BESIII上超子打靶的研究

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Outline

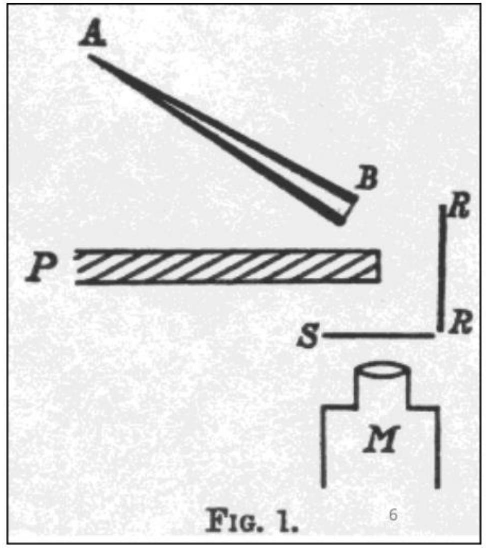
- Introduction
- Study of $\Xi^0 n \to \Xi^- p$
  PRL 130, 251902 (2023)
- Study of $\Lambda N \to \Sigma^+ X$
  PRC 109, L052201 (2024)
- Study of $\Lambda p \to \Lambda p$ and $\bar{\Lambda} p \to \bar{\Lambda} p$
  PRL 132, 231902 (2024)
- Summary

Scattering experiments of particle beams bombarding target materials

1911


Ernest Rutherford

$\alpha + \mathrm{Au}$



→ Nuclear structure model of atom

1919 $\alpha + \mathrm{N}$ → Observation of proton

1932 $\alpha + \mathrm{Be}$ → Observation of neutron

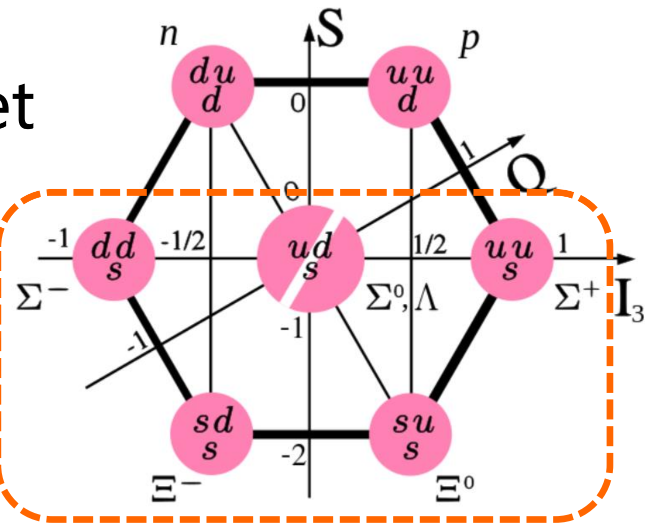

James Chadwick

Scattering experiment must have **particle source**, target material, and detector.

Hyperon source

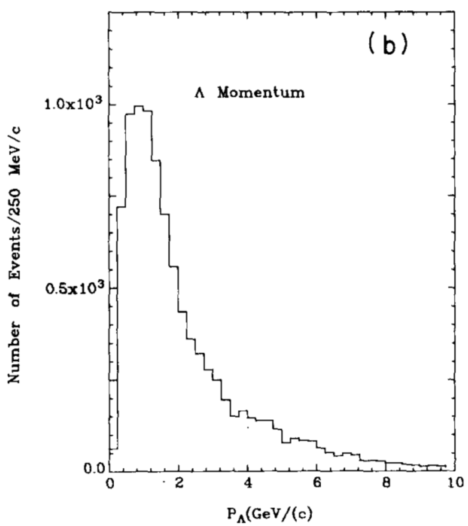
Baryon octet

One of main goals of nuclear physics is to understand baryon-baryon interaction in a unified perspective

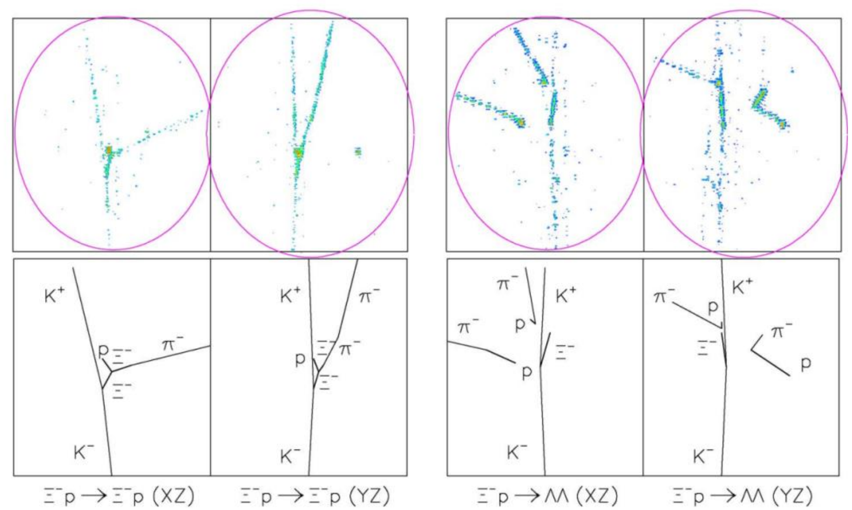


Limited by availability and short-lifetime of hyperon beams

- Hyperons are obtained by bombarding hydrogen bubble chamber or scintillating fiber target with K^{-}.



NPB 125, 29 (1977)



PLB 633, 214 (2006)

Hyperon source

- Hyperons are obtained by bombarding hydrogen bubble chamber or scintillating fiber target with K^-.
- Intensity of hyperon beams is low, experimental measurements are scarce and have large uncertainty.
- No antihyperon source.

Reaction	Number of events	
$\Lambda p \to \Lambda p$ (elastic)	584	(1)
$\Lambda p \to \Sigma^- p \pi^+$	132	(2)
$\Lambda p \to \Sigma^+ p \pi^-$	60	(3)
$\Lambda p \to \Lambda p \pi^+ \pi^-$	181	(4)
$\Lambda p \to \Sigma^0 p$	35	(5)
various $\Xi^0 p$ interactions	25	

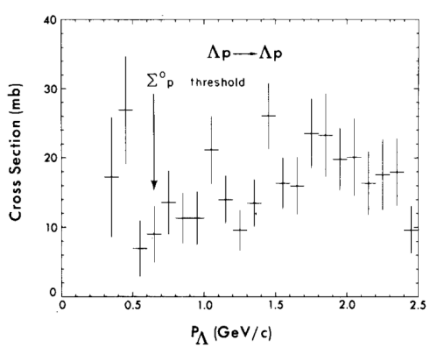
PLB 38, 123 (1972)

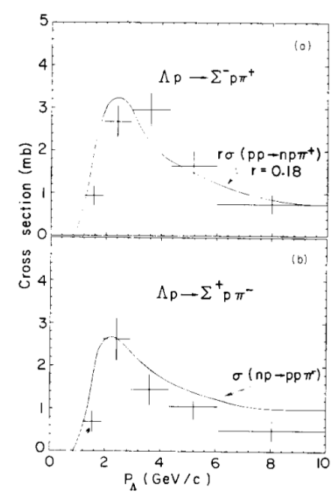
reaction	events *	signature	cross-section events **	cross-section (mb)
$\Xi^0 + p \to \Xi^0 + p$	2	K, Λ	1	8
$\Xi^0 + p \to \Lambda + \Sigma^+$	6	Λ	4	24
$\Xi^0 + p \to \Sigma^0 + \Sigma^+$	1	Λ	1	6
$\Xi^0 + p \to \pi^+ + \Lambda + \Lambda$	1	K, Λ	1	6
$\Xi^0 + p \to \pi^0 + \Lambda + \Sigma^+$	1	Λ	1	6
$\Xi^0 + p \to \pi^+ + \Xi^- + p$	1	K or Λ	1	5
$\Xi^0 + p \to \pi^+ + \pi^+ + \Xi^- + n$	1	K, Λ	1	6
$\Xi^0 + p \to \Xi^- + p$	2	Λ	2	8
$\Xi^0 + p \to \Sigma^- + \Sigma^+$	1	K	1	4
$\Xi^0 + p \to \Sigma^- + K^0 + p$	1	K	1	4

PLB 32, 720 (1970)

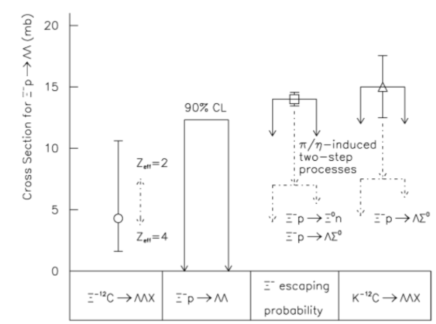
Reaction	Momentum interval (GeV/c)	Number of events	σ (mb)
$\Lambda p \to$ all	0.5 → 1.0		25.8 ± 6.2
	1.0 → 1.5		31.3 ± 6.5
	1.5 → 2.0		42.8 ± 7.1
	2.0 → 2.5		37.5 ± 7.2
	2.5 → 3.0		34.1 ± 8.3
	3.0 → 4.0		41.8 ± 10.0
$\Lambda p \to \Lambda p$	0.5 → 1.0	20	22.2 ± 5.0
	1.0 → 1.5	21	12.9 ± 2.8
	1.5 → 2.0	37	22.0 ± 3.6
	2.0 → 2.5	28	16.1 ± 3.1
	2.5 → 3.0	12	11.0 ± 3.2
	3.0 → 4.0	13	12.5 ± 3.4
$\Lambda p \to \Sigma^0$	0.66 → 4.0	11	1.5 ± 0.5
$\Lambda p \to \Lambda p \pi^0$	0.88 → 4.0	29	4.1 ± 0.8
$\Lambda p \to \Lambda p \pi^+ \pi^-$	1.36 → 4.0	12	1.9 ± 0.6
$\Sigma^+ p \to \Sigma^+ p$	0.5 → 1.5	10	31.2 ± 10.1
	1.5 → 2.5	8	18.7 ± 6.6
	2.5 → 4.0	4	15.3 ± 7.8
$\Sigma^- p \to \Sigma^- p$	0.5 → 1.5	6	13.2 ± 4.7
	1.5 → 2.5	11	13.9 ± 4.1
	2.5 → 4.0	4	7.5 ± 3.8
$\Xi^- p \to \Xi^- p$	1.0 → 4.0	6	13 ± 6
$\Xi^0 p \to \Xi^0 p$	1.0 → 4.0	4	19 ± 10

NPB 125, 29 (1977)



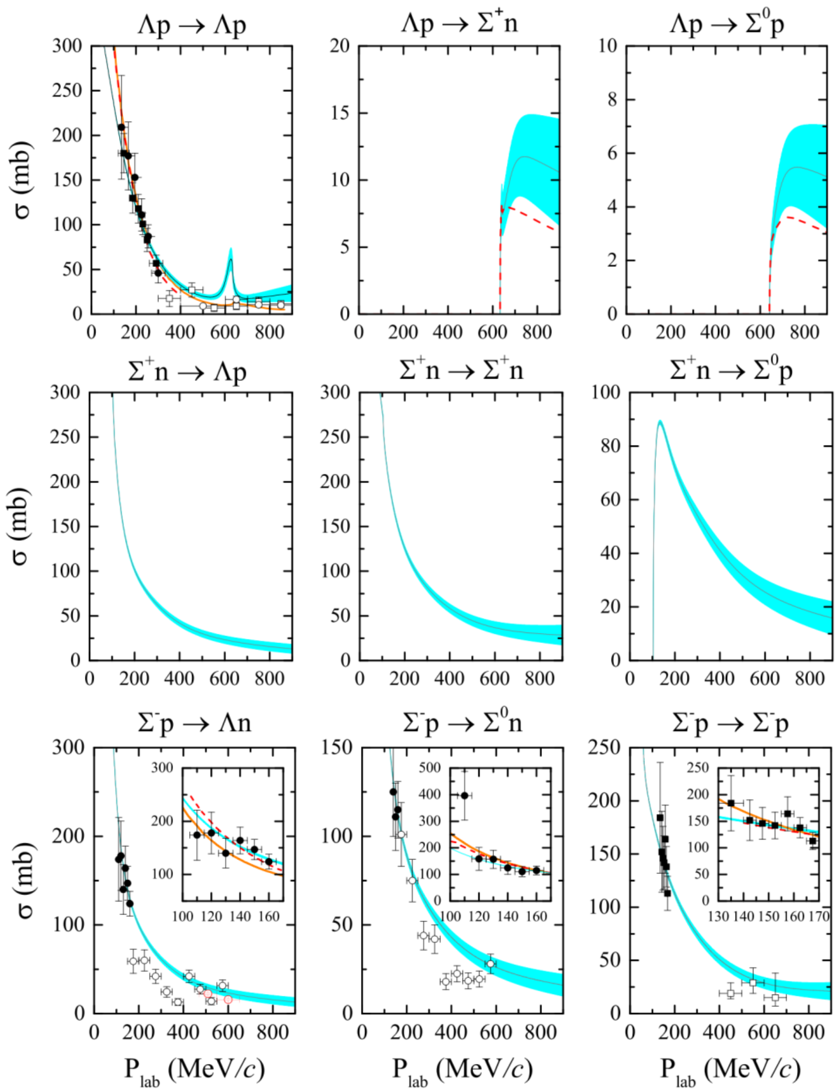


PLB 633, 214 (2006)



Theory of hyperon-nucleon (YN) interaction has large uncertainty due to lack of relevant measurements

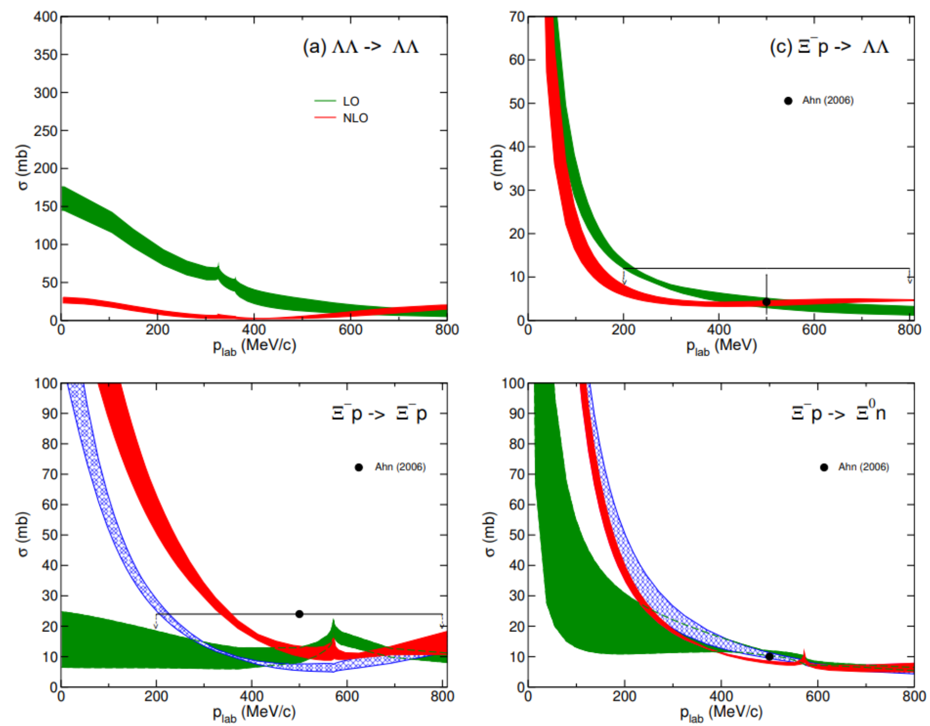
PRC 105, 035203 (2022)



LO : H. Polinder, J.H., U.-G. Meißner, PLB 653 (2007) 29

NLO16: J.H., U.-G. Meißner, S. Petschauer, NPA 954 (2016) 273

NLO19: J.H., U.-G. Meißner, EPJA 55 (2019) 23



“Hyperon puzzle” of neutron stars

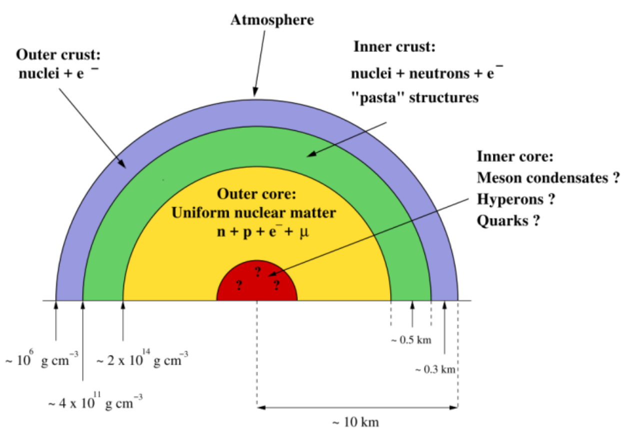
- Hyperons are believed to be appeared in inner core of neutron stars.

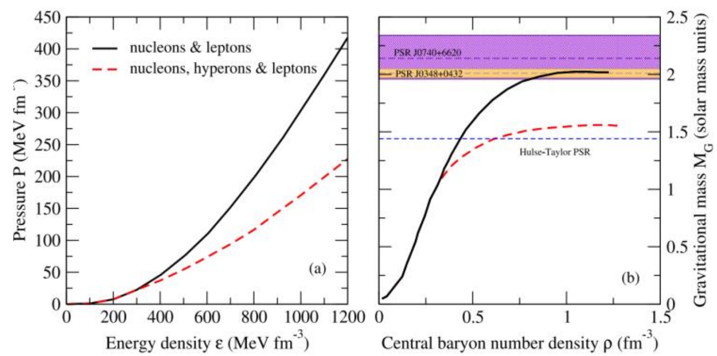
$$B_1 \to B_2 + l + \bar{\nu}_l,\ B_2 + l \to B_1 + \nu_l$$

$$n \to p + e^- + \bar{\nu}_e, p + e^- \to n + \nu_e \qquad \Sigma^- \to n + e^- + \bar{\nu}_e, n + e^- \to \Sigma^- + \nu_e$$

$$\Lambda \to p + e^- + \bar{\nu}_e, p + e^- \to \Lambda + \nu_e \qquad \Xi^- \to \Lambda + e^- + \bar{\nu}_e, \Lambda + e^- \to \Xi^- + \nu_e$$

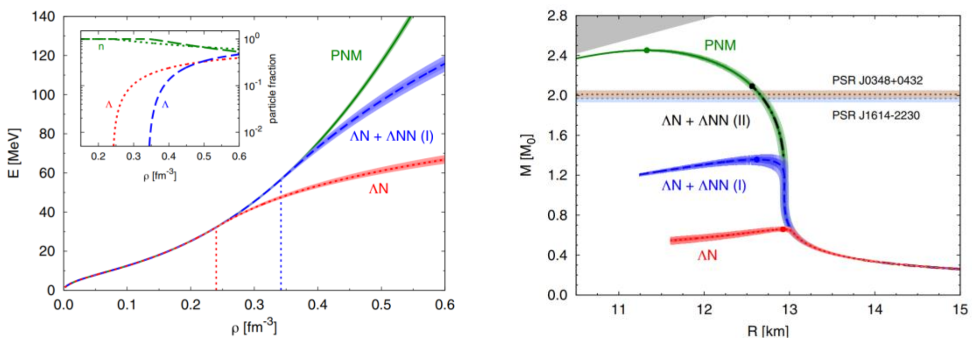
- Appearance of hyperons softens equation of state, lead to maximum mass that neutron stars can sustain is less than mass of already-observed neutron stars.
- A repulsive force is introduced to stiffen equation of state in theory, such as a combination of ΛN and ΛNN interactions. Study of hyperon-nucleon interaction is crucial to solve “hyperon puzzle” of neutron stars.



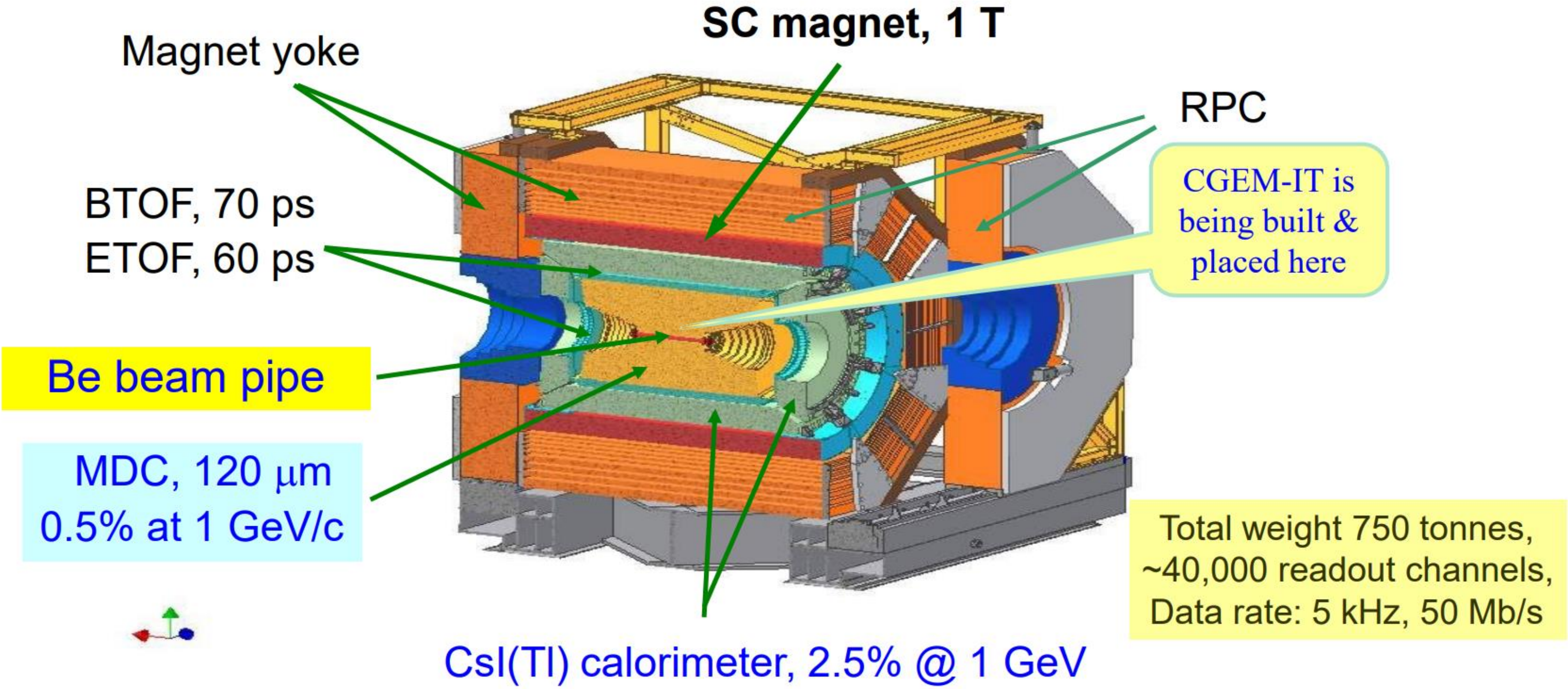


PPNP 112, 103770 (2020)

PRL 114, 092301 (2015)



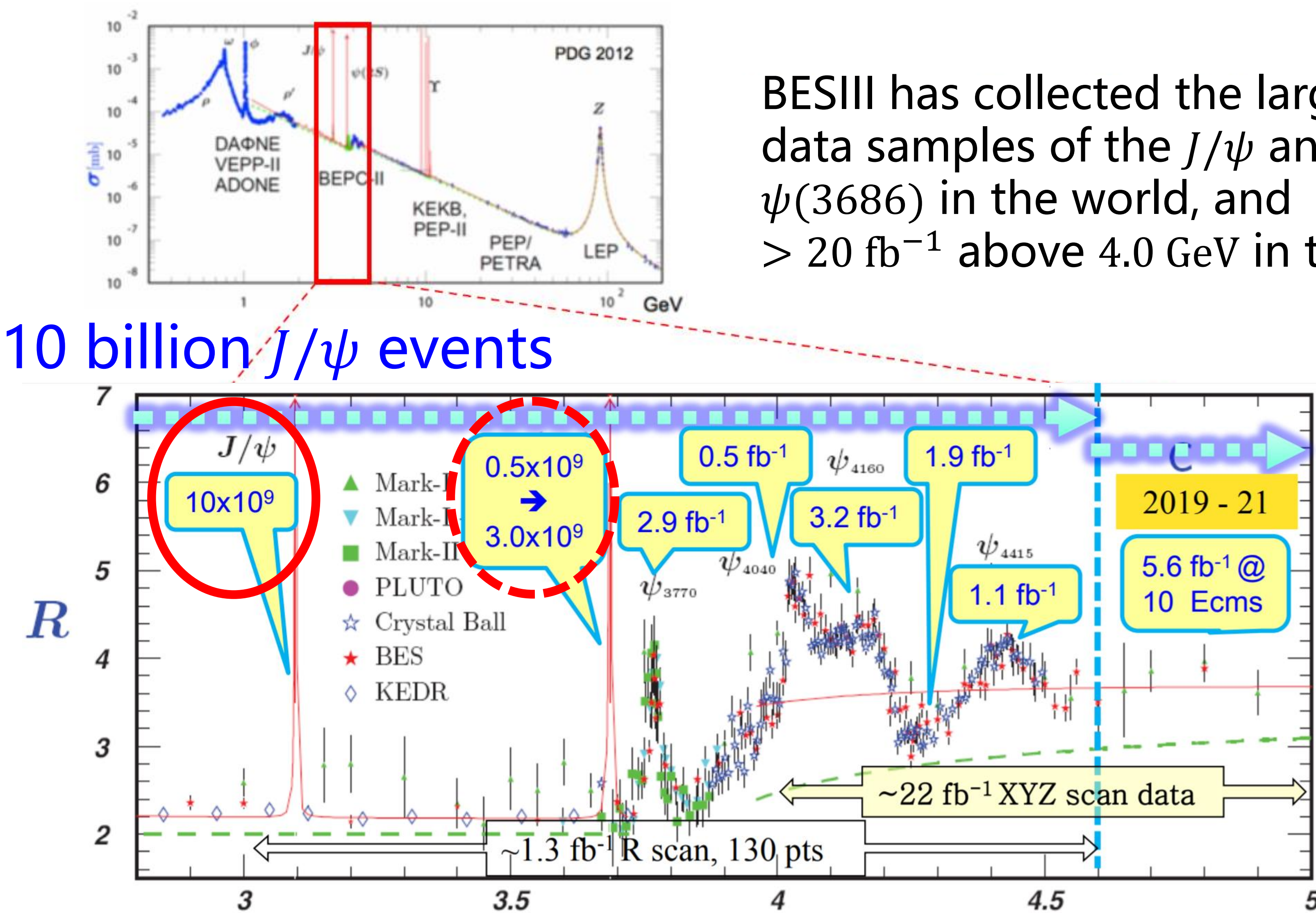
BESIII detector



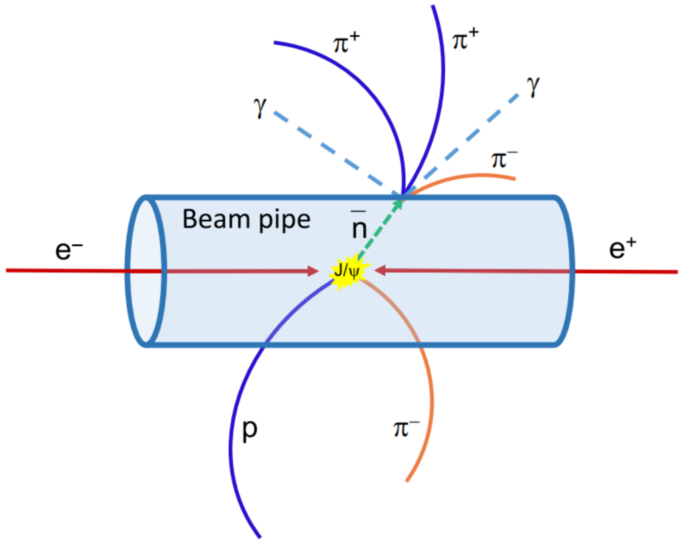
Has been in full operation since 2008,
all subdetectors are in very good status!

BESIII data samples

BESIII has collected the largest data samples of the J/ψ and $\psi(3686)$ in the world, and $> 20\ \mathrm{fb}^{-1}$ above $4.0\ \mathrm{GeV}$ in total.

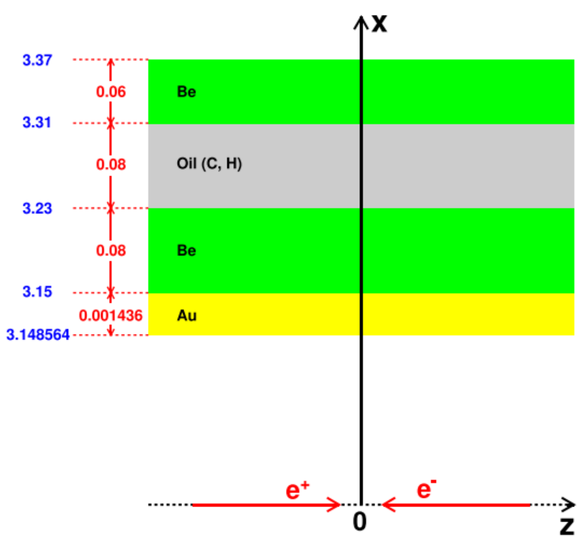


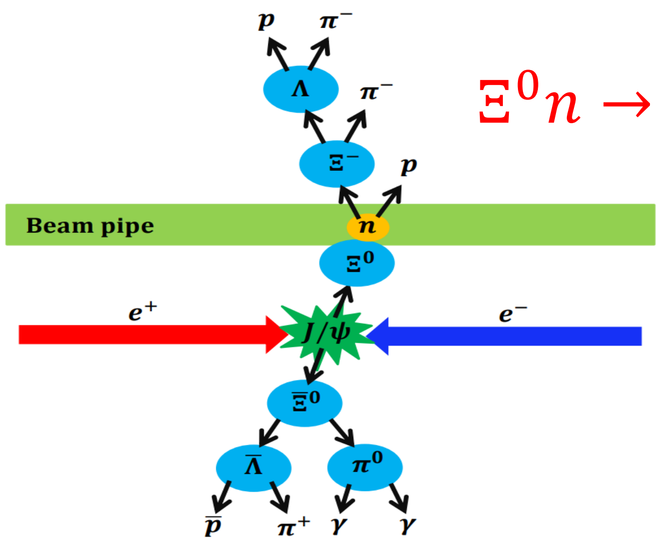
Experimental study on particle targeting at BESIII



PRL 127, 012003 (2021)
CPC 48, 073003 (2024)

$\bar{n}p \to \pi^+\pi^+\pi^-\pi^0, \pi^0 \to \gamma\gamma$





$\Xi^0 n \to \Xi^- p$

particle source: hyperon from J/ψ decays
target material: beam pipe
detector: BESIII detector

Experimental study on particle targeting at BESIII

Hyperon/Antihyperon	τ ($\times 10^{-10}$s)	Decay mode	$\mathcal{B}$ ($\times 10^{-3}$)	P (GeV/c)	$E_{\rm cm}$ (GeV)	N ($\times 10^5$)	$N^{\rm bp}$ ($\times 10^5$)
$\Lambda/\bar{\Lambda}$	2.63	$J/\psi \to \Lambda\bar{\Lambda}$	1.89	1.074	2.24	189	103
$\Sigma^+/\bar{\Sigma}^-$	0.80	$J/\psi \to \Sigma^+\bar{\Sigma}^-$	1.07	0.992	2.28	107	15
$\Xi^0/\bar{\Xi}^0$	2.90	$J/\psi \to \Xi^0\bar{\Xi}^0$	1.17	0.818	2.35	117	51
$\Xi^-/\bar{\Xi}^+$	1.64	$J/\psi \to \Xi^-\bar{\Xi}^+$	0.97	0.807	2.35	97	23
$\Lambda/\bar{\Lambda}$	2.63	$\psi(2S) \to \Lambda\bar{\Lambda}$	0.38	1.467	2.36	11	7
$\Sigma^+/\bar{\Sigma}^-$	0.80	$\psi(2S) \to \Sigma^+\bar{\Sigma}^-$	0.24	1.408	2.40	7	2
$\Xi^0/\bar{\Xi}^0$	2.90	$\psi(2S) \to \Xi^0\bar{\Xi}^0$	0.23	1.291	2.47	7	4
$\Xi^-/\bar{\Xi}^+$	1.64	$\psi(2S) \to \Xi^-\bar{\Xi}^+$	0.29	1.284	2.47	9	3
$\Omega^-/\bar{\Omega}^+$	0.82	$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.06	0.774	2.67	2	0.1

The hyperon-antihyperon pair is produced, also as antihyperon source.

Recent results on hyperon-nucleon scattering at BESIII

- **First Study of Reaction $\Xi^0 n \to \Xi^- p$ Using Ξ^0-Nucleus Scattering at an Electron-Positron Collider**
  PRL 130, 251902 (2023)

- **First measurement of ΛN inelastic scattering with Λ from $e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}$**
  PRC 109, L052201 (2024)

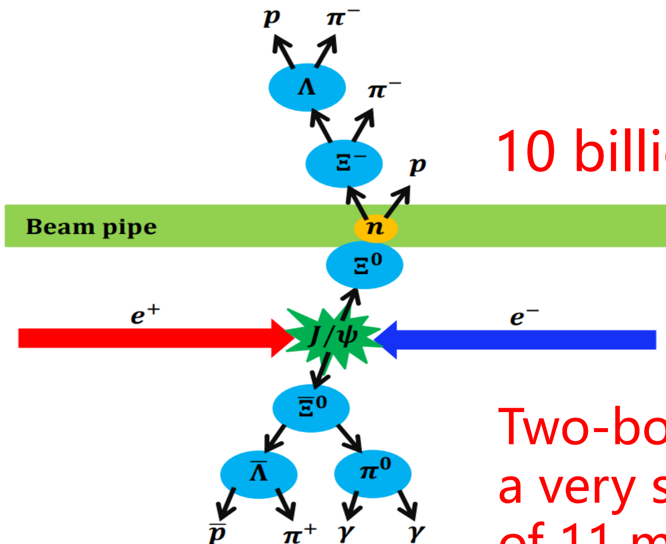
- **First Study of Antihyperon-Nucleon Scattering $\bar{\Lambda}p \to \bar{\Lambda}p$ and Measurement of $\Lambda p \to \Lambda p$ Cross Section**
  PRL 132, 231902 (2024)

Study of $\Xi^0 n \to \Xi^- p$

PRL 130, 251902 (2023)

Reaction chain :

$J/\psi \to \Xi^0\bar{\Xi}^0$, $\bar{\Xi}^0 \to \bar{\Lambda}\pi^0$, $\bar{\Lambda} \to \bar{p}\pi^+$, $\pi^0 \to \gamma\gamma$,
$\Xi^0 n \to \Xi^- p$, $\Xi^- \to \Lambda\pi^-$, $\Lambda \to p\pi^-$.



10 billion J/ψ data

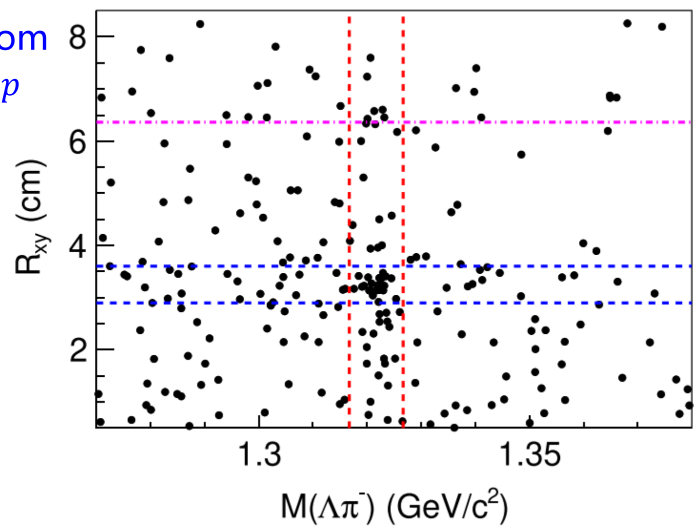
Two-body decay, $P_{\Xi^0} \approx 0.818\ \mathrm{GeV}/c$, a very small horizontal crossing angle of 11 mrad for e^+ and e^- beams.

Analysis method :

Using $\bar{\Xi}^0$ to tag the event and requiring the recoiling mass in Ξ^0 region. Then reconstructing Ξ^- and p in the signal side.

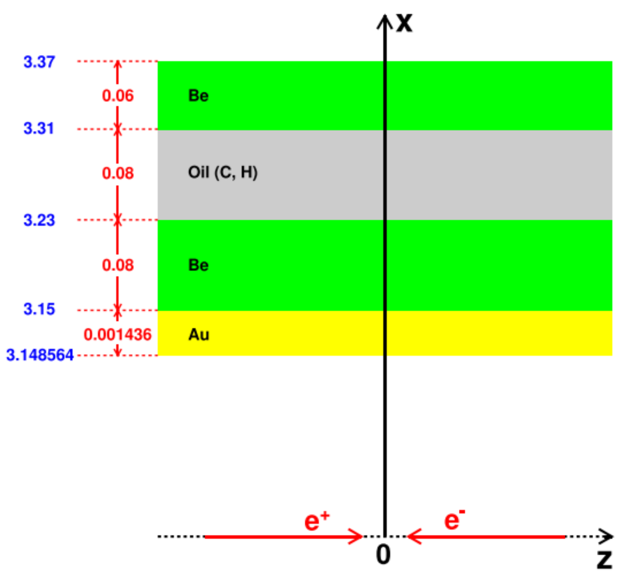
Study of $\Xi^0 n \to \Xi^- p$

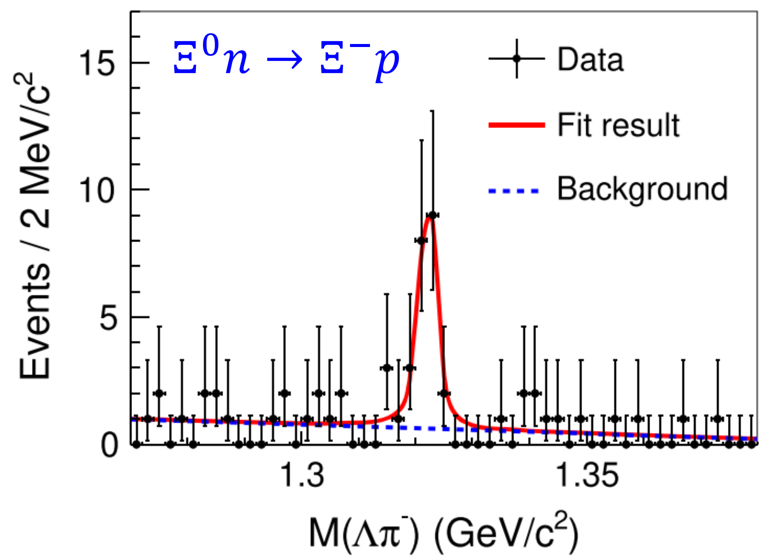
R_{xy} is distance from reconstructed $\Xi^- p$ vertex to z axis



Inner wall of MDC

Beam pipe





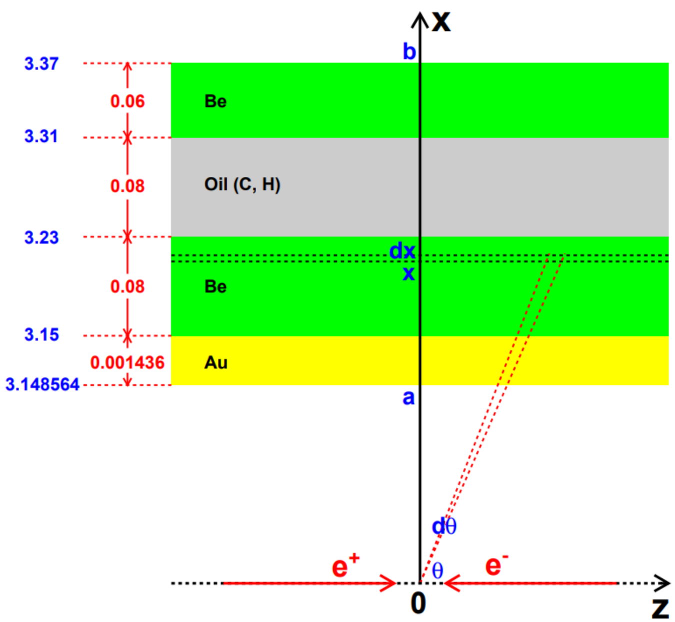
$N = 22.9 \pm 5.5$

$S = 7.1\sigma$

Cross section of $\Xi^0 + {}^9\text{Be} \to \Xi^- + p + {}^8\text{Be}$

$$\sigma(\Xi^0 + {}^9\text{Be} \to \Xi^- + p + {}^8\text{Be}) = \frac{N^{\text{sig}}}{\epsilon \mathcal{B} \mathcal{L}_{\text{eff}}}$$

$$\mathcal{L}_{\text{eff}} = \frac{N_{J/\psi}\mathcal{B}_{J/\psi}}{2+\frac{2}{3}\alpha}\int_a^b\int_0^\pi (1+\alpha\cos^2\theta)e^{-\frac{x}{\sin\theta\beta\gamma L}}N(x)C(x)d\theta dx$$



Parameter	Result
N^{sig}	22.9 ± 5.5
ϵ	1.873%
$\mathcal{B}$	$(40.114 \pm 0.444)\%$ [53]
$N_{J/\psi}$	$(1.0087 \pm 0.0044) \times 10^{10}$ [46]
$\mathcal{B}_{J/\psi}$	$(0.117 \pm 0.004)\%$ [53]
α	0.514 ± 0.016 [56]
L	(8.69 ± 0.27) cm [53]
E_{beam}	1.5485 GeV
m_{Ξ^0}	$(1.31486 \pm 0.00020)\ \text{GeV}/c^2$ [53]
a	3.148564 cm [45]
b	3.37 cm [45]
$N(x)$	$\begin{cases} 5.91 \times 10^{22}\ \text{cm}^{-3}, & 3.148564 \le x \le 3.15\ \text{cm} \\ 1.24 \times 10^{23}\ \text{cm}^{-3}, & 3.15 < x \le 3.23\ \text{cm} \\ 3.45 \times 10^{22}\ \text{cm}^{-3}, & 3.23 < x \le 3.31\ \text{cm} \\ 1.24 \times 10^{23}\ \text{cm}^{-3}, & 3.31 < x \le 3.37\ \text{cm} \end{cases}$
$C(x)$	$\begin{cases} 8.437(23.6), & 3.148564 \le x \le 3.15\ \text{cm} \\ 1.000(1.00), & 3.15 < x \le 3.23\ \text{cm} \\ 1.090(1.20), & 3.23 < x \le 3.31\ \text{cm} \\ 1.000(1.00), & 3.31 < x \le 3.37\ \text{cm} \end{cases}$

$\sigma \propto A^{\alpha'}$

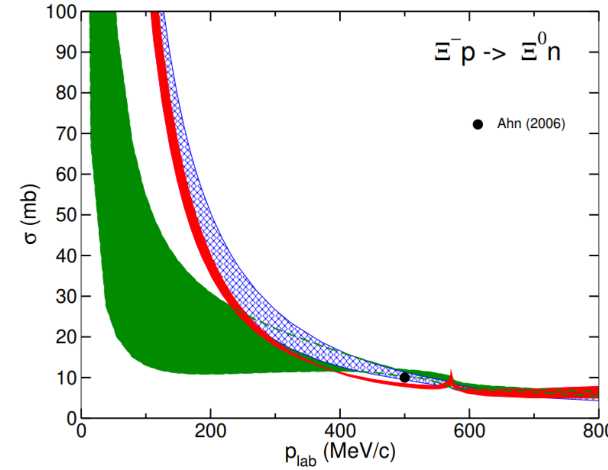
α' is about $\frac{2}{3}\sim 1$

pure surface process assumption
(proportional to number of neutrons)

Study of $\Xi^0 n \to \Xi^- p$

The measured cross section of the reaction process $\Xi^0 + {}^9\mathrm{Be} \to \Xi^- + p + {}^8\mathrm{Be}$ is $\sigma(\Xi^0 + {}^9\mathrm{Be} \to \Xi^- + p + {}^8\mathrm{Be}) = (22.1 \pm 5.3_{\mathrm{stat}} \pm 4.5_{\mathrm{sys}})$ mb at $P_{\Xi^0} \approx 0.818\ \mathrm{GeV}/c$.

If we take the effective number of reaction neutrons in ${}^9\mathrm{Be}$ nucleus as 3, the cross section of $\Xi^0 n \to \Xi^- p$ for single neutron is determined to be $\sigma(\Xi^0 n \to \Xi^- p) = (7.4 \pm 1.8_{\mathrm{stat}} \pm 1.5_{\mathrm{sys}})$ mb, consistent with theoretical predictions.



LO : H. Polinder, J.H., U.-G. Meißner, PLB 653 (2007) 29
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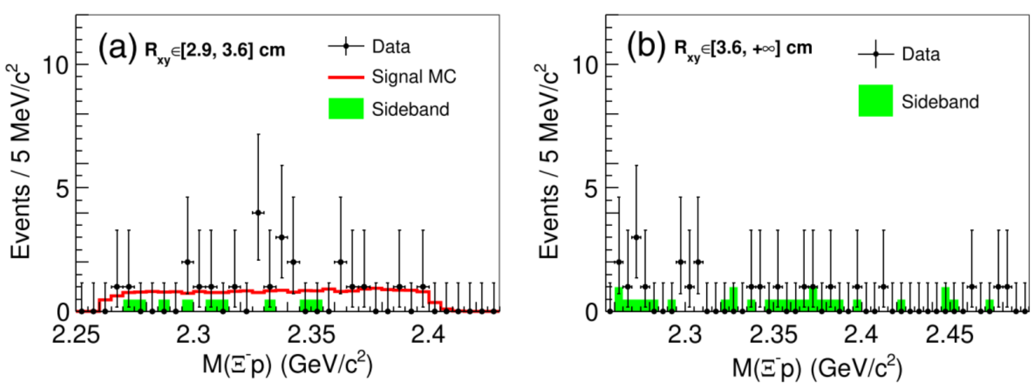


No significant H-dibaryon signals are seen

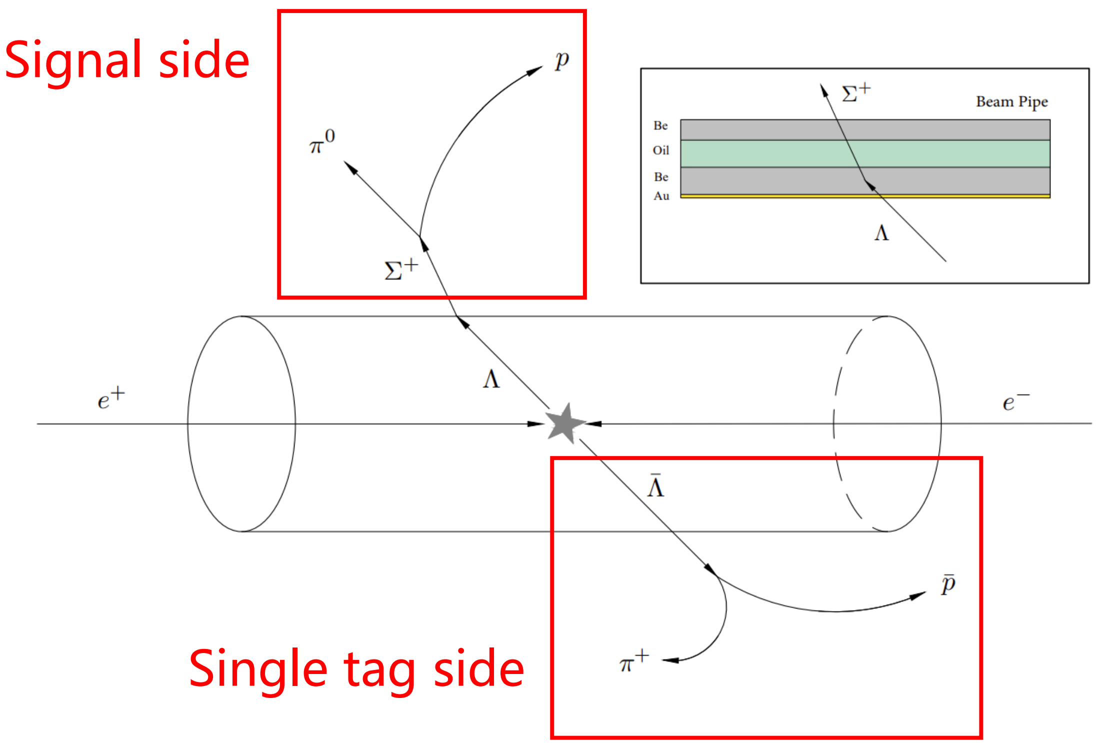
This work is the first study of hyperon-nucleon interaction in electron-positron collisions, and opens up a new direction for such research.

Study of $\Lambda N \to \Sigma^+ X$

PRC 109, L052201 (2024)

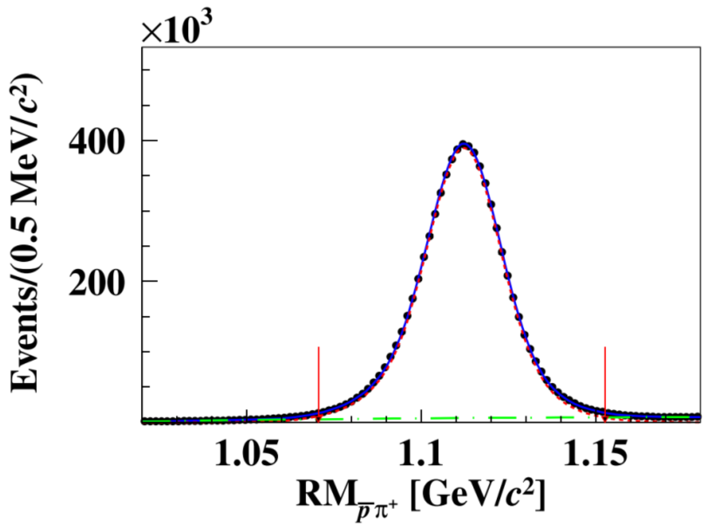
Reaction chain :

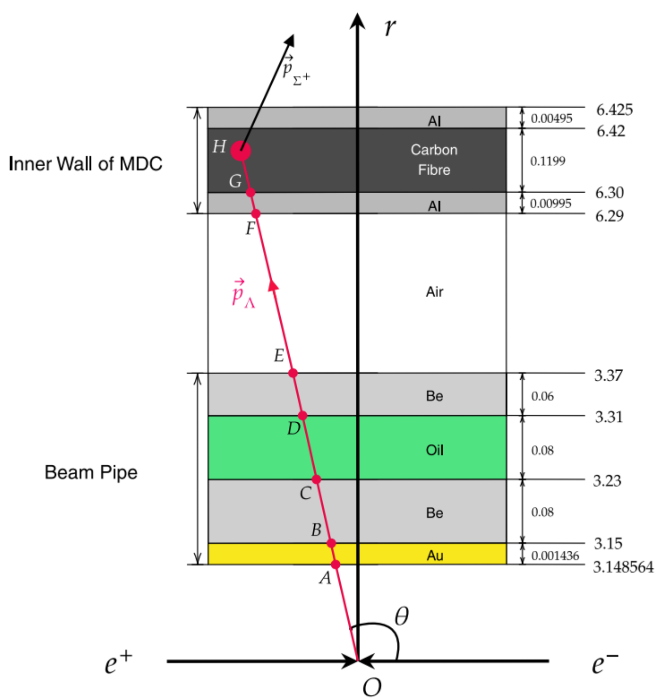
$J/\psi \to \Lambda\bar{\Lambda}$, $\bar{\Lambda} \to \bar{p}\pi^+$, $\Lambda + N(\text{nucleus}) \to \Sigma^+ + X(\text{anything})$, $\Sigma^+ \to p\pi^0$, $\pi^0 \to \gamma\gamma$.



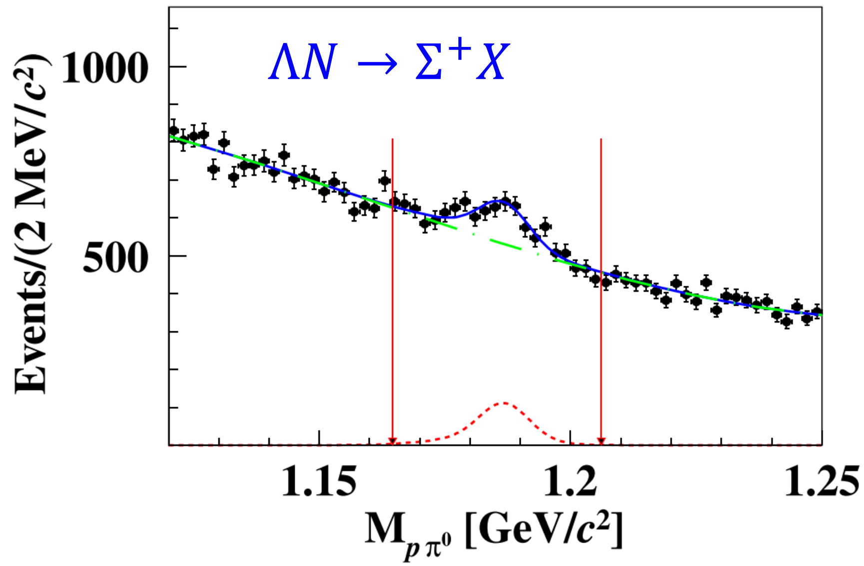
Two-body decay,
$P_\Lambda \approx 1.074\ \text{GeV}/c$,
a very small horizontal crossing angle of 11 mrad for e^+ and e^- beams, resulting in a small range of $0.017\ \text{GeV}/c$ above and below $1.074\ \text{GeV}/c$ for P_Λ.

Study of $\Lambda N \to \Sigma^+ X$





$N_{ST} = 7207565 \pm 3741$



$N_{DT} = 795 \pm 101$

The reaction position can not be determined. These signal events mainly come from the reaction with beam pipe and inner wall of MDC.

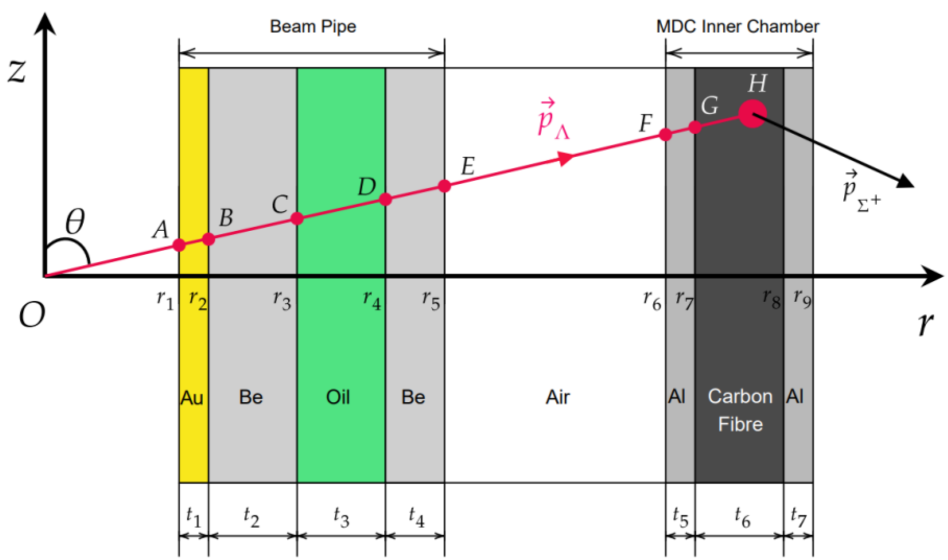
Cross section of $\Lambda + {}^{9}\mathrm{Be} \to \Sigma^{+} + X$

$$\sigma(\Lambda + {}^{9}\mathrm{Be} \to \Sigma^{+} + X) = \frac{N_{\mathrm{DT}}}{\epsilon_{\mathrm{sig}} \mathcal{L}_{\Lambda}} \frac{1}{\mathcal{B}(\Sigma^{+} \to p\pi^{0})}$$

$$\mathcal{L}_{\Lambda} = N_{\mathrm{ST}} \frac{N_A}{N_{\mathrm{ST}}^{\mathrm{MC}}} \sum_{j}^{7} \sum_{i}^{N_{\mathrm{ST}}^{\mathrm{MC}}} \frac{\rho_T^j l^{ij}}{M^j} \mathcal{R}_{\sigma}^{j}$$

path length of incident Λ of i_{th} event inside j_{th} layer

pure surface process assumption (proportional to number of protons)



Parameter	Value
N_{DT}	795 ± 101
ϵ_{sig}	24.32%
$\mathcal{L}_{\Lambda}$	$(17.00 \pm 0.01) \times 10^{28}\ \mathrm{cm}^{-2}$
$\mathcal{B}(\Sigma^{+} \to p\pi^{0})$	$(51.57 \pm 0.30)\%$

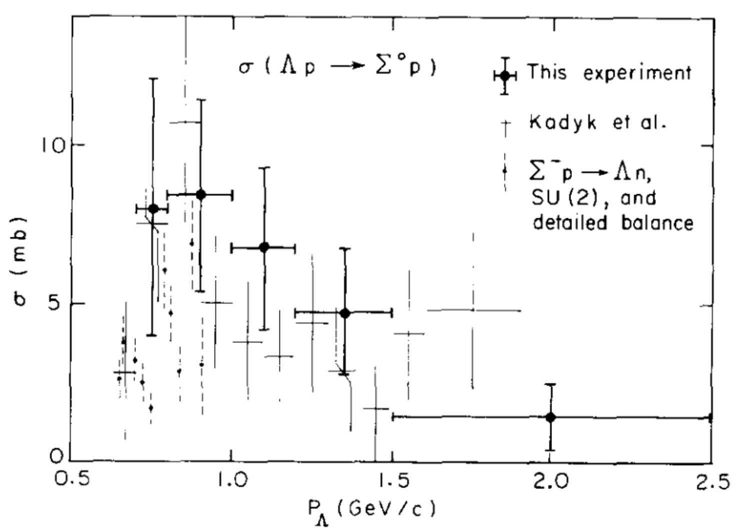
Study of $\Lambda N \to \Sigma^+ X$

The measured cross section of the reaction process $\Lambda + {}^9\mathrm{Be} \to \Sigma^+ + X$ is $\sigma(\Lambda + {}^9\mathrm{Be} \to \Sigma^+ + X) = (37.3 \pm 4.7_{\mathrm{stat}} \pm 3.5_{\mathrm{sys}})$ mb at $P_\Lambda \approx 1.074$ GeV/c. This work represents the first attempt to investigate Λ-nucleus interaction at an e^+e^- collider.

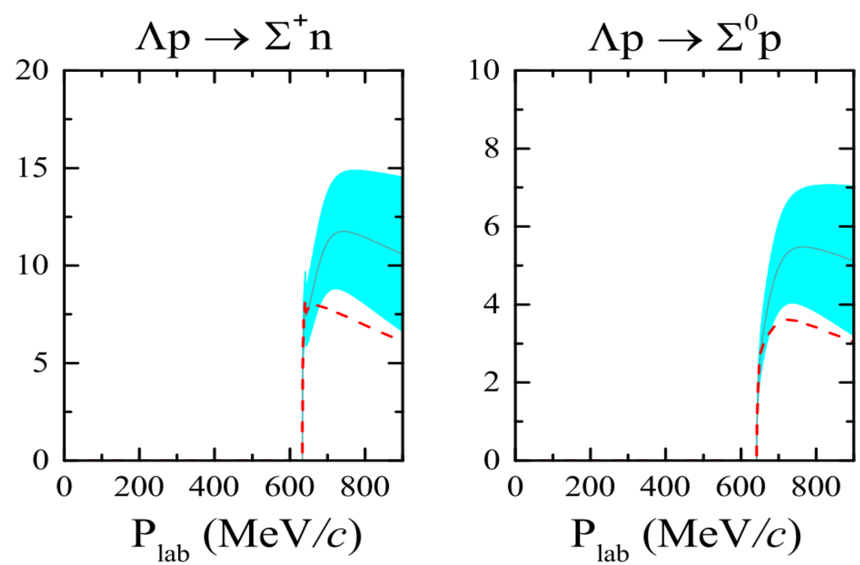
If taking the effective number of reaction protons in ${}^9\mathrm{Be}$ nucleus as 1.93, the cross section of $\Lambda p \to \Sigma^+ X$ for single proton is determined to be $\sigma(\Lambda p \to \Sigma^+ X) = (19.3 \pm 2.4_{\mathrm{stat}} \pm 1.8_{\mathrm{sys}})$ mb.

$\sigma(\Lambda p \to \Sigma^+ n)$ is twice of $\sigma(\Lambda p \to \Sigma^0 p)$

NPB 125, 29 (1977)

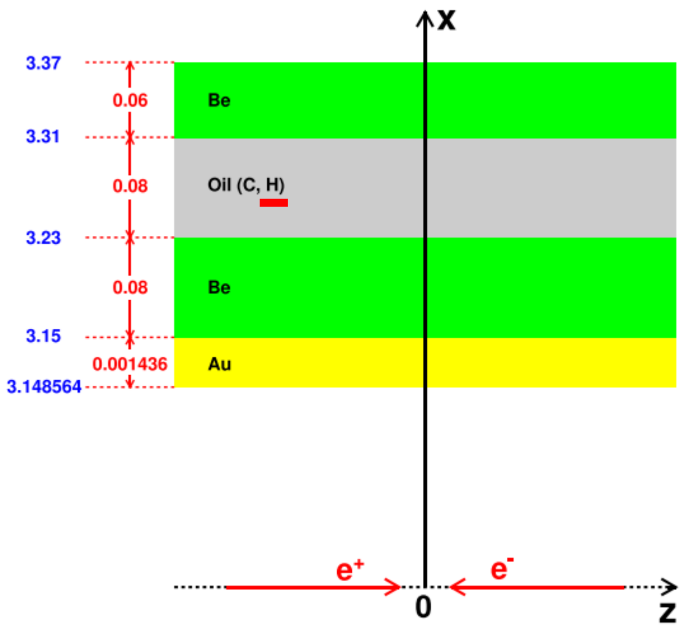


PRC 105, 035203 (2022)



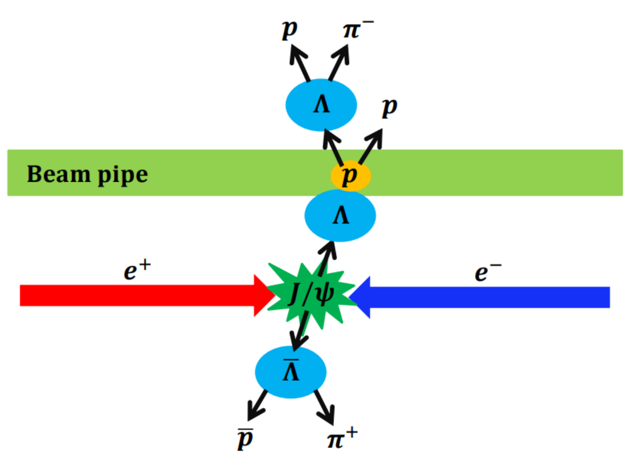
Study of $\Lambda p \to \Lambda p$ and $\bar{\Lambda} p \to \bar{\Lambda} p$

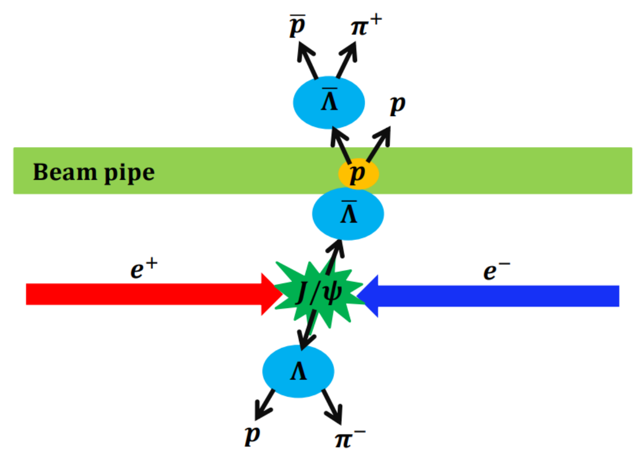
PRL 132, 231902 (2024)



Taking the hydrogen in the cooling oil of the beam pipe as target material, the information on the hyperon-proton scattering can be extracted directly.

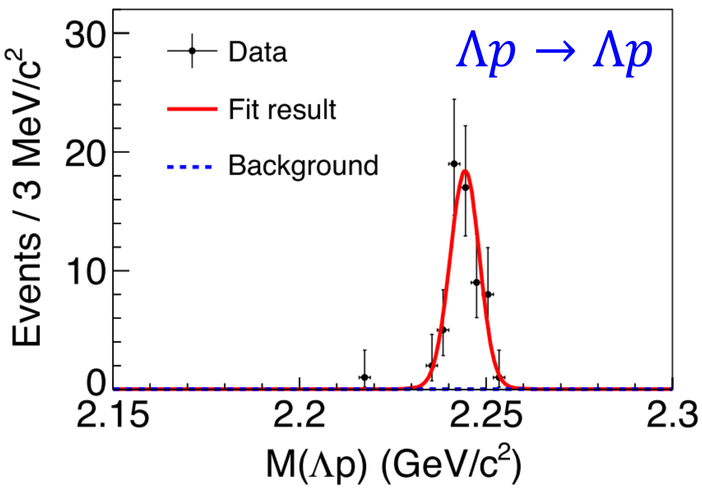
Two-body decay, $P_{\Lambda/\bar{\Lambda}} \approx 1.074\ \mathrm{GeV}/c$

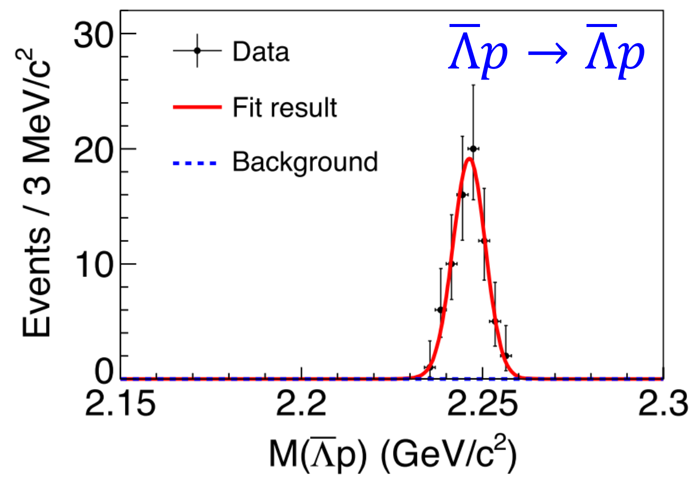




Study of $\Lambda p \to \Lambda p$ and $\bar{\Lambda} p \to \bar{\Lambda} p$

The center-of-mass energy for the incident $\Lambda/\bar{\Lambda}$ and a static p is about 2.243 GeV/c^2.



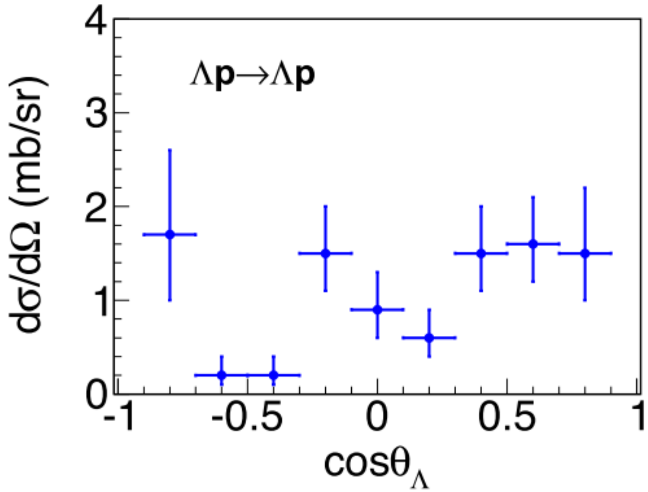


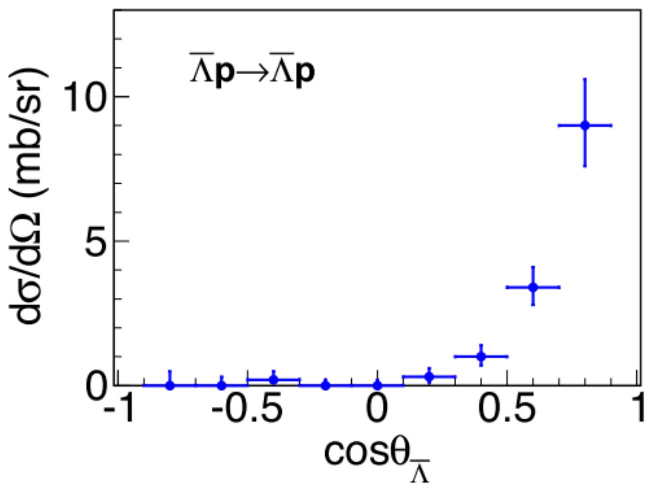
$$\sigma(\Lambda p \to \Lambda p/\bar{\Lambda} p \to \bar{\Lambda} p) = \frac{N^{\mathrm{sig}}_{\Lambda p/\bar{\Lambda} p}}{\epsilon_{\Lambda p/\bar{\Lambda} p} \mathcal{B} \mathcal{L}_{\mathrm{eff}}}$$

$$\mathcal{L}_{\mathrm{eff}} = \frac{N_{J/\psi} \mathcal{B}_{J/\psi}}{2 + \frac{2}{3}\alpha} \int_a^b \int_0^\pi (1 + \alpha \cos^2\theta) e^{-\frac{x}{\sin\theta \beta\gamma L}} N_H \mathrm{d}\theta \mathrm{d}x$$

$$\left(\frac{d\sigma}{d\Omega}\right)_i = \frac{N^{\mathrm{sig}}_i}{\epsilon_i \mathcal{B} \mathcal{L}_{\mathrm{eff}} \Delta\Omega}$$

Study of $\Lambda p \to \Lambda p$ and $\bar{\Lambda} p \to \bar{\Lambda} p$



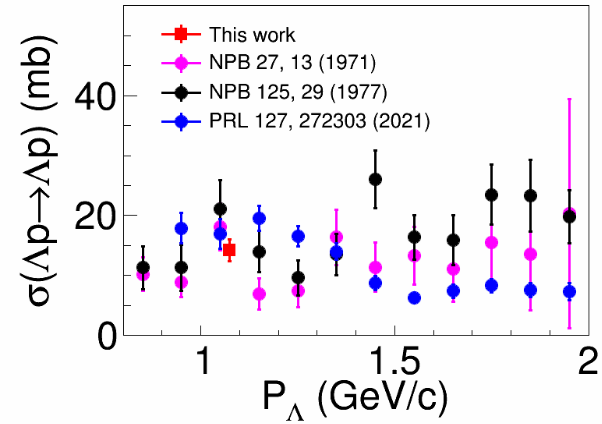


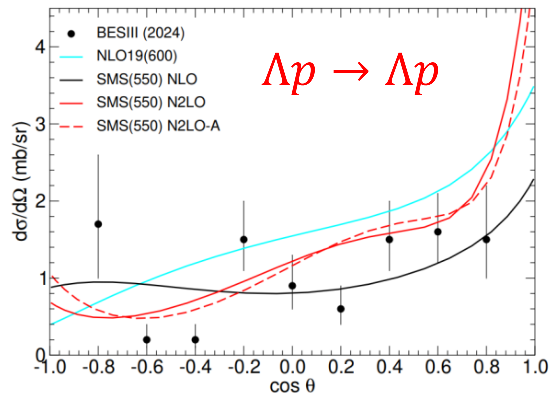
$\cos\theta_{\Lambda/\bar{\Lambda}}$	N_i^{sig}	ϵ_i (%)	$(d\sigma/d\Omega)$ (mb/sr)
$[-0.9, -0.7]$	$(5.0^{+2.6}_{-1.9}, 0.0^{+1.1}_{-0.0})$	(6.94,4.93)	$(1.7^{+0.9}_{-0.7}, 0.0^{+0.5}_{-0.0})$
$(-0.7, -0.5]$	$(1.0^{+1.4}_{-0.7}, 0.0^{+1.1}_{-0.0})$	(14.13,10.44)	$(0.2^{+0.2}_{-0.1}, 0.0^{+0.3}_{-0.0})$
$(-0.5, -0.3]$	$(1.0^{+1.4}_{-0.7}, 1.0^{+1.4}_{-0.7})$	(17.32,13.27)	$(0.2^{+0.2}_{-0.1}, 0.2^{+0.3}_{-0.1})$
$(-0.3, -0.1]$	$(11.0^{+3.7}_{-3.0}, 0.0^{+1.1}_{-0.0})$	(17.74,14.66)	$(1.5^{+0.5}_{-0.4}, 0.0^{+0.2}_{-0.0})$
$(-0.1, 0.1]$	$(6.9^{+3.0}_{-2.3}, 0.0^{+1.1}_{-0.0})$	(19.11,15.79)	$(0.9^{+0.4}_{-0.3}, 0.0^{+0.2}_{-0.0})$
$(0.1, 0.3]$	$(5.0^{+2.6}_{-1.9}, 2.0^{+1.8}_{-1.1})$	(19.53,16.82)	$(0.6^{+0.3}_{-0.2}, 0.3^{+0.3}_{-0.2})$
$(0.3, 0.5]$	$(12.0^{+3.8}_{-3.1}, 7.0^{+3.0}_{-2.3})$	(19.21,17.68)	$(1.5^{+0.5}_{-0.4}, 1.0^{+0.4}_{-0.3})$
$(0.5, 0.7]$	$(13.0^{+3.9}_{-3.3}, 25.0^{+5.3}_{-4.7})$	(19.71,17.60)	$(1.6^{+0.5}_{-0.4}, 3.4^{+0.7}_{-0.6})$
$(0.7, 0.9]$	$(6.0^{+2.8}_{-2.1}, 37.0^{+6.4}_{-5.8})$	(9.80,9.93)	$(1.5^{+0.7}_{-0.5}, 9.0^{+1.6}_{-1.4})$

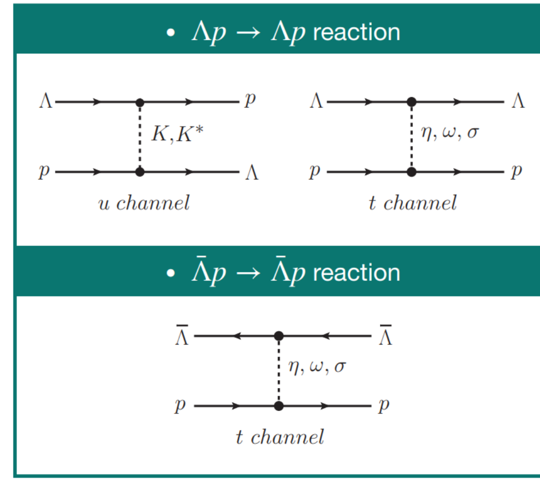
Cross sections in $-0.9 \leq \cos\theta_{\Lambda/\bar{\Lambda}} \leq 0.9$ are measured to be
$\sigma(\Lambda p \to \Lambda p) = (12.2 \pm 1.6_{\mathrm{stat}} \pm 1.1_{\mathrm{sys}})$ mb and
$\sigma(\bar{\Lambda} p \to \bar{\Lambda} p) = (17.5 \pm 2.1_{\mathrm{stat}} \pm 1.6_{\mathrm{stat}})$ mb

Total cross sections are determined to be
$\sigma_t(\Lambda p \to \Lambda p) = (14.2 \pm 1.8_{\mathrm{stat}} \pm 1.3_{\mathrm{sys}})$ mb and
$\sigma_t(\bar{\Lambda} p \to \bar{\Lambda} p) = (27.4 \pm 3.2_{\mathrm{stat}} \pm 2.5_{\mathrm{sys}})$ mb

Study of $\Lambda p \to \Lambda p$ and $\bar{\Lambda} p \to \bar{\Lambda} p$







J. Haidenbauer and U. G. Meiβner, EPJA 60, 119 (2024)

X. Y. Wang, Y. Gao and X. Liu, arXiv:2410.17842

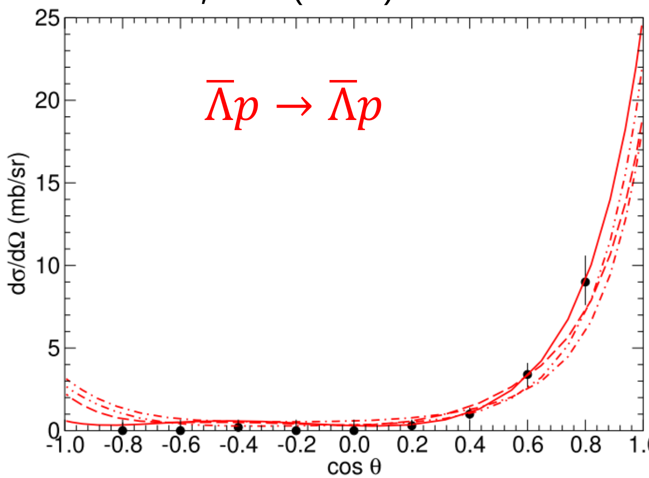
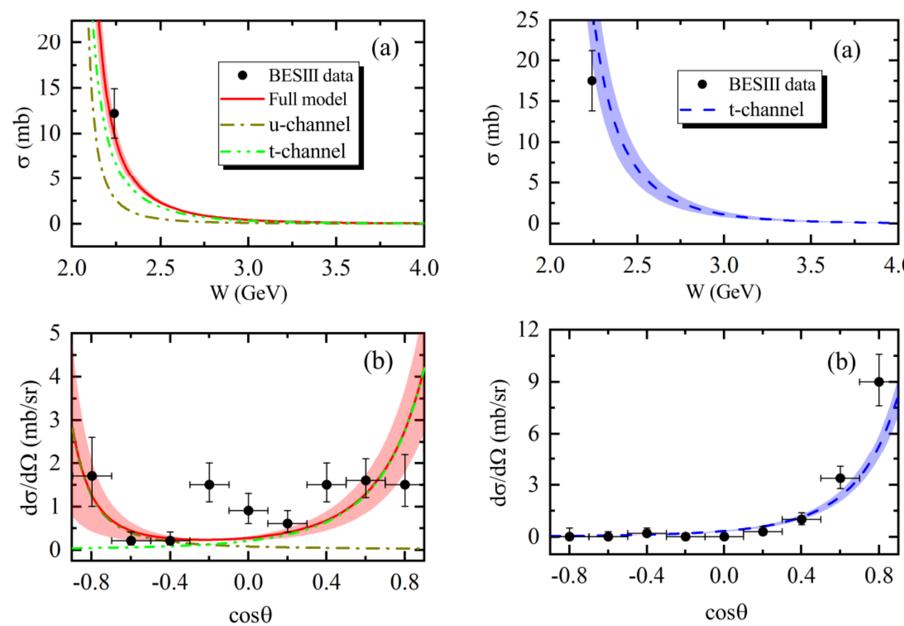


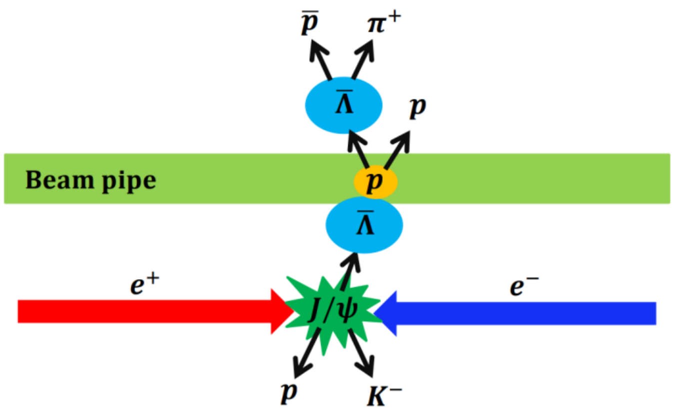
Fig. 1 Differential cross section for $p\bar{\Lambda}$ scattering at $p_{lab} = 1.074 \pm 0.017$ GeV [59]. The curves are predictions by the $\Lambda\bar{\Lambda}$ interactions I-IV, see Ref. [35], at 1.05 GeV/c



Some ongoing researches on (anti)hyperon-nucleon scattering at BESIII

- $\Sigma^+ n \rightarrow \Lambda p$, $\Sigma^+ n \rightarrow \Sigma^0 p$
- $\Xi^0 n \rightarrow \Lambda\Lambda$, $\Xi^- p \rightarrow \Lambda\Lambda$
- $\Lambda p \rightarrow \Sigma^0 p$, $\bar{\Lambda} p \rightarrow \bar{\Sigma}^0 p$
- $\Sigma^+ p \rightarrow \Sigma^+ p$, $\bar{\Sigma}^- p \rightarrow \bar{\Sigma}^- p$
- $\Xi^- p \rightarrow \Xi^- p$, $\bar{\Xi}^+ p \rightarrow \bar{\Xi}^+ p$

……



$\Lambda p \rightarrow \Lambda p / \bar{\Lambda} p \rightarrow \bar{\Lambda} p$ is studied using three-body decays $J/\psi \rightarrow pK\Lambda$, momentum-dependent cross section measurement.

More results will come out soon !!!

Summary

1. Using a novel method, hyperon-nucleon scattering can also be measured at BESIII now.
   - $\Xi^0 n \to \Xi^- p$
   - $\Lambda N \to \Sigma^+ X$
   - $\Lambda p \to \Lambda p$
   - $\bar{\Lambda} p \to \bar{\Lambda} p$

2. This is the first study of hyperon-nucleon scattering in electron-positron collisions, and opens up a new direction for such research. Especially, antihyperon-nucleon scattering is studied for the first time.

3. With more statistics in future super tau-charm facilities, the momentum-dependent cross section or differential cross section distributions can be studied based on the hyperons from multibody decays of J/ψ or other charmonia.

Thanks for your attention!