

Супер чарм-тау фабрика 中国超级陶粲装置

**cornucopia of antineutrons and hyperons
from super J/ψ factory
for next-generation nuclear and particle physics
high-precision experiments**

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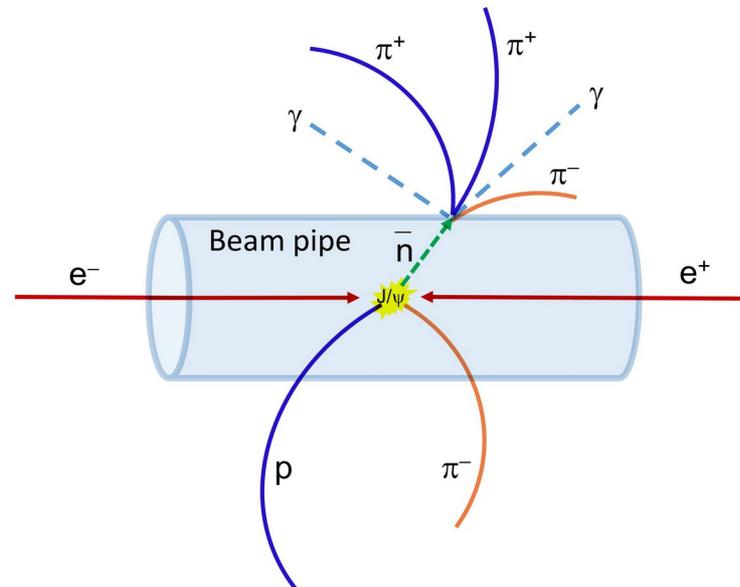
QWG2021, March 19, 2021

<https://arxiv.org/abs/2103.06658>

executive summary

- N - N and N - \bar{N} forces fundamental to visible universe
- p - p , p - n , n - n , p - \bar{p} , n - \bar{p} well studied,
but scarce data on p - \bar{n} and n - \bar{n}
- new high-quality source of \bar{n} : $e^+e^- \rightarrow J/\psi \rightarrow \bar{n}p\pi^-$
with J/ψ at rest
- p , π^- tagged $\implies \bar{n}$ momentum determined precisely
on event-by-event basis
- $\text{BR}(J/\psi \rightarrow \bar{n}p\pi^-) = (2.12 \pm 0.09) \times 10^{-3}$
BESIII : 10^{10} J/ψ -s \implies 20 million \bar{n} ; under study now
super charm factory: 10^{12} J/ψ -s \implies 2 billion \bar{n}
select \bar{n} with specific \vec{p} \implies high-quality tunable virtual \bar{n} beam
- use variety of custom removable targets; in BESIII: beam pipe
- similarly: all (anti)hyperons – $\Lambda, \Sigma, \Xi, \Omega^-$, strangeness-tagged K^0, \bar{K}^0
- $N\bar{N}$ annihilation, $s\bar{s}$ in N , ~~QZI~~, (multi-strange) hypernuclei, exotics. . .

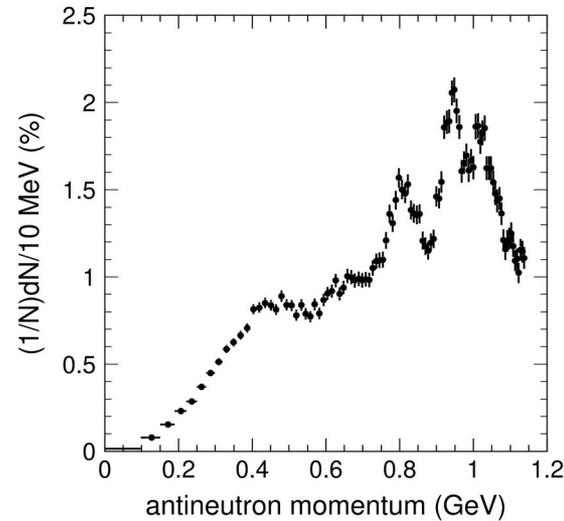
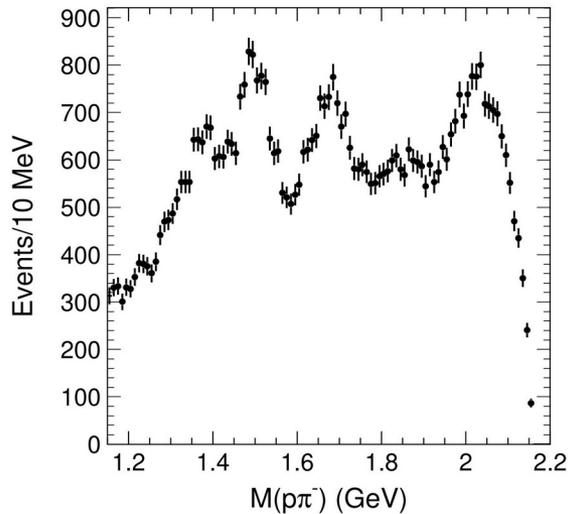
- previously \bar{n} from $\bar{p}p \rightarrow \bar{n}n$:
 BNL E-767, $100 < p_{\bar{n}} < 500$ MeV
 OBELIX, $50 < p_{\bar{n}} < 400$ MeV
 $\bar{n}N$ vs. $\bar{p}N$: $\bar{N}N$ annihilation w/o Coulomb corrections
 but in $\bar{p}p \rightarrow \bar{n}n$: low stats, $p_{\bar{n}}$ hard to control
- $J/\psi \rightarrow \bar{n}p\pi^-$ in BESIII:



Schematic diagram of $e^+e^- \rightarrow J/\psi \rightarrow p\pi^-\bar{n}$, followed by \bar{n} interaction with a proton in the beam pipe material, $\bar{n}p \rightarrow \pi^+\pi^+\pi^-\pi^0$, $\pi^0 \rightarrow \gamma\gamma$.

BESIII:

$$0 < p_{\bar{n}} < 1174 \text{ MeV}$$



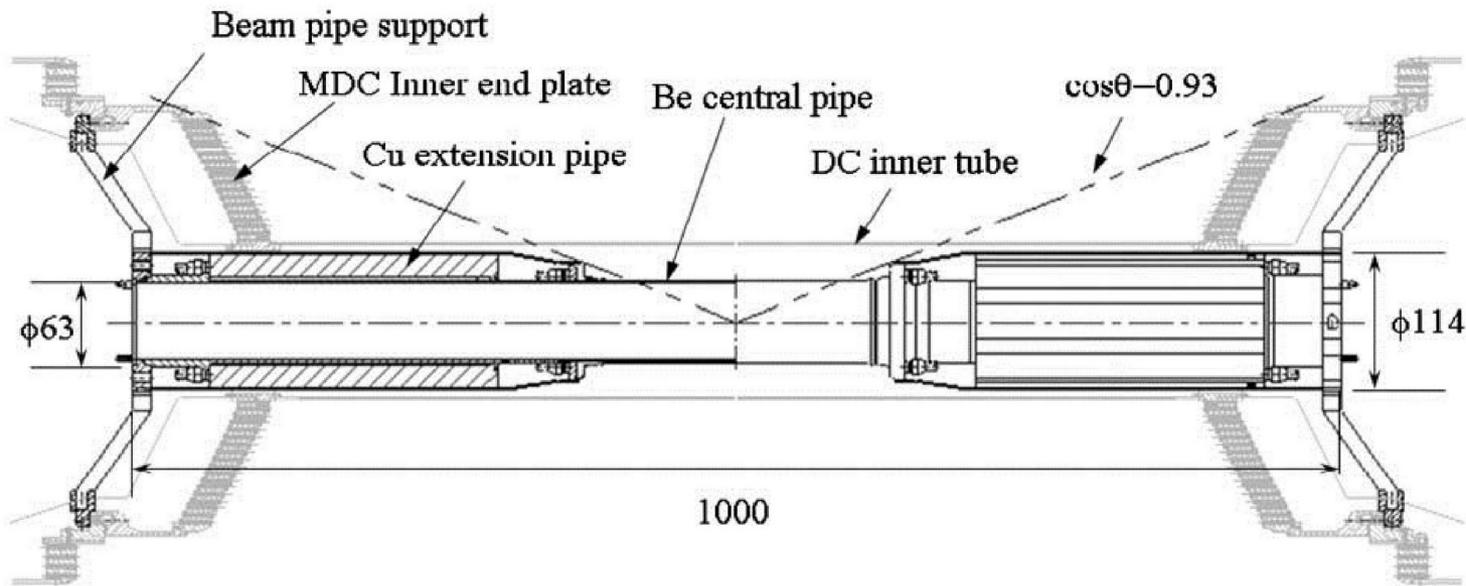
Invariant mass distribution of $p\pi^-$ from $J/\psi \rightarrow p\pi^-\bar{n}$ selected from BES experiment (left), and the corresponding antineutron momentum distribution (fraction of events in 10 MeV/c) (right). The plots have been remade with data in Ref. [25].

$$\Delta|p_{\bar{n}}| < \text{few MeV} \quad \Delta(p_{\bar{n}} \text{ direction}) < \text{few mrad}$$

$$\sim 40\% \text{ tagging efficiency} \implies 8 \text{ million tagged } \bar{n}$$

under study now in BESIII

BESIII data already taken, but detector material close to the interaction point in the inner detector serves as effective Be and C targets.
 + can put other target material into current detector



Cross sectional view of the BESIII interaction region . The dimensions are in mm.

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

Hyperon and antihyperon sources from J/ψ decays

- Λ , $\Sigma^{+,-}$, $\Xi^{0,-}$ & $\bar{\Lambda}$, $\bar{\Sigma}^{-,+}$, $\bar{\Xi}^{0,+}$
 can be produced copiously in J/ψ decays & tagged like \bar{n}
 $c\tau \sim \text{few cm} \implies$ only some make it to beam pipe/MDC
 but surviving fraction significant

TABLE I: Hyperon and antihyperon production at BESIII. The yield of hyperons is the same as that of antihyperons, since particles and antiparticles are produced with the same rates in J/ψ (or $\psi(2S)$) decays via strong or electromagnetic interactions. p_{max} is the maximum momentum of the antihyperon, n_{BP}^Y is the number of tagged antihyperons reaching the beam pipe; “—” means not available.

Antihyperon	$c\tau$ (cm)	decay mode	Branching Fraction ($\times 10^{-3}$)	p_{max} (MeV/c)	n_{BP}^Y ($\times 10^5$)
$\bar{\Lambda}$	7.89	$J/\psi \rightarrow \Lambda \bar{\Lambda}$	1.89	1074	26
		$J/\psi \rightarrow p K^- \bar{\Lambda}$	0.87	876	9
$\bar{\Sigma}^-$	2.40	$J/\psi \rightarrow \Sigma^+ \bar{\Sigma}^-$	1.50	992	4
		$J/\psi \rightarrow \Lambda \pi^+ \bar{\Sigma}^-$	0.83	950	1
$\bar{\Sigma}^+$	4.43	$J/\psi \rightarrow \Lambda \pi^- \bar{\Sigma}^+$	—	945	—
$\bar{\Xi}^0$	8.71	$J/\psi \rightarrow \Xi^0 \bar{\Xi}^0$	1.17	818	7
		$J/\psi \rightarrow \Xi^- \pi^+ \bar{\Xi}^0$	—	685	—
$\bar{\Xi}^+$	4.91	$J/\psi \rightarrow \Xi^- \bar{\Xi}^+$	0.97	807	3
		$J/\psi \rightarrow \Xi^0 \pi^- \bar{\Xi}^+$	—	686	—
$\bar{\Omega}^+$	2.46	$\psi(2S) \rightarrow \Omega^- \bar{\Omega}^+$	0.05	774	0.05
		$\psi(2S) \rightarrow K^- \Xi^0 \bar{\Omega}^+$	—	606	—

super J/ψ factory: plentiful source of \bar{n} and (anti)hyperons

- design $\mathcal{L} \gtrsim \mathcal{O}(100) \times$ current \mathcal{L} avail. at BESIII
specific proposals: STCF (Beijing), SCTF (Novosibirsk)
- detectors improvements vs. BESIII: tracking, particle id, γ detection
- 10^{12} J/ψ events/yr = $100 \times$ BESIII total dataset
- likely much more, due to accelerator & detector improvements
BEPCII: $\Delta E_{CM} @ J/\psi = 0.9$ MeV, vs. $\Gamma(J/\psi) = 93$ keV
proposed monochromator scheme: ΔE_{CM} much smaller
 \implies further dramatic increase in peak xsec
- expanded range of physics topics
via interchangeable custom targets inside the detector
- higher momenta of baryons & antibaryons from
asymmetric e^+e^- beams $\implies J/\psi$ in motion & $\psi(2S)$
- subdetector for specific final states, e.g. d , triton, heavier nuclei...

super J/ψ factory: cornucopia of quality beams

- traditional setups:
 - need many different kinds of beams
 - for different dedicated experiments
- need to share accelerator time among them,
require large manpower and funding
- in contrast,
 - here expts with different beams at same time
 - no additional infrastructure
 - minimal further investments