超级τ-Charm装置上的物理研究亮点及预研进展

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理论与实验联合专题研讨会, 2019年11月24日，暨南大学

Outline

超级τ-Charm装置

Super Tau Charm Facility (STCF)

- ✦ Selected Highlight topics & CDR
- ✦ Strategy & Prospect of Science-Technology Review
- ✦ Funding Status & Candidate sites
- ✦ Summary

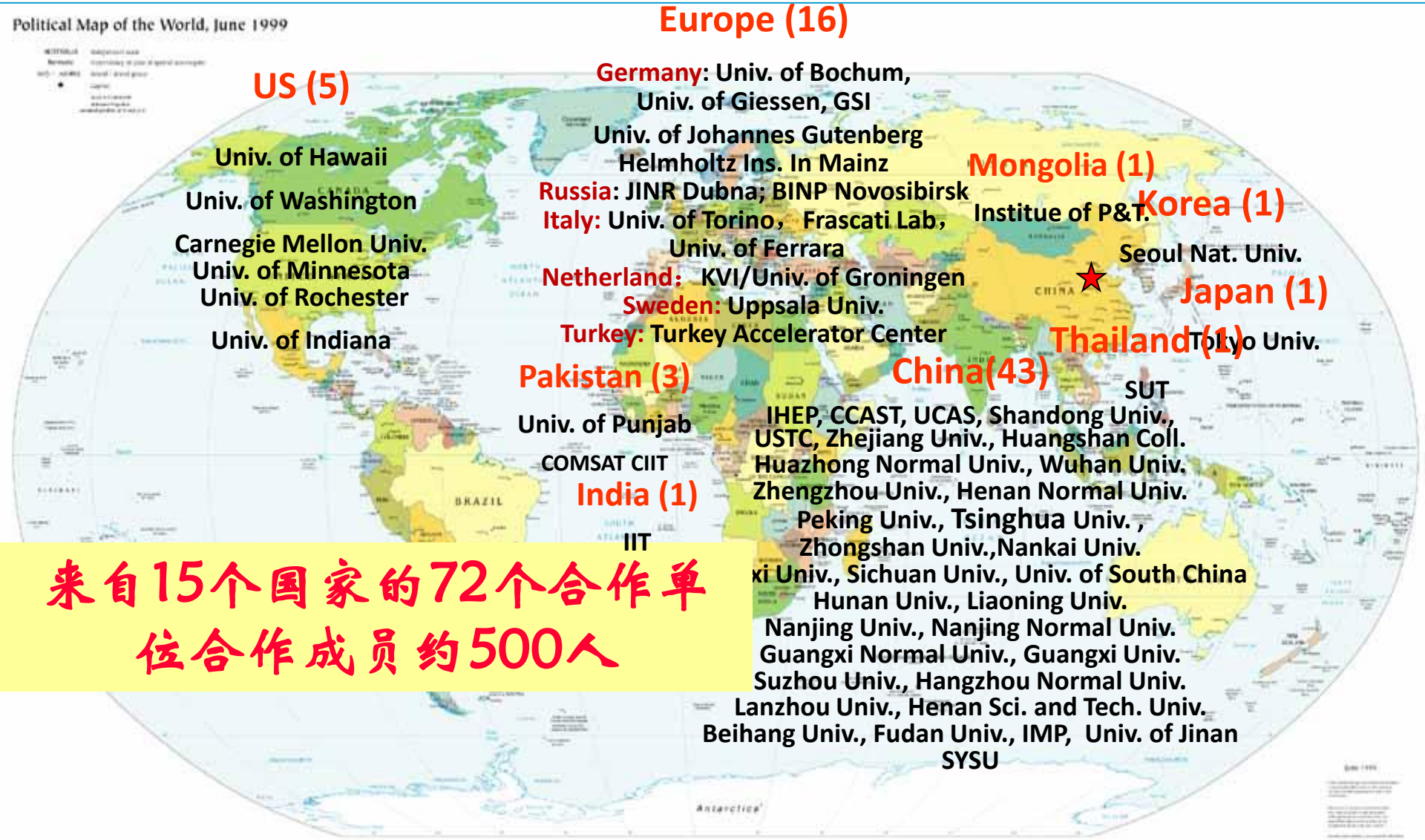
粲工厂 -- LHCb实验

- 强子对撞实验（粲强子产生截面巨大，能量Boost）
- ~3 fb^{-1}：60 x 10^{11} 个$c\underline{c}$，未来将 > 50 fb^{-1}
- 在长寿命带电径迹末态衰变中，优势巨大（电子末态除外）
- 部分重建 ⇒ 可重建ν（半轻衰变）
- 劣势：测量包含中性末态粒子γ, π^0的衰变道，电子末态，顶点不能太远

粲工厂 -- Belle/Belle-II实验

- 正负电子对撞实验（触发效率接近100%）
- Belle （亮度世界纪录：2.1 x 10^{34} 积分亮度： ~1000 fb^{-1}）：1.3 x 10^{9} 个粲介子
  - $c\underline{c}$的统计量少于LHCb，但多于BESIII
- 能量Boost ⇒ 粲强子衰变顶点重建
- Belle-II的亮度再提高了40倍！
- ISR ⇒ 对撞质心系能量覆盖τ-Charm能区

BESIII实验合作组



US (5)

Univ. of Hawaii

Univ. of Washington

Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester

Univ. of Indiana

Europe (16)

Germany: Univ. of Bochum,
Univ. of Giessen, GSI

Univ. of Johannes Gutenberg
Helmholtz Ins. In Mainz

Russia: JINR Dubna; BINP Novosibirsk

Italy: Univ. of Torino， Frascati Lab，
Univ. of Ferrara

Netherland: KVI/Univ. of Groningen

Sweden: Uppsala Univ.

Turkey: Turkey Accelerator Center

Mongolia (1)

Institue of P&T.

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Thailand (1)

SUT

Pakistan (3)

Univ. of Punjab

COMSAT CIIT

India (1)

IIT

China(43)

IHEP, CCAST, UCAS, Shandong Univ.,
USTC, Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
xi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Beihang Univ., Fudan Univ., IMP, Univ. of Jinan
SYSU

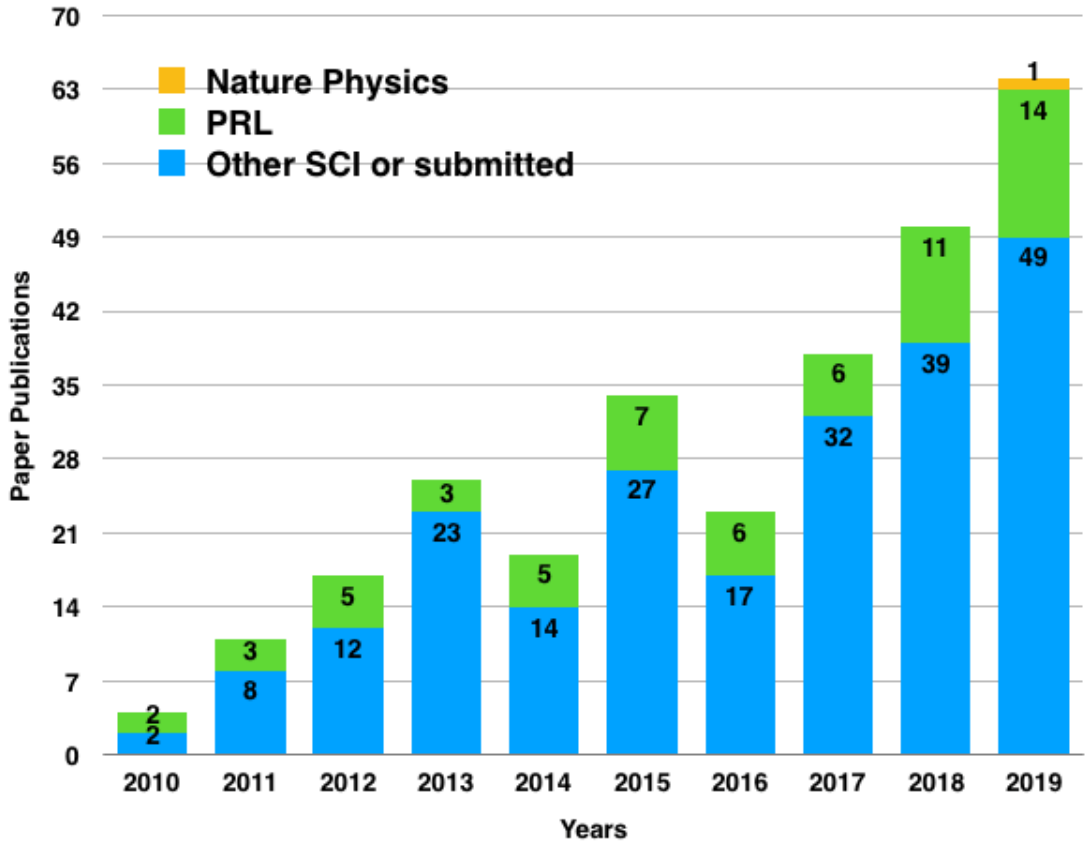
来自15个国家的72个合作单位合作成员约500人

BES实验的部分亮点

- τ质量测量
- R scan
- X(1835)
- Zc系列
- Λc产生衰变测量
- CKM & Decay constants & δ
- Polarization of Baryons in J/ψ
- …

Threshold

Publication of BESIII



Up to November, 2019: 286 publications, 62 PRL,

Excellent in both number and quality

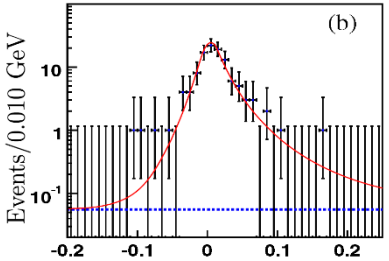
http://bes3.ihep.ac.cn/pub/physics.htm

~20 PhD / year

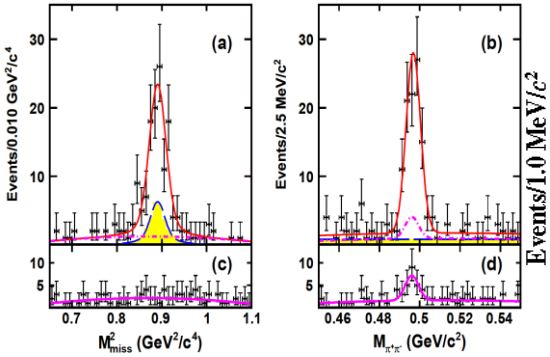
Λ_c 衰变相关的物理结果产出

基于BESIII实验35天采集的Λ_c数据，发表了16篇文章 (7 PRLs)
代表性成果如下：

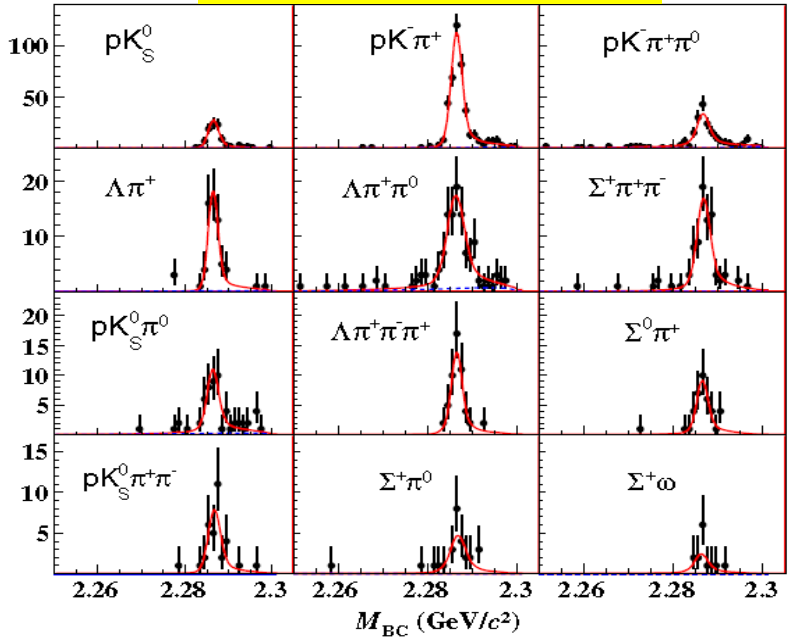
PRL,115,221805(2015)



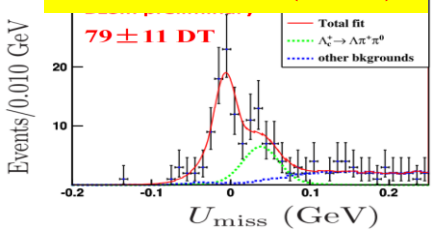
PRL 118, 112001 (2017)



PRL,116,052001) (2016)



PLB,767,42 (2017)



- 测量了一系列近20个衰变道的模型无关绝对分支比
- 刷新了实验测量精度 ⇒ BESIII实验为强子QCD理论工具的开发提供了重要的实验数据

分支比测量精度大幅度改善

PDG2014

$\Gamma(p\overline{K}^0\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_7/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.66±0.05±0.07	774	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(p\overline{K}^0\eta)/\Gamma(pK^-\pi^+)$ — Γ_8/Γ_2

Unseen decay modes of the η are included.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.25±0.04±0.04	57	AMMAR	95	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(p\overline{K}^0\pi^+\pi^-)/\Gamma(pK^-\pi^+)$ — Γ_9/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.51±0.06 OUR AVERAGE					
0.52±0.04±0.05	985	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$
0.43±0.12±0.04	83	AVERY	91	CLEO	e^+e^- 10.5 GeV
0.98±0.36±0.08	12	BARLAG	90D	NA32	π^- 230 GeV

$\Gamma(pK^-\pi^+\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_{10}/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.67±0.04±0.11	2606	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(pK^*(892)^-\pi^+)/\Gamma(p\overline{K}^0\pi^+\pi^-)$ — Γ_{11}/Γ_9

Unseen decay modes of the $K^*(892)^-$ are included.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.44±0.14	17	ALEEV	94	BIS2	nN 20–70 GeV

$\Gamma(p(K^-\pi^+)_{\text{nonresonant}}\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_{12}/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.73±0.12±0.05	67	BOZEK	93	NA32	π^- Cu 230 GeV

PDG2019

$\Gamma(pK^0_S\pi^0)/\Gamma_{\text{total}}$ — Γ_7/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
1.96±0.13 OUR FIT Error includes scale factor of 1.1.					
1.87±0.13±0.05	558	ABLIKIM	16	BES3	$e^+e^- \to \Lambda_c\overline{\Lambda}_c$, 4.599 GeV

$\Gamma(pK^0_S\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_7/Γ_2

Measurements given as a $\overline{K}^0$ ratio have been divided by 2 to convert to a K^0_S ratio.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.314±0.018 OUR FIT					
0.33 ±0.03 ±0.04	774	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(nK^0_S\pi^+)/\Gamma_{\text{total}}$ — Γ_8/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
1.82±0.23±0.11	83	ABLIKIM	17H	BES3	e^+e^- at 4.6 GeV

$\Gamma(p\overline{K}^0\eta)/\Gamma(pK^-\pi^+)$ — Γ_9/Γ_2

Unseen decay modes of the η are included.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.25±0.04±0.04	57	AMMAR	95	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(pK^0_S\pi^+\pi^-)/\Gamma_{\text{total}}$ — Γ_{10}/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
1.59±0.12 OUR FIT Error includes scale factor of 1.2.					
1.53±0.11±0.09	485	ABLIKIM	16	BES3	$e^+e^- \to \Lambda_c\overline{\Lambda}_c$, 4.599 GeV

$\Gamma(pK^0_S\pi^+\pi^-)/\Gamma(pK^-\pi^+)$ — Γ_{10}/Γ_2

Measurements given as a $\overline{K}^0$ ratio have been divided by 2 to convert to a K^0_S ratio.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.255±0.015 OUR FIT Error includes scale factor of 1.1.					
0.257±0.031 OUR AVERAGE					
0.26 ±0.02 ±0.03	985	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$
0.22 ±0.06 ±0.02	83	AVERY	91	CLEO	e^+e^- 10.5 GeV
0.49 ±0.18 ±0.04	12	BARLAG	90D	NA32	π^- 230 GeV

$\Gamma(pK^-\pi^+\pi^0)/\Gamma_{\text{total}}$ — Γ_{11}/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
4.42±0.31 OUR FIT Error includes scale factor of 1.5.					
4.53±0.23±0.30	1849	ABLIKIM	16	BES3	$e^+e^- \to \Lambda_c\overline{\Lambda}_c$, 4.599 GeV

$\Gamma(pK^-\pi^+\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_{11}/Γ_2

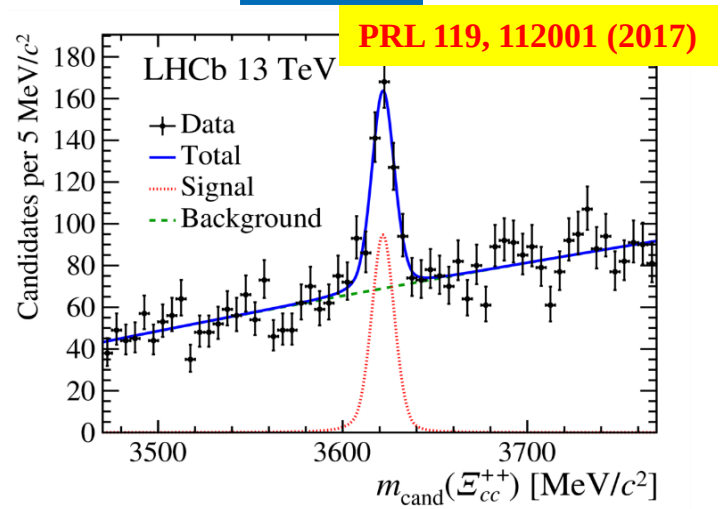
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT

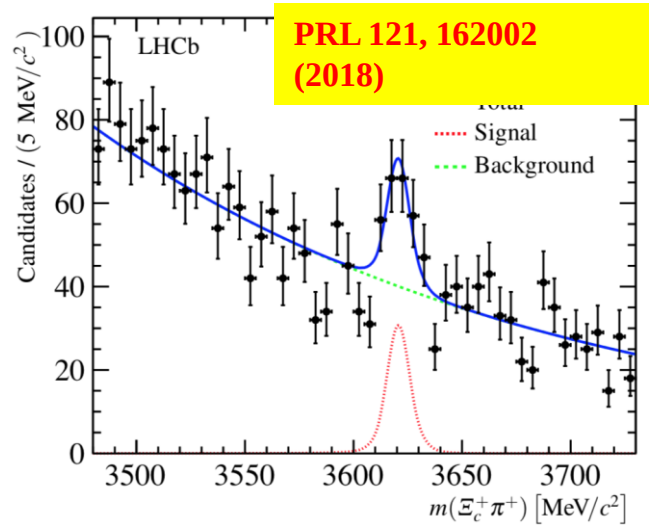
- BESIII的贡献使得多数分支比结果由相对测量改为绝对测量。
- BESIII对黄金道$\Lambda_c^+ \to pK\pi$的测量 ⇒ “模型依赖”变为“模型无关”。
- BESIII贡献发现了更多以前没发现的衰变道(比如含中子末态的衰变)。

Contributions to Ξ_{cc}^{++} observation

- LHCb observed Ξ_{cc}^{++} from $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_c^+ \pi^+$ decays
- Credits from theorists
  - $\tau(\Xi_{cc}^{++}) \approx 3\,\tau(\Xi_{cc}^{+})$ (Chang, Li, Wang, Karliner, et al.)
  - "Discovery channels of $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_c^+ \pi^+$ was predicted benefited from BESIII Λ_c^+ measurem,ents "

(FSY, Jiang, Li, Lyu, Wang, Zhao '17)

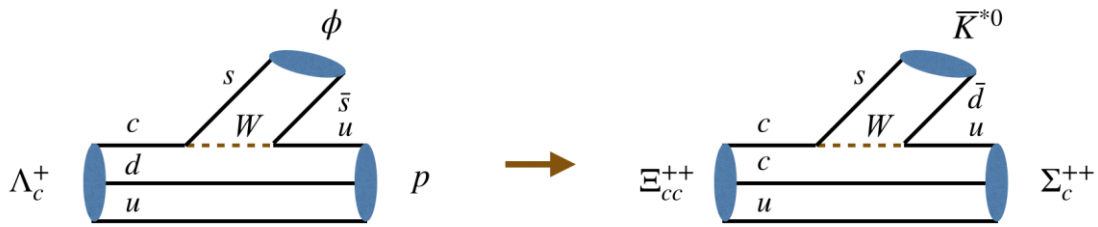




A theoretical Framework for Charmed Hadrons

- **Topological diagrams + Symmetries + Experimental inputs ⇒ to understand the decaying dynamics, predicting double-charm baryon decays, CPV, etc. (Chau, Cheng('80 – '86) ⇒ predictive power)**
  - **Λ_c^+ branching fractions used for global analysis**

    ⇒ $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_c^+ \pi^+$ are large enough for observation.



$Br(\Lambda_c^+ \to p\phi)/|V_{us}|^2$ = 2 % → $Br\left(\Xi_{cc}^{++} \to \Sigma_c^{++} \bar{K}^{*0}\right)$ = O(%)

↓

$\Xi_{cc}^{++} \to \Lambda_c^+ \pi^+ K^- \pi^+$

Large enough for observation

Λ_c^+ BFs from BESIII ⇒ Stronger predictive power

Some limitations for BEPCII/BESIII

- **BEPCII/BESIII have run 10 years, and are playing a leading role in tau-charm physics area.**
- **Limited by length of storage ring, no space and potential for the upgrade.**
- **Physics study limited by the Statistics (luminosity), CME ……**
- **Challenged by Belle II**
- **BEPCII/BESIII will end her mission in 4 - 6 years (?)**

A Super τ-charm Facility is the nature extension and a viable option for a post-BEPCII HEP project in China

Accelerator based project in China

Consensus in HEP community (about on accelerator based particle physics project)

http://www.ihep.cas.cn/xh/gnwlxh/zxdt/201609/t20160912_4661283.html

www.ihep.cas.cn/xh/gnwlxh/zxdt/201609/t20160912_4661283.html

bank 首页-中国科学院研究 科学网—构建全球华 Indico [BESIII] Particle Data Group 京东网上商城-综合网 BESIII DAQ WEB SE BESIII RUI

Welcome to High Energy Physics Association of China

当前位置：最新动态》中国物理学会高能物理分会关于基于加速器的中国高能物理未来发展的意见

中国物理学会高能物理分会关于基于加速器的中国高能物理未来发展的意见

中国物理学会高能物理分会第九届常务委员会第四次（扩大）会议

中国物理学会高能物理分会

关于基于加速器的中国高能物理未来发展的意见

2016年8月20日至21日，中国物理学会高能物理分会第六次战略研讨会在中国科学技术大学召开。2016年8月24日经过高能物理分会常务委员会议讨论，形成了关于基于加速器的中国高能物理未来发展的意见。

中国高能物理未来发展的可能选项有大型环型正负电子对撞机（CEPC： Circular Electron Positron Collider，它包括Higgs工厂和Z工厂）、高亮度正负电子加速器（HIEPA：High Intensity Electron Positron Accelerator ）。委员会对它们的前沿科学问题、技术先进性及在国际上的地位进行了深入分析和讨论。认为CEPC是我国未来高能加速器物理发展的首选项目。我国高能物理学界应该以CEPC作为发展战略目标，积极争取成为中国发起的国际大科学工程之一。在实现这一战略目标的过程中，要充分发挥和利用现有的BEPC的作用（包括升级改造及在该能区进一步发展），布置

最新

Division of High Energy Physics, Chinese Physics Society,

There are viable options for China's next big project in High Energy Physics :CEPC (includes a Higgs factory and a Z factory) and HIEPA.

the CEPC project is the top choice for future development in High-energy Accelerator Physics in China.

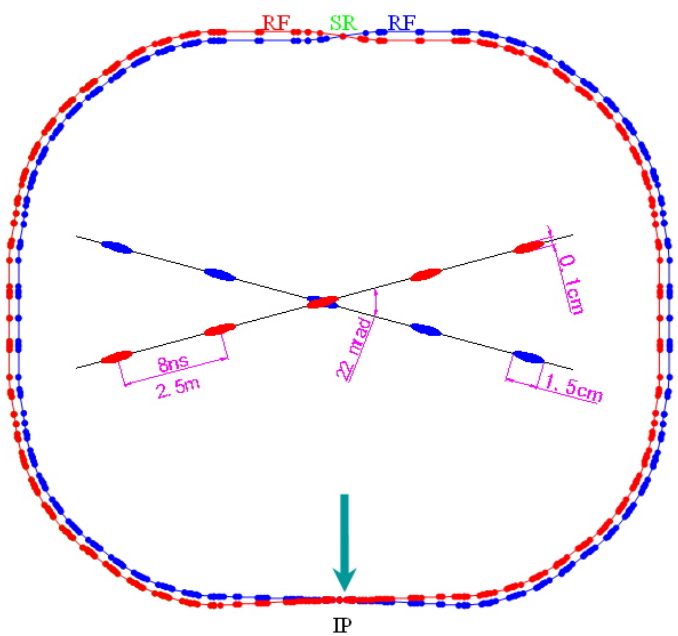
BEPCII vs STCF

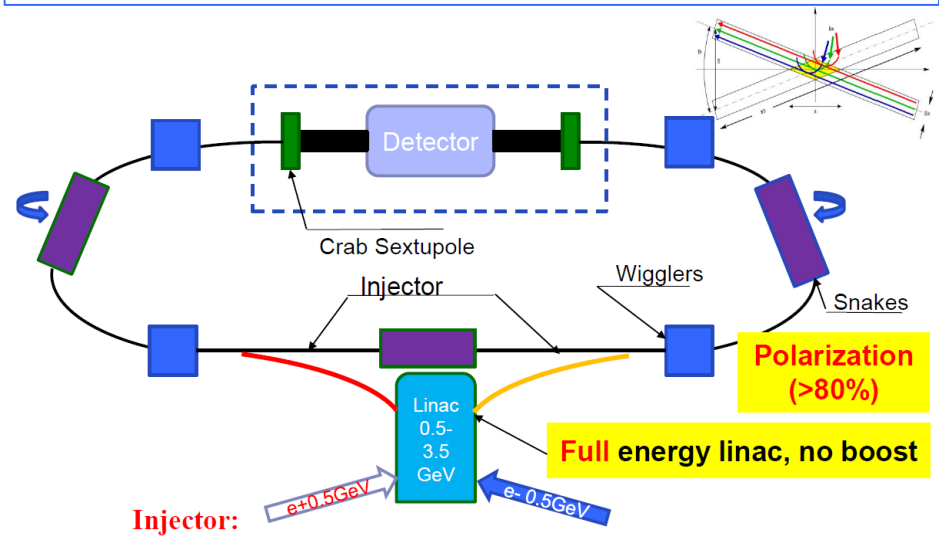
BEPCII

- **Peak luminosity 0.6-1×10^{33} $cm^{-2}s^{-1}$ at 3.773 GeV**
- **Energy range E_{cm} = 2 – 4.6 GeV**
- **No Polarization**

Designed STCF

- **Peak luminosity 0.5-1×10^{35} $cm^{-2}s^{-1}$ at 4 GeV**
- **Energy range E_{cm} = 2–7 GeV**
- **Single Beam Polarization (Phase II)**





Injector:

- e+, a convertor, a linac and a damping ring, 0.5GeV
- e-, a polarized e- source, accelerated to 0.5GeV

Benchmark Processes

CME (GeV)	Lumi (ab^{-1})	samples	σ(nb)	No. of Events	remark
3.097	1	J/ψ	3400[1]	3.4×10^{12}	
3.670	1	$\tau^+\tau^-$	2.4	2.4×10^9	
3.686	1	$\psi(3686)$	640	6.4×10^{11}	
		$\tau^+\tau^-$	2.4	2.4×10^9	
		$\psi(3686) \to \tau^+\tau^-$		2.0×10^9	
3.770	1	$D^0\bar{D}^0$	3.6	3.6×10^9	
		$D^+\bar{D}^-$	2.8	2.8×10^9	
		$D^0\bar{D}^0$		7.9×10^8	Single Tag
		$D^+\bar{D}^-$		5.5×10^8	Single Tag
		$\tau^+\tau^-$	2.9	2.9×10^9	
4.040	1	$\gamma D^0\bar{D}^0$	1.3	1.3×10^9	$CP_{D^0\bar{D}^0} = +1$[3]
		$\pi^0 D^0\bar{D}^0$	2.7	2.7×10^9	$CP_{D^0\bar{D}^0} = -1$
		$D^{*+}\bar{D}^-$+c.c	4.0	4.0×10^9	
		$D^{*+}\bar{D}^{*-}$+c.c	2.0	2.0×10^9	
		$D_s^+D_s^-$	0.20	2.0×10^8	
		$D_s^+D_s^-$		2.3×10^7	Single Tag
		$\tau^+\tau^-$	3.5	3.5×10^9	
4.180	1	$\gamma D^0\bar{D}^0$	0.4	4.0×10^8	$CP_{D^0\bar{D}^0} = +1$
		$\pi^0 D^0\bar{D}^0$	0.8	8.0×10^8	$CP_{D^0\bar{D}^0} = -1$
		$D^{*+}\bar{D}^-$+c.c	1.0	1.0×10^9	
		$D_s^{+*}D_s^-$+c.c.	0.90	9.0×10^8	
		$D_s^{+*}D_s^-$+c.c.		1.3×10^8	Single Tag
		$\tau^+\tau^-$	3.6	3.6×10^9	
4.230	1	$D_s^{+*}D_s^{-*}$	0.4	4.0×10^8	
		$J/\psi\pi^+\pi^-$	0.085	8.5×10^7	
		$\tau^+\tau^-$	3.6	3.6×10^9	
		$\gamma X(3872)$	0.01[4]	1.0×10^7	
4.360	1	$\psi(3686)\pi^+\pi^-$	0.058	5.8×10^7	
		$\tau^+\tau^-$	3.5	3.5×10^9	
4.420	1	$\psi(3686)\pi^+\pi^-$	0.040	4.0×10^7	
		$\tau^+\tau^-$	3.5	3.5×10^9	
4.630	1	$\psi(3686)\pi^+\pi^-$	0.033	3.3×10^7	
		$\Lambda_c\bar{\Lambda}_c$	0.56	5.6×10^8	
		$\Lambda_c\bar{\Lambda}_c$		6.4×10^7	Single Tag
		$\tau^+\tau^-$	3.4	3.4×10^9	
4.0-7.0	3	300 points scan with 10 MeV step, 1 fb^{-1}/point			
> 5	2-7	several ab^{-1} high energy data, details dependent on scan results			

Search for CPV in hyperons:
$J/\psi \to \Lambda\bar{\Lambda}, \Xi^-\bar{\Xi}^+$

Semi-leptonic decay of D(test LFU):
$D \to \pi\mu\upsilon$

Leptonic decay of D_s(test LFU):
$D_s^+ \to \mu^+\upsilon_\mu, D_s^+ \to \tau^+\upsilon_\tau$

Search for CPV in τ lepton:
$\tau \to K^0\pi\nu$

Search for cLFV in τ lepton:
$\tau \to \gamma\mu$和$\tau \to \mu\mu\mu$

Collins effect at high energy:
ππ+inclusive, KK+inclusive

Highlight: Matter-Antimatter Asymmetry

CPV in K, B meson system ⇒ 1980, 2008 Nobel Prizes

2019 LHCb: CPV in D meson system!

What about CPV in Baryon & Lepton system?

CPV in Hyperon Decays

- In 1958, Okubo: CPV in hyperon-antihyperon allows ⇒ "Okubo effect"(Direct CPV) Phys. Rev. 109, 984 (1958).
- In 1959, Pais: extended Okubo's proposal to asymmetry parameters in Λ and $\underline{\Lambda}$ decays. Phys. Rev. Lett. 3, 242 (1959).
- In the '80s, a number of calculations were made. CKM predictions, CPV in Λ: $10^{-4} \sim 10^{-5}$
- One example: Phys. Rev. D34, 833 (1986).

PHYSICAL REVIEW D VOLUME 34, NUMBER 3 1 AUGUST 1986

Hyperon decays and *CP* nonconservation

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Xiao-Gang He and Sandip Pakvasa
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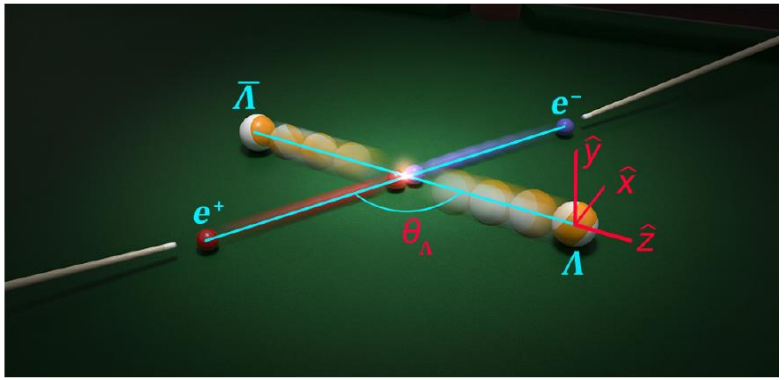
(Received 7 March 1986)

We study all modes of hyperon nonleptonic decay and consider the *CP*-odd observables which result. Explicit calculations are provided in the Kobayashi-Maskawa, Weinberg-Higgs, and left-right-symmetric models of *CP* nonconservation.

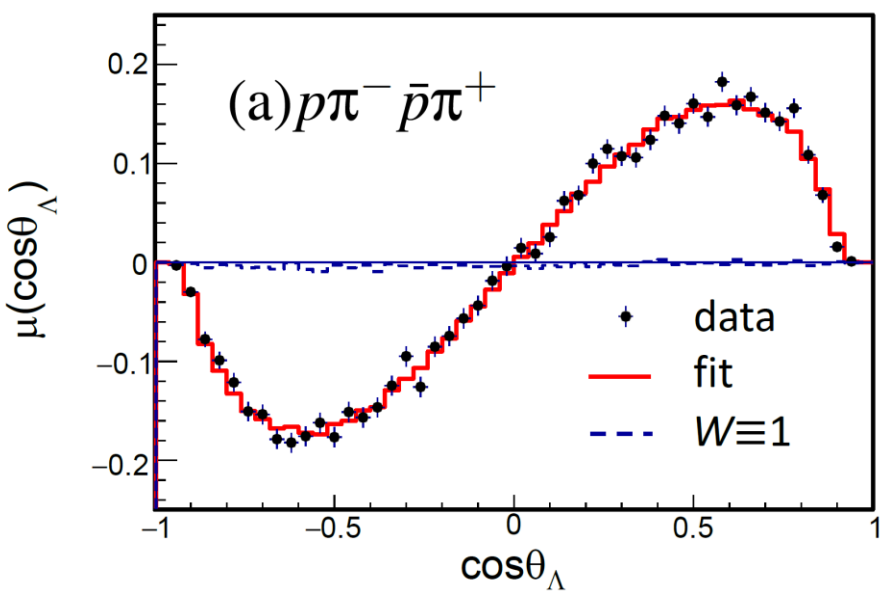
Spin polarization of Λ in $J/\psi \to \Lambda\bar{\Lambda}$



BESIII **Nature Physics**
arXiv:1808.08917

1.31 billion J/ψ events

Quantum correlation in Λ pair



Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [14]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)^\circ$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [16]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [16]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [16]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–

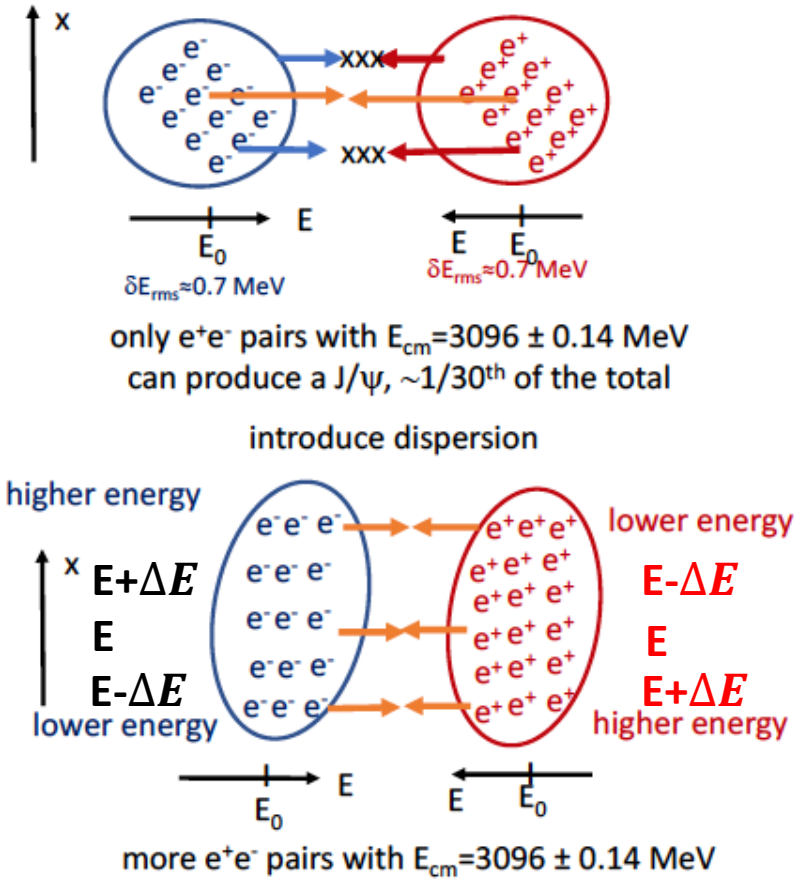
CP test

$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

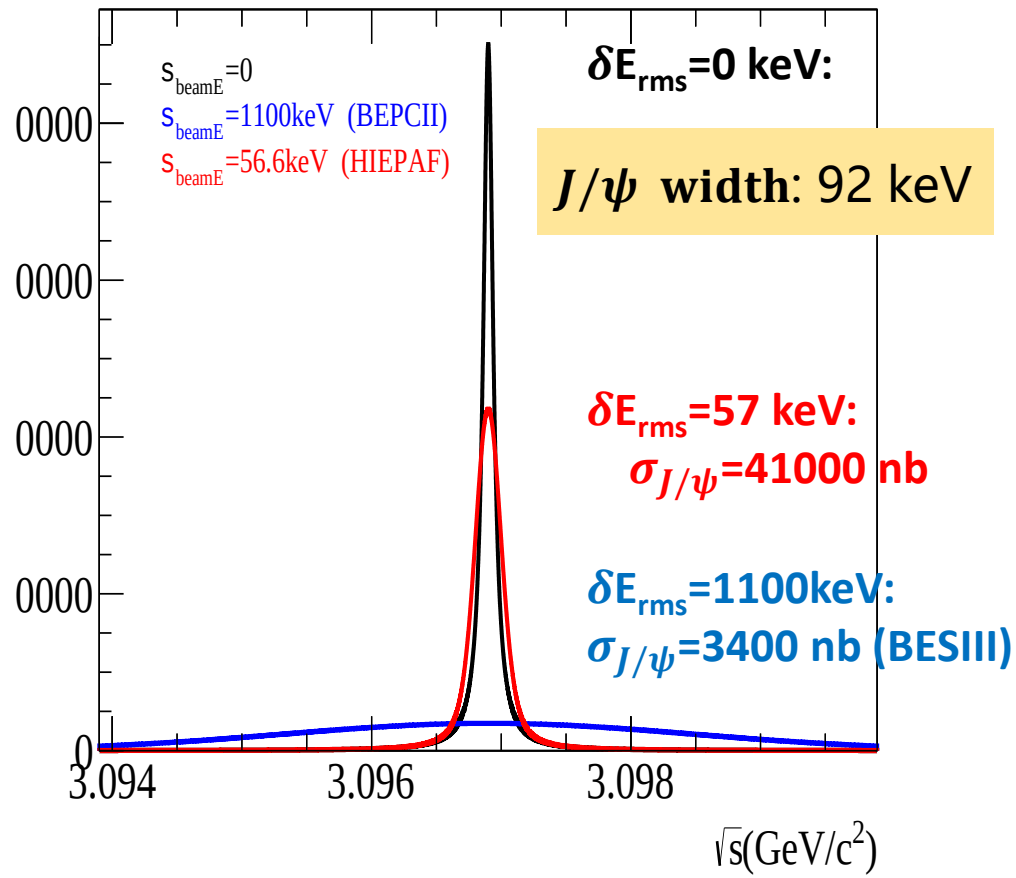
A_{CP} Sensitivities in STCF

- 4 trillion J/ψ events ⇒ $\Delta A_{CP} \sim 10^{-4}$
  - Luminosity optimized at J/ψ resonance
  - Luminosity of STCF: × 100
  - 1 – 2 years data taking
  - No polarization beams are needed
- Beam energy trick ⇒ small beam energy spread ⇒ J/ψ cross-section: × 10 ⇒ $\Delta A_{CP} \sim 10^{-5}$?
- Challenge: Systematics control
- Full simulation results are necessary!

Monochromatic collision



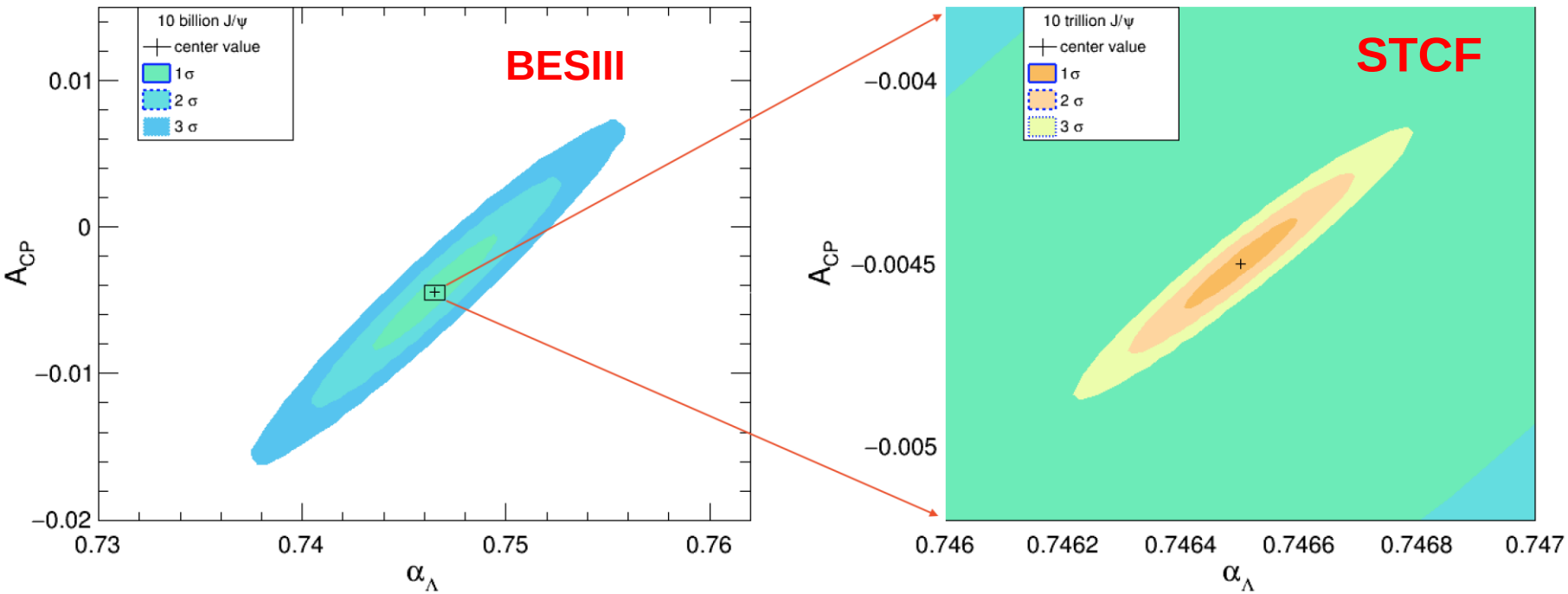
J/ψ production cross-section



Xiaoshuai Qin

Alexander Zholents
CERN SL/92-27/AP

A_{CP} VS. α_Λ



$A_{CP} = ??\ \pm 0.012 \pm 0.003$

BESIII: 1.3 billion result

τ Highlights

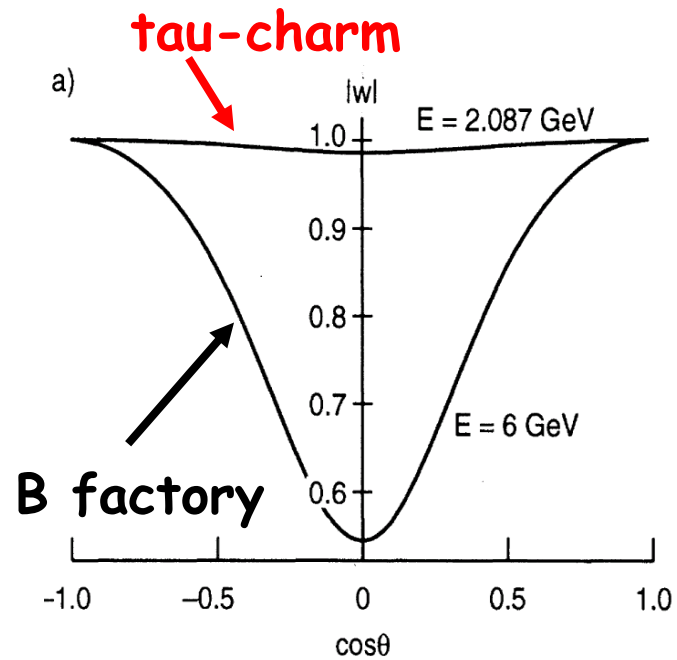
CPV in τ decays

- **Measurement on the angular CPV asymmetry is desirable**
- **Use T-odd rotationally invariant products in >=2 hadrons, such as**

  $\tau^- \to \pi^-\pi^0\nu_\tau / k^-\pi^0\nu_\tau$, $\tau^- \to \pi^-\pi^+\pi^-\nu_\tau / K^-\pi^+\pi^-\nu_\tau$: $P_2^\tau \cdot (\vec{P}_{\pi^+} \times \vec{P}_{\pi^0})$
- **Polarized of τ and beam are necessary**
- **Figure of Merits**

$$\begin{aligned} \text{merit} &= \text{luminosity} \times \bar{w}_Z \times \text{ total cross section} \\ &\propto \text{luminosity} \times (w_1 + w_2) \\ &\quad \times \sqrt{1-a^2}\,a^2(1+2a)\ , \end{aligned}$$

Y. S. TSAI, PRD 51 (1995) 3172



BESIII @ 4.25 ($10^{33}cm^{-2}s^{-1}$) FOM=1

STCF @ 4.25 ($10^{35}cm^{-2}s^{-1}$) FOM=100

SuperKEKB @ ($8x10^{35}cm^{-2}s^{-1}$) FOM=52

Experimental challenge:
reconstruction of τ (No secondary vertices)

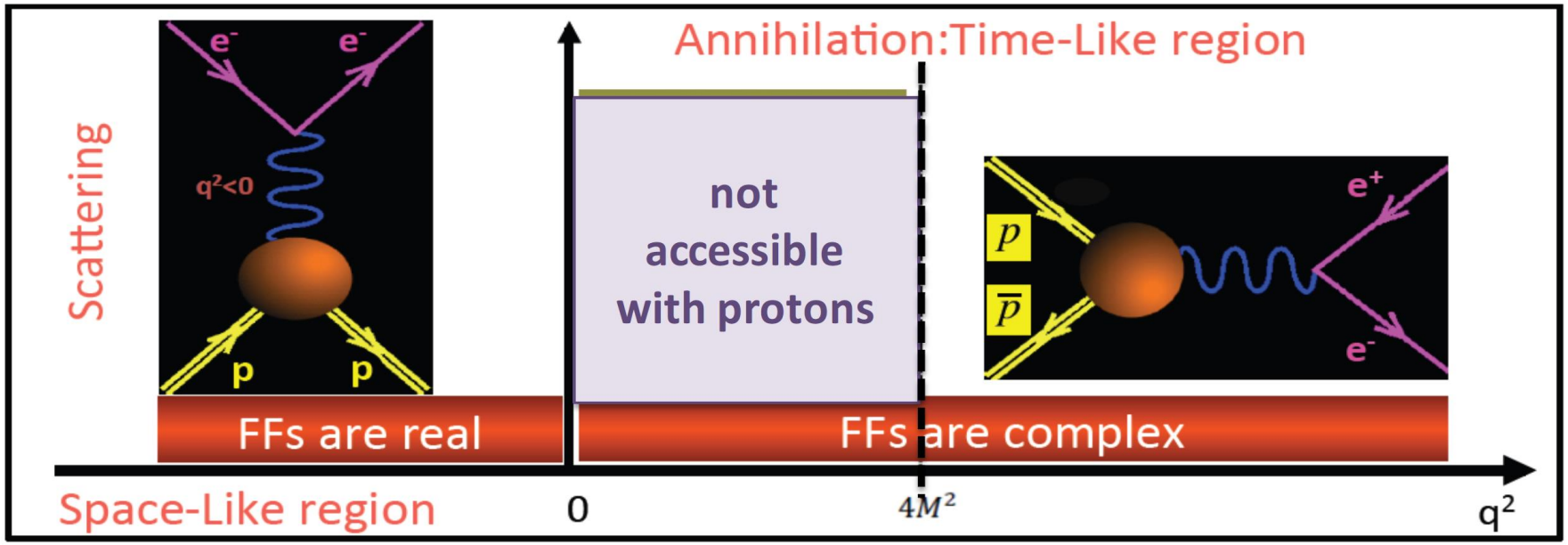
R/QCD Highlights

Baryon Form Factors

- for B=p: JLAB & e^+e^- are complementary

Crossing symmetry:

$$\langle N(p')|j^\mu|N(p)\rangle \rightarrow \langle \bar{N}(p')N(p)|j^\mu|0\rangle$$



$$J^\mu = \langle N(p')|j^\mu|N(p)\rangle = e\bar{u}(p')\left[\gamma^\mu F_1(q^2) + \frac{i\sigma^{\mu\nu}q_\nu}{2M}F_2(q^2)\right]u(p)$$

Fermi & Dirac form factors

$e^+e^- \to p\bar{p}, n\bar{n}, \Lambda\bar{\Lambda}$ threshold

Integrated cross section:

$$\sigma_{p\bar{p}} = \frac{4\pi\alpha^2 \beta C}{3m^2} \left| G_{eff}(m_{p\bar{p}}) \right|^2 (1 + 1/2\tau)$$

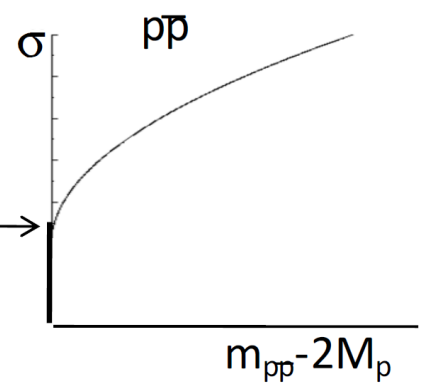
for $p\bar{p}$: $C = \dfrac{\pi\alpha/\beta}{1 - \exp(-\pi\alpha/\beta)} \to \dfrac{\pi\alpha}{\beta}$

Sommerfeld resummation factor

in point-like approx:

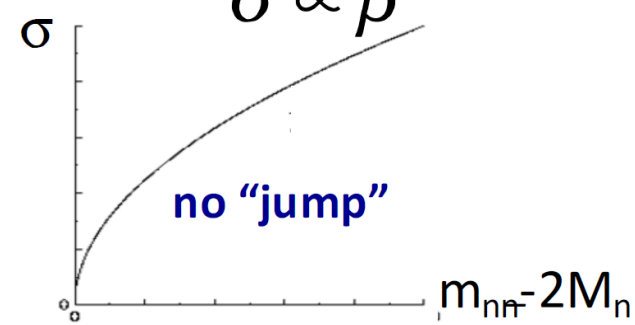
$$\sigma_0 = \frac{\pi^2\alpha^3}{2M_p^2} \left| G_{eff}(2M_p) \right|^2$$

$$\approx 0.85\text{nb} \left| G_{eff}(2M_p) \right|^2 \longrightarrow$$

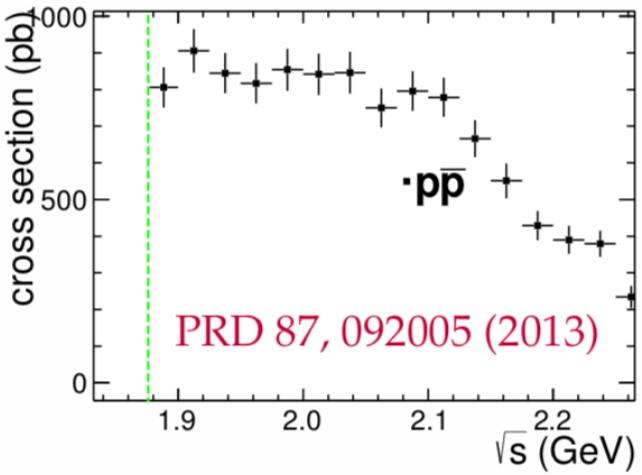


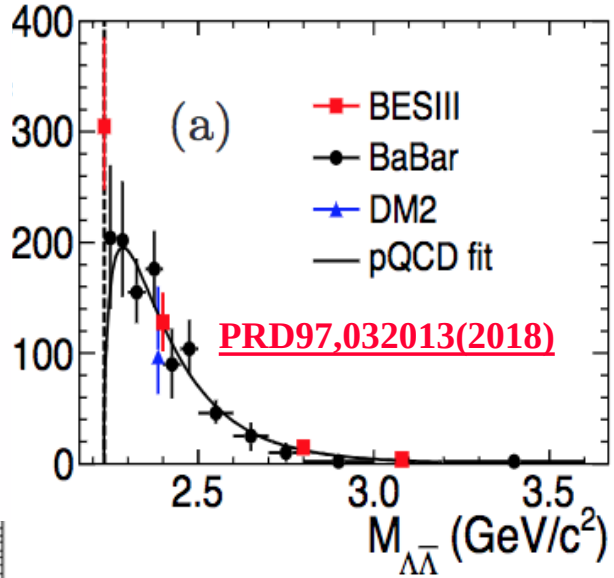
for $n\bar{n}$ ($\Lambda\bar{\Lambda}$): $C=1$

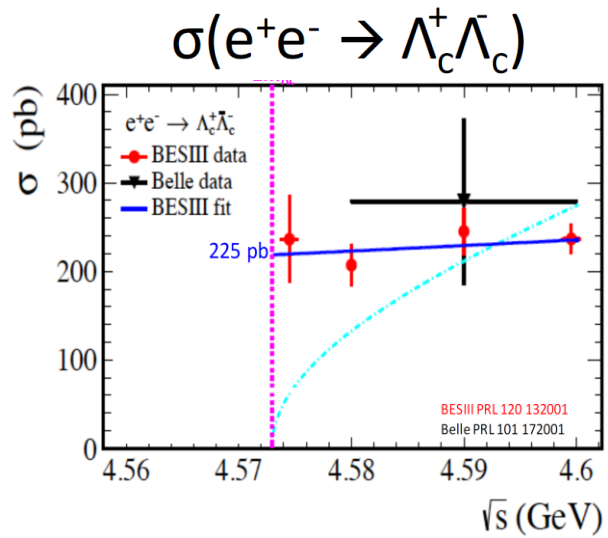
$$\sigma \propto \beta$$

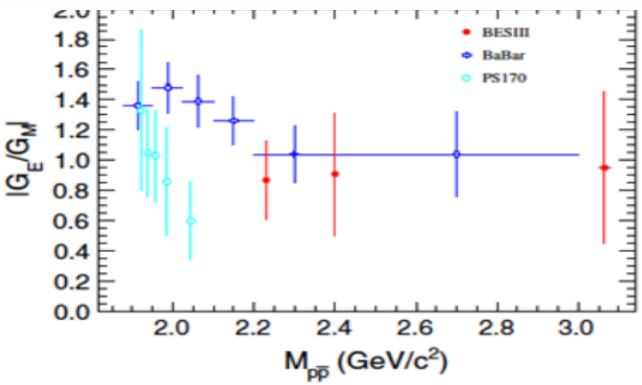


The threshold production of baryon pair





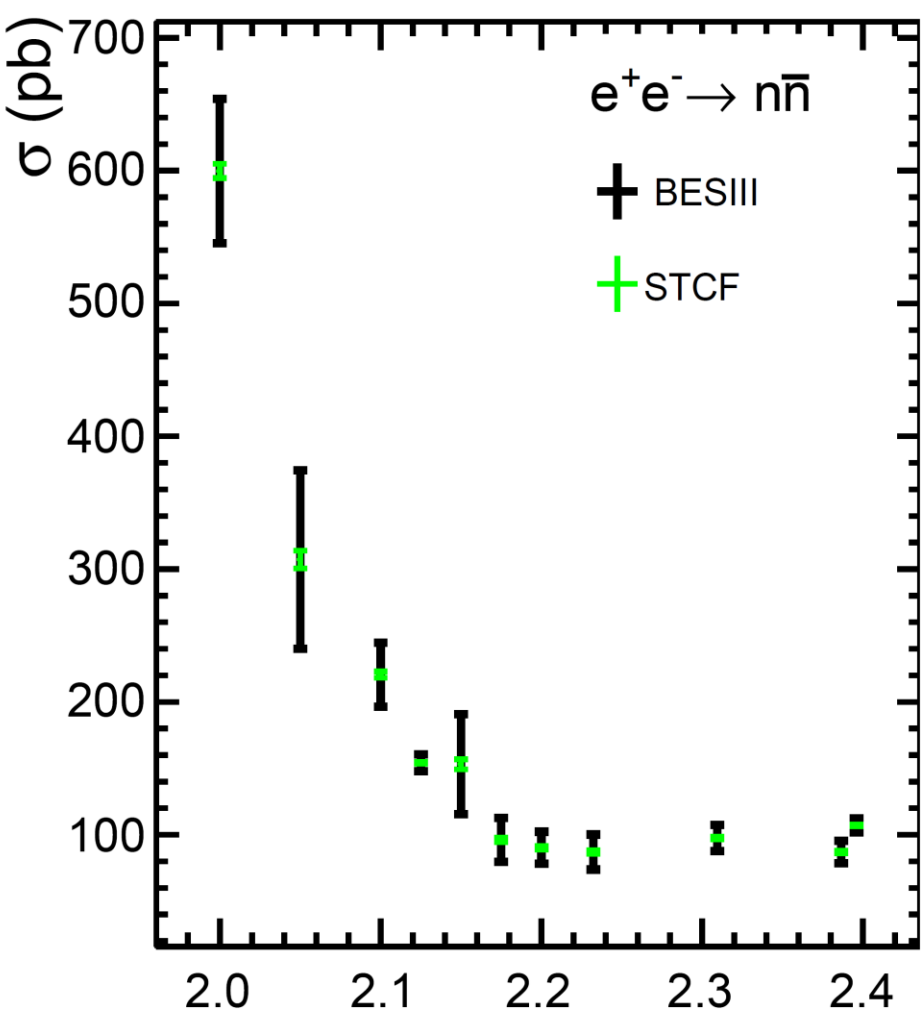


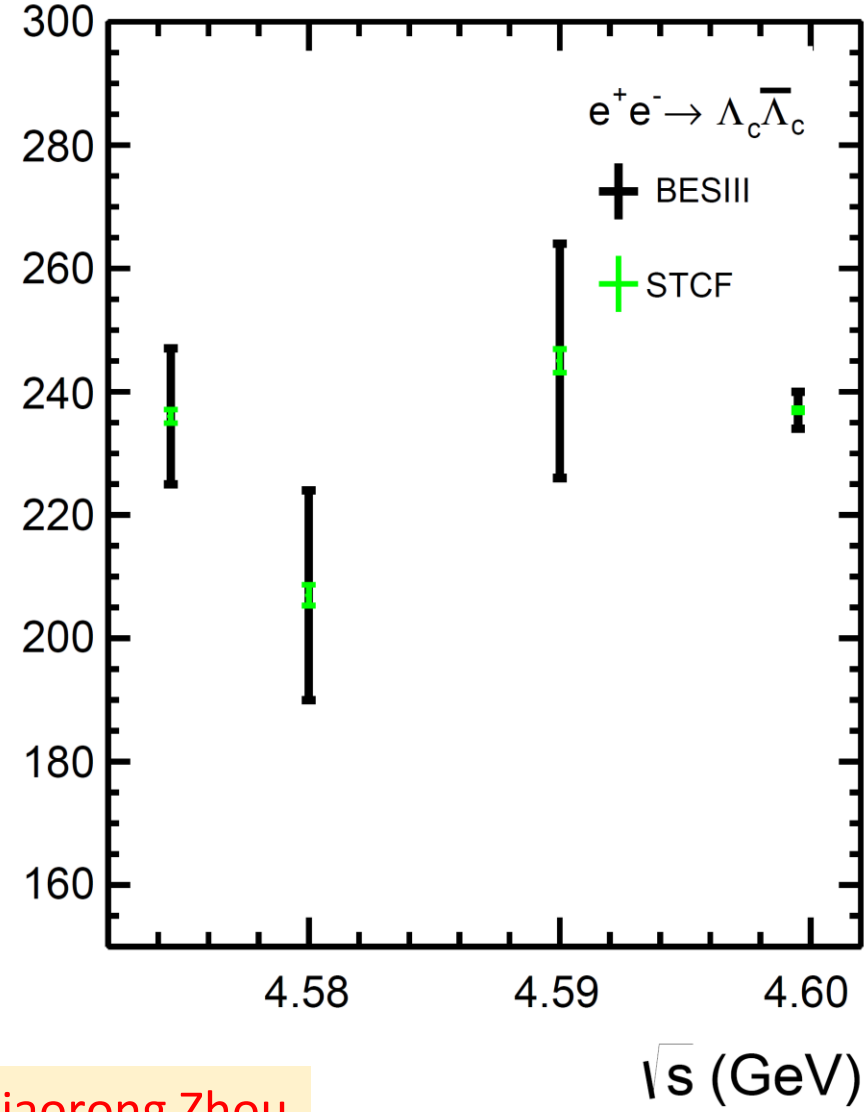


Form factor reflects spatial distributions of electric charge and current inside the nucleon

STCF: 100× more statistics will much enhance the understandings of these 'unexpected' threshold enhancement! (Study $e^+e^- \to p\bar{p}, n\bar{n}, \Lambda\bar{\Lambda}, \Sigma\bar{\Sigma}, \Xi\bar{\Xi}, \Omega\bar{\Omega}, \Lambda_c\overline{\Lambda_c}, \Sigma_c\overline{\Sigma_c}, \Xi_c\overline{\Xi_c}, \Omega_c\overline{\Omega_c}$ … @threshold)

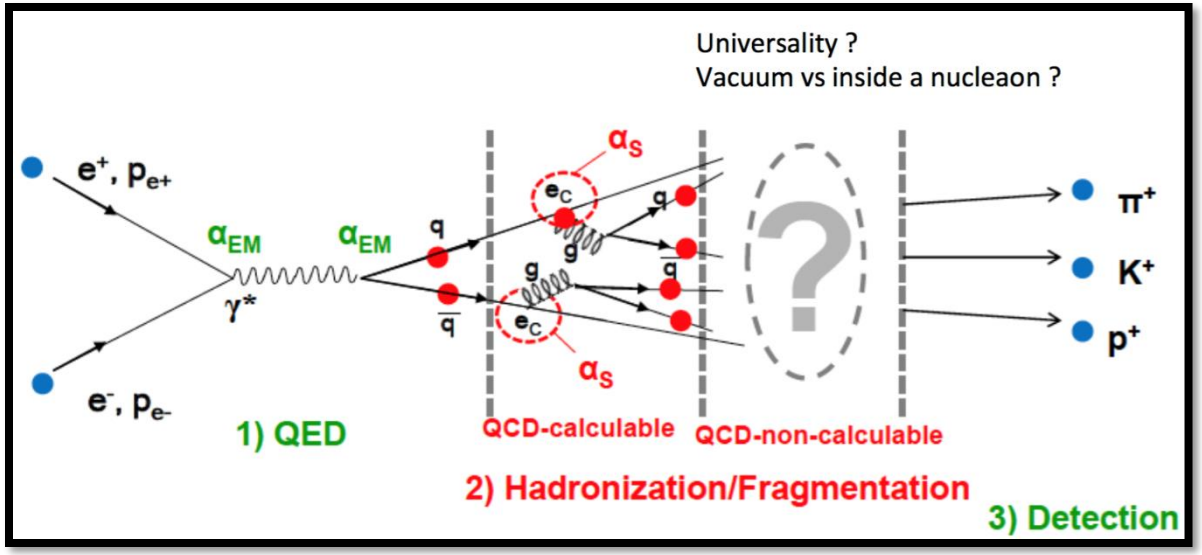
The threshold production of baryon pair





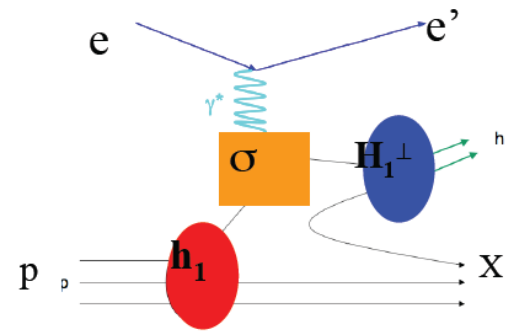
Xiaorong Zhou

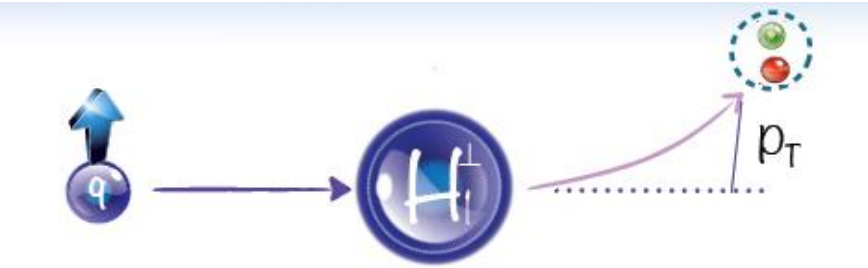
极化依赖的Collins碎裂函数测量



SIDIS

Transversity ⊗ Collins FF

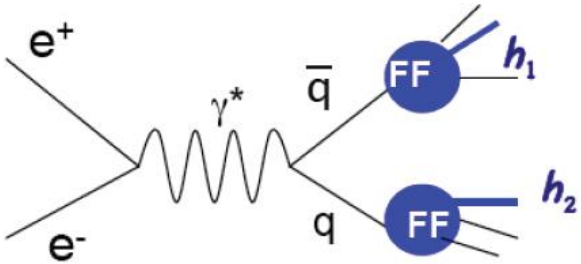




J. C. Collins, Nucl.Phys. B396, 161 (1993)

e+ e-

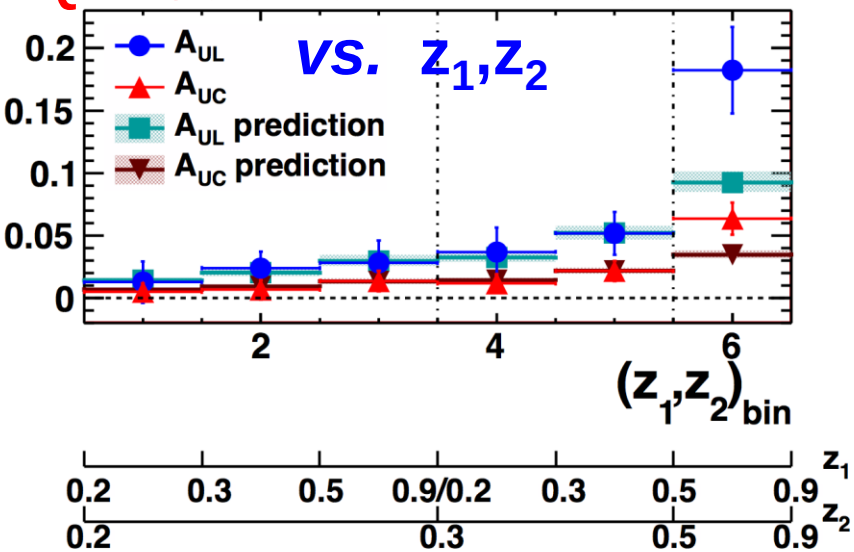
Collins FF ⊗ Collins FF

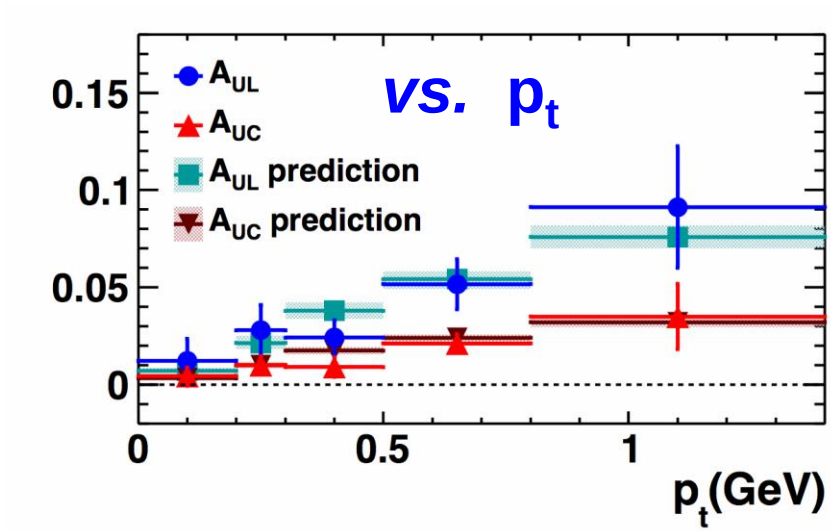


Collins effect at BESIII

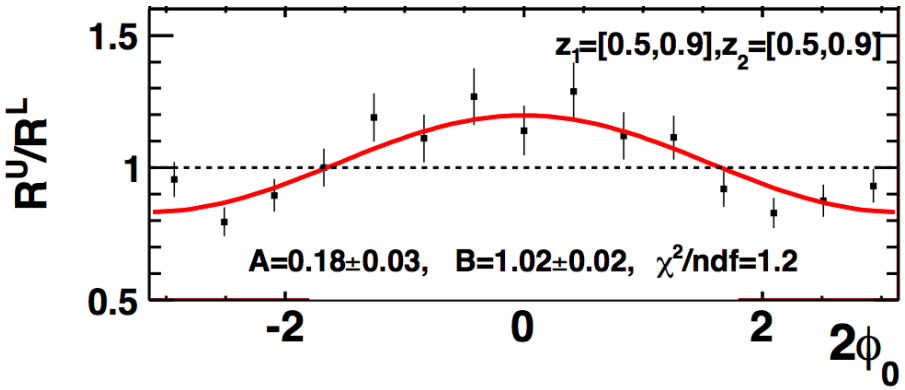
PRL 116, 042001 (2016)

First time measurement in Low Q^2~13GeV^2 at e+e- collision





A_{UL}, A_{UC} enote asymmetries for UL and UC ratios, respectively



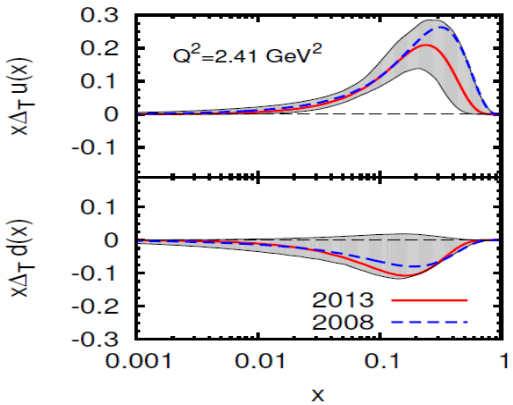
- ~62 pb $^{-1}$ @3.65GeV
  - Continuum region
- Nonzero Collins effect at BESIII
- Basically consistent with predictions from PRD 88. 034016 (2013) .
- important inputs for understanding the spin structure of the nucleon
- valuable to explore the energy evolution of the spin-dependent fragmentation function.

Global Analysis on Collins FF

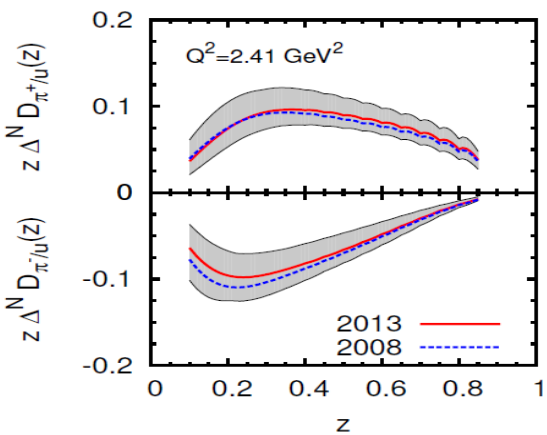
Anselmino et al., PRD 87, 094019 (2013)

Using data from HERMES, COMPASS, Belle

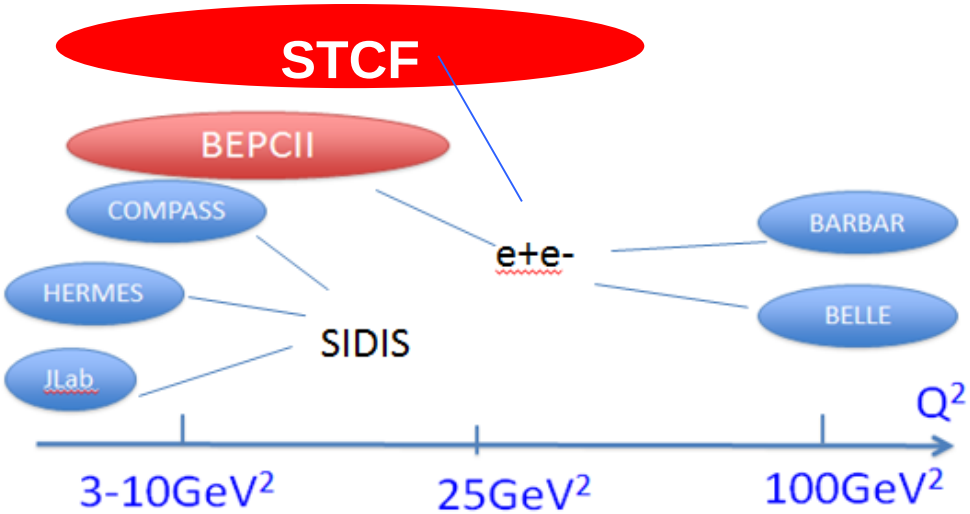
Transversity



Collins pion



- The Q^2 evolution of Collins FFs was assumed following the extrapolation in the unpolarized FF, and this has not been validated.
- Low Q^2 data from e^+e^- collider is useful.
- BEPCII / STCF
  - Similar Q^2 coverage with SIDIS in EicC

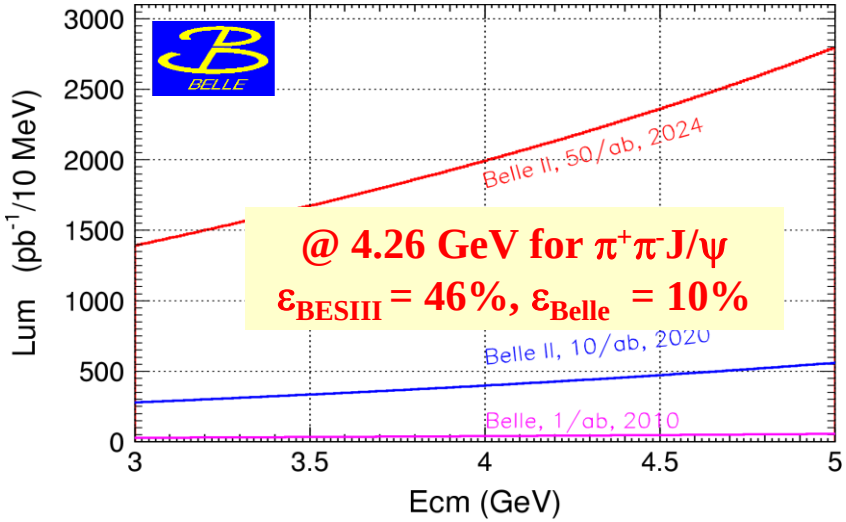


Highlights： Spectroscopy

Charmonium-Like Physics (XYZ)

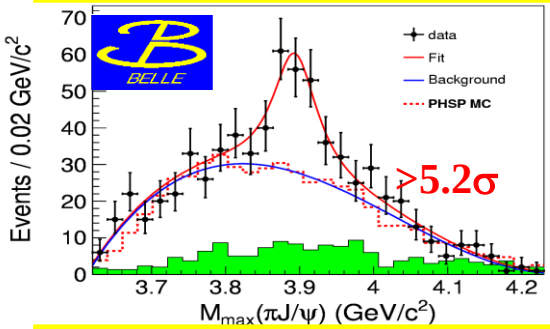
No challenge from Super KEKb/Belle II

- **τ-C Factory : $e^+e^- \rightarrow Y/\psi \rightarrow Z_c + X$**

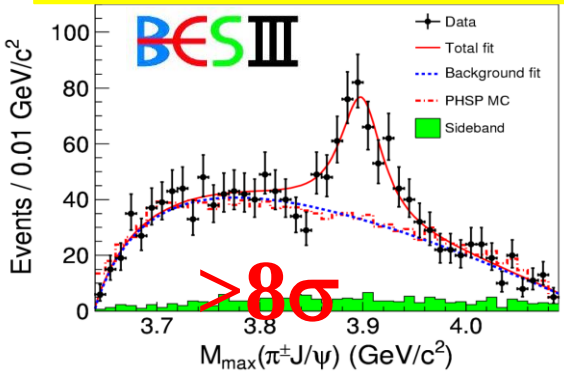


- **B Factory : ISR, B decay**

Belle with ISR: PRL110, 252002
967 fb^{-1} in 10 years running time



BESIII at 4.260 GeV: PRL110, 252001
0.525 fb^{-1} in one month running time



- **B factory : Total integrate effective luminosity between 4-5 GeV is 0.23ab^{-1} for 50 ab^{-1} data**
- **τ-C factory : scan in region 4-5 GeV, 10 MeV/step, every point have 20 fb^{-1}/year, 10 time of Belle II for 50 ab^{-1} data**
- **τ-C factory have much higher efficiency than B Factory**

Highlights on Charm Hadron?

- ✦Topological diagram framework?
- ✦Flavor physics & CPV in charm hadrons?
- ✦Any other idea?

STCF CDR status

Parameters and Plan of STCF

Parameters	Phase 1	Phase 2
Circumference/m	600-800	600-800
Optimized Beam Energy/GeV	2	2
Energy Range/GeV	1-3.5	1-3.5
Current/A	1.5	2
Emittance$(\varepsilon_x/\varepsilon_y)$/nm·rad	5/0.05	5/0.05
β Function @ IP (β_x^*/β_y^*)/mm	100/0.9	67/0.6
Collision Angle(full θ)/mrad	60	60
Tune Shift ξ_y	0.06	0.08
Hour-glass Factor	0.8	0.8
Luminosity/$\times 10^{35}$cm^{-2}s^{-1}	~0.5	~1.0
Dynamic Aperture	15σ	15σ
Total Lifetime	~1800s	~1800s

Basic Features:

Large Piwinski angle collision

+ crabbed waist

Siberia snake for polarization

Strategy :

(Phase 0) Pilot: 0.5×10^{35}

(Phase I) Nominal: 1.0×10^{35}

(Phase II) Polarized beam

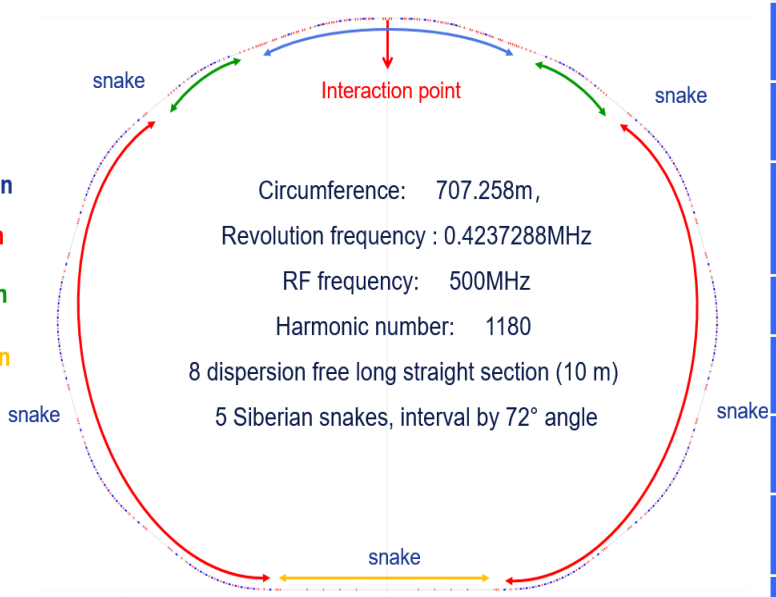
Final:

90% Polarization e-injection, 80% Polarization @IP

Upgrade: Polarized e+

Accelerator (Achieved Parameters)

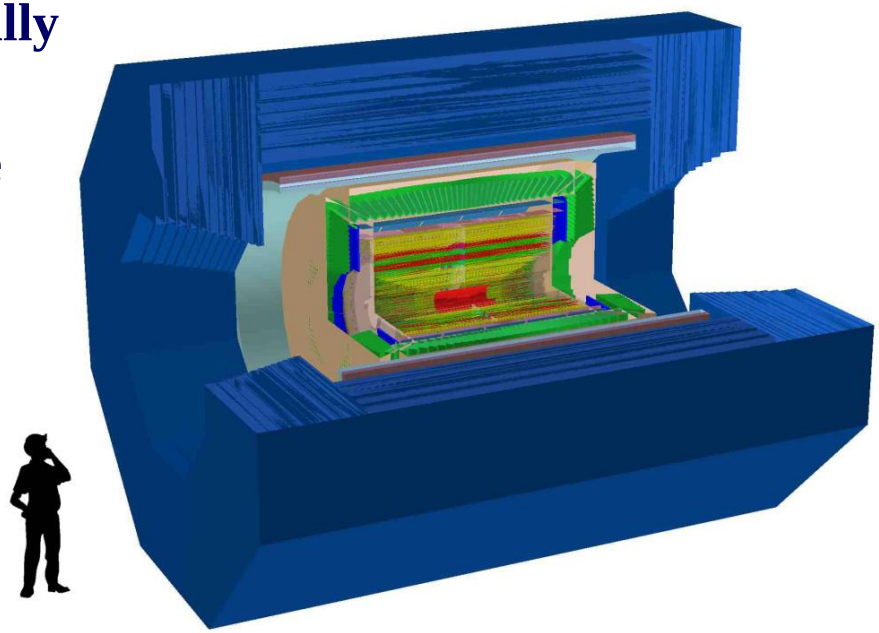
1. Interaction region
2. Long arc section
3. Short arc section
4. Technical section



Parameters	Phase 1
Circumference/m	~400
Beam Energy/GeV	2
Current/A	1.5
Emittance$(\varepsilon_x/\varepsilon_y)$/nm·rad	2.4/0.03
β Function @ IP (β_x^*/β_y^*)/mm	66.5/0.55
ν_x /υ_y	17.2/10.7
Collision Angle(full θ)/mrad	60
Tune Shift ξ_y	0.06 (goal)
Hour-glass Factor	0.8 (goal)
Luminosity/$\times 10^{35}$cm^{-2}s^{-1}	~0.8 estimated

Detector Layout and General Consideration

- Much larger radiation tolerance, especially at IP and forward regions
- Efficient event triggering, exclusive state reconstruction and tagging
- The Systematic uncertainty control
- Reasonable cost
- STCF Detector team has been formed. (Currently, USTC team is playing the leading role.)
- Lots of progress on Tracking, PID, EMC and Muon system R&D.
  - Tracking: Several Micro-Pattern Detector (DEPFET, MAPS, GEM/MicroMegas/ uRWELL) Technologies for inner tracking are testing.
  - PID: RICH/DIRC for Barrel and DIRC-like TOF for EndCap
  - EMC: CsI(Tl), CsI, BSO, PbWO4, LYSO
  - Muon Counter with precise timing (σ_T<80 ps, Space reolution ~0.6 mm)



Strategy & Activities

CDR → TDR → project application → construction → commissioning

- **Strategy: focus on CDR (2 years) and TDR (6 years) depend**

中国物理学会高能物理分会

第十届委员会常务委员会第三次会议纪要

[2019] 002

时　间：2019 年 3 月 1 日

地　点：高能所主楼 A418 会议室

主持人：王贻芳

出席常委：金山、刘建北、娄辛丑、王贻芳、岳崇兴、赵强、赵政国、郑阳恒、朱守华

特邀专家：彭海平

记　录：邱雯

二、 讨论报告框架中第四部分内容：我国牵头组织国际大科学的路线图

经过与会人员充分讨论，得出如下结论：

1. 大家一致同意 CEPC 项目最符合以我为主的国际大科学计划和大科学工程战略规划条件，这也符合中国高能物理长期战略研讨所形成的发展规划，即 CEPC 是我国未来高能加速器物理发展的首选项目，应该积极争取使其成为我国发起的国际大科学工程之一；基于以上这些考虑，本次国际大科学的培育推选 CEPC。

2. 大家一致同意支持 SCTF 的预研，虽然 SCTF 的建设规模要比 CEPC 小很多，但是作为我国高能实验物理在高亮度前沿的布局，积极开展项目预研是很有必要的，特别是该项目应该和 BEPCII 的升级改造相结合，充分挖掘其丰富的物理内容。建议由科大和国科大联合申请科学院先导 B，或申请科技部的重点研发计划来支持 STCF 的预研。

- **Regular weekly meetings for Accelerator/Detector Design!**

Activities

Workshop on Physics at Future High Intensity Collider @ 2-7GeV in China

13-16 January 2015
USTC
Asia/Shanghai timezone

Overview
Scientific Programme
Timetable
Contribution List
Author index
Registration
Registration Form
List of registrants

Tue 13/01 | Wed 14/01 | Thu 15/01 | Fri 16/01 | All days

Print | PDF | Full screen | Detailed view | Filter

08:00
Registration: Registration — USTC — 08:00 - 08:30
Welcome — USTC — 08:30 - 08:40
Introduction to Future High Intensity Collider @ 2-7 GeV in China — *Prof. Zhengguo ZHAO* — USTC — 08:40 - 09:05
09:00
XYZ from B factories [Belle, Babar] and prospects at BelleII — *Roman MIZUK* — USTC — 09:05 - 09:35
XYZ results from hadron colliders — *Dr. Liming Zhang ZHANG* — 09:35 - 10:05
10:05 - 10:25
Prof. Changzheng YUAN — 10:25 - 10:55
Frank NERLING — 10:55 - 11:25
Ce MENG — USTC — 11:25 - 11:55
12:00
LQCD results on hadron spectroscopy — *Ying CHEN* — USTC — 11:55 - 12:25

High Luminosity Tau Charm Physics

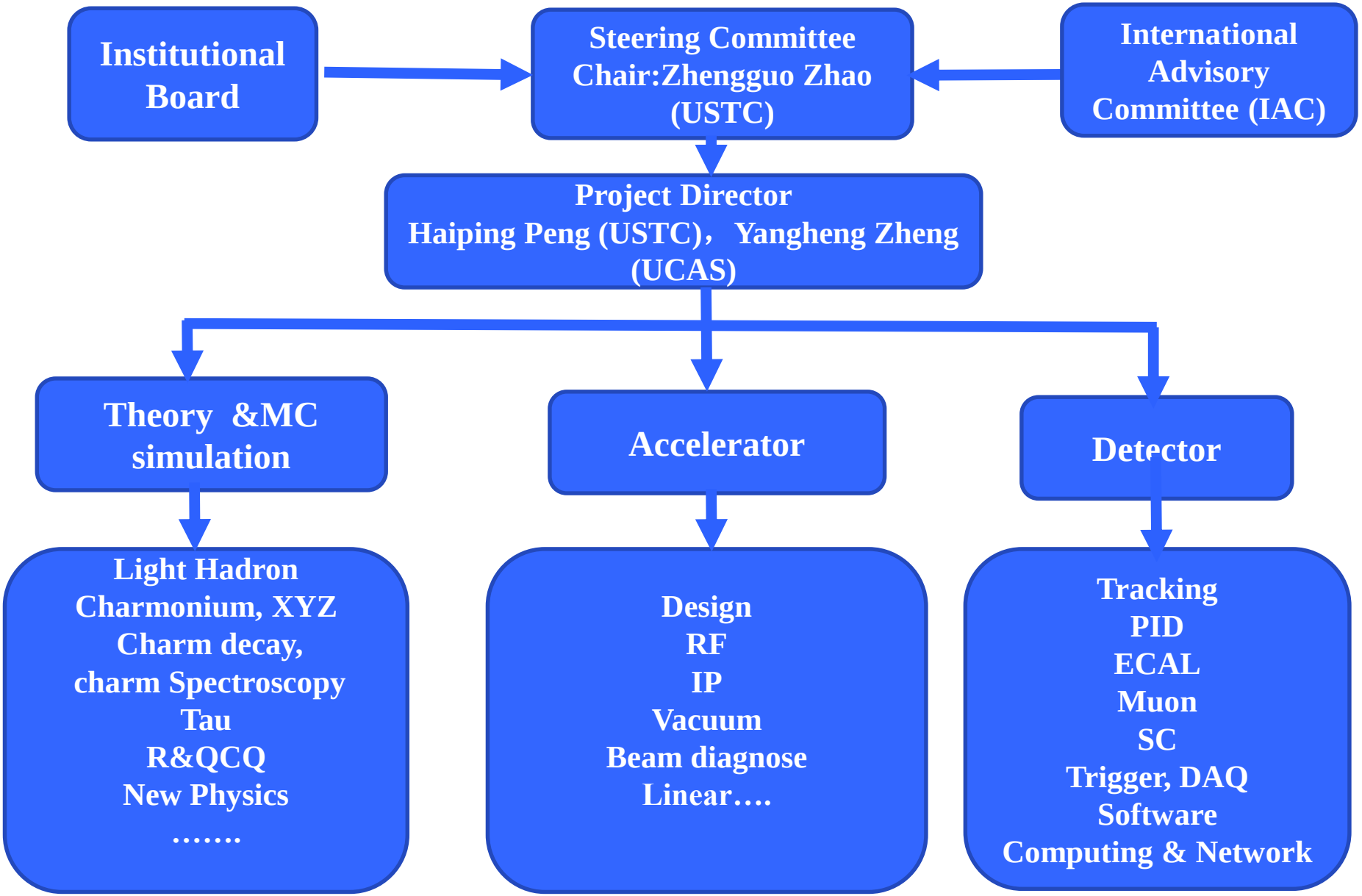
Indico for High Luminorcity Tau Charm Physics R&D

STCF Steering Committee	1 event	
STCF Accelerator	39 events	45
STCF Physics	17 events	
STCF Detector	135 events	141
STCF Accelerator-Detector Joint meetings	5 events	7
STCF International Conference	9 events	
STCF Domestic meeting	8 events	

USTC Scientific Committee Review

- **USTC president agreed, and scientific committee endorsed supporting R&D → 10 M RMB**

Organization



Tentative Plan & Estimated Budget

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030-2040	2041-2042
Form International Collaboration														
Conception Design Report (CDR)														
Technical Design Report (TDR)														
Construction														
Commissioning														
Upgrade														

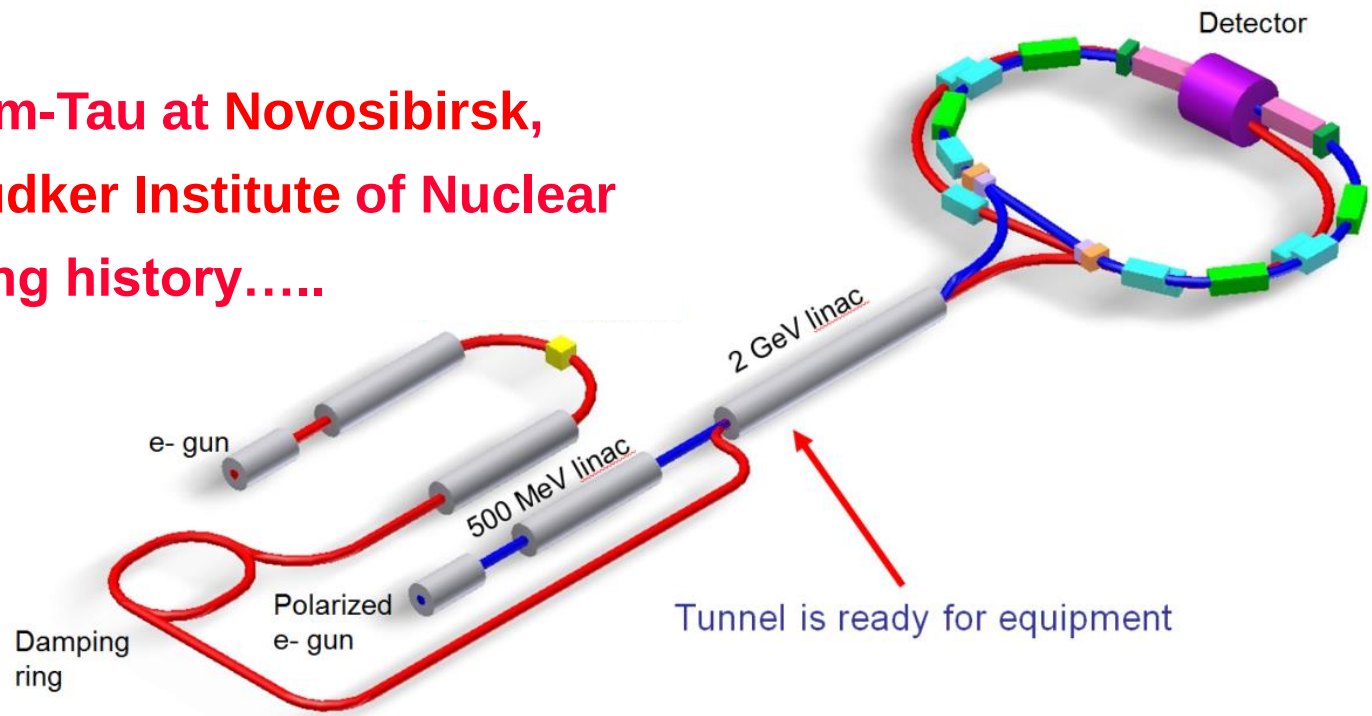
A unique precision frontier in the world for 30 years!

R&D budget: 200M RMB
Total budget: 4B RMB
(estimated in 2014)

单位：亿元	
eLinac	4.0+1.0 (阻尼环)
Electron ring	7.0
Positron ring	7.0
束线	1.2
实验谱仪	8.0
低温	1.0
配套设施	1.8
装置土建	6.0
不可预见	3.0
合计	40

International Collaboration

Super Charm-Tau at Novosibirsk, RUSSIA, Budker Institute of Nuclear Physics Long history…..



- **Pre-Agreement of Joint effort on R&D, details are under negotiation**
- **Joint workshop between China, Russia, and Europe**
  - **2018 UCAS (March), Novosibirsk (May), Orsay (December)**
  - **2019 …..**

Institutions shown Interest

- University of Science and Technology of China
- Institute of High Energy Physics, CAS
- Institute of Theoretical Physics, CAS
- Tsinghua University
- University of Chinese Academy of Sciences
- Shandong University
- Shanghai Jiaotong University
- Peking University
- Zhejiang University
- Nanjing University
- Nankai University
- Wuhan University
- Central China Normal University Lanzhou University
- University of Southern China
- Beijing University of Aeronautics and Astronautics
- SUN YAT-SEN UNIVERSITY
- …….
- Institute for Basic Science, Daejeon, Korea
- Dubna, Russia
- Budker Institute and Novosibirsk University, Russia
- T. Shevchenko National University of Kyiv, Kyiv, Ukraine
- University Ljubljana and Jozef Stefan Institute Ljubljana, Slovenia
- Jozef Stefan Institute Ljubljana, Slovenia

- **Stanford University, USA**
- **Wayne State University, USA**
- **Carnegie Mellon University, USA**
- **GSI Darmstadt and Goethe University Frankfurt, Germany**
- **Goethe University Frankfurt, Germany**
- **GSI Darmstadt, Germany**
- **Johannes Gutenberg University Mainz, Germany**
- **Helmholtz Institute Mainz, Germany**
- **LAL (IN2P3/CNRS and Paris-Sud University), Orsay, France**
- **Sezione di Ferrara, Italy**
- **L'Istituto di Fisica Nucleare di Torino, Italy**
- **L'Istituto di Fisica Nucleare di Firenze, Italy**
- **Scuola Normale Superiore, Pisa, Italy**
- **University of Silesia, Katowice, Poland**
- **Laboratori Nazionali di Frascati, Italy**
- **INFN, Padova, Italy**
- **University of Pavia, Pavia, Italy**
- **University of Parma, Italy**

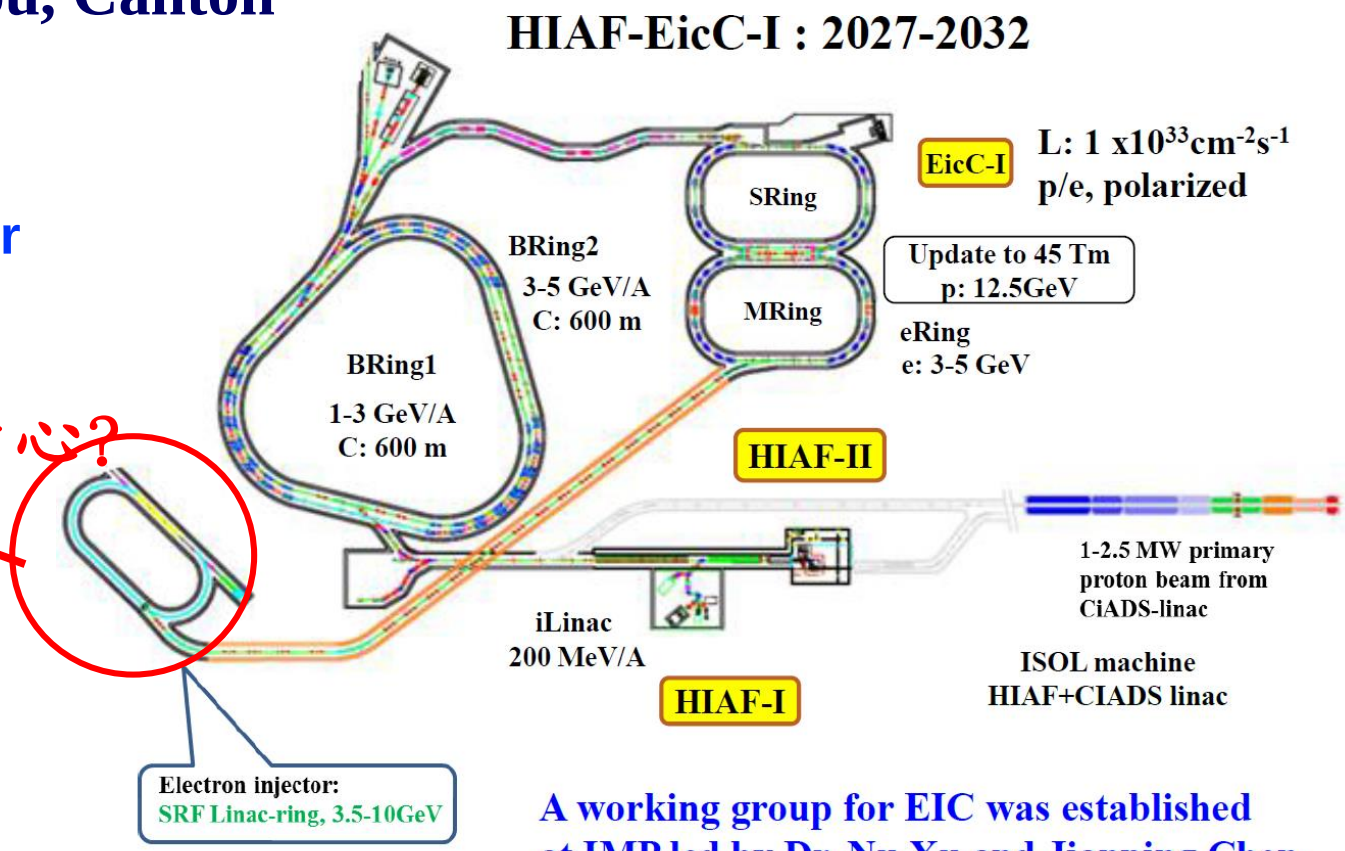
Conceptual Design Report

Candidate site 1: 广东

- Institute of Modern Physics, CAS, proposed building HIAF-EicC in Huizhou, Canton

STCF Share the design effort of the electron accelerator of EicC?

⇒ QCD 国家中心?

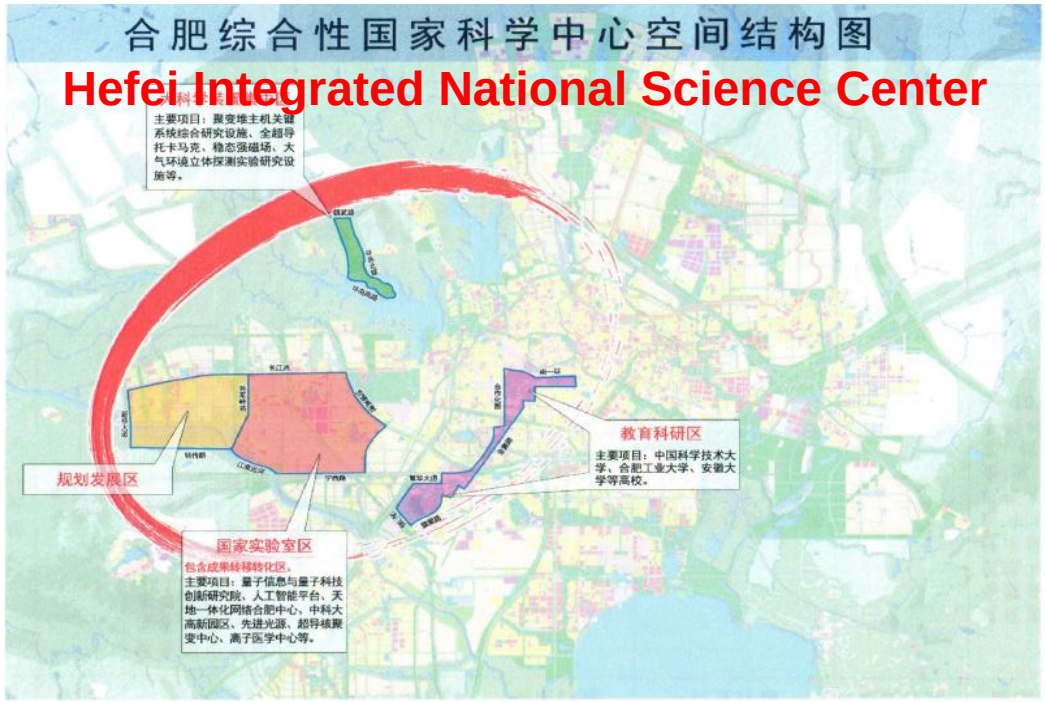


A working group for EIC was established at IMP led by Dr. Nu Xu and Jianping Chen.

- SUN YAT-SEN UNIVERSITY proposed building Southern Synchrotron Radiation light source in Canton

Candidate site 2: 安徽合肥

One of three integrated national science centers, which will play important role in 'Megascience' of China in near future



- ✦ **University of Science and Technology of China (USTC)**
- ✦ **National Synchrotron Radiation Lab and Hefei Light Source, operated by USTC**
- ✦ **The only National Lab operated by University in China. (Totally Four officially approved National Labs in China)**

- **Pay a lot of attention on accelerator facilities**
- **Hefei Advanced light source is under design**
- **STCF is listed in future plan**

Summary

- **Super τ-c Facility (STCF): nature extension and a viable option for a post-BEPCII project**
- **Status of STCF project in China:**
  - **Physics: Rich & unique for physics with c quark and τ leptons.**
  - **Detector & Electronics: Significant progress in R&D at USTC**
  - **Accelerator: Design group is formed and working hard, progress are ongoing. More experts are needed.**
  - **Funding: 10M RMB for initial R&D from USTC; More communication to CAS and Local governments**
  - **An international collaboration is under preparing**
- **Strategy & Plan**
  - **Complete CDR in 2 years, TDR in 6 years**
  - **Construction site: Currently open**

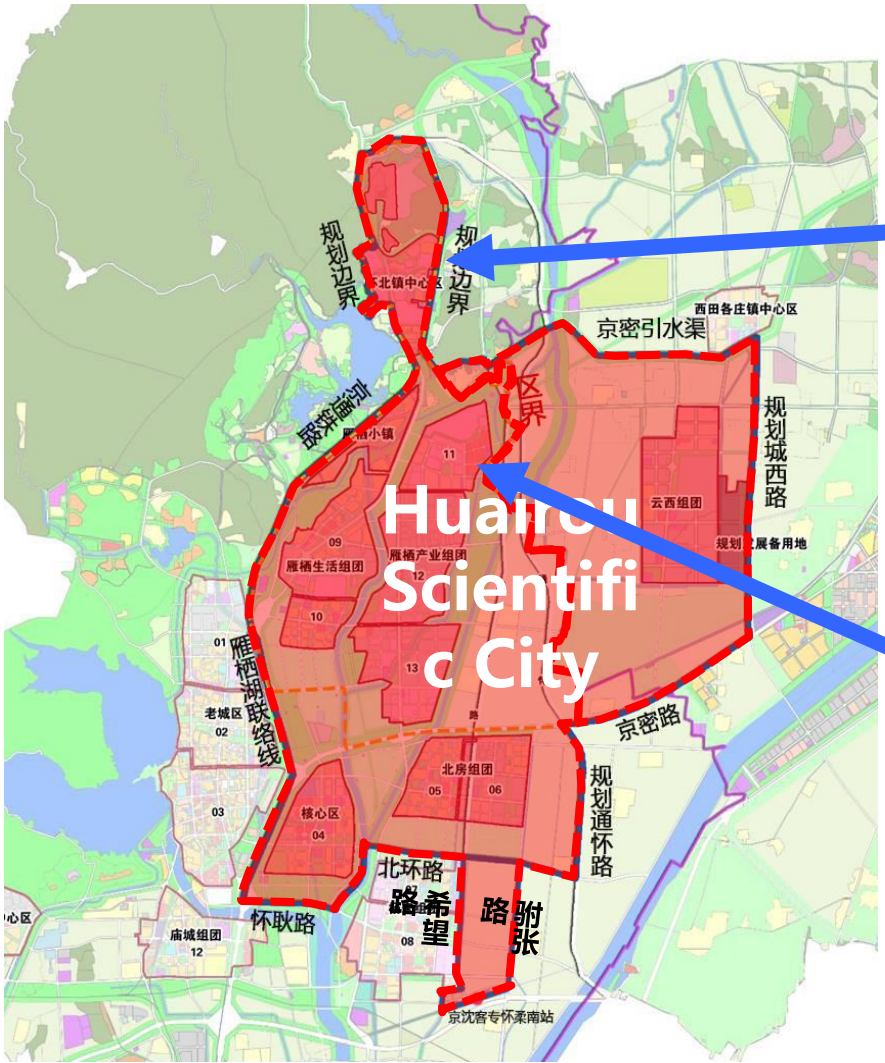
Welcome to join the effort

Thank you!

Backup Slides

Candidate site 3: 北京怀柔

- Planned Scientific City : 100.9 km^2 (One of three **integrated national science centers**)

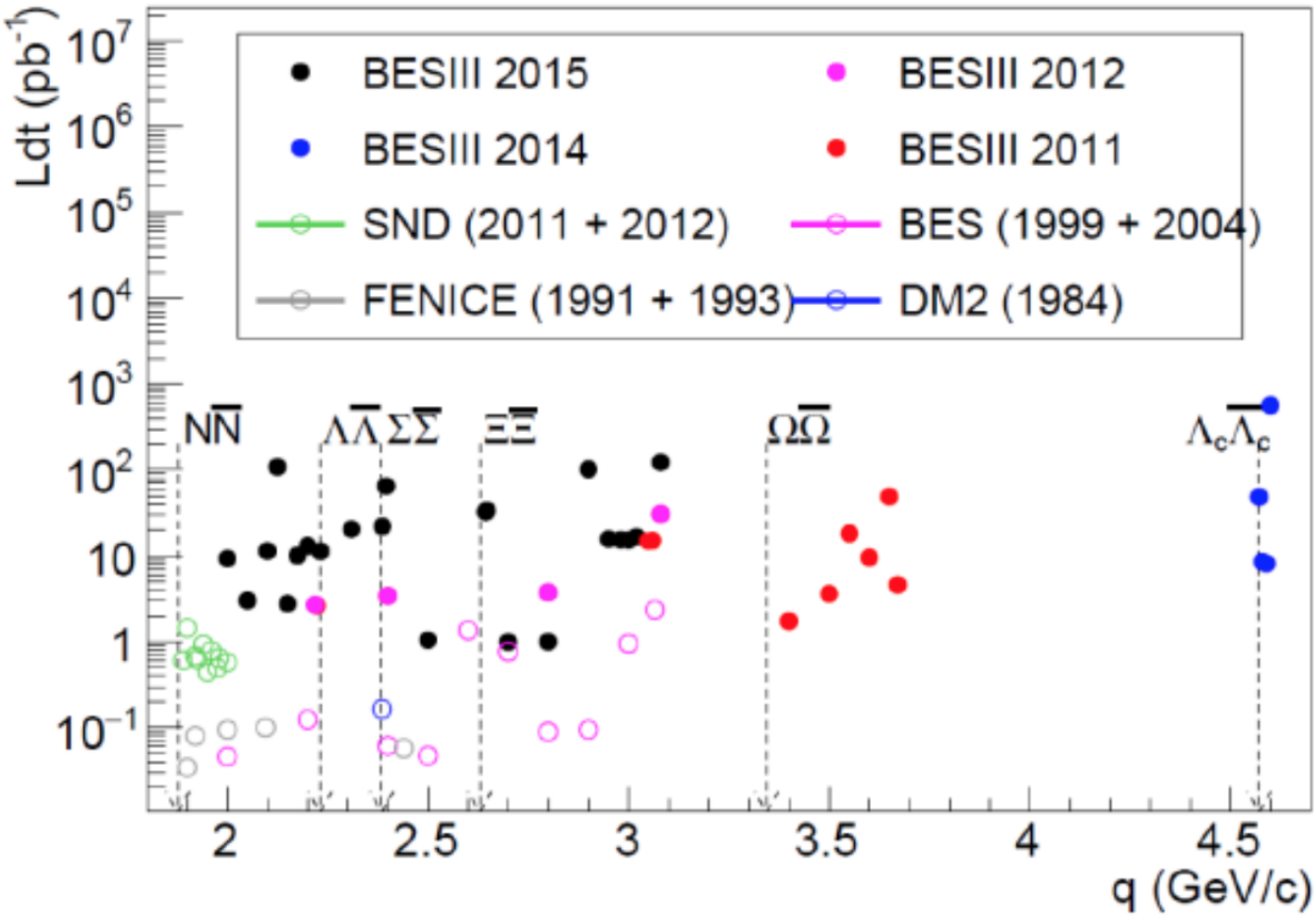


UCAS

Synchrotron radiation light source

So far, no dedicated facility for particle physics yet!

Energy scan 2014-2015 at BESIII



- World leading scan from 2.0 GeV – 3.08 GeV energy region
- Nucleon and Hyperon form-factor available

Rich Physics programs @ STCF

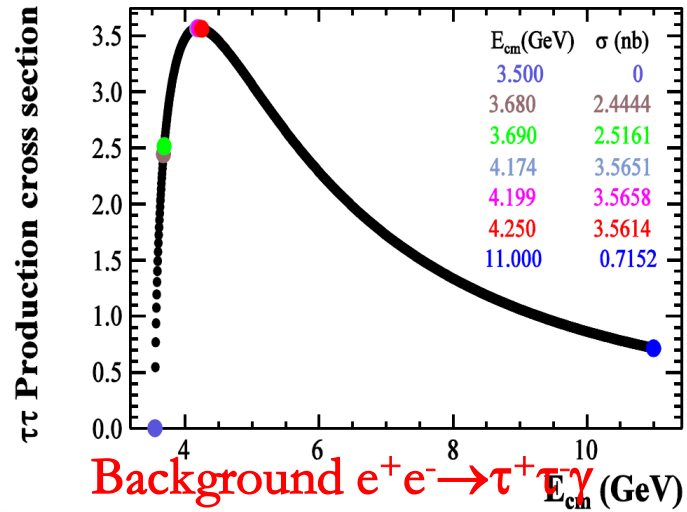
Unique for physics with c quark and τ leptons, important playground for study of QCD, exotic hadrons and search for new physics.

- **Charmonium & Chramonium-like XYZ (Luminosity & CME)**
- **Charmed hadrons (Luminosity & CME)**
- **τ Lepton CP (Luminosity & polarized beam)**
- **New physics (Luminosity)**
- **R / QCD (Luminosity & CME)**
- **…**

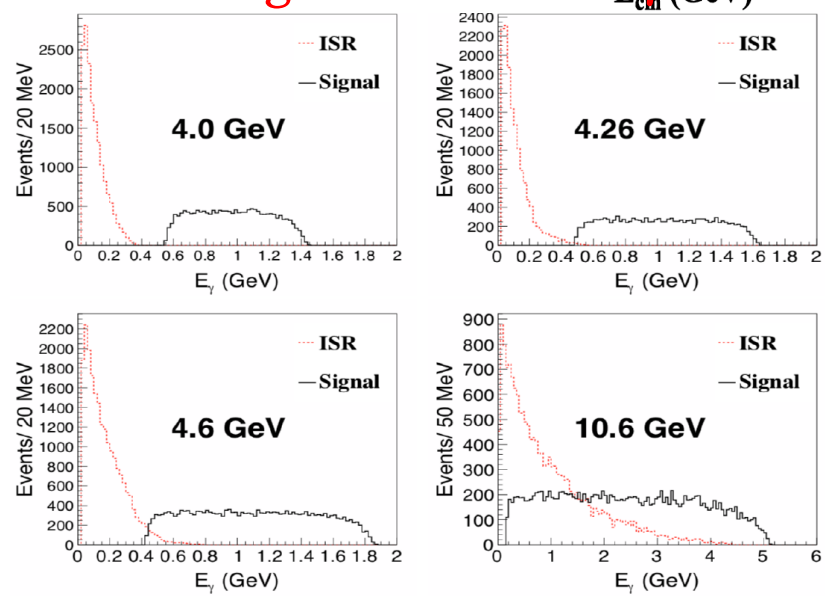
More information can be found in Bingsong Zou's "Physics Summary of STCF", presented at Joint Workshop of future tau-charm factory, December 2018.

cLFV Decay $\tau \to \mu\gamma$

- Charge Lepton Flavor Violation $\tau \to \gamma\mu$
  - New physics beyond SM, constraint many modes.
  - Current limit: 4.4×10^{-8} at Babar with 0.9×10^{9} τ pairs
- Cross section grows from 0.1 nb near threshold to 3.5 nb to 4.25 GeV.
  - At BelleII:
    - 10^{10} τ pairs/year
    - ISR background dominant: $e+e- \to \gamma\tau+\tau-$
    - Expected limit: 3×10^{-9}@50 ab^{-1}
  - At STCF:
    - 7.0×10^{9} τ pairs/year at 4.25 GeV
    - $e+e- \to \gamma\tau+\tau-$ background not contribute at 4.25 GeV.
    - Dominant background: $\gamma\mu+\mu-$, $\tau \to \pi\upsilon$
    - 4.4×10^{-8} @ 6.34 ab^{-1} estimated at BESIII
    - Much lower μ/π misID rate is needed
    - Fast simulation on this process is progressing



Background $e^+e^-\to\tau^+\tau^-\gamma$



Does not contribute below $\sqrt{s} \approx 4m_\tau/\sqrt{3} \approx 4.1$ GeV.

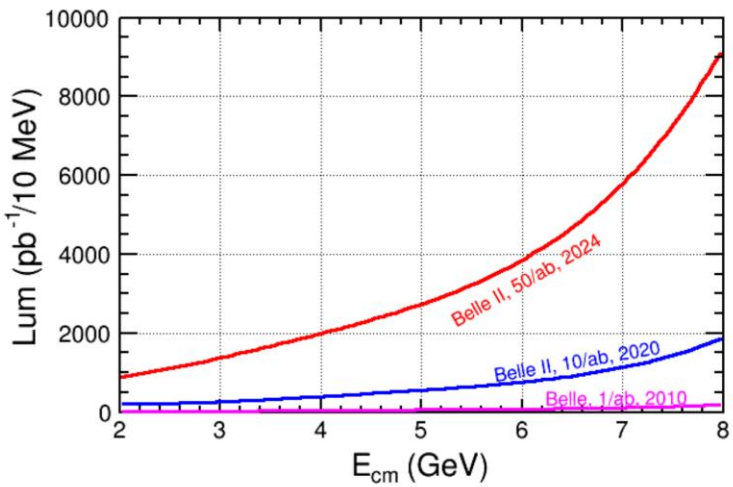
Integrated Luminosity of STCF

- Assume running time 9 months/year, data taking efficiency 90%

$10^{35}cm^{-2}s^{-1} \times 86400s \times 270days \times 90\% \sim$ **$2.0ab^{-1}$ /year**

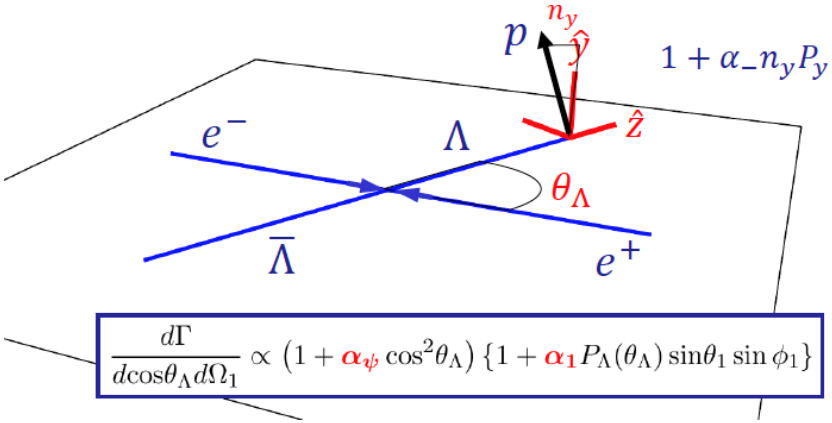
10 years data taking, total 20 ab^{-1} conservatively

Excellent opportunities for the τ-charm physics



- **B factory**: Total integrated effective luminosity between 2-7 GeV is ~1.5ab^{-1} for 50 ab^{-1} data.
- **STCF** is expected to have higher detection efficiency
  - e.g. @4.26 GeV for $\pi^+\pi^- J/\psi$, $\varepsilon_{\mathrm{BESIII}} = 46\%$, $\varepsilon_{\mathrm{Belle}}$=10%
- **STCF** has low backgrounds for productions at threshold.

$e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}$

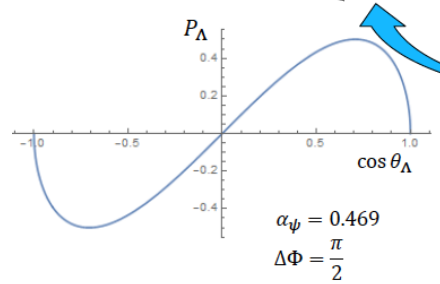


$$\frac{d\Gamma}{d\cos\theta_\Lambda d\Omega_1} \propto \left(1 + \alpha_\psi \cos^2\theta_\Lambda\right)\left\{1 + \alpha_1 P_\Lambda(\theta_\Lambda)\sin\theta_1 \sin\phi_1\right\}$$

$\Lambda \to p\pi^-$: $\Omega_1 = (\cos\theta_1, \phi_1)$: $\alpha_1 \to \alpha_-$

For unpolarized e+e- beams

$$\bar{P}_\Lambda(\theta_\Lambda) = \frac{\sqrt{1-\alpha_\psi}\cos\theta_\Lambda \sin\theta_\Lambda}{1+\alpha_\psi\cos^2\theta_\Lambda}\sin(\Delta\Phi)\hat{y}$$



$\Delta\Phi \neq 0$

$$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\pi^+)$$

Göran Fäldt, AK
PLB772 (2017) 16

$$d\sigma \propto \mathcal{W}(\boldsymbol{\xi})\ d\cos\theta\ d\Omega_1 d\Omega_2$$

$\Lambda \to p\pi^-$: $\Omega_1 = (\cos\theta_1, \phi_1)$ $\qquad \alpha_- = \alpha_1$

$\bar{\Lambda} \to \bar{p}\pi^+$: $\Omega_2 = (\cos\theta_2, \phi_2)$ $\qquad \alpha_+ = \alpha_2$

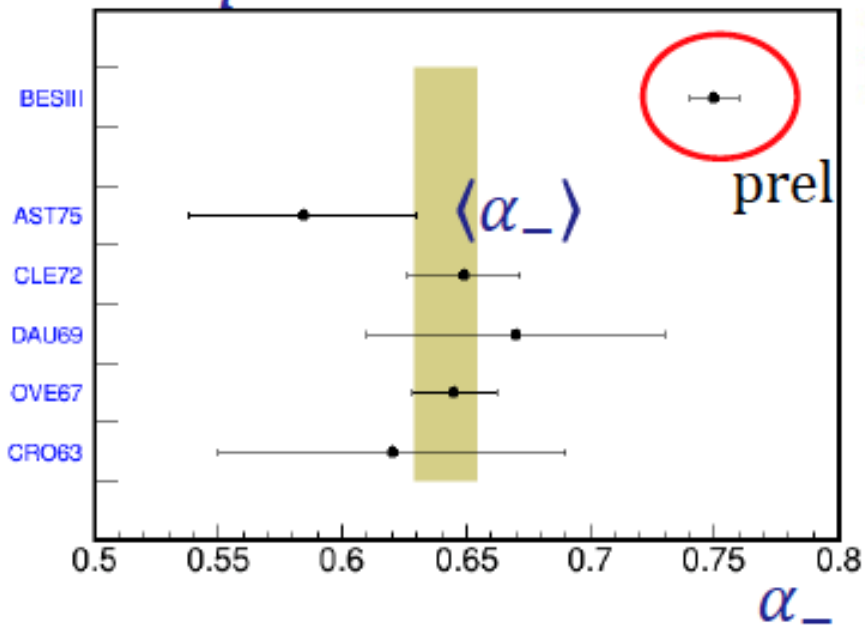
$\boldsymbol{\xi}$: $(\cos\theta, \Omega_1, \Omega_2)$

Spin correlations

$$\mathcal{W}(\boldsymbol{\xi}) = 1 + \alpha_\psi \cos^2\theta$$
$$+ \boxed{\alpha_1\alpha_2\left(\mathcal{T}_1(\boldsymbol{\xi}) + \sqrt{1-\alpha_\psi{}^2}\cos(\Delta\Phi)\mathcal{T}_2(\boldsymbol{\xi}) + \alpha_\psi\mathcal{T}_6(\boldsymbol{\xi})\right)}$$
$$+ \sqrt{1-\alpha_\psi{}^2}\sin(\Delta\Phi)\ \sin\theta\cos\theta\left(\alpha_1\sin\theta_1\sin\phi_1 + \alpha_2\sin\theta_2\sin\phi_2\right)$$

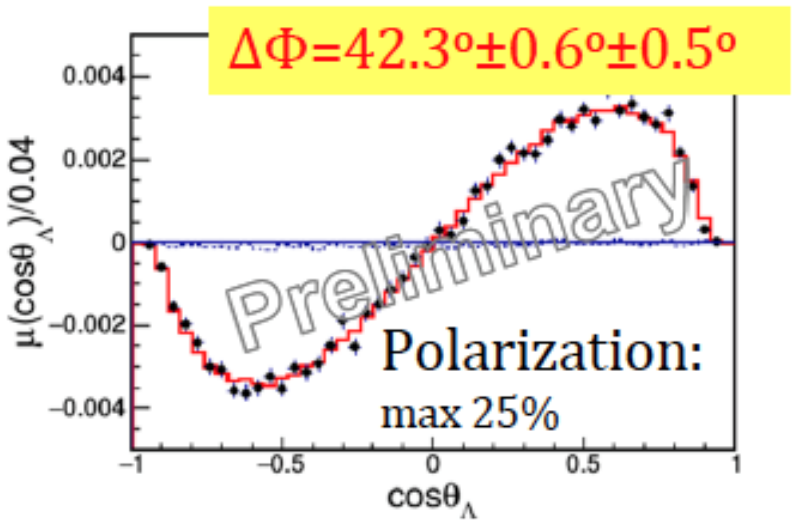
Observation of the spin polarization of Λ hyperons in the $J/\psi \to \Lambda\bar{\Lambda}$ decay

$\Lambda \to p\pi^-$: α_-



BESIII

17% larger than PDG avg
> 5 σ difference



CP test

$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

A_{CP} = -0.006 ± 0.012± 0.007 prel

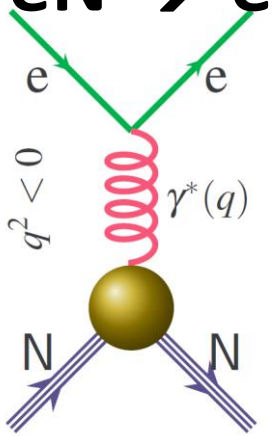
A_{CP}= 0.013 ± 0.021
PS185 PRC54(96)1877
CKM $A_{CP} \sim 10^{-4}$

STCF: $\Delta A_{CP} = 10^{-4}$

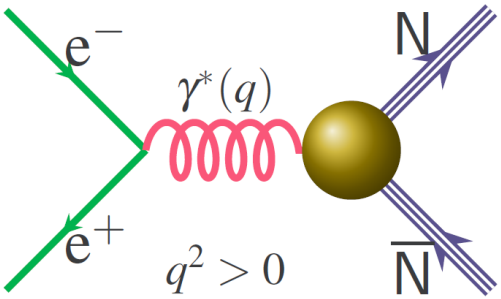
Time-Like Baryon Form Factors

Space-like:
FF real

eN → eN



$e^+e^- \leftrightarrow N\bar{N}, \Lambda\bar{\Lambda}$



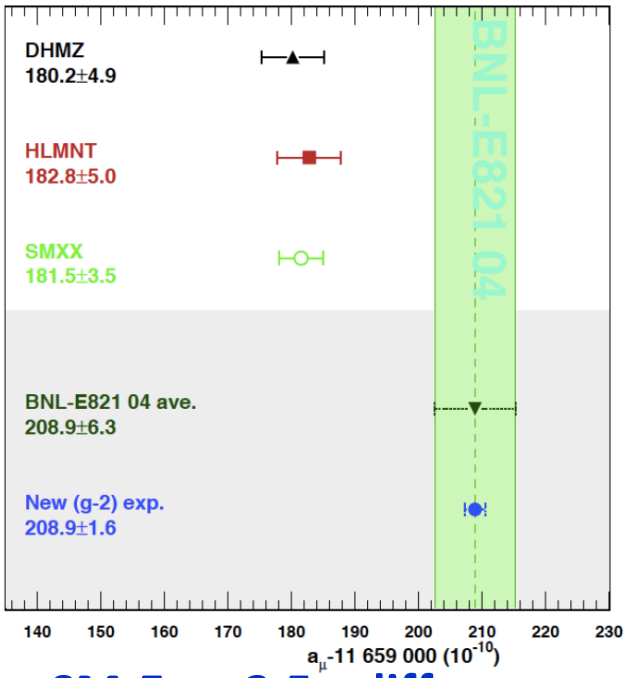
Time-like:
FF complex

- **Fundamental properties of the baryon**
- **QCD predictions:**
  - **at large q^2, absolute value of $FF(q^2)=FF(-q^2)$**
  - **Experiment: time-like FF much larger than space-like FF**
- **Squared ratio of n/p form factors ≈ 0.25**
  - **Problem: only very poor data for neutron form factor**

Impact on $(g_\mu-2)/2$

At present, the anomalous magnetic moment of the muon $a_\mu = (g-2)_\mu/2$ are known with an uncertainty of about one half per million!

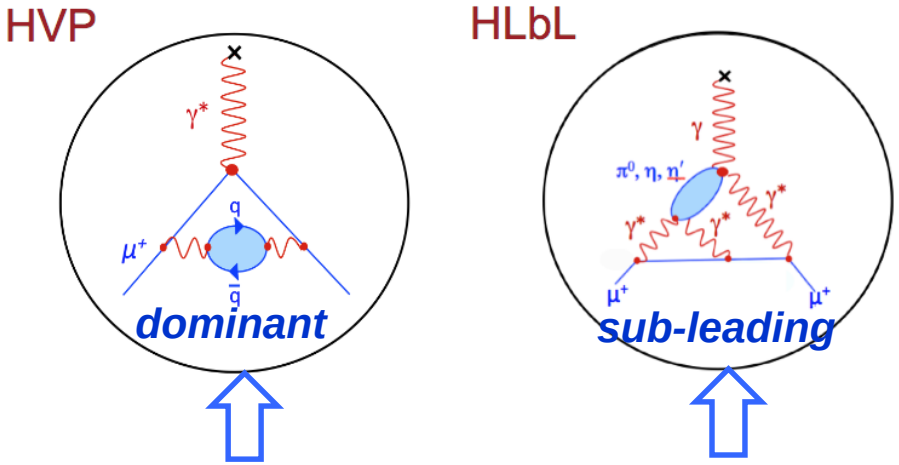
$$a_\mu^{\rm SM} = (11\,659\,180.2 \pm 4.9)\cdot 10^{-10}\,,$$
$$a_\mu^{\rm exp} = (11\,659\,208.9 \pm 6.3)\cdot 10^{-10}\,.$$



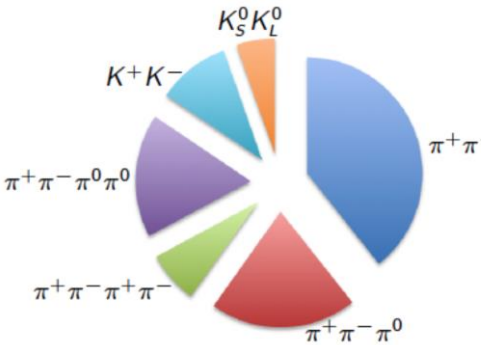
SM-Exp: 3.5σ difference

Sensitive to probe new physics.

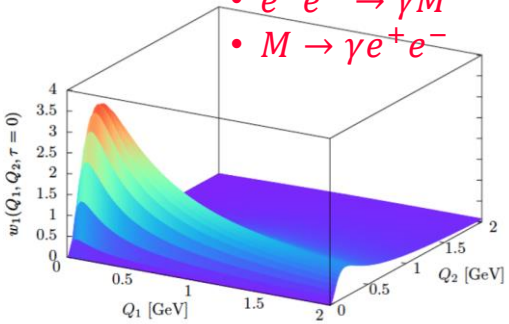
Data-driven approach: reduce model uncertainty to 10-20%



- $e^+e^- \to \gamma_{ISR} hadrons$



- $\gamma\gamma * \to$ M
- $e^+e^- \to \gamma M$
- $M \to \gamma e^+e^-$

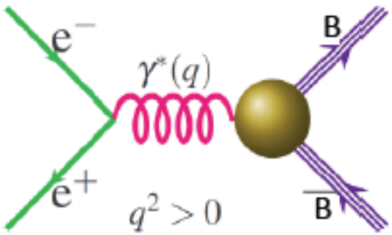


High Luminosity of STCF will largely improve the SM precisions

$e^+e^- \to$ Baryon-Antibaryon Pair

Born cross section:

$e^+e^- \leftrightarrow N\bar{N}, \Lambda\bar{\Lambda}, \ldots$



$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2 \beta\, C}{4m_{B\bar{B}}^2}\left[\left(1+\cos^2\theta\right)\left|G_M(m_{B\bar{B}})\right|^2 + \frac{1}{\tau}\sin^2\theta\left|G_E(m_{B\bar{B}})\right|^2\right]$$

$$\tau = \frac{m_{B\bar{B}}^2}{4M_B^2} \qquad \beta = \sqrt{1-\frac{1}{\tau}}$$

Coulomb enhancement factor

$$c_{\text{charged}} = \frac{\pi\alpha/\beta}{1-\exp(-\pi\alpha/\beta)} \xrightarrow{(\beta\to 0)} \pi\alpha/\beta$$

$$c_{\text{neutral}} = 1$$

in point-like approx

integrated cross section:

$$\sigma_{B\bar{B}}(m_{B\bar{B}}) = \frac{4\pi\alpha^2\beta C}{3m^2}\left[\left|G_M(m_{B\bar{B}})\right|^2 + \frac{1}{2\tau}\left|G_E(m_{B\bar{B}})\right|^2\right] = \frac{4\pi\alpha^2\beta C}{3m^2}\left|G_{eff}(m_{B\bar{B}})\right|^2\left(1+1/2\tau\right)$$

"effective" form factor

effective form factor:

$$\left|G_{eff}\right|^2 = \frac{\left|G_M\right|^2 + \frac{1}{2\tau}\left|G_E\right|^2}{1+\frac{1}{2\tau}}\sigma_{B\bar{B}}(m_{B\bar{B}}) \Rightarrow \left|G_{eff}\right| = \left(\frac{3m_{B\bar{B}}^2}{\pi\alpha^2\beta C\left(1+\frac{1}{2\tau}\right)}\right)^{\frac{1}{2}}\sqrt{\sigma_{B\bar{B}}}$$

analyticity:

$$G_M(4M_B^2) = G_E(4M_B^2) \Rightarrow G_{eff}(4M_B^2) = G_M(4M_B^2)$$

Selected Highlight topics

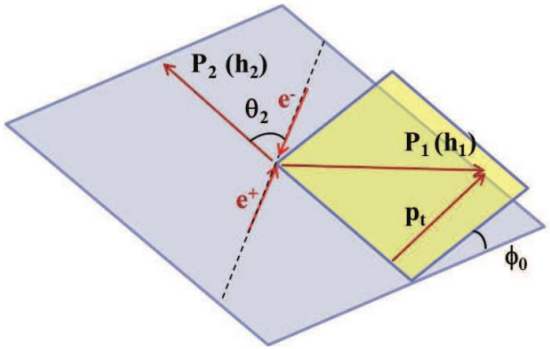
- Time-like Form factors of Baryon pair
- Collins Fragmentation functions; MLLA/LPHP prediction
- Polarization & CPV of Hyperon
- $(g_\mu - 2)/2$, 92% from < 2GeV, 7% from 2-5GeV

Collins Fragmentation Function(FF)

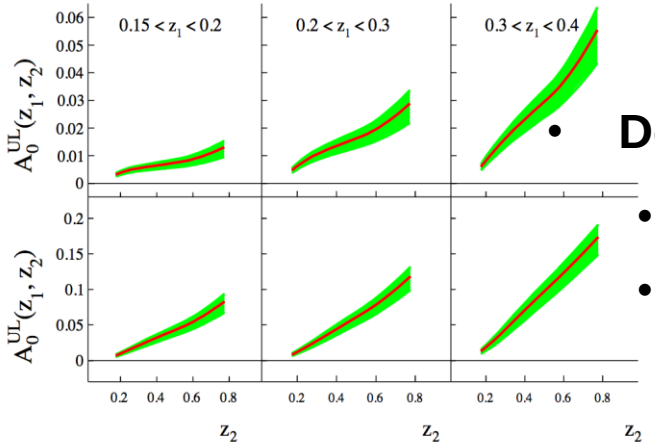
✦**Experimentally**

D. Boer Nucl.Phys.B806:23(2009):

$$e^+ e^- \to q\bar{q} \to \pi_1{}^{\pm}\pi_2{}^{\mp}X$$



P. Sun, F. Yuan, PRD 88. 034016 (2013)
Predicted Collins asymmetries for BESIII :



- **Double Ratio to cancel detection effects**
- **Unlike-sign** $(\pi^{\pm}\pi^{\mp})$ **; Like-sign** $(\pi^{\pm}\pi^{\pm})$
- **Charged:** $(\pi\pi)$

$$A_{UL(C)} = \frac{R^U}{R^{L(C)}} = Acos(2\phi) + B$$

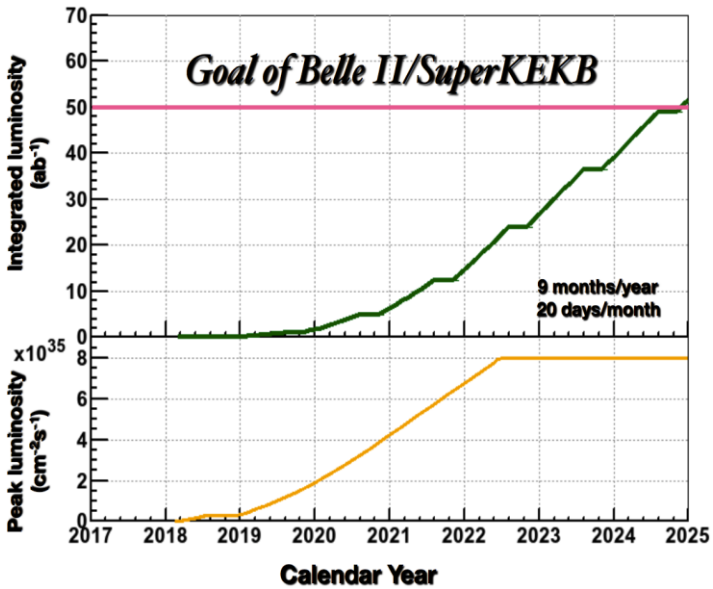
Integral Luminosity of STCF

- No Synchrotron radiation mode, assume running time 9 months/year
- Assume data taking efficiency 90%

$10^{35}cm^{-2}s^{-1} \times 86400s \times 270days \times 90\% \sim 2.0ab^{-1}/year$

10 years data taking, total 20 ab^{-1} conservatively

Excellent opportunities for the τ-charm physics



BELLE-II

- each 1 ab^{-1} dataset provides
  - $\sim 1.1 \times 10^9$ $B\bar{B} \Rightarrow$ a B-factory;
  - $\sim 1.3 \times 10^9$ $c\bar{c} \Rightarrow$ a charm factory;
  - $\sim 0.9 \times 10^9$ $\tau^+\tau^- \Rightarrow$ a τ factory;
  - wide $E_{CM}^{eff.}$=[0.5-10] GeV via ISR.

Native question : Compete between STCF and BELLE-II ?

Data samples

Data samples with 1 ab^{-1} integral luminosity

	STCF					Belle II		
Data Set	process	σ/nb	N	ST eff./%	ST N	σ/nb	N	Tag N
J/ψ	–	–	1.0×10^{12}	–	–	–	–	–
$\psi(2S)$	–	–	3.0×10^{11}	–	–	–	–	–
D^0	$D^0\bar{D}^0(3.77)$	~ 3.6	3.6×10^9	10.8	0.78×10^9	–	1.4×10^9	–
D^+	$D^+D^-(3.77)$	~ 2.8	2.8×10^9	9.4	0.53×10^9	–	7.7×10^8	–
D_s	$D_sD_s^*(4.18)$	~ 0.9	0.9×10^9	6.0	0.11×10^9	–	2.5×10^8	–
τ^+	$\tau^+\tau^-(3.68)$	~ 2.4	2.4×10^9	–	–	0.9	0.9×10^9	–
	$\tau^+\tau^-(4.25)$	~ 3.6	3.5×10^9	–	–	–	–	–
Λ_c	$\Lambda_c\Lambda_c(4.64)$	~ 0.6	5.5×10^8	5.0	0.55×10^8	–	1.6×10^8	$3.6 \times 10^{4*}$

* process $e^+e^- \to D^{(*)-}\bar{p}\pi^+\Lambda_c^+$.

- STCF have more yields /per luminosity
- STCF is expected to have higher detection efficiency
- Belle II can have larger integral luminosity

Detail simulations are ongoing to study the potential for the physics research.

R and QCD Physics

Detailed study of exclusive processes $e^+ e^- \rightarrow (2\text{-}10)h$, $h=\pi, K, \eta, p\ldots$

Scan between 2-7GeV and ISR $\sqrt{s}<2$GeV

- Meson Spectroscopy
- Intermediate dynamics
- Search for exotic states (tetraquarks, hybrids, glueballs)
- Form factors

High precision determination of $R=\sigma(e^+ e^- \rightarrow \text{hadrons})/\sigma(e^+ e^- \rightarrow \mu^+\mu^-)$ at low energies and fundamental quantities

- $(g_\mu-2)/2$, 92% from < 2GeV, 7% from 2-5GeV
- $\alpha(M_z)$, 19.0% from < 2GeV, 18.1% from 2-5GeV
- QCD parameters (charm quark masses)

Inclusive cross section $e^+ e^- \rightarrow h + X$

- QCD parameters (α_s, quark and gluon condensates)
- Fragmentation functions; MLLA/LPHP prediction
- Spin alignment of vector

Two photon Physics

- Measurement of $\Gamma_{\gamma\gamma}$ for $J^{PC} = 0^{-+}, 0^{++}, 2^{-+}, 2^{++}$ states
- Study of $\gamma\gamma^* \rightarrow R$, $R= 1^{++}$
- Transition Form Factors in $\gamma^*\gamma^* \rightarrow R$
- Cross section of $\gamma\gamma \rightarrow$ hadrons

Key Technologies

- **Polarization**
  - Spin Polarized Electron Source
  - Polarization Rotation and Maintenance for Rings and Final Focus
- **RF**
  - Superconducting Cavities, Deflecting Cavities, Higher Harmonic Cavities, etc.
- **Magnets**
  - High Quality Magnets with high strength, Superconducting Magnets and Solenoids
- **Diagnostics and Control**
  - Low Emittance Measurement, Transverse and Longitudinal Feedback, etc.

Collaboration Needed

- **Accelerator Physics**
  - IR Design
  - Polarization: Spin Rotation and Maintenance
  - Collective Effects: Simulation and Bench Measurements
  - Advanced Computational Accelerator Physics
- **Accelerator Technologies**
  - Superconducting Cavities and Magnets
  - Polarized Beam Sources
  - Ultrahigh Vacuum Chamber with Small Aperture, Optimized Impedance and Low SEE