建造“超级J/ψ工厂”，做固定靶实验

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第十六届粒子物理、核物理和宇宙学交叉学科前沿问题研讨会

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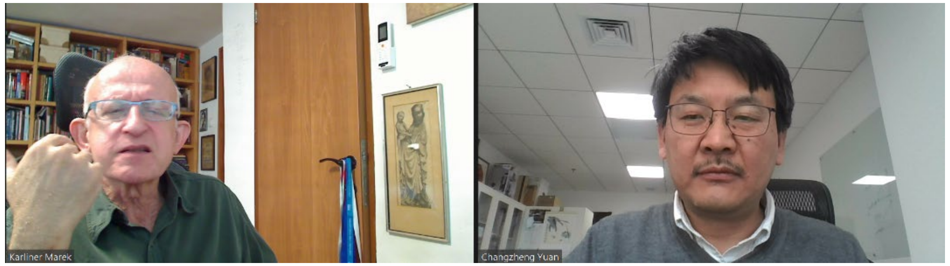
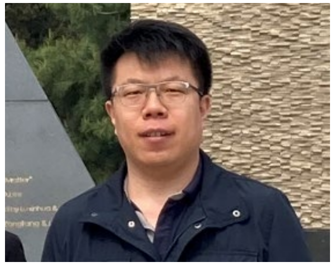




- C. Z. Yuan & M. Karliner, PRL 127, 012003 (2021) [arXiv:2103.06658]

  “Editors’ suggestion” & “Featured in *Physics*”
- 宋维民、苑长征，*物理* 51，255 (2022)：超级J/ψ工厂里的“子弹”

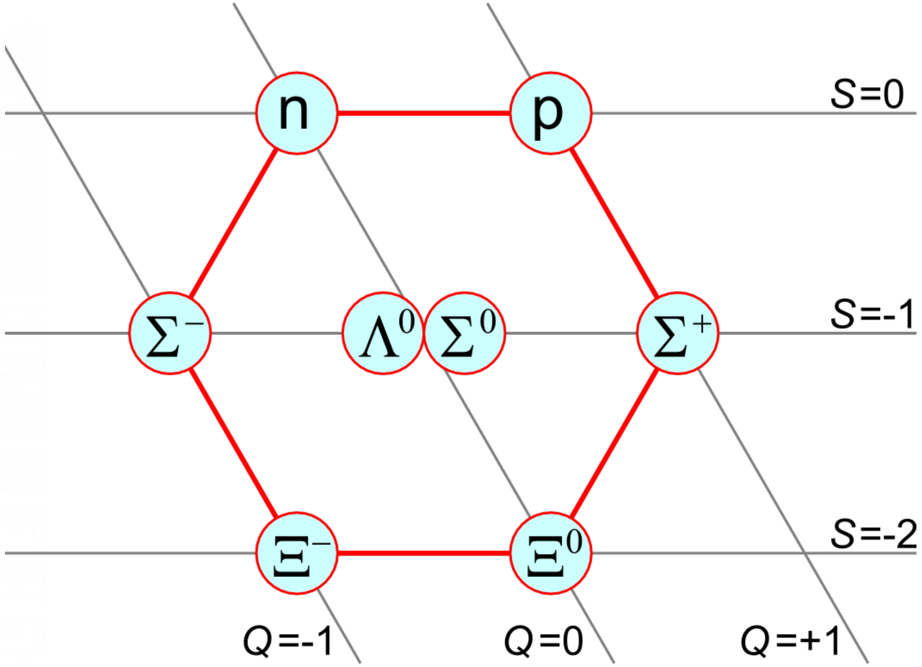
PRL paper title:

① Cornucopia of antineutrons and hyperons

② from a super J/ψ factory

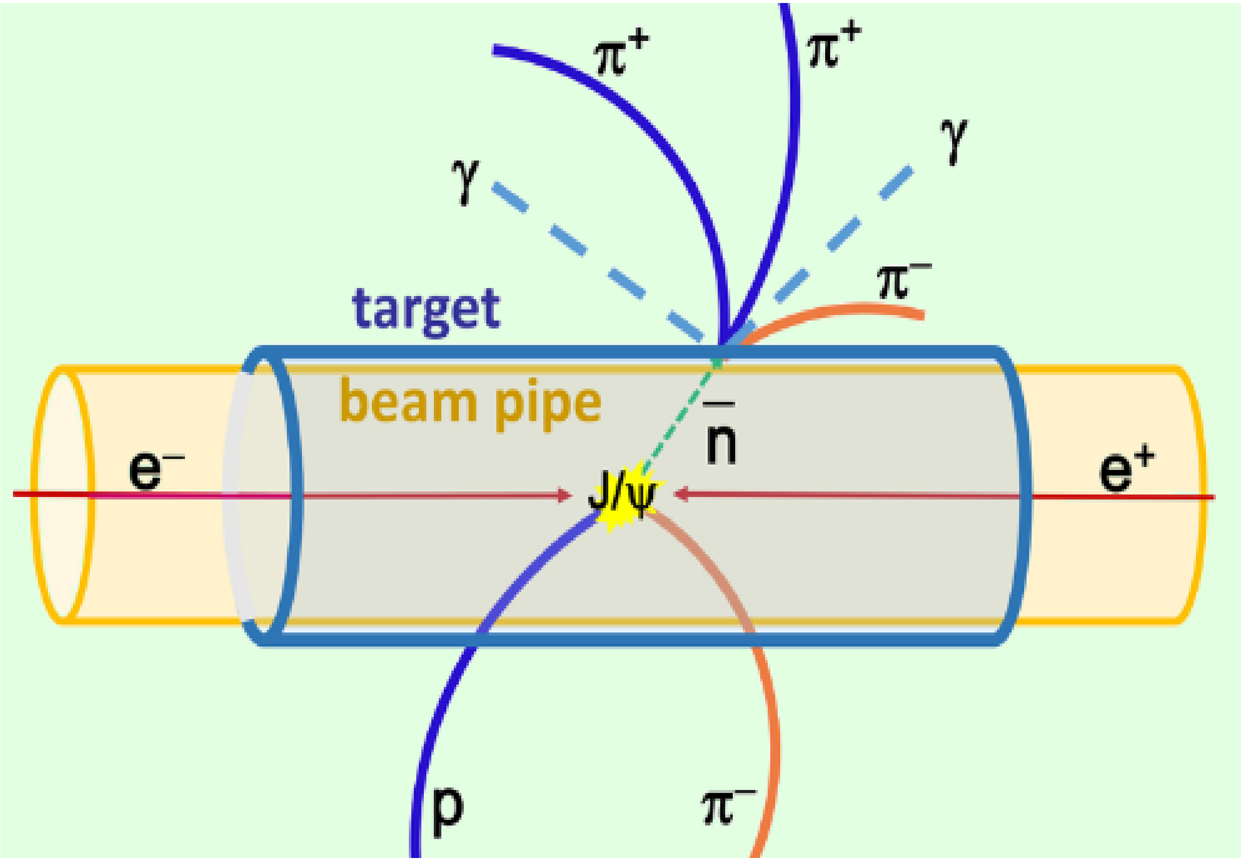
③ for next-generation nuclear and particle physics

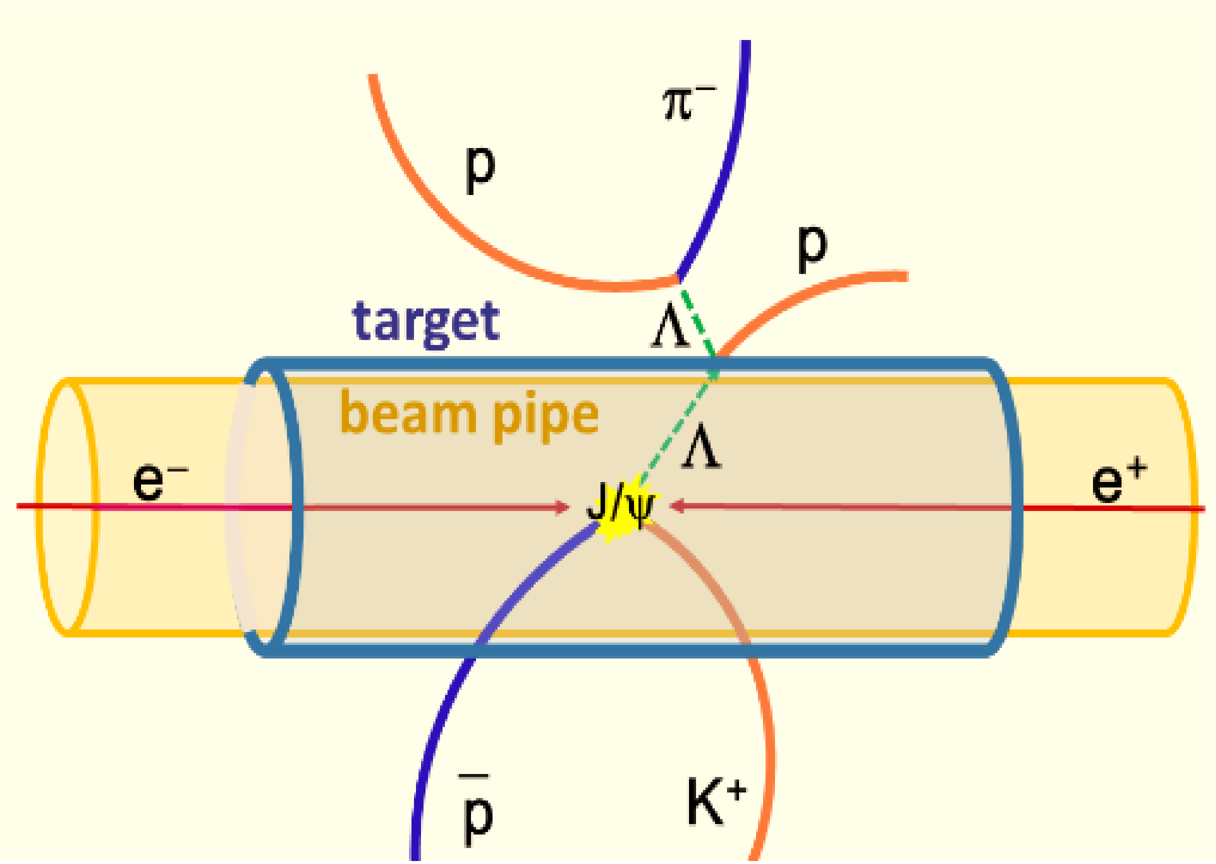
④ high-precision experiments



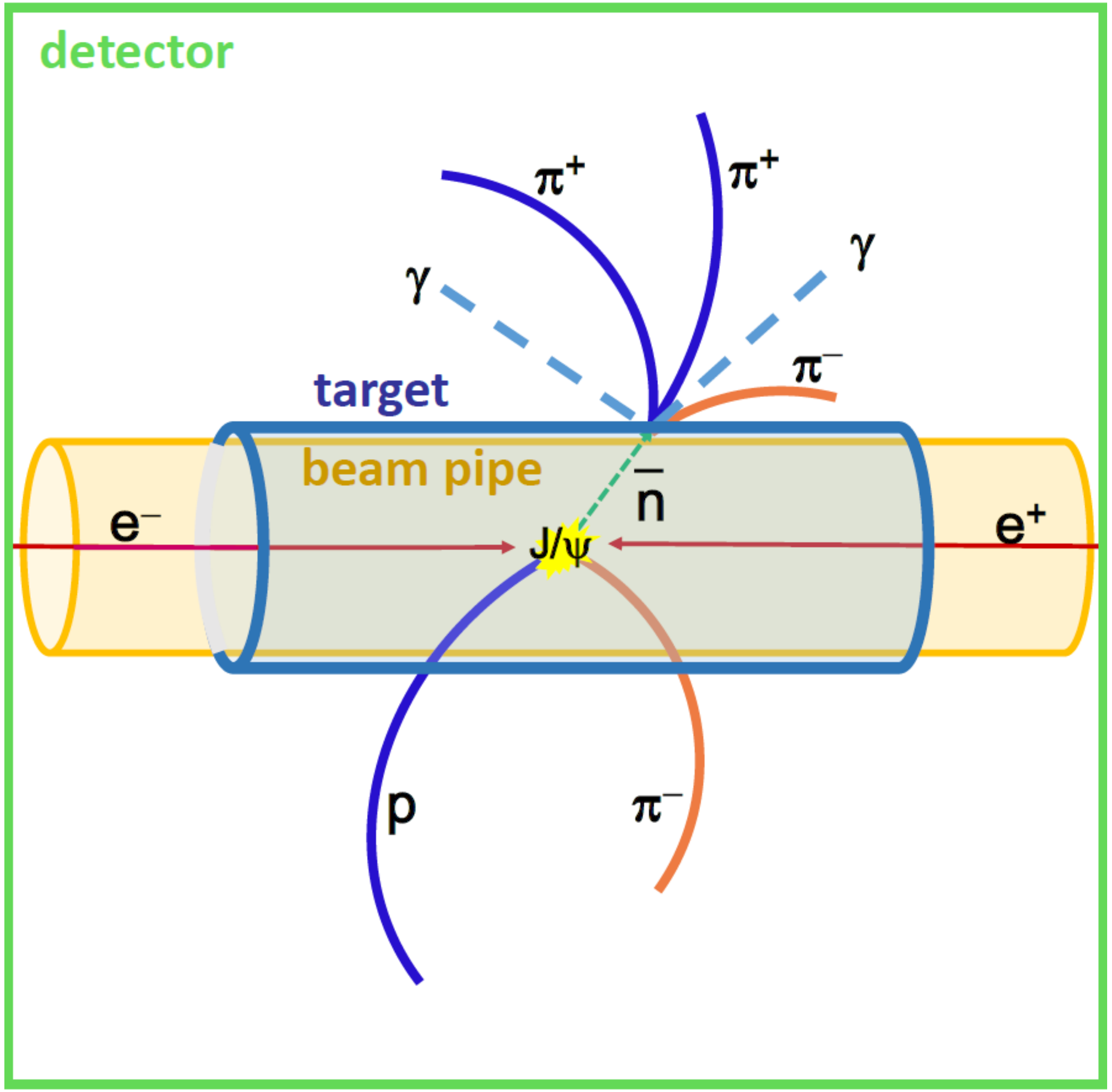
+ their antiparticles

Do fixed target experiments @ a super J/ψ factory





Do fixed target experiments @ a super J/ψ factory



- Super J/ψ factory
  - e^+e^- annihilation @ 3.097 GeV
  - $O(10^{12})$ or more J/ψ events/year
- J/ψ decays into final states with nucleons or hyperons and their antiparticles
  - Branching Fraction ~ 10^{-3}
  - Tag efficiency ~ (10-50)%
- High quality sources of (anti-)nucleon and long lived (anti-)hyperons
  - $O(10^8)$ tagged source particles per year
  - Well known momentum and direction
- Use variety of custom removable targets
- State of the art detector
- No need to share beam time
- NN, $\bar{N}$N, YN, $\bar{Y}$N, hypernuclei, neutron star, …

outline

- Why particle sources are important &
  Why some of the sources are very rare
- Why J/ψ decays
- BESIII experiment as a "proof of concept"
- A super J/ψ factory with 10^{12} J/ψ events per year
- A hyper J/ψ factory with 10^{14} J/ψ events
- Potential physics discoveries
- Summary

Geiger–Marsden experiment (Rutherford gold foil experiment)

- AB： conical glass tube containing “radium emanation” (radon), “radium A” (actual radium), and “radium C” (bismuth-214); its open end sealed with mica [云母]
- P： lead plate
- S： fluorescent zinc sulfide screen
- R： metal foil
- M： microscope

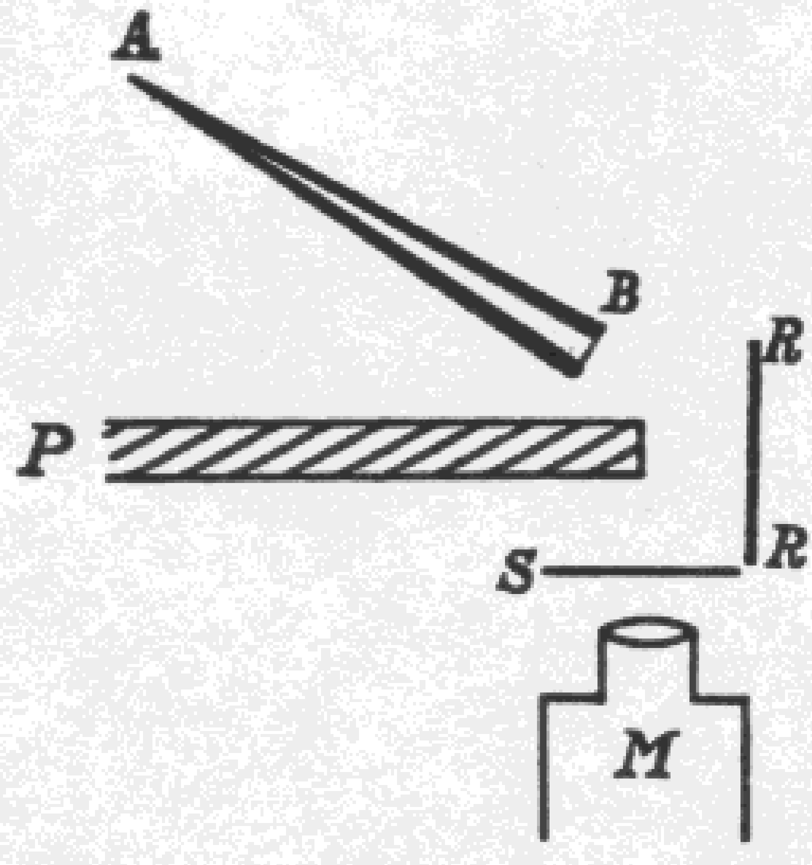


FIG. 1.

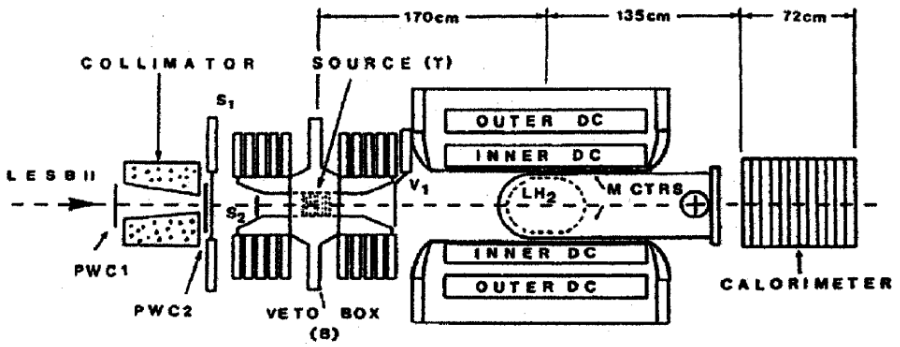
Geiger, Hans; Marsden, Ernest (1909). "On a Diffuse Reflection of the α-Particles". *Proceedings of the Royal Society of London A*. **82** (557): 495.

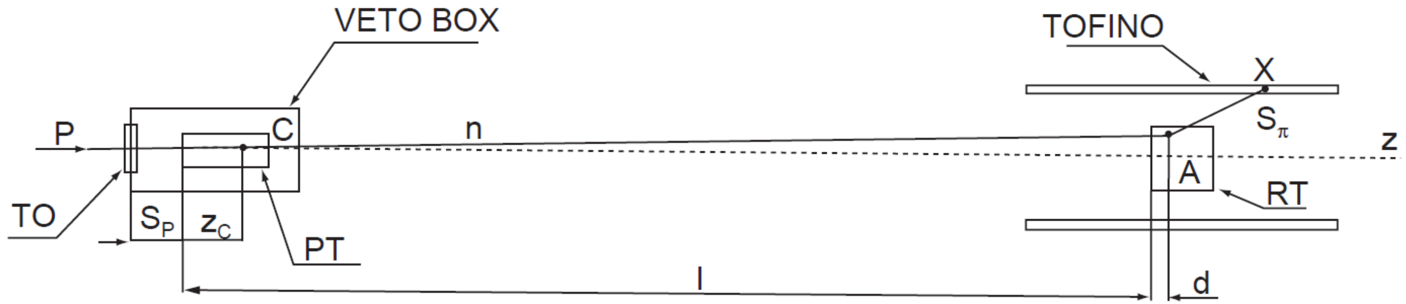
Why particle sources are important

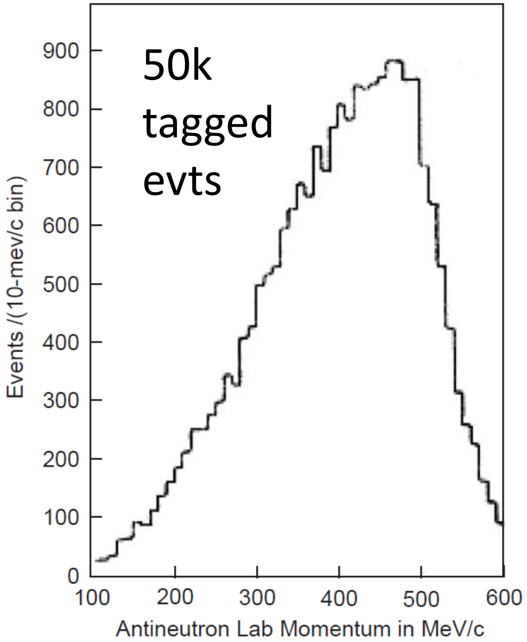
- Scattering experiments using many different kinds of beams are the mainstay of experiments investigating the fundamental interactions and structure of matter at the subatomic level.
- Beams of long-lived charged particles and of photons are easy to produce, and so many experiments using charged projectiles have been carried out during the more than 100 years since the trailblazing experiment shooting α particles into gold foil that enabled Rutherford to infer the existence of the atomic nucleus.
- Since then, e, μ, π, K, proton, antiproton, photon, and various heavy ion beams have been produced and have served as enablers of many scientific breakthroughs.
- Beams of some neutral particles, like neutrons and neutrinos, are relatively easy to produce but difficult to control; i.e., they have a large momentum spread.
- Beams of other neutral particles, such as antineutrons, K^0 and $\overline{K}^0$, long-lived hyperons (Λ, $\Sigma^{\pm}$, $\Xi^{0/-}$) and their antiparticles ($\overline{\Lambda}$, $\overline{\Sigma}^{\pm}$, $\overline{\Xi}^{0/+}$) have great physics potential, but they are typically much more difficult to produce and control.

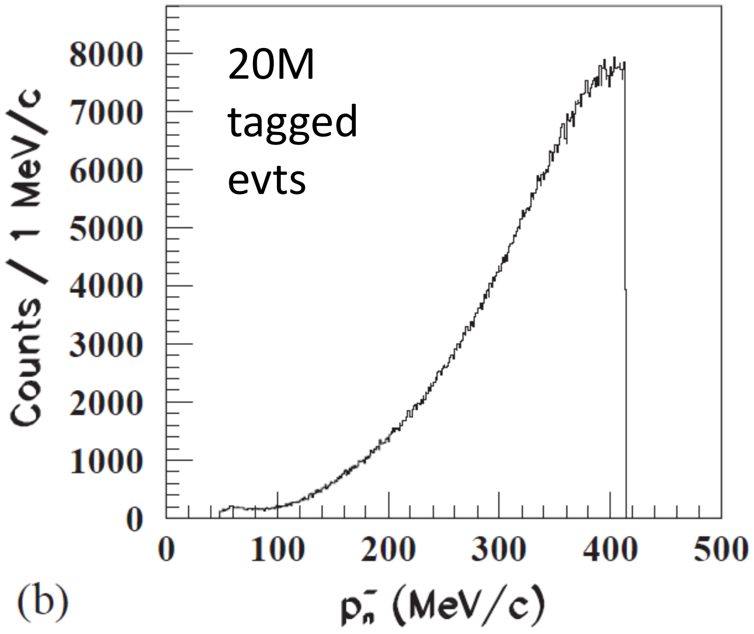
$\bar{n}$ sources in history

- $\bar{p}p \rightarrow \bar{n}n$ @ E-767@BNL & OBELIX@CERN









Limited statistics

36 $\bar{n}$ per 10^6 $\bar{p}$

[2×10^7 collected in 5 years]

Limited momentum range

Uncertainty in flux~7%

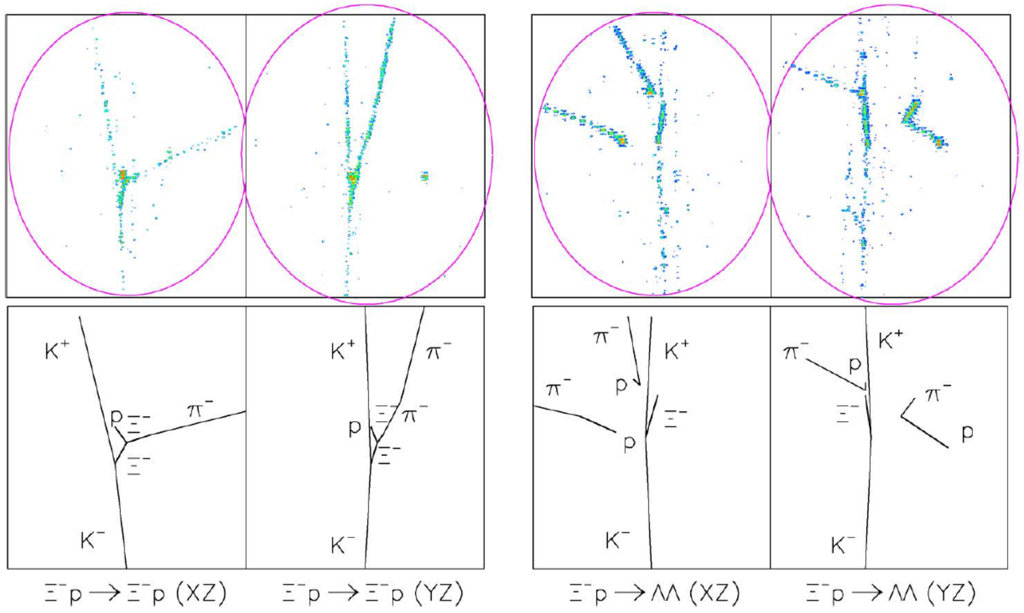
$\sigma p_{\bar{n}}$ = 3% @ 50 MeV/c

= 5% @ 400 MeV/c

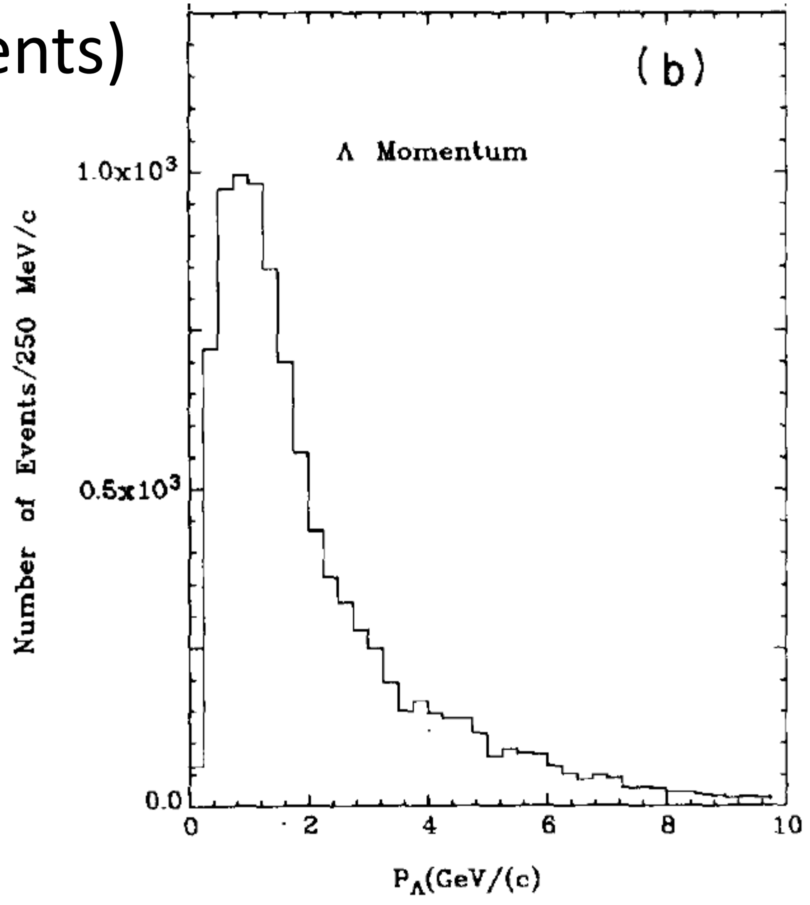
Sources of Λ & other hyperons

- Bubble chamber experiments with hyperons from K^{-}+target
- Emulsion experiments with K^{-}+target → K^{+}+X, K^{+}+K^{+}+X, …
- A few to about 10^{4} events (typical O(100) tagged events)
- No anti-hyperon sources!

J.K. Ahn et al. / Physics Letters B 633 (2006) 214–218



KEK, K^{-} + SCIFI → Ξ^{-} X



SLAC HBC, Nuclear Physics B125 (1977) 29-51

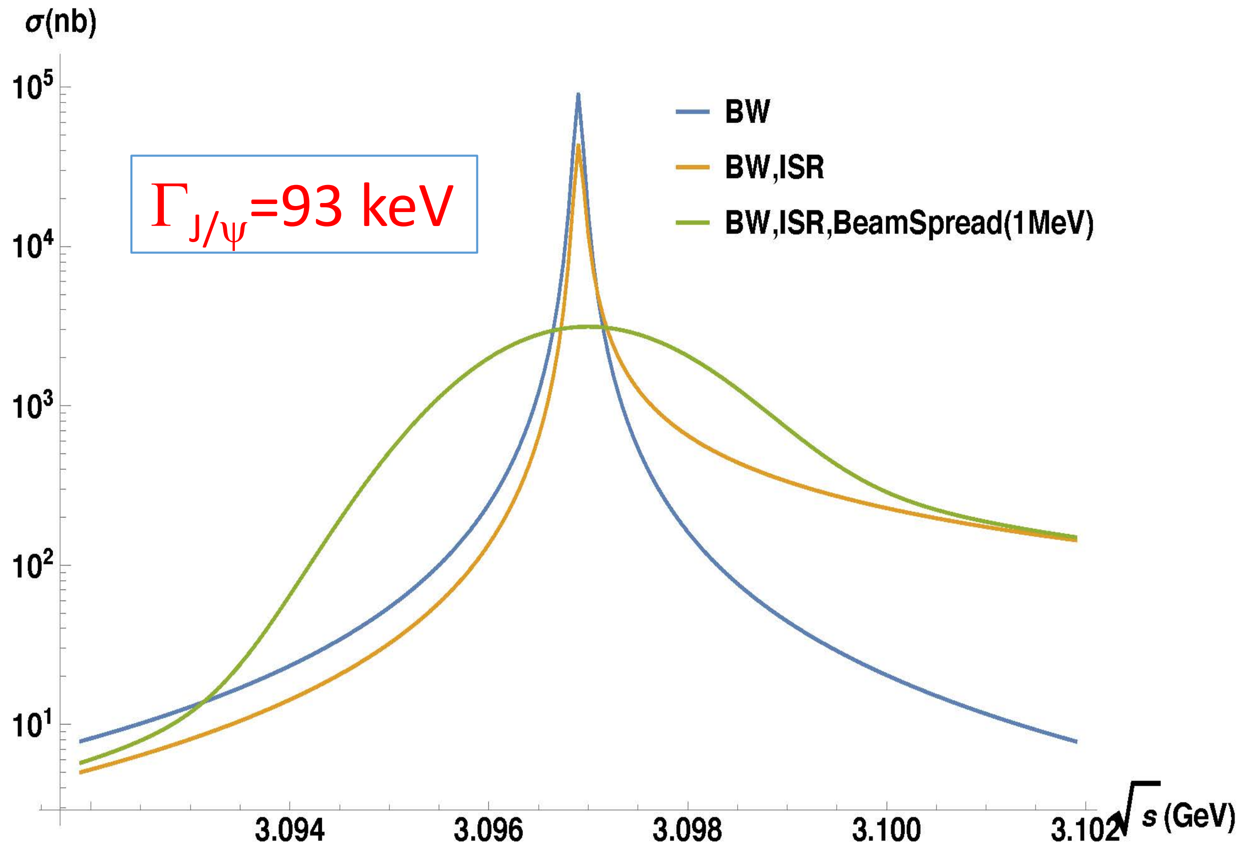
Why J/ψ decays: (1) huge cross section of $e^+e^- \rightarrow J/\psi$

$$\sigma_{Born}(s) = \frac{12\pi\Gamma_{ee}\Gamma_f}{(s-M^2)^2+\Gamma_t^2 M^2}$$

$$\sigma_{r.c.}(s) = \int_0^{x_m} dx F(x,s) \frac{\sigma_{Born}(s(1-x))}{|1-\Pi(s(1-x))|^2}$$

$$\sigma_{exp}(W) = \int_0^{\infty} dW' \sigma_{r.c.}(W') G(W',W)$$

$$G(W,W') = \frac{1}{\sqrt{2\pi}\Delta} e^{-\frac{(W-W')^2}{2\Delta^2}}$$



at J/ψ peak	Born	ISR	Δ=1 MeV
σ (nb)	9.1×10^4	4.4×10^4	3,100

Formulas from PLB 557 (2003) 192

Numbers & plot from Yuping Guo

$\mathcal{L}$ = 0.5 $nb^{-1}s^{-1}$ @ BEPCII

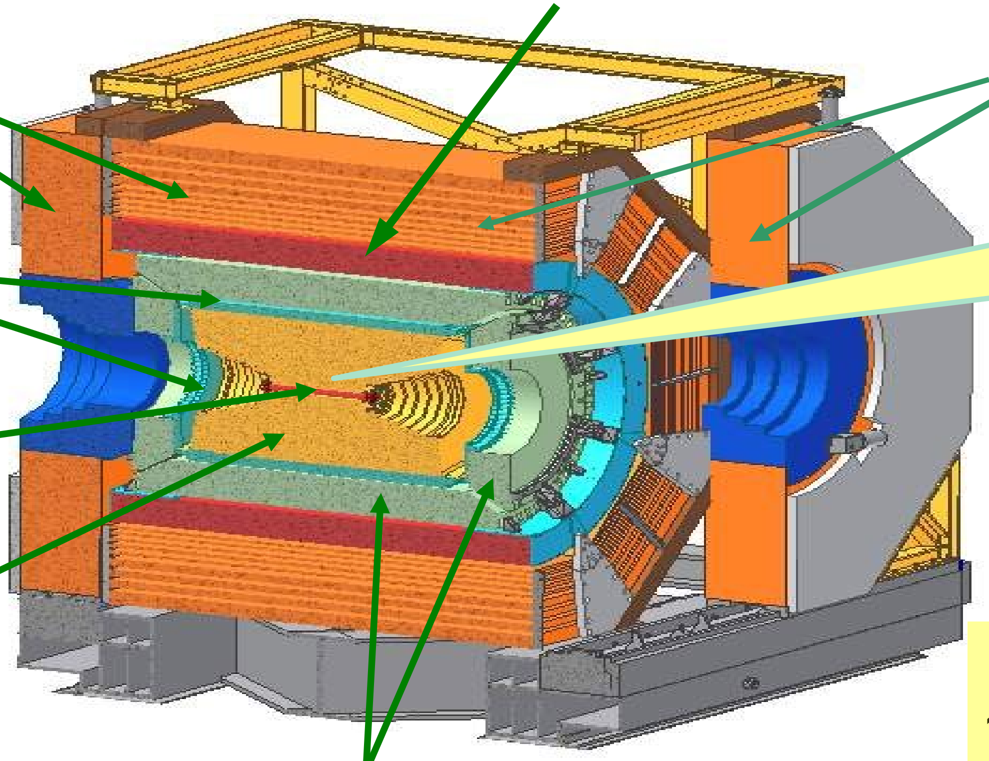
Why J/ψ decays: (2) big B(J/ψ→baryons)

decay mode	$\mathcal{B}$ ($\times 10^{-3}$)	$p_{\max}$ (MeV/c)
$J/\psi \to p\pi^-\bar{n}$	2.12	1174
$J/\psi \to \bar{\Lambda}\Lambda$	1.89	1074
$J/\psi \to \bar{p}K^+\Lambda$	0.87	876
$J/\psi \to \bar{\Sigma}^-\Sigma^+$	1.50	992
$J/\psi \to \bar{\Lambda}\pi^-\Sigma^+$	0.83	950
$J/\psi \to \bar{\Lambda}\pi^+\Sigma^-$	—	945
$J/\psi \to \bar{\Xi}^0\Xi^0$	1.17	818
$J/\psi \to \bar{\Xi}^+\pi^-\Xi^0$	—	685
$J/\psi \to \bar{\Xi}^+\Xi^-$	0.97	807
$J/\psi \to \bar{\Xi}^0\pi^+\Xi^-$	—	686
$\psi(2S) \to \bar{\Omega}^+\Omega^-$	0.05	774
$\psi(2S) \to \bar{\Xi}^0K^+\Omega^-$	—	606

Why J/ψ decays: (3) high tag efficiency

decay mode	$\mathcal{B}_{\text{tag}}$ (%)	ε_{tag} (%)
$J/\psi \to p\pi^-\bar{n}$	100	50
$J/\psi \to \bar{\Lambda}\Lambda$	64	40
$J/\psi \to \bar{p}K^+\Lambda$	100	
$J/\psi \to \bar{\Sigma}^-\Sigma^+$	52	40
$J/\psi \to \bar{\Lambda}\pi^-\Sigma^+$	64	
$J/\psi \to \bar{\Lambda}\pi^+\Sigma^-$	64	20
$J/\psi \to \bar{\Xi}^0\Xi^0$	64	20
$J/\psi \to \bar{\Xi}^+\pi^-\Xi^0$	64	
$J/\psi \to \bar{\Xi}^+\Xi^-$	64	20
$J/\psi \to \bar{\Xi}^0\pi^+\Xi^-$	64	
$\psi(2S) \to \bar{\Omega}^+\Omega^-$	44	20
$\psi(2S) \to \bar{\Xi}^0K^+\Omega^-$	64	

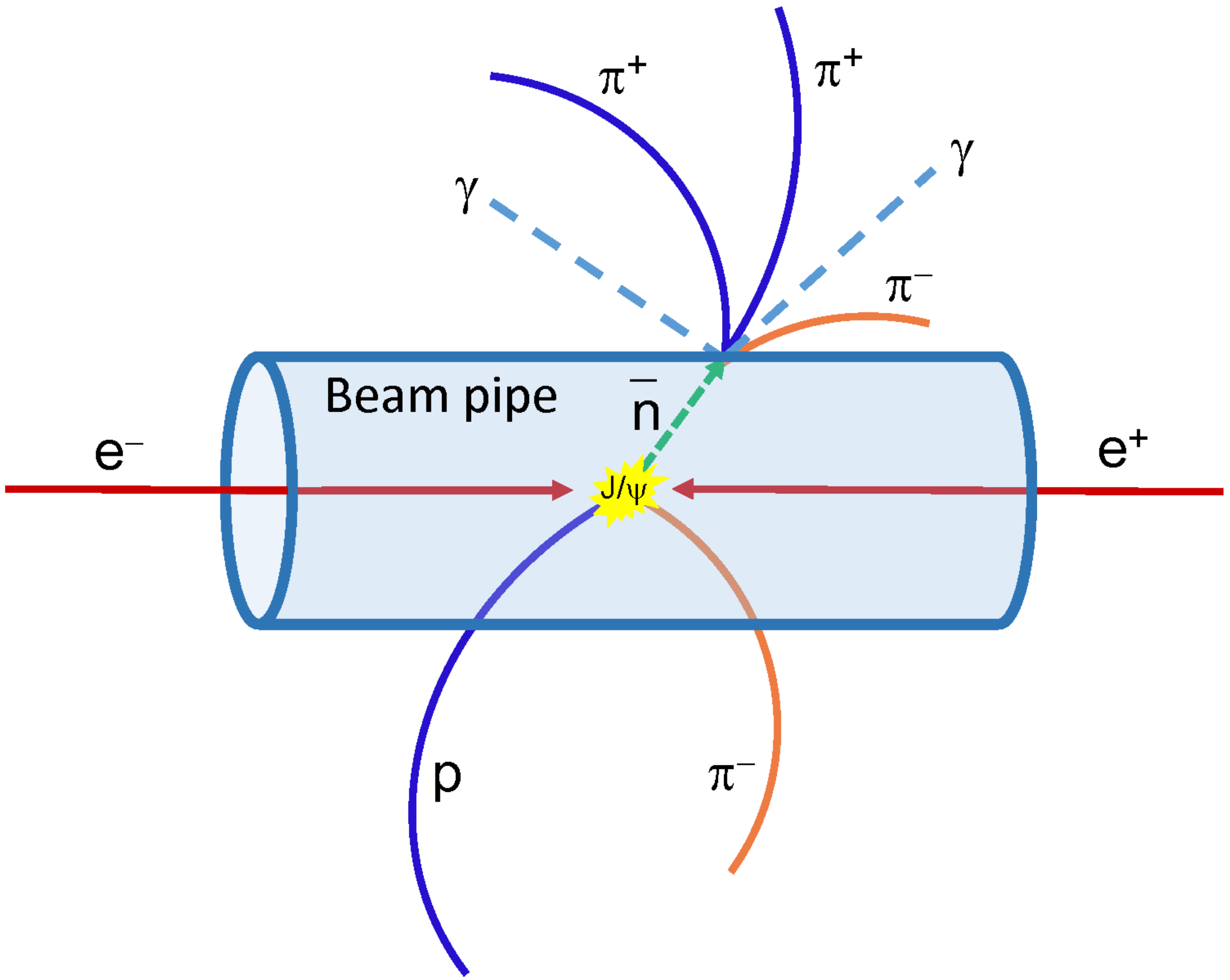
Proof of concept: study @ BESIII experiment



Total weight 750 tonnes,
~40,000 readout channels,
Data rate: 5 kHz, 50 Mb/s

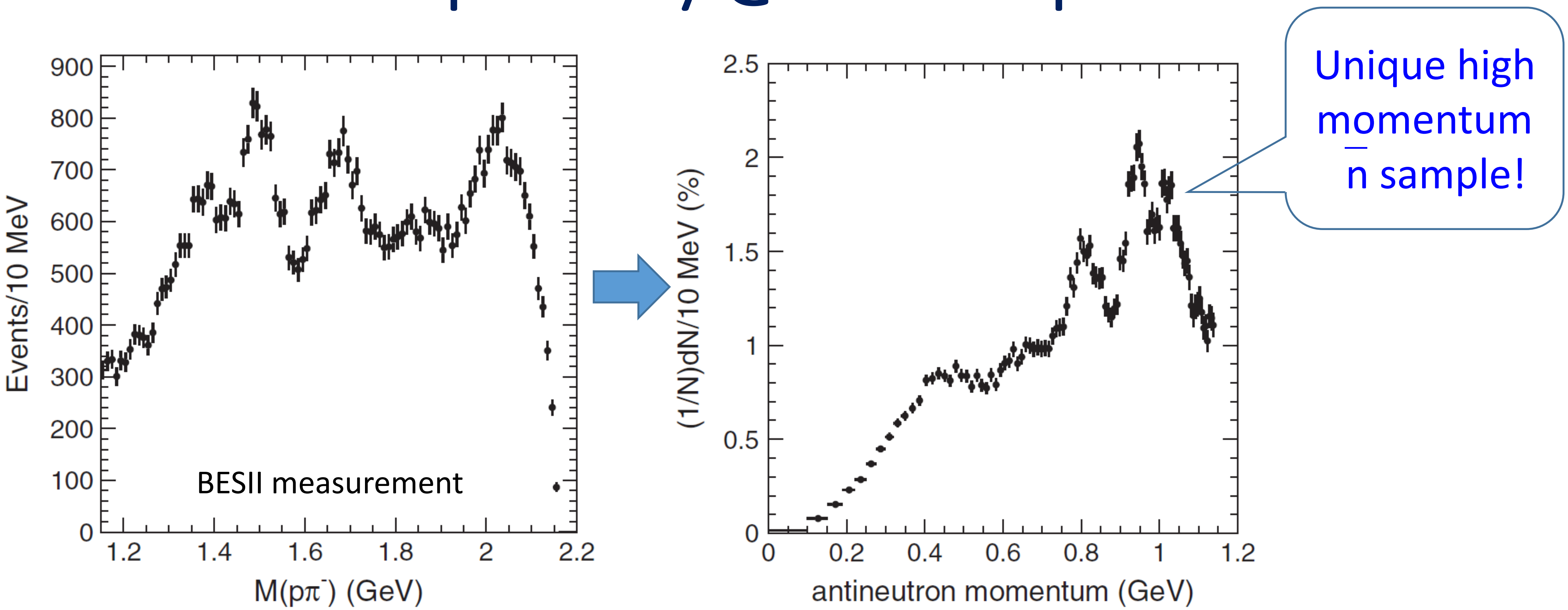
Has been in full operation since 2008,
all subdetectors are in very good status!

Proof of concept: study @ BESIII experiment



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

Proof of concept: study @ BESIII experiment

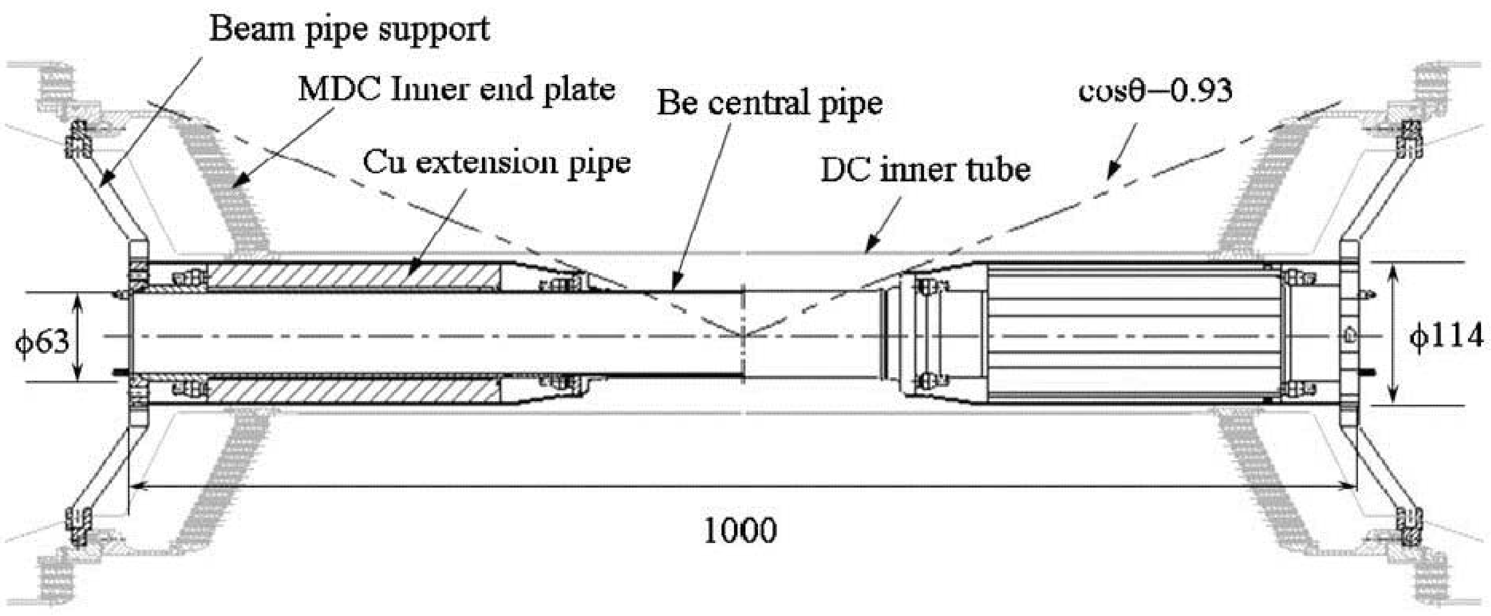


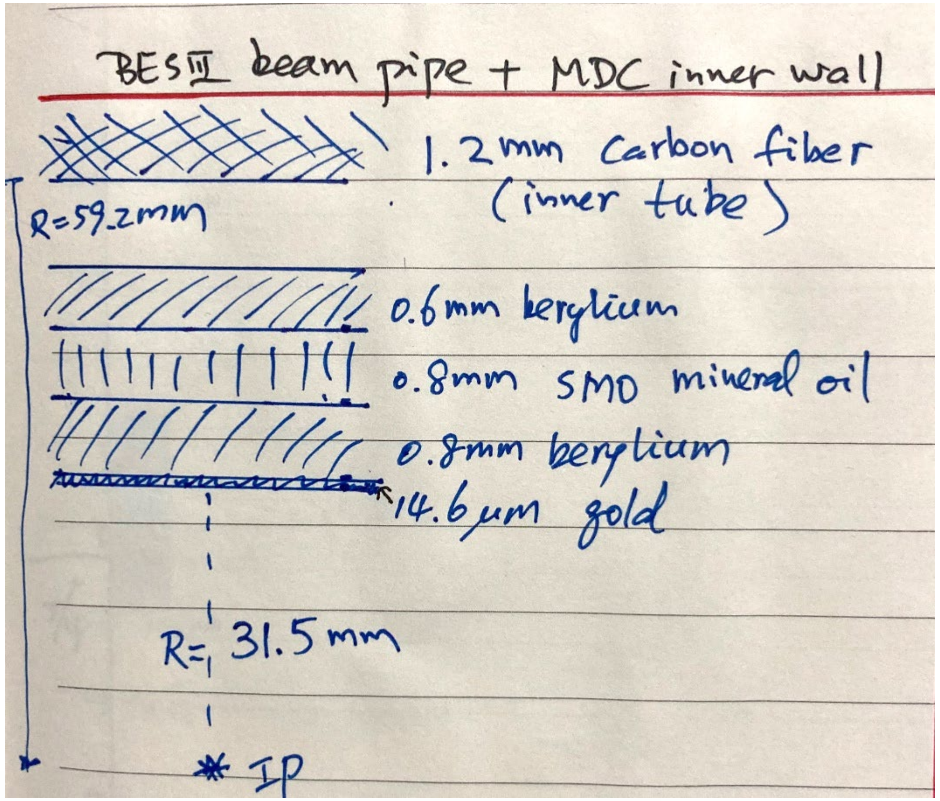
- N(J/ψ) = 10^{10}
- $B(J/\psi \to p\pi^{-}\bar{n}) = (2.12 \pm 0.09) \times 10^{-3}$
- ε = 40%
- Tagged $\bar{n}$ = 10^{10}x2.12x10^{-3}x40% = 8 million!

- $0<p_{\bar{n}}<1174$ MeV/c
- σp: ~7 MeV/c
- $\bar{n}$ direction: O(mrad)

Proof of concept: study @ BESIII experiment

The BESIII J/ψ data sample has been collected already, the detector material close to the interaction point in the inner detector serves as an effective target.





with $\sigma(\bar{n}p) \approx \sigma(\bar{n}n) \approx 100$ mb
expect 1–2% of tagged $\bar{n}$-s interact with Be & 1-2% with C fiber target

so $\sim 100,000$ $\bar{n}$ + Be events and $\sim 100,000$ $\bar{n}$ + C events

Hyperons and anti-hyperons at BESIII experiment

Baryon	$c\tau$ (cm)	decay mode	$\mathcal{B}$ ($\times 10^{-3}$)	$p_{\max}$ (MeV/c)	n_{BP}^{B} ($\times 10^{5}$)
$\bar{n}$	2.6×10^{13}	$J/\psi \to p\pi^-\bar{n}$	2.12	1174	80
Λ	7.89	$J/\psi \to \bar{\Lambda}\Lambda$	1.89	1074	26
		$J/\psi \to \bar{p}K^+\Lambda$	0.87	876	9
Σ^+	2.40	$J/\psi \to \bar{\Sigma}^-\Sigma^+$	1.50	992	4
		$J/\psi \to \bar{\Lambda}\pi^-\Sigma^+$	0.83	950	1
Σ^-	4.43	$J/\psi \to \bar{\Lambda}\pi^+\Sigma^-$	—	945	—
Ξ^0	8.71	$J/\psi \to \bar{\Xi}^0\Xi^0$	1.17	818	7
		$J/\psi \to \bar{\Xi}^+\pi^-\Xi^0$	—	685	—
Ξ^-	4.91	$J/\psi \to \bar{\Xi}^+\Xi^-$	0.97	807	3
		$J/\psi \to \bar{\Xi}^0\pi^+\Xi^-$	—	686	—
Ω^-	2.46	$\psi(2S) \to \bar{\Omega}^+\Omega^-$	0.05	774	0.05
		$\psi(2S) \to \bar{\Xi}^0K^+\Omega^-$	—	606	—

reference

The Ω hyperons are produced from 3 billion $\psi(2S)$ event sample.

All these particles can also be produced in decays of other charmonia.

Observation of Ξ^0+n→Ξ^-+p at BESIII experiment

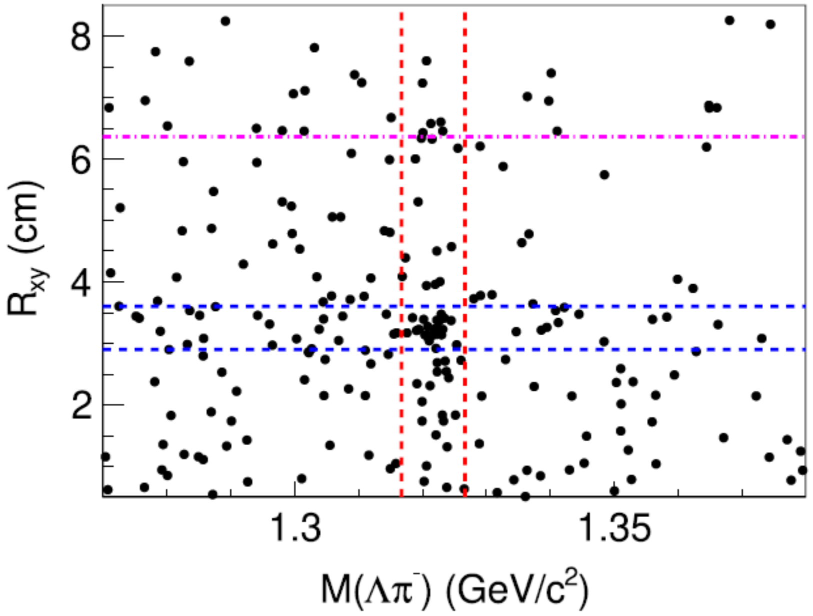


FIG. 2. Distribution of R_{xy} versus $M(\Lambda\pi^-)$ for data. The blue horizontal dashed lines denote the beam pipe region, the pink horizontal dashed-dotted line denotes the position of inner wall of MDC, and the red vertical dashed line marks the Ξ^- signal region.

From 10^{10} J/ψ events

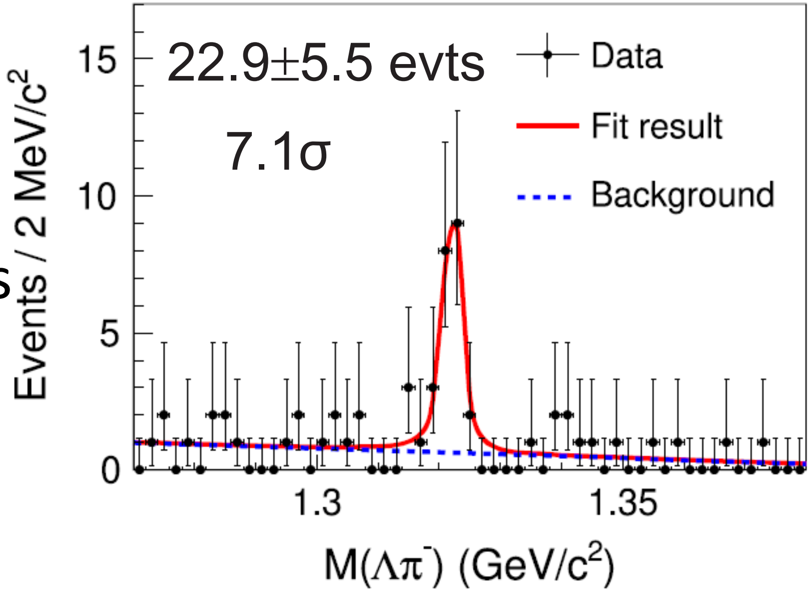


FIG. 3. Distribution of $M(\Lambda\pi^-)$ in data (dots with error bars). The red solid curve is the total fit result and the blue dashed curve is the background component.

$$\sigma(\Xi^0 + {}^9\mathrm{Be} \to \Xi^- + p + {}^8\mathrm{Be}) = (22.1 \pm 5.3_{\mathrm{stat}} \pm 4.5_{\mathrm{sys}})\ \mathrm{mb}$$

$$\sigma(\Xi^0 n \to \Xi^- p) = (7.4 \pm 1.8_{\mathrm{stat}} \pm 1.5_{\mathrm{sys}})\ \mathrm{mb}$$

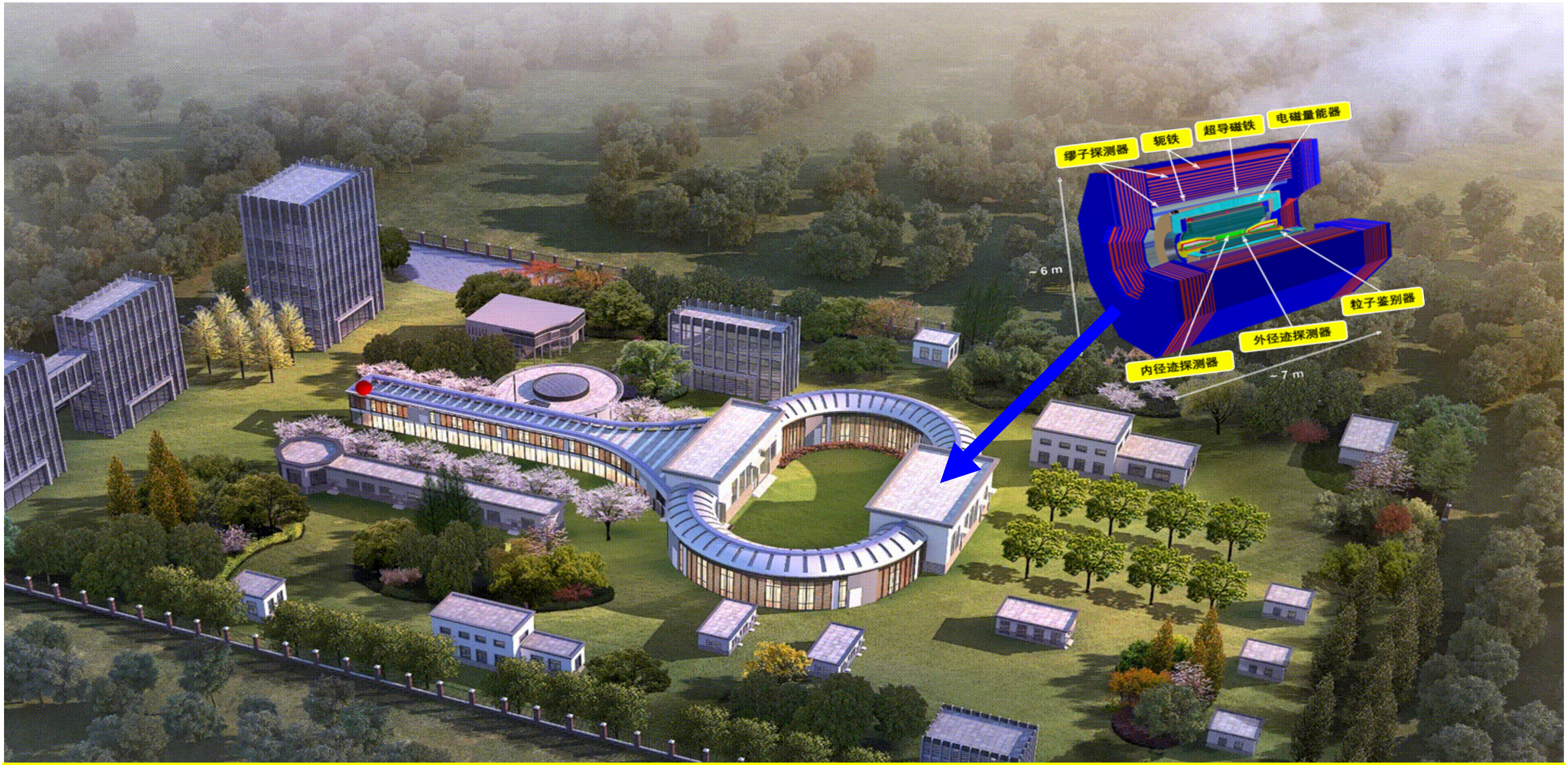
$$P_{\Xi^0} = 0.818\ \mathrm{GeV}/c$$

BESIII: PRL 130, 251902 (2023)

A super J/ψ factory with 10^{12} J/ψ events per year

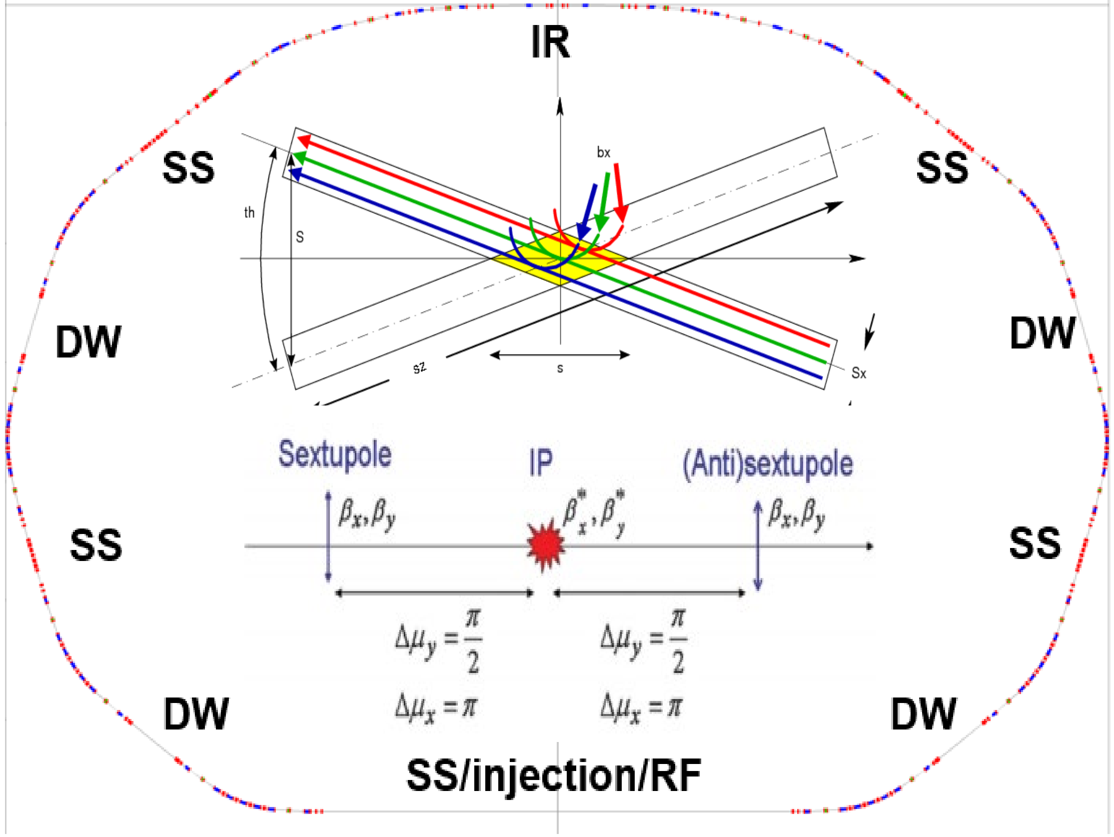
- Design luminosity = O(100) × $\mathscr{L}$ @BESIII ~ 10^{35} $cm^{-2}s^{-1}$
  - ✓ Existing proposals: STCF (China), SCT (Novosibirsk)
- Detector improvements vs. BESIII: tracking, PID, γ detection
- (1-3)×10^{12} J/ψ events/year = 100 × BESIII sample
- Further improvements to expand range of physics topics
  - ✓ Reduce the diameter of the beam pipe
  - ✓ Interchangeable custom targets inside the detector
  - ✓ Subdetector for specific final states, e.g. deuteron, triton, …

STCF in China



- CM Energy : 2-7 GeV
- Peaking $\mathcal{L}$: $>5\times10^{34}$ cm^{-2} s^{-1}
- Potential to further improve the $\mathcal{L}_{peak}$ and realize polarized beam
- Double storage ring : ~800 m , injection : ~ 300m
- BESIII-Like detector
- Cost 4.5B RMB

Accelerator Conceptual Design



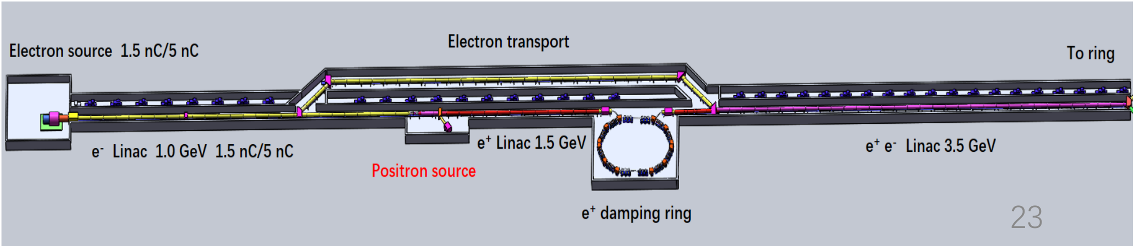
Parameters	Unit	Value
Circumference	m	574.78
Distance from final defocusing quadrupole to IP	m	0.9
Optimized energy	GeV	2.0
Total beam current	A	2
Horizontal/Vertical beta @ IP	m	0.09/0.0006
Total crossing angle (2θ)	mrad	60
Piwinski angle (ϕ)	rad	18.9
Beam-beam tune shift (ξ_x/ξ_y)	—	0.0038/0.0835
Coupling ratio	—	0.5%
Natural chromaticities (C_x/C_y)	—	-87/-513
Horizontal emittance (ϵ_x) without/with IBS	nmrad	2.76/4.17
Horizontal beam size @ IP without/with IBS	μm	15.77/19.37
Vertical beam size @ IP without/with IBS	μm	0.091/0.117
Energy spread ($\frac{\sigma_{\Delta E}}{E}$) without/with IBS	$\times 10^{-4}$	5.3/7.2
Momentum compaction factor	—	7.2×10^{-4}
RF frequency	MHz	499.67268
RF voltage	MV	1.2
Harmonic number	—	958
Bunch length (σ_z)	mm	12.2
Particle number per bunch (N_b)	—	5.0×10^{10}
Energy loss per turn	MeV	0.1315
Synchrotron tune (ν_s)	—	0.00388
Damping times ($\tau_x/\tau_y/\tau_s$)	ms	58.51/58.33/29.12
Peak luminosity	$cm^{-2}s^{-1}$	1.2×10^{35}
Touschek lifetime	s	35

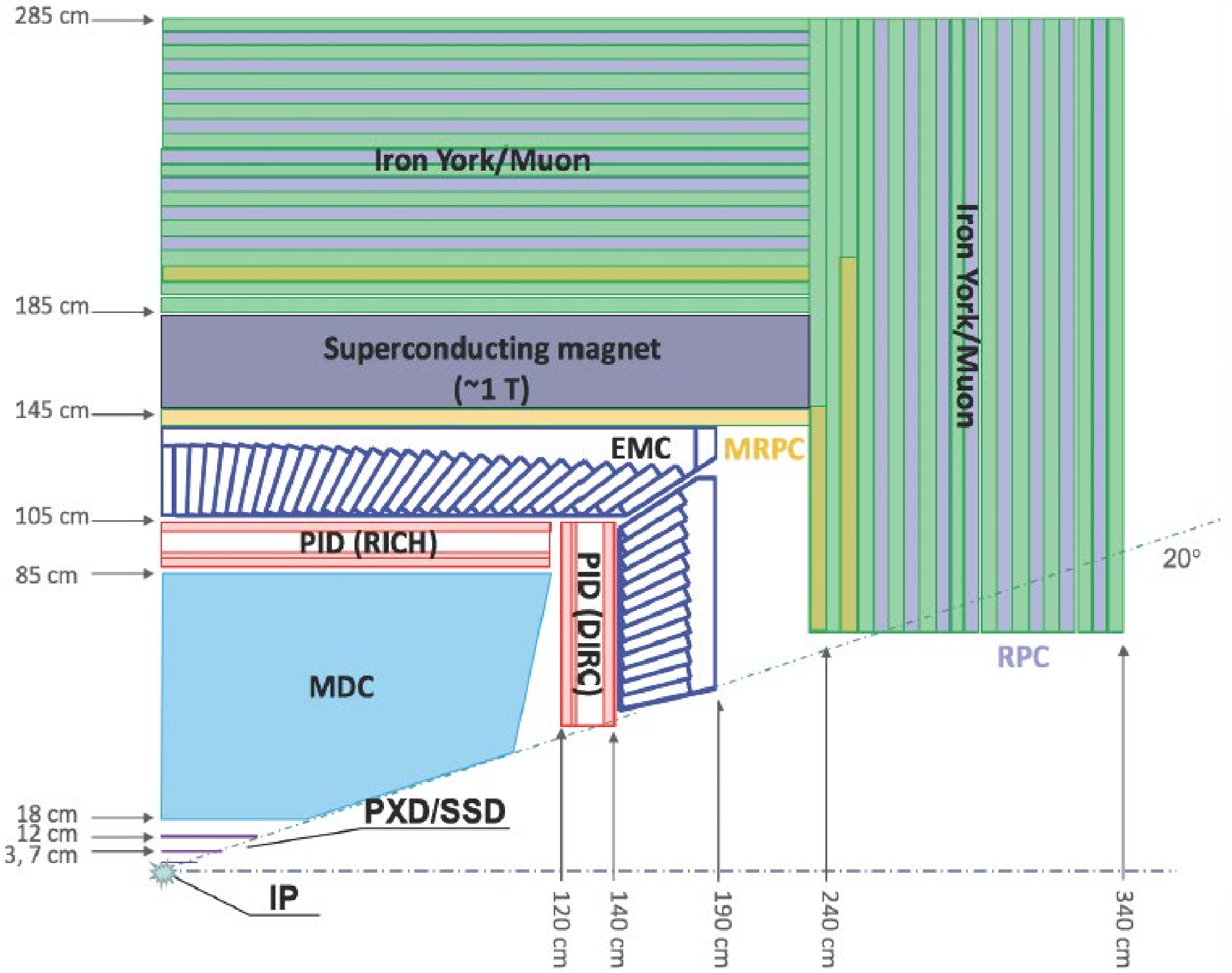
Interaction region :

- **Large Piwinski-Angle Collision + Crab Waist**

Linac Injector:

- **No booster, full energy injection (1-3.5 GeV)**
- **Possible polarized e^- beam**





PXD

- ~<0.25%X_0 / layer
- σ_{xy}< 130 μm

MDC

- σ_{xy}< 130 μm
- σ_p/p ~ 0.5% @ 1 GeV
- dE/dx~6%

PID

- π/K (and K/p) 3-4σ separation up to 2GeV/c

EMC

E range: 0.025-2GeV

σ_E (%) @ 1 GeV

Barrel: 2 .5

Endcap: 4

Pos. Res. : ~ 4 mm

MUD

- 0.4 - 1.8 GeV
- π suppression >30

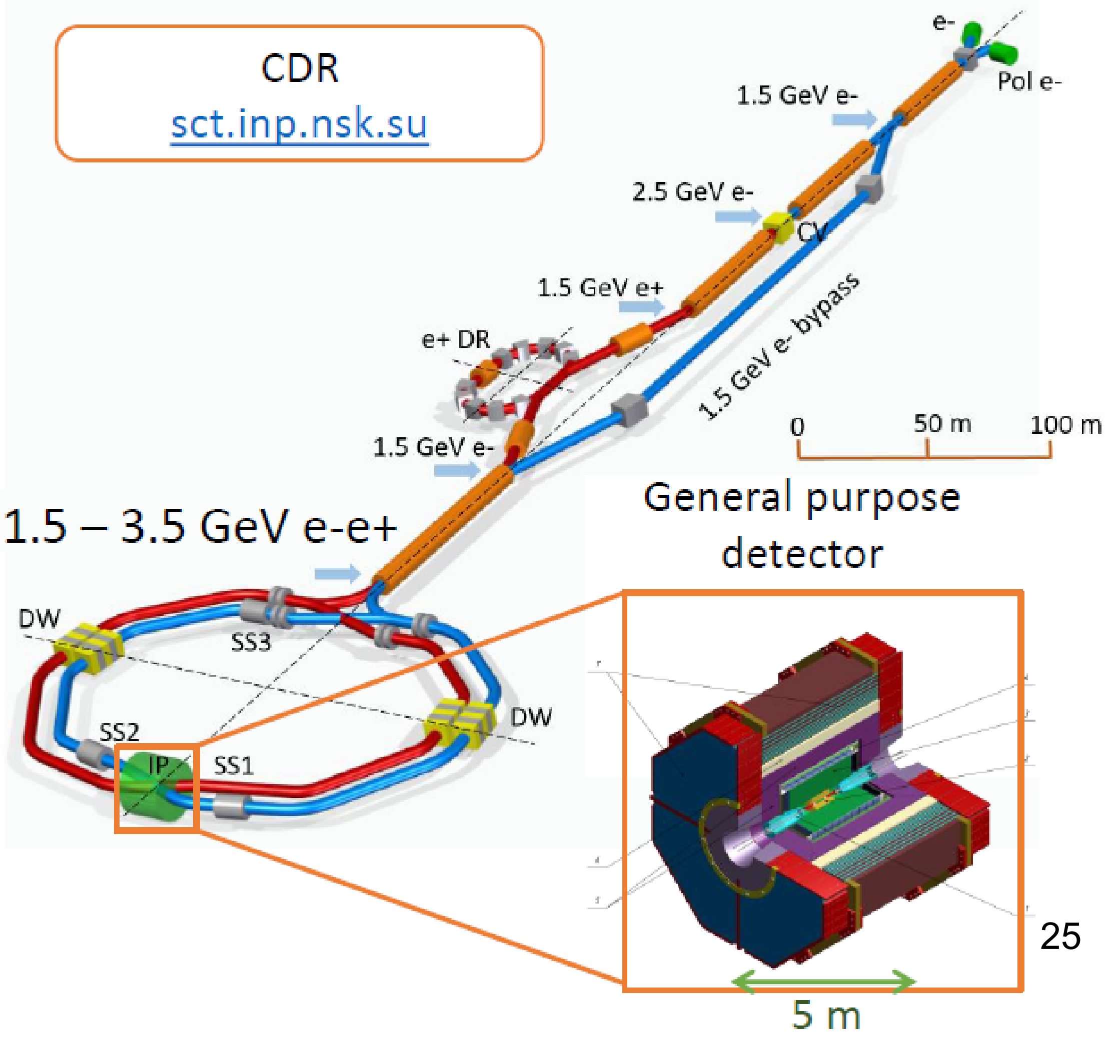
Sarov, Russia

Ivan Logashenko (BINP)
PhiPsi2022

Super charm-tau factory

- Super charm-tau factory is e^+e^- collider, dedicated to precision study of properties of charm-quark, tau-lepton, study of strong interactions, search of BSM physics
  - Beam energy from 1.5 (1.0) to 3.5 GeV
  - Luminosity $\mathcal{L} = 10^{35}\ cm^{-2}c^{-1}$ @ 2 GeV
  - Longitudinally polarized electron beam
- Experiments will be conducted using state-of-the-art general purpose detector
  - Tracking (including low p_t)
  - Calorimetry (high resolution, fast, π^0/γ sep.)
  - Particle ID ($\mu/\pi/K/p$ up to 1.5 GeV/c)

CDR
sct.inp.nsk.su



Sarov, Russia

Ivan Logashenko (BINP)
PhiPsi2022

Design parameters (2021)

- Design parameters meet the luminosity requirements
- Similar parameters have been achieved at other colliders
- Dynamic aperture was not taken into account

The key problem now is to find configuration with sufficient dynamic aperture

E(MeV)	1500	2000	2500	3000	3500
Π(m)	870.949				
F_{RF}(MHz)	350				
2θ(mrad)	60				
$\varepsilon_y/\varepsilon_x$(%)	0.5				
β_x^*/β_y^* (mm)	100/1				
I(A)	2	2	2	2	2
$N_{e/bunch} \times 10^{-10}$	9	8	7	8	[illegible]
N_b	420	472	540	47[illegible]	[illegible]
U_0(keV)	115.6	294	516	845	1314
V_{RF}(kV)	1500	2300	3000	3500	4500
ν_s	0.0152	0.0162	0.0165	0.0162	0.0168
δ_{RF}(%)	1.9	2	2	1.8	1.8
$\sigma_e \times 10^3$ (SR/IBS+WG)	0.28/1.1	0.37/1.1	0.5/1.1	0.6/1.2	0.7/1.5
σ_s(mm) (SR/IBS+WG)	3.6/14	5/14	6/14	7/15	8/15
ε_x(nm) (SR/IBS+WG)	2.3/7.3	4/4.9	6/4.3	[illegible]	[illegible]
$L_{HG} \times 10^{-35} (cm^{-2}s^{-1})$	0.87	1.1	1	1	1
ξ_x/ξ_y	0.008/0.17	0.005/0.14	0.004/0.1	0.003/0.09	0.003/0.07
$\tau_{Luminosity}$ (s)	2400	2100	2300	2300	2400

SuperKEKB 03.12.2019 $\beta_y^* = 1\ mm$

PEPII: I(e+)=3.2 A PEPII
DAFNE : I(e-)=2.45A

SuperKEKB: $L = 4.7 \times 10^{34}$

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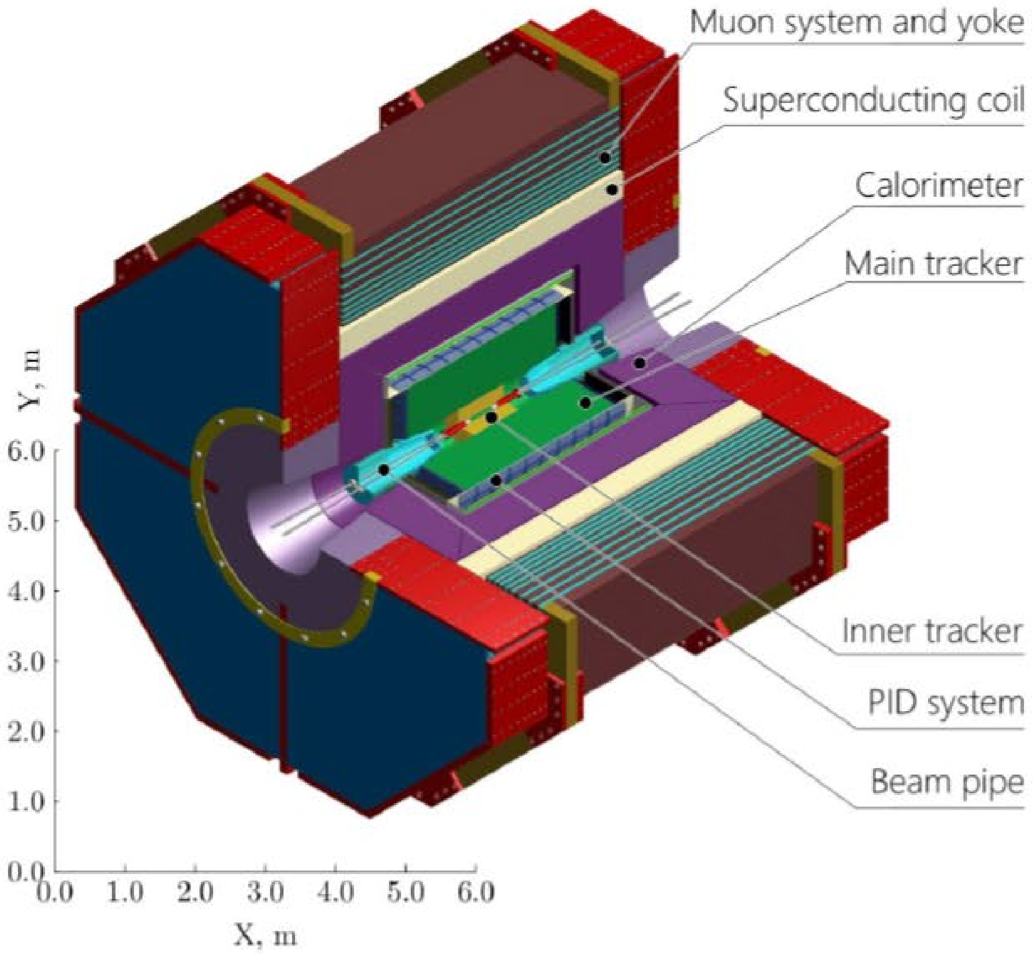
Detector concept



Momentum resolution $\sigma_p/p \leq 0.4\%$ at 1 GeV

Very symmetric and hermetic

Able to detect soft tracks ($p_t \geq 50\ MeV/c$)
- Inner tracker should be able to handle 10^4 tracks/cm²s

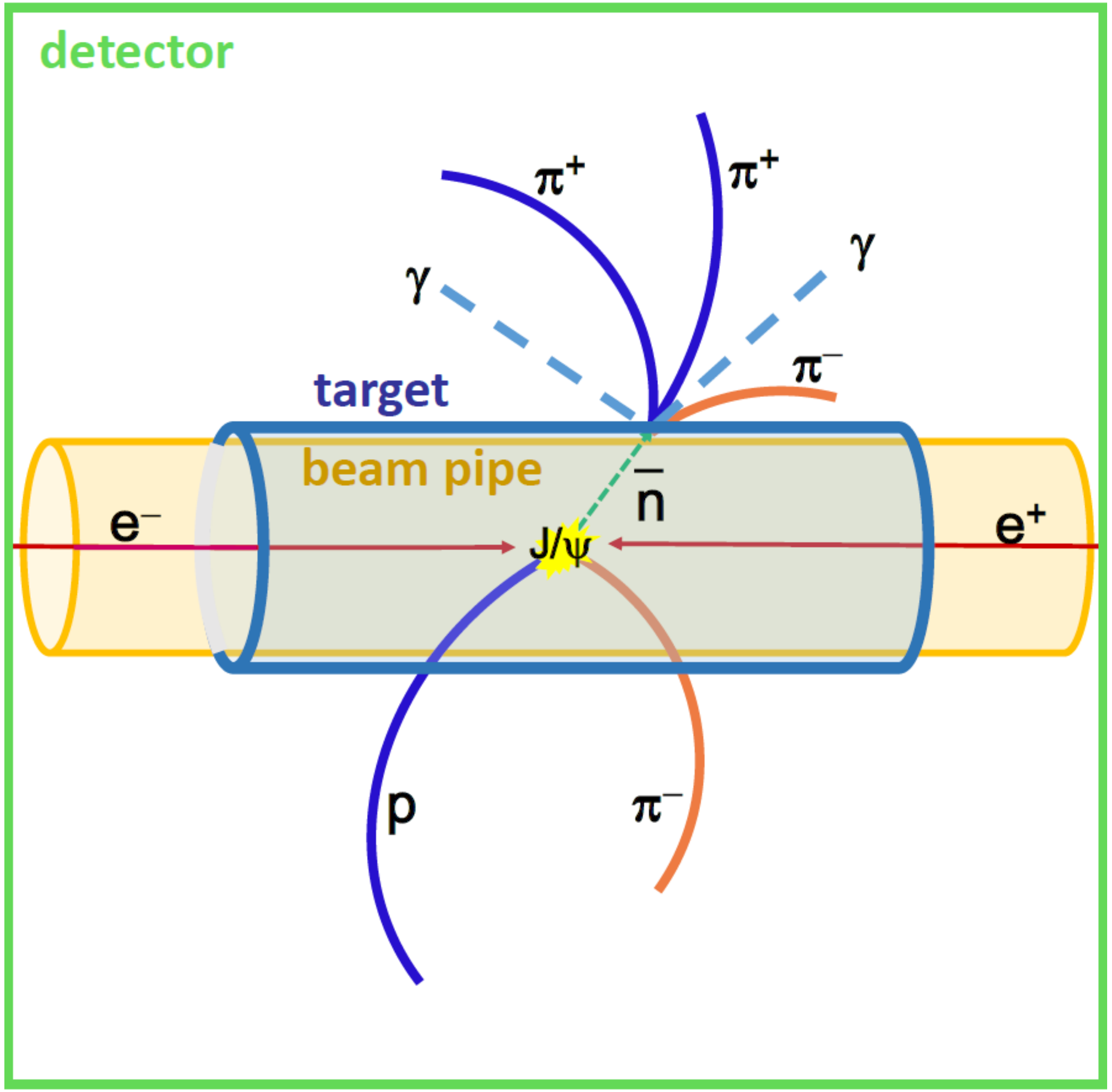
Very good particle identification: $e/\mu/\pi/K$
- π/K in the whole energy range, e.g. for $D\overline{D}$ mixing
- μ/π up to 1.5 GeV, e.g. for $\tau \to \mu\gamma$ search
- dE/dx better than 7%

Able to detect γ from 10 MeV to 3.5 GeV, good π^0/γ separation
- Calorimeter energy resolution $\sigma_E/E \leq 1.8\%$ at 1 GeV
- Calorimeter time resolution $\sigma_t \leq 1$ ns

Efficient “soft” trigger

Ability to operate at high luminosity, up to 300 kHz at J/ψ

Do fixed target experiments @ a super J/ψ factory



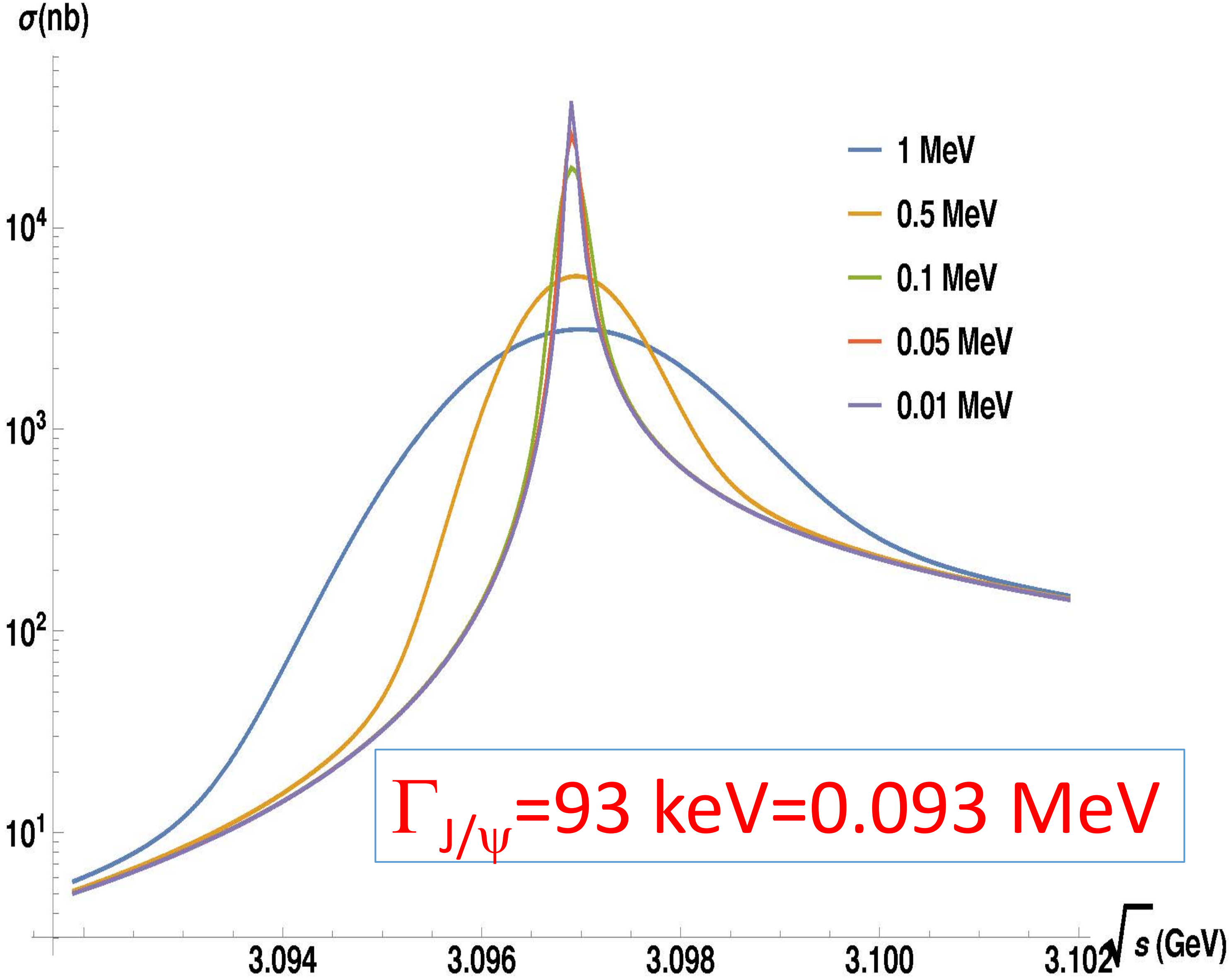
- Super J/ψ factory
  - e^+e^- annihilation @ 3.097 GeV
  - $O(10^{12})$ or more J/ψ events/year
- A small beam pipe
- State of the art detector
- Variety of custom removable targets
- Run@ψ(2S) for higher-p sources
- Asymmetric collision, large angle collision to expand the p range
- Special detector for high mass particles, deuteron, triton, …

Baryons and anti-baryons at a super J/ψ factory

重子	$c\tau$/cm	衰变模式	B_{tag}/%	ε_{tag}/%	$f^{B}_{1\,\text{cm}}$/%	$f^{B}_{2\,\text{cm}}$/%	$N^{B}_{1\,\text{cm}}/(\times 10^{6})$	$N^{B}_{2\,\text{cm}}/(\times 10^{6})$
$\bar{n}$	2.6×10^{13}	$J/\psi \to p\pi^{-}\bar{n}$	100	50	100	100	850	850
Λ	7.89	$J/\psi \to \bar{\Lambda}\Lambda$	64	40	76	65	370	310
		$J/\psi \to \bar{p}K^{+}\Lambda$	100		70	55	240	190
Σ^{+}	2.40	$J/\psi \to \bar{\Sigma}^{-}\Sigma^{+}$	52	40	49	27	150	84
		$J/\psi \to \bar{\Lambda}\pi^{-}\Sigma^{+}$	64		38	17	81	36
Σ^{-}	4.43	$J/\psi \to \bar{\Lambda}\pi^{+}\Sigma^{-}$	64	40	56	35	—	—
Ξ^{0}	8.71	$J/\psi \to \bar{\Xi}^{0}\Xi^{0}$	64	20	72	57	110	85
		$J/\psi \to \bar{\Xi}^{+}\pi^{-}\Xi^{0}$	64		66	49	—	—
Ξ^{-}	4.91	$J/\psi \to \bar{\Xi}^{+}\Xi^{-}$	64	20	60	40	74	50
		$J/\psi \to \bar{\Xi}^{0}\pi^{+}\Xi^{-}$	64		52	30	—	—
Ω^{-}	2.46	$\psi(2S) \to \bar{\Omega}^{+}\Omega^{-}$	44	20	31	11	1.4	0.5
		$\psi(2S) \to \bar{\Xi}^{0}K^{+}\Omega^{-}$	64		18	4	—	—

10^{12} J/ψ or ψ(2S) events per year, target at 1 cm or 2 cm.

A hyper J/ψ factory with 10^{14} J/ψ events?



Two ways of improving J/ψ production rate:

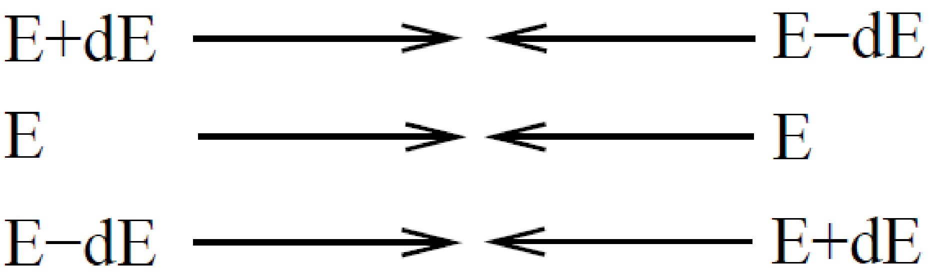
1. Increase luminosity
2. Reduce energy spread

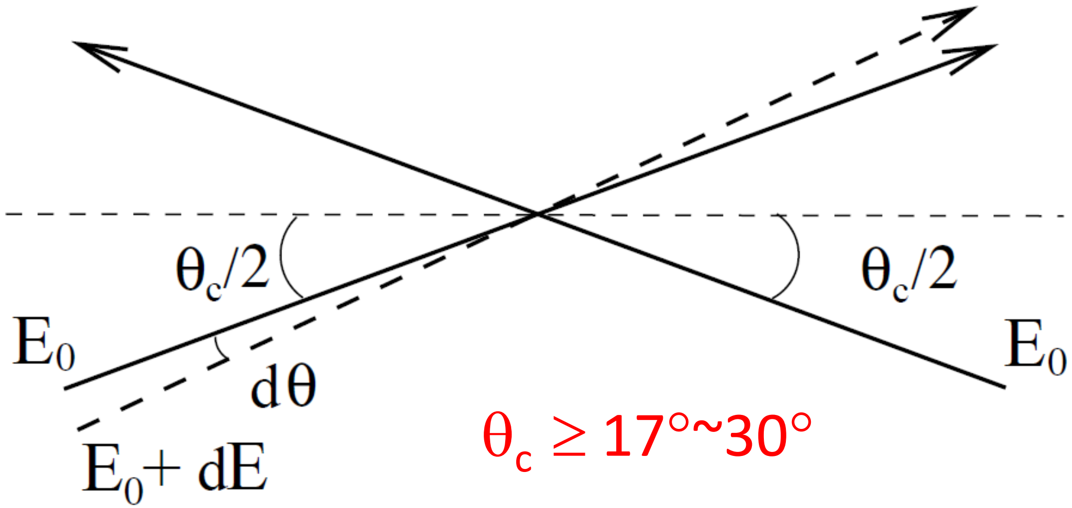
Energy spread (MeV)	Cross section (nb)
1	3,100
0.5	5,700
0.1	20,000
0.05	29,000
0.01	42,000

Numbers & plot from Yuping Guo

A new scheme of monochromatization?

V. I. Telnov, 2008.13668v3
Monochromatization of e^+e^- colliders with a large crossing angle





$\theta_c \geq 17°\sim30°$

Existing monochromatization scheme for head-on collisions will reduce luminosity significantly

$$\sigma_W/W \sim (3\text{–}5) \times 10^{-6}$$

New scheme: Provide the beams with an angular dispersion such that a beam particle arrives to the IP with a horizontal angle that depends on its energy.

σW=10-15 keV @ J/ψ peak
and J/ψ is moving!

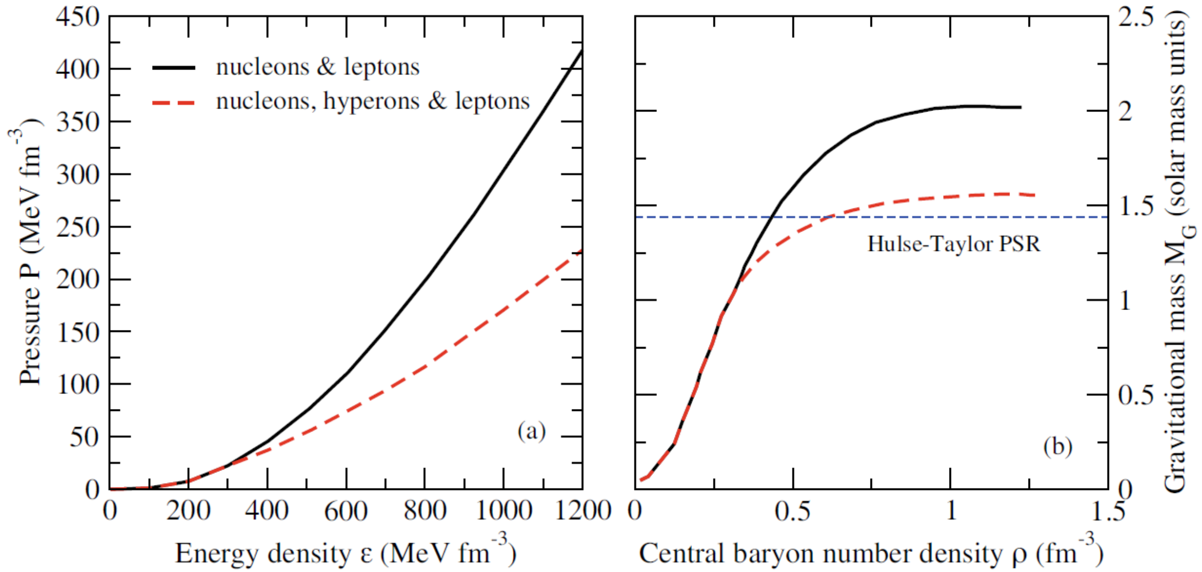
Potential physics studies

- antinucleon-nucleon interaction
- OZI violation
- nonvalence $s\bar{s}$ components of the nucleon
- (anti)hyperon-nucleon interaction
- (multi-strange) hypernuclei
- light hadron spectroscopy, including exotics and many others
- cross sections of antineutrons with material for the calibration of Monte Carlo simulation codes for particle physics and medical applications, such as FLUKA and GEANT4
- Hyperon puzzle and size of neutron stars
- Maybe more topics from nuclear physics community

Size of neutron stars & hyperon puzzle

For a review, see Chatterjee & Vidana, Eur. Phys. J. A (2016) **52**: 29

$$n \to p + e^- + \bar{\nu}; \quad p + e^- \to n + \nu,$$
$$\Lambda \to p + e^- + \bar{\nu}; \quad p + e^- \to \Lambda + \nu,$$
$$\Sigma^0 \to p + e^- + \bar{\nu}; \quad p + e^- \to \Sigma^0 + \nu,$$
$$\Sigma^- \to n + e^- + \bar{\nu}; \quad n + e^- \to \Sigma^- + \nu,$$
$$\Xi^- \to \Lambda + e^- + \bar{\nu}; \quad \Lambda + e^- \to \Xi^- + \nu,$$
$$\Xi \to \Sigma^0 + e^- + \bar{\nu}; \quad \Sigma^0 + e^- \to \Xi^- + \nu,$$



A conclusive observation of multiply strange nuclear systems is absolutely necessary for a better understanding of the role of strangeness in neutron stars. The theories for the description of strangeness in massive neutron stars cannot be answered without the improved knowledge of $\Lambda\Lambda$ interaction, for which one requires careful high precision series of investigations of such an interaction.

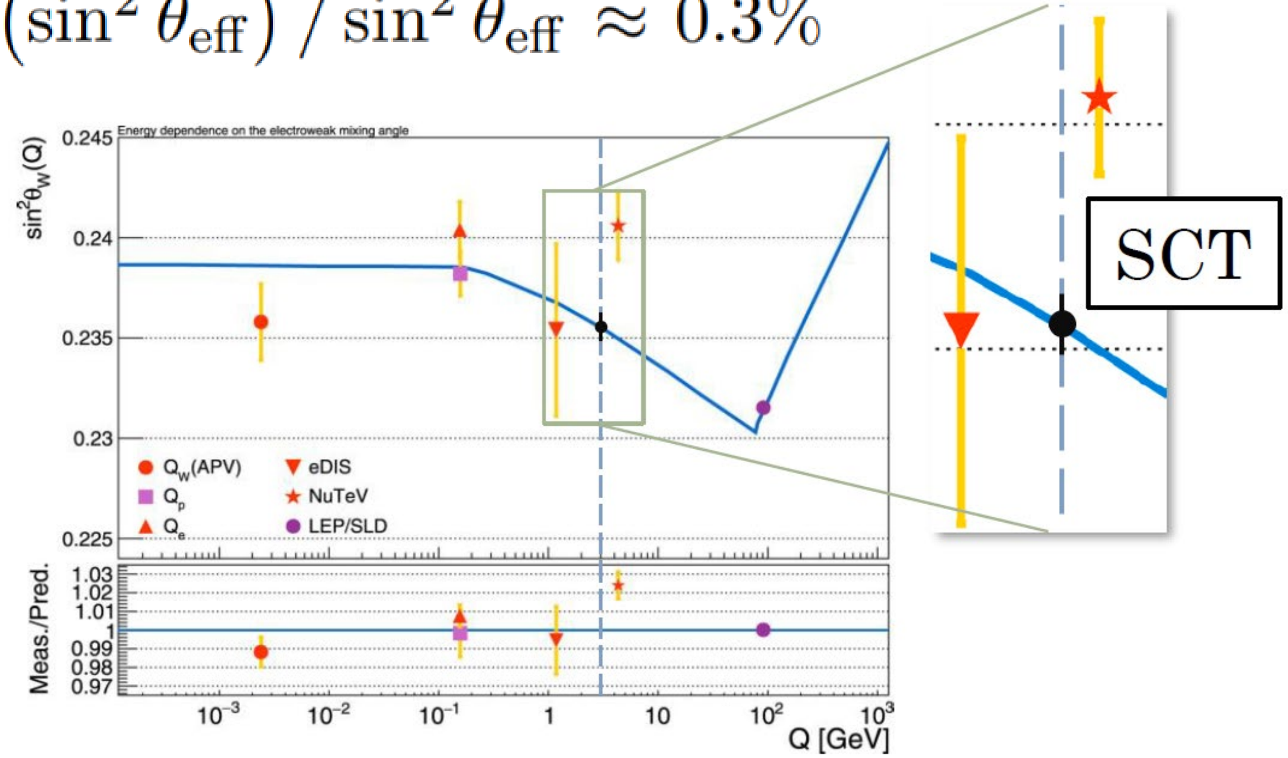
There are several new facilities planned or under construction such as in GSI in Germany, JLAB in USA and J-PARC in Japan. These facilities will hopefully provide much more precise updates on the properties of hyperon-nucleon and hyperon-hyperon interactions. Experimental hypernuclear physics is still an extremely active field of research.

These can be studied @ super J/ψ factory with hyperons (and BESIII)!

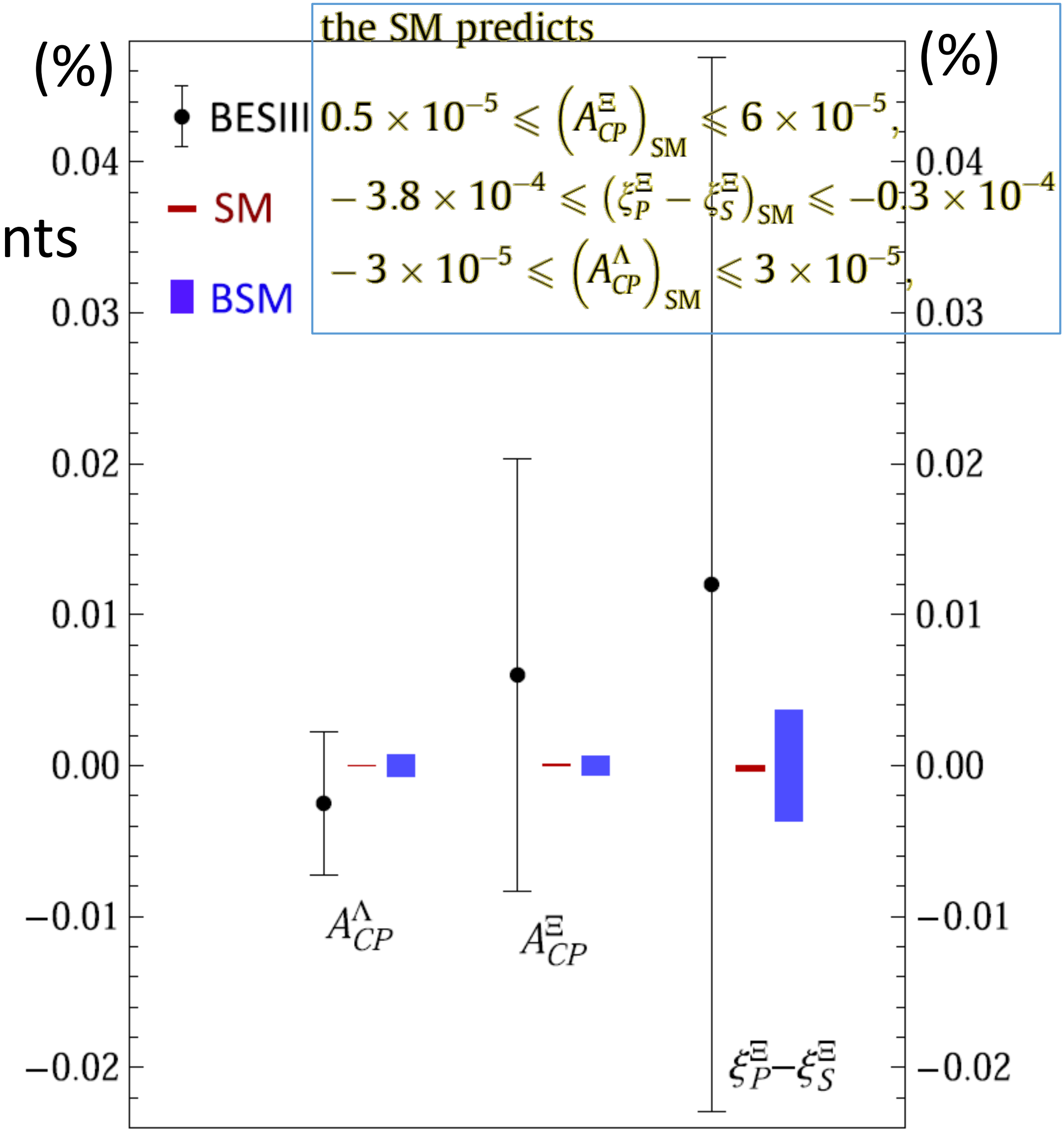
Potential physics with direct J/ψ decays

1. Precision measurement of Weinberg angle
2. CPV in hyperon decays
3. New physics searches with $10^{12\sim14}$ produced J/ψ events

$$\delta\left(\sin^2\theta_{\text{eff}}\right)/\sin^2\theta_{\text{eff}} \approx 0.3\%$$

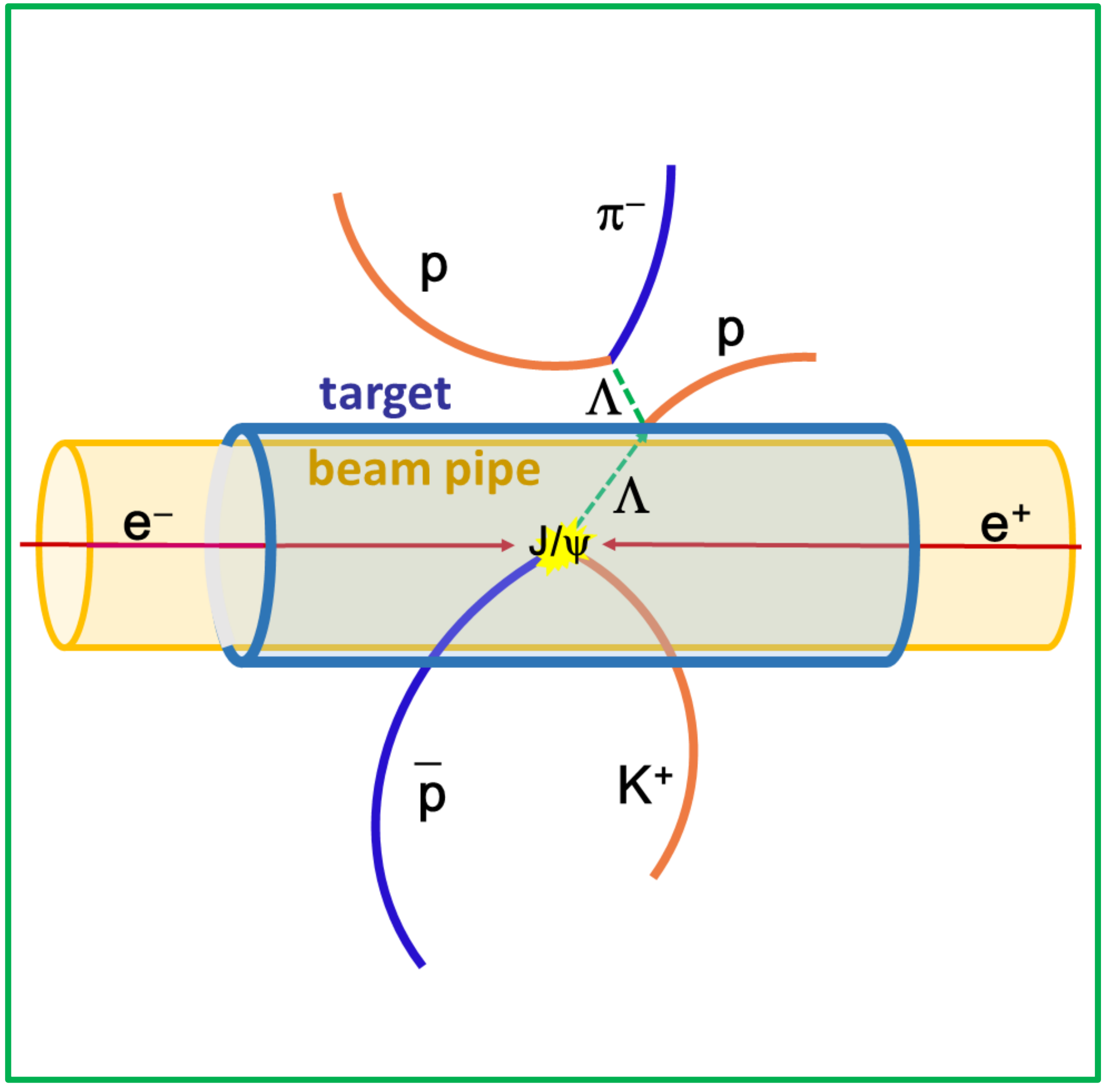


A. Bondar et al., JHEP 2020 (2020) 76



X. G. He et al., arXiv:2209.04377

我们建造一个“超级J/ψ工厂”=“超子工厂”吧！



- Super (or hyper) J/ψ factory
  - e^+e^- annihilation @ 3.097 GeV; $O(10^{12\text{-}13})$ J/ψ events/year
- State of the art detector
- Variety of custom removable targets
- High quality sources of long lived (anti-)hyperons and $\bar{n}$ for many different kinds of experiments
- Same software, similar systematic effects
- No need to share beam time
- No need for additional resources, additional infrastructure, minimal further investments
- Physics highlights
  ① NN, $\overline{\text{N}}$N, YN, $\overline{\text{Y}}$N, hypernuclei, neutron star, …
  ② Precision measurement of Weinberg angle
  ③ Search for new CPV source in hyperon decays

谢谢！

Comments on the $\bar{n}$ sources

- Although potentially extremely useful for investigating nonperturbative QCD and nuclear structure, experimental studies using antineutron beams have been very limited till now, due to the severe difficulties in accumulating a sufficient number of antineutrons with known flux and momentum.
- The antineutron sources enabling quite a wide range of physics topics to be studied, from nuclear physics to hadron spectroscopy, albeit with limited statistics. The scattering of antineutrons on nuclei made it possible to investigate nucleon-antinucleon annihilation inside matter without complications due to Coulomb interaction.
- The disadvantages of CEX are obvious: the production rate is low, and the antineutron momentum and direction are hard to control. The selection of anti-neutrons with momentum in a specific direction results in discarding a large fraction of antineutrons.

Comments on the Y and $\overline{Y}$ sources

- Ground-state SU(3) octet hyperons (Λ, $\Sigma^{\pm}$, $\Xi^{0/-}$) and their antiparticles have relatively long lifetimes (with a typical $c\tau$ of a few centimeters) and are essential for investigating several important physics questions, including hyperon-nucleon interaction and the possible role of hyperons in neutron stars.
- The relevant experimental studies started in the 1960s and have lasted for more than half a century, using π or K beams shot into bubble chambers or scintillating fiber (SciFi) targets. The statistics of these experiments are low, with typically a few tens to a few hundreds of observed events.
- New ways of high efficiency hyperon production are essential.