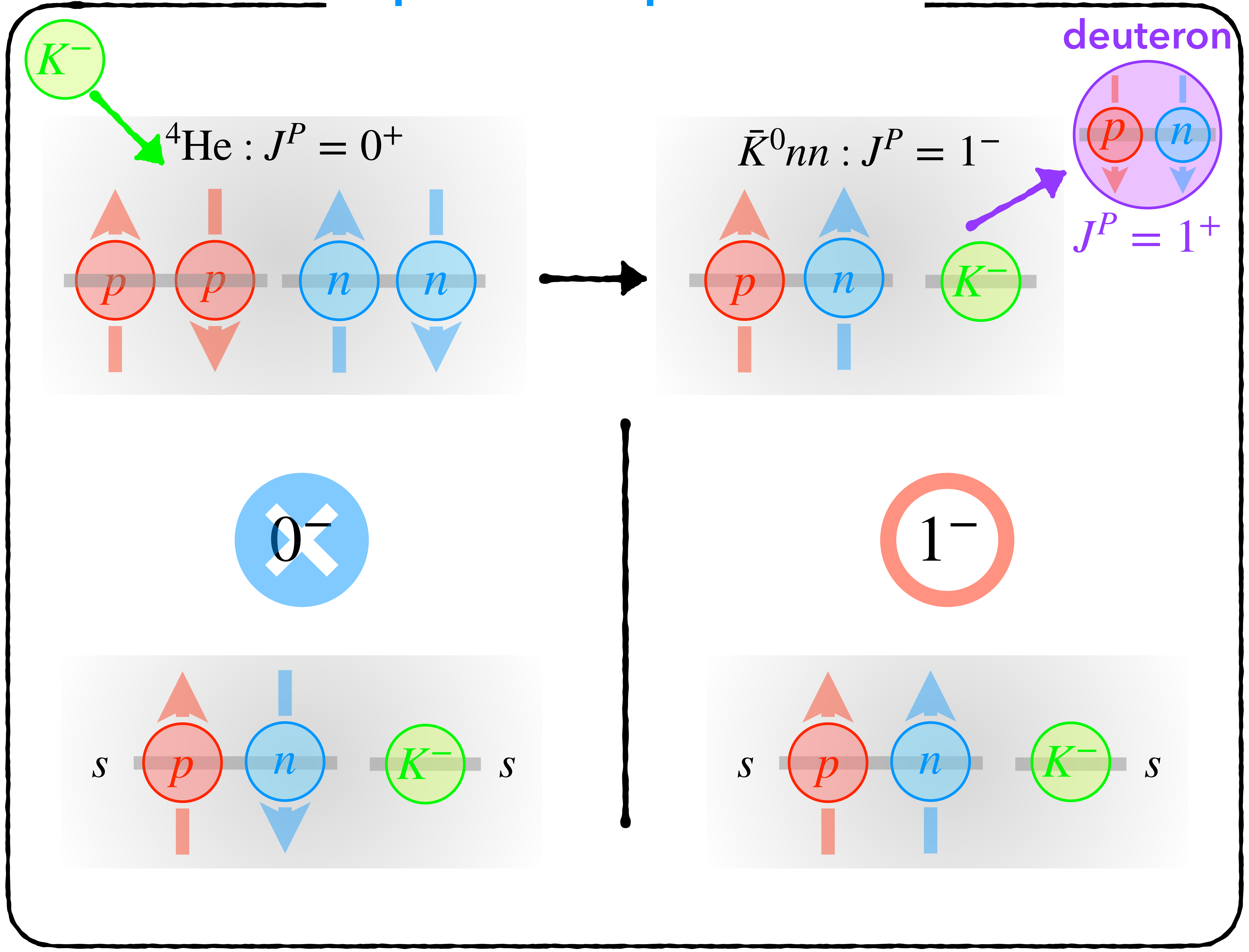
*Assuming effective proton number = 2

$\bar{K}^0 nn$ production in $K^- +\ {}^4\mathrm{He}$ reaction

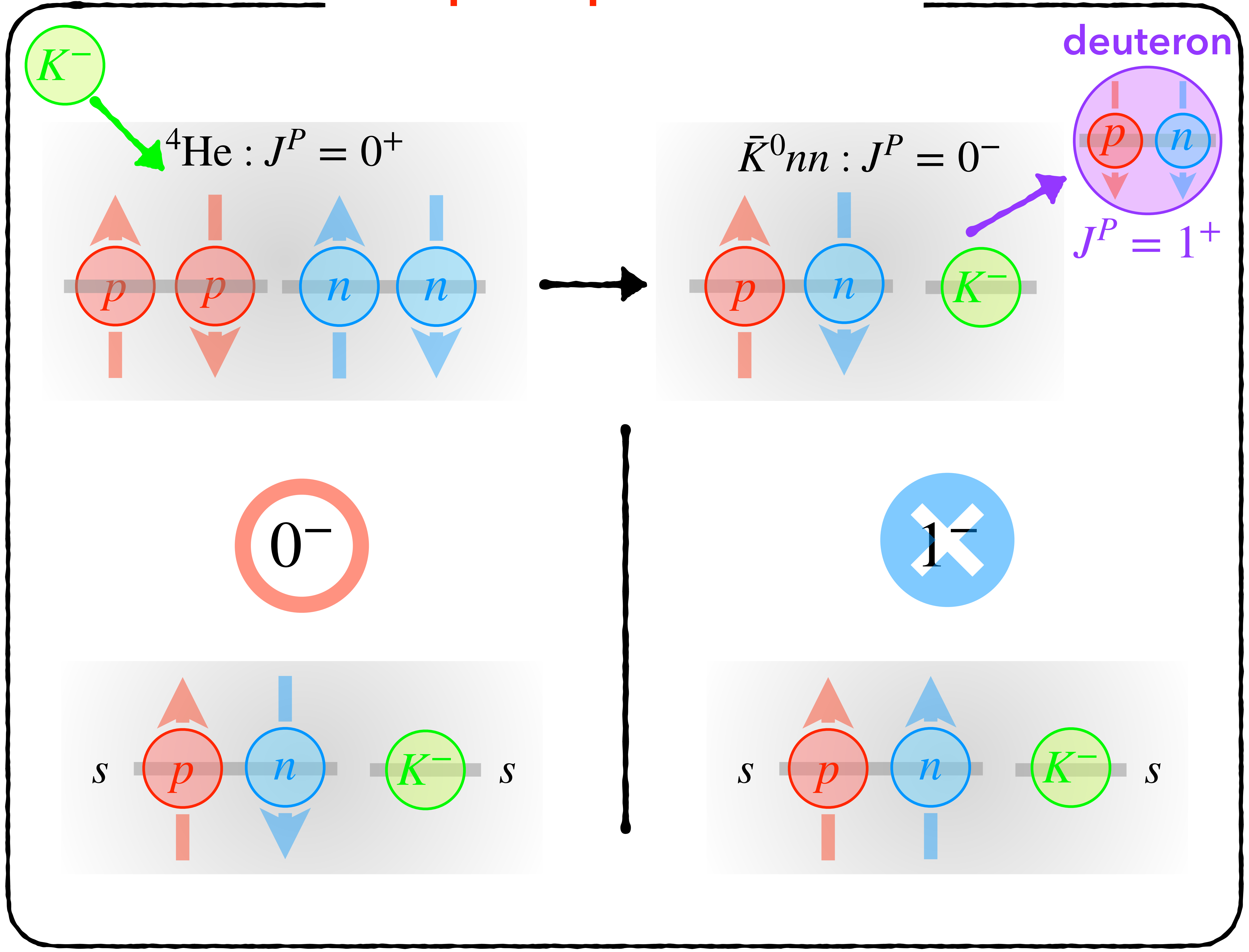
$K^- + {}^4\mathrm{He} \to \bar{K}^0 nn + d$ reaction

– Another possibility to distinguish 0^- & 1^- –

Spin non-flip reaction



Spin flip reaction



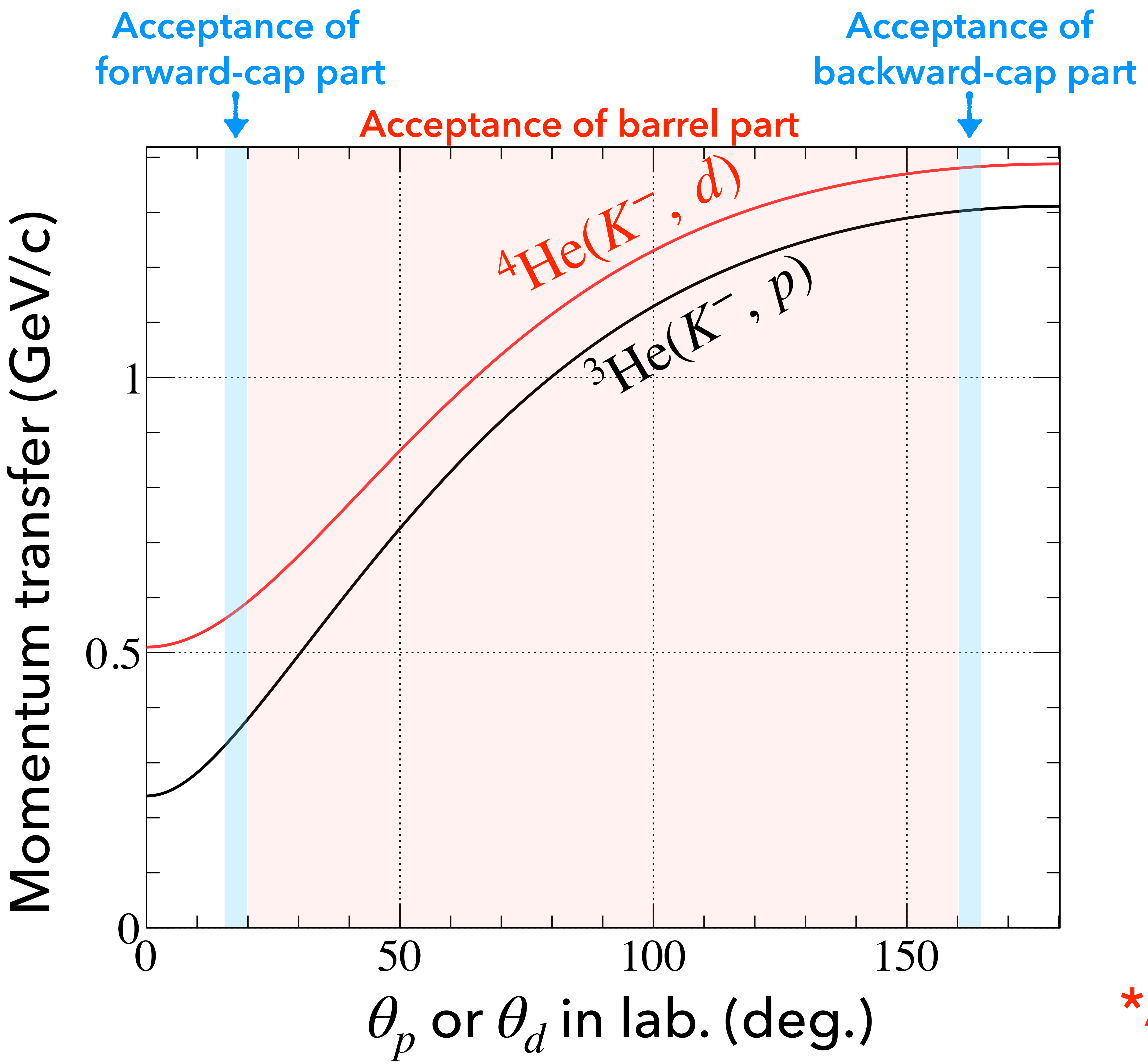
$K^- + {}^4\mathrm{He} \to \bar{K}^0 nn + d$ reaction

– Production ratio between ${}^3\mathrm{He}(K^-, p)$ & ${}^4\mathrm{He}(K^-, d)$ –

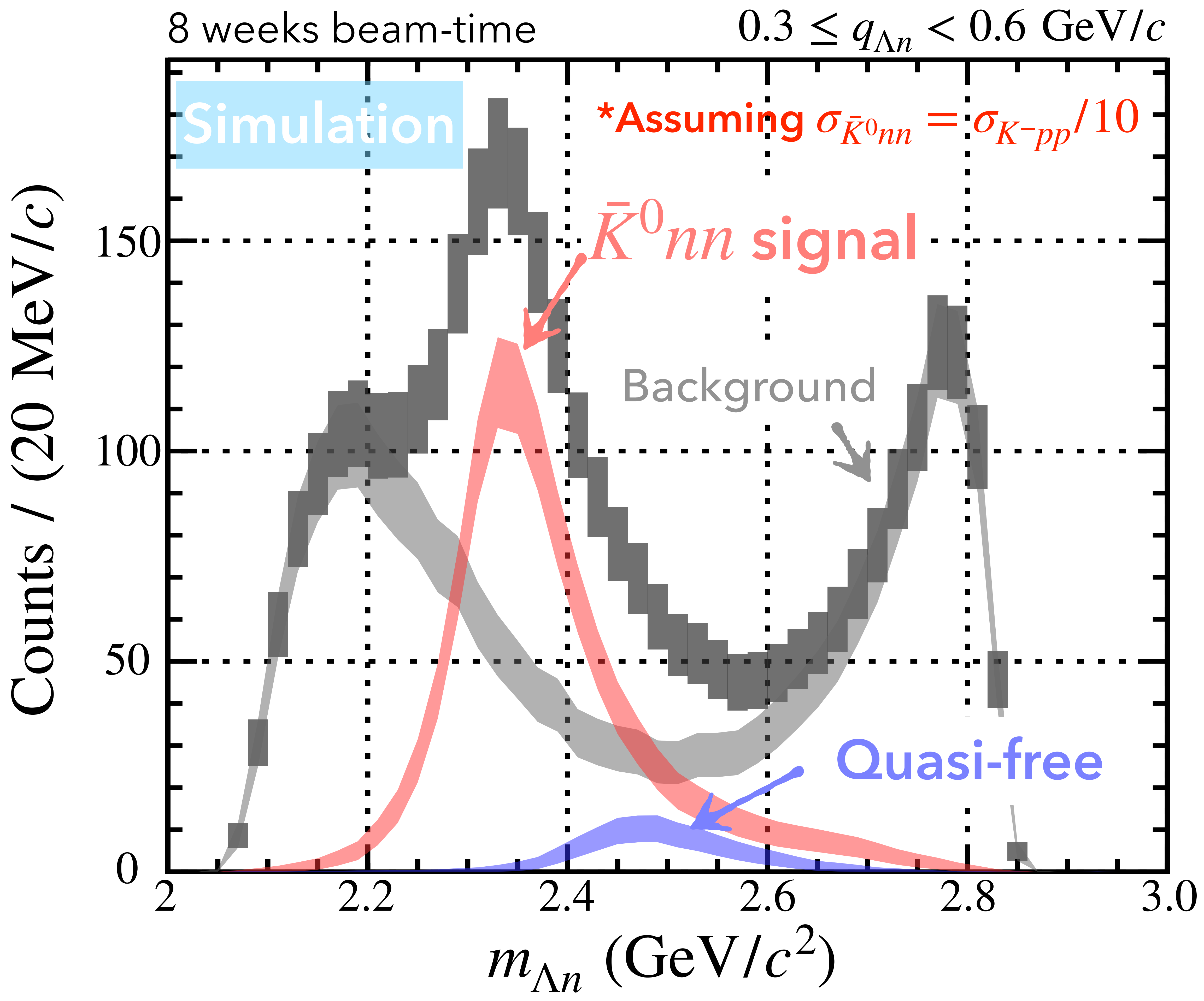
$\sigma_{\bar{K}^0 nn}$ in ${}^3\mathrm{He}(K^-, p) : \sigma_{\bar{K}^0 nn}$ in ${}^4\mathrm{He}(K^-, d)$

	Spin non-flip dominant	Comparable	Spin flip dominant
$J^P = 0^-$	$\sigma_{K^-p} : 0$	$\sigma_{K^-p} : \frac{1}{2}\sigma_{K^-d}$	$\sigma_{K^-p} : \sigma_{K^-d}$
$J^P = 1^-$	$3\sigma_{K^-p} : \sigma_{K^-d}$	$3\sigma_{K^-p} : \frac{1}{2}\sigma_{K^-d}$	$3\sigma_{K^-p} : 0$

Momentum transfer of $^3\mathrm{He}(K^-, p)$ & $^4\mathrm{He}(K^-, d)$



*Assuming BE ~ 40 MeV



8 weeks beam-time
$0.3 \leq q_{\Lambda n} < 0.6$ GeV/c
Simulation
*Assuming $\sigma_{\bar{K}^0 nn} = \sigma_{K^-pp}/10$
$\bar{K}^0 nn$ signal
Background
Quasi-free
Counts / (20 MeV/c)
$m_{\Lambda n}$ (GeV/c^2)
0
50
100
150
2
2.2
2.4
2.6
2.8
3.0