新强子物理平台

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2020. 12. 4， 高能所

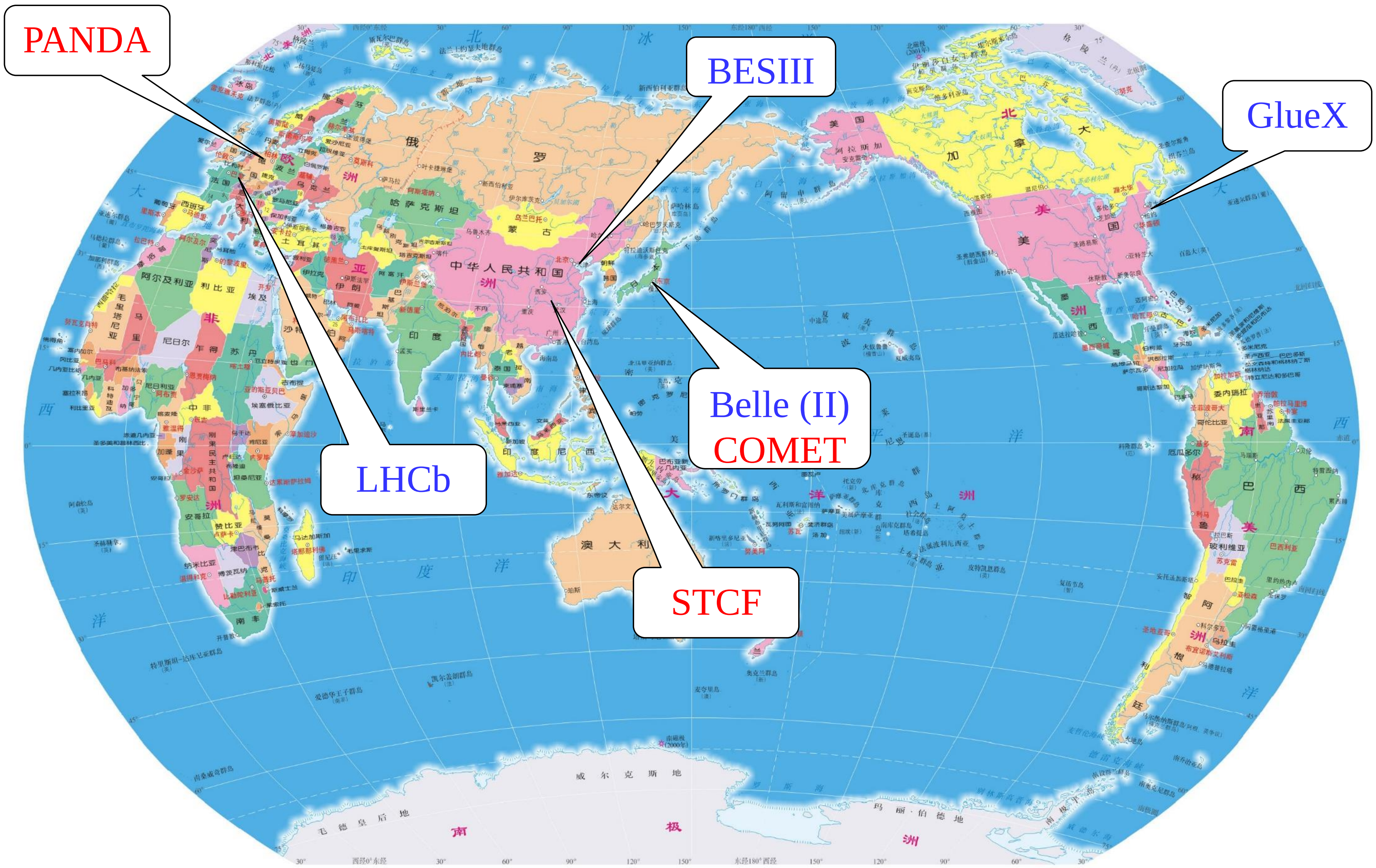
报告提纲

- 研究进展
- 未来规划

下午安排了3个专门的报告：

1. 刘北江（IHEP）： light hadrons @ BESIII
2. 张艳席（PKU）： exotics @ LHCb
3. 郭奉坤（ITP）：theory on exotic hadrons

参加的实验+理论合作者



我们不仅仅作强子物理

- 强子物理（QCD）
  - 介子谱、重子谱、奇特强子态
  - 形状因子、碎裂函数、产生机制、衰变机制
- 味物理（EW & QCD）
  - 粲物理、B物理、τ物理、超子
  - CKM & CPV
- 新物理（超出标准模型）
  - 轻子味破坏
  - 暗光子、暗物质
  - 对称性破坏

BESIII

Data taking plan for 2019-20 running year

From	To	Task	Duration
2019.12.13	2019.12.17	Switch to collision operation	5 days
2019.12.18	**2020.06.21**	**Data taking @ Y(4660) & Λ_c**	**187 days**
2020.06.22	2020.06.24	Switch to SR operation	3 days

3.5~4.0 fb^{-1}

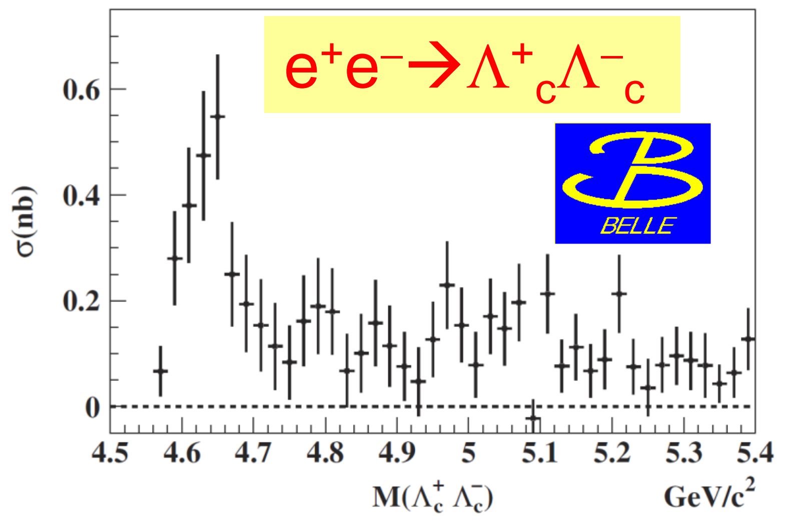
500 pb^{-1} per point at Ecm=4.62, 4.64, 4.66, 4.68 and 4.70 GeV

1.0~1.5 fb^{-1} at the maximum cross section of Λ_c

If BEPCII still keep the same lucky (No serious failure), same high beam power, same high beam performance, and with top-up operation

$$\frac{24+20}{2}\times 80\%\times 80\%\times(1+20\%)*187=3160/pb$$

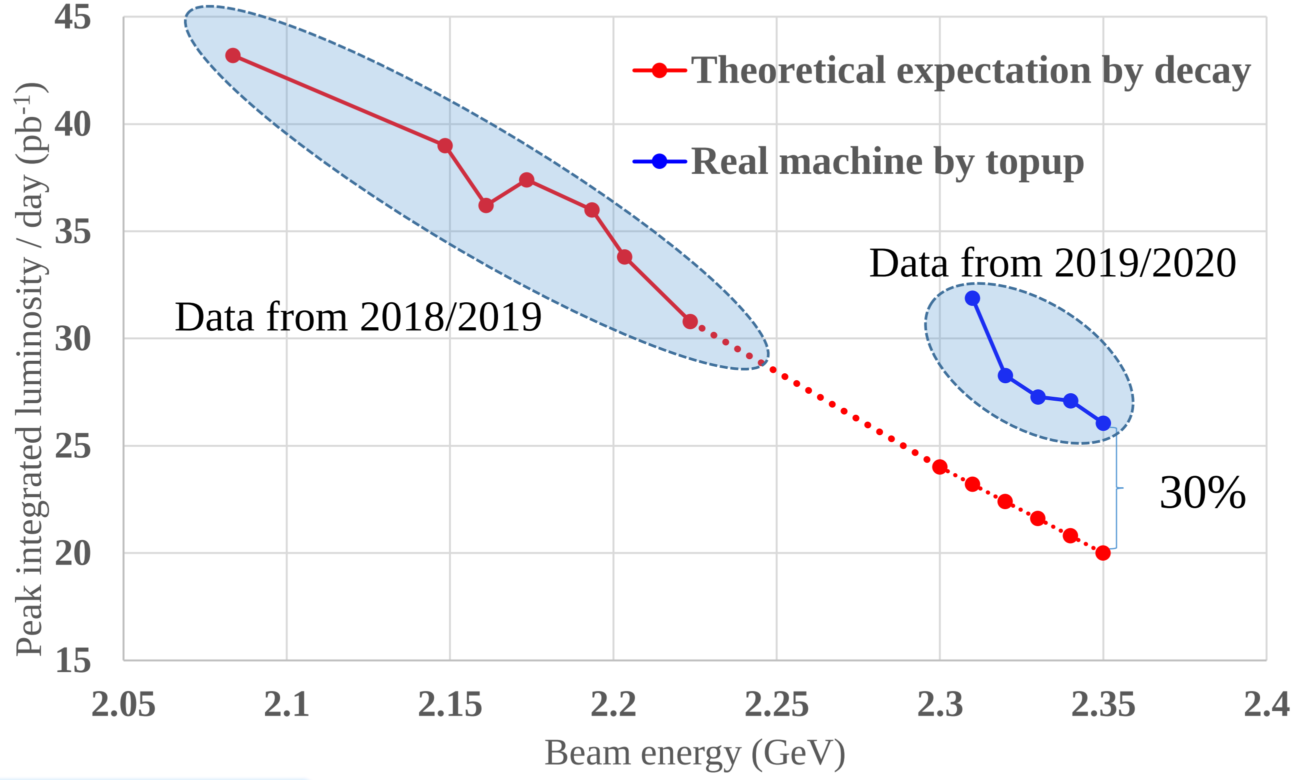
+5% +5% +5% =3716

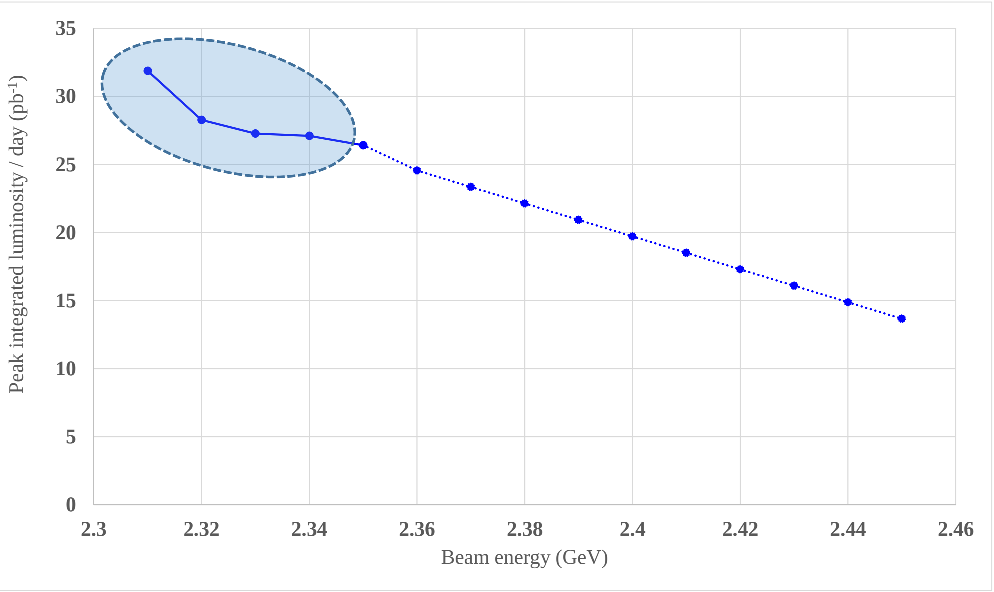


BEPCII is a excellent machine. But still not powerful enough to finish the scheduled data.

于程辉，BESIII合作组会报告，2019年11月

Data taking above 2.35GeV





Estimation above 2.35GeV

Beam energy (GeV)	Peak integral luminosity/day (pb^{-1})	average int. luminosity/day (pb^{-1})
2. 36	24. 6	21. 6
2. 37	23. 4	20. 5
2. 38	22. 1	19. 5
2. 39	20. 9	18. 4
2. 40	19. 7	17. 4
2. 41	18. 5	16. 3
2. 42	17. 3	15. 2
2. 43	16. 1	14. 2
2. 44	14. 9	13. 1
2. 45	13. 7	12. 0

Peak integral Lum. with decay operation

Average day integral Lum.

Data taking time

Gain from Topup operation

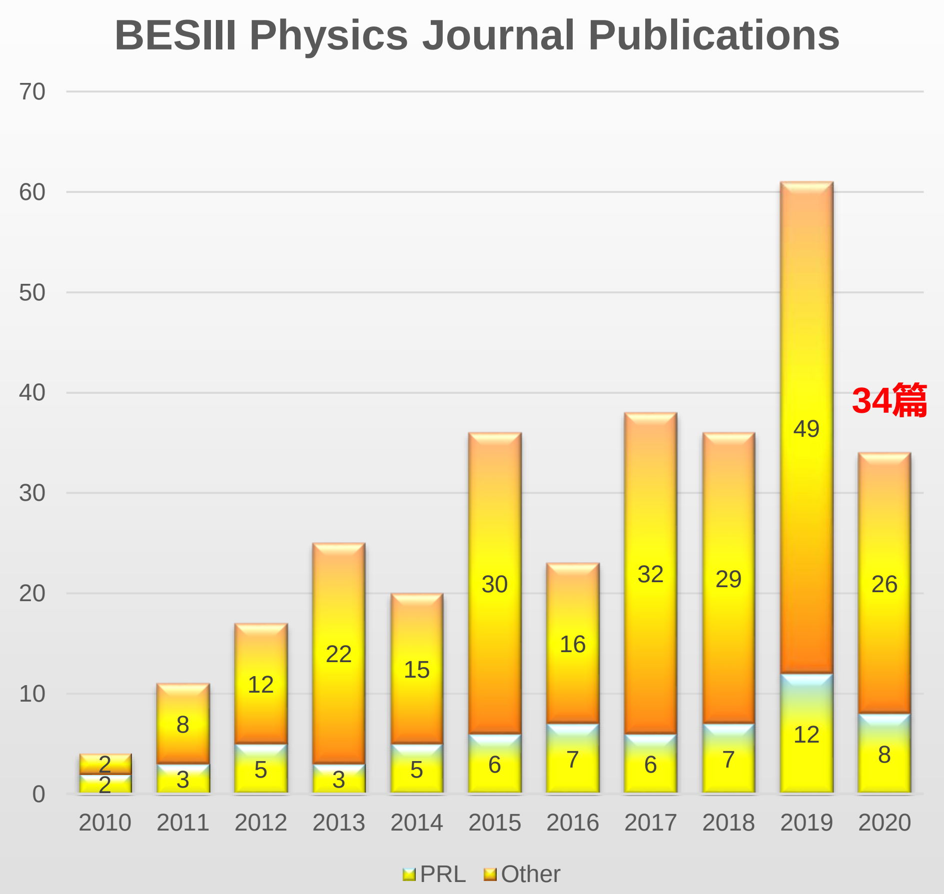
Operation days

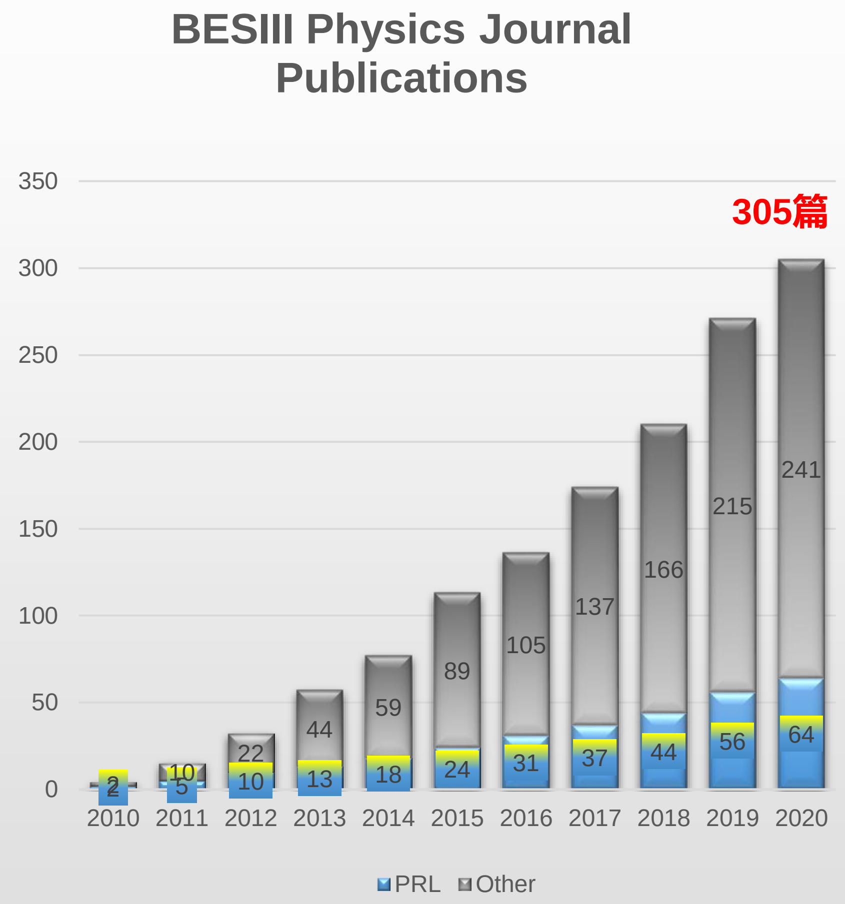
Real status

$$\frac{24+20}{2}\times 88\%\times 78.7\%\times(1+30\%)\times 186 = 3696\ /pb$$

于程辉，BESIII合作组会报告，2020年11月

BESIII发表文章（截止2020年12月3日）





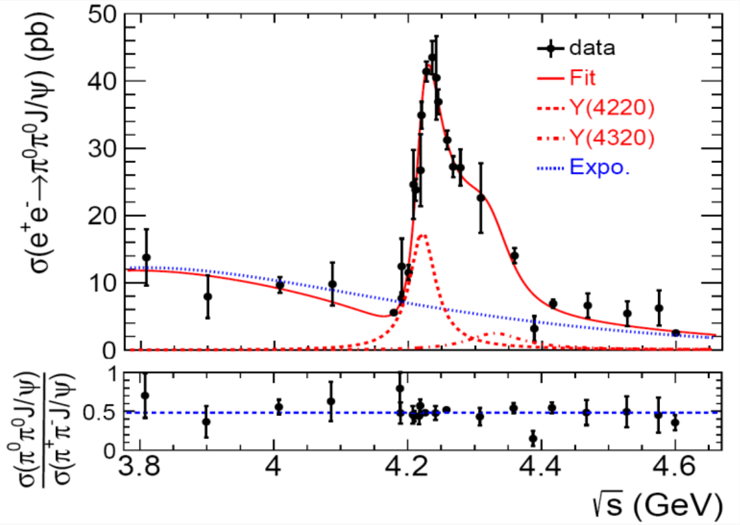
34 papers published in 2020

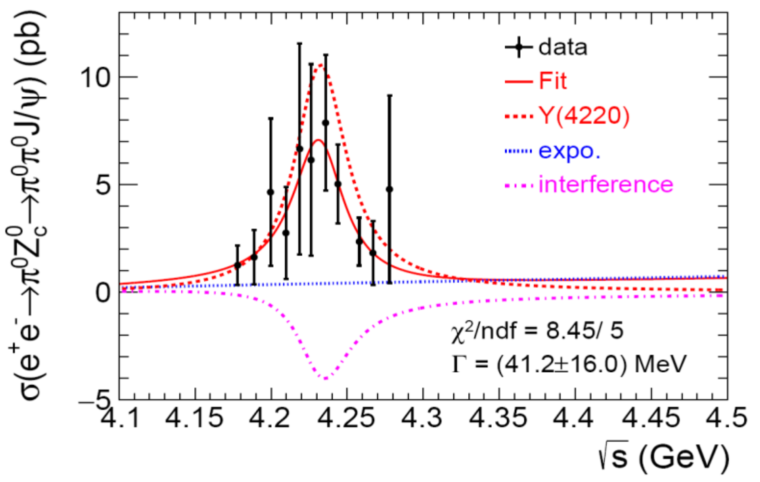
发现 Y(4220) → π Z_c(3900) 衰变

强子态是夸克和胶子通过强相互作用的组成的束缚态，它表现了夸克和胶子间的相互作用性质。特别是量子色动力学（QCD）预言的多夸克态、强子分子态、胶球和混杂态等尚未被确认。因此寻找这些奇特强子态是强子物理的重要课题，对进一步检验和发展QCD理论有重要意义。

Y(4220)是BESIII合作组发现的奇特强子态候选者。BESIII首次通过分波分析测量了$e^+e^- \to \pi Zc(3900) \to \pi\pi J/\psi$的截面，在 4.22 GeV 观测到了明显的结构增强。确认两个类粲偶素态Y(4220)和Z_c(3900)间有密切的关联。

这项工作首次测量 Y(4220) → π Z_c(3900) 截面线型，对研究矢量奇特强子态和带电奇特强子态有着重要意义。



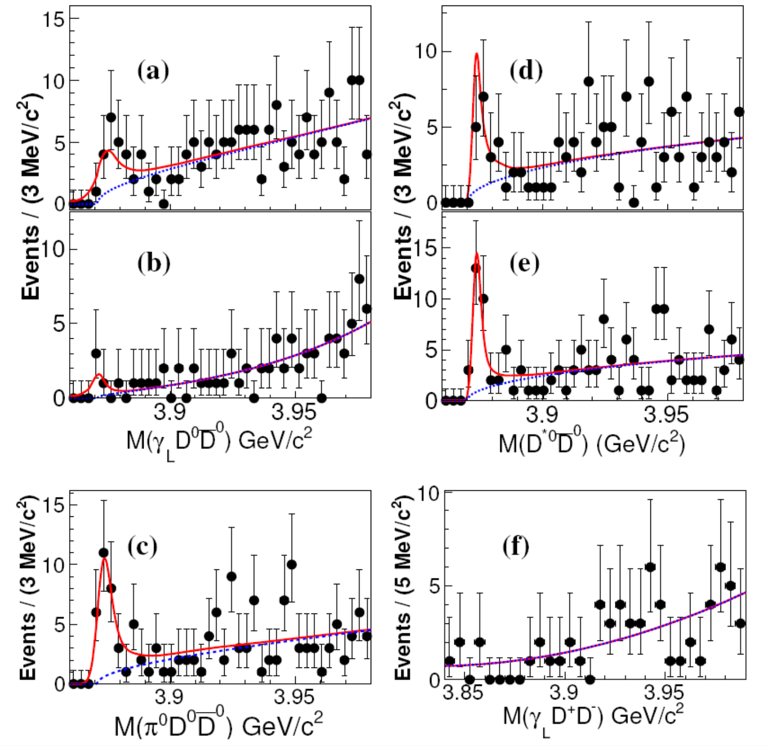


$e^+e^- \to \pi Zc(3900) \to \pi\pi J/\psi$截面及拟合结果

研究成果发表在Phys. Rev. D 102, 012009 (2020)。

系统研究 X(3872)的衰变性质

- 自2003年X(3872) 被Belle实验在B衰变中发现以来，因为其质量在DD*的阈值附近且非常窄，一直被认为是多夸克态或强子分子态的有力候选者。对X(3872)的衰变的研究，可以提供关于它的更多性质并有助于揭示它的本性。
- BESIII利用效率高、本底低的优势，系统研究了X(3872)的开粲和隐粲衰变模式，发现了新的衰变过程ωJ/ψ等，对LHCb和BaBar的γψ(2S)衰变提出了质疑，确定了所以已知衰变过程的相对分支比，在研究X(3872)的性质中推进了一大步。
- 利用BESIII积累的实验数据，对X(3872)的研究得到国际物理界的普遍关注。



上图：X(3872)信号；
下表：各过程与ππJ/ψ分支比的比值。

mode	ratio
$\gamma J/\psi$	0.79 ± 0.28
$\gamma\psi'$	-0.03 ± 0.22
$\gamma D^0\bar{D}^0$	0.54 ± 0.48
$\pi^0 D^0\bar{D}^0$	-0.13 ± 0.47
$D^{*0}\bar{D}^0 + c.c.$	11.77 ± 3.09
γD^+D^-	$0.00^{+0.48}_{-0.00}$
$\omega J/\psi$	$1.6^{+0.4}_{-0.3} \pm 0.2$ [18]
$\pi^0\chi_{c1}$	$0.88^{+0.33}_{-0.27} \pm 0.10$ [31]

研究成果发表在 Phys. Rev. Lett. 124, 242001 (2020)。

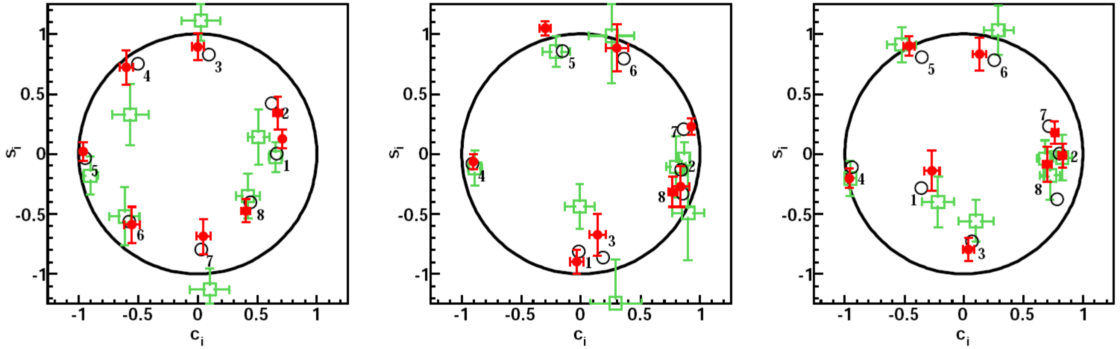
发表$D^0 \to K_{S/L}\pi^+\pi^-$衰变最精确强相差测量结果

- 强相位产生于衰变末态强子之间的相互作用，它不能通过理论计算得到可靠的结果，只能通过实验测量得到。在所有可能的强子末态中，$K_{S/L}\pi^+\pi^-$ 的强相差是当前国际上最关心的参数，因为它能够为测量粒子物理标准模型理论中的其他重要基本参数提供关键和亟需的实验输入。这些重要基本参数包含（但不限于）描述第一代夸克家族和第三代夸克家族混合的CKM相位角γ和描述中性D介子和它的反粒子振荡的混合参数等。
- 利用BESIII的强相差参数测量值作为输入，预期可以将γ的主导系统误差首次降低至约 1 度甚至更低的水平。在未来10年内，BESIII合作组精确测量的强相差参数可以确保LHCb和Belle II实验上的γ测量精度不受强相差输入精度的限制。此外，BESIII的强相差测量工作也对味物理实验中正在开展的一系列γ测量工作及相关的其它实验测量有着深远的影响。

CLEOc contribution to σγ=2° (0.8 fb^{-1})

BESIII contribution to σγ=0.7° (2.9 fb^{-1})

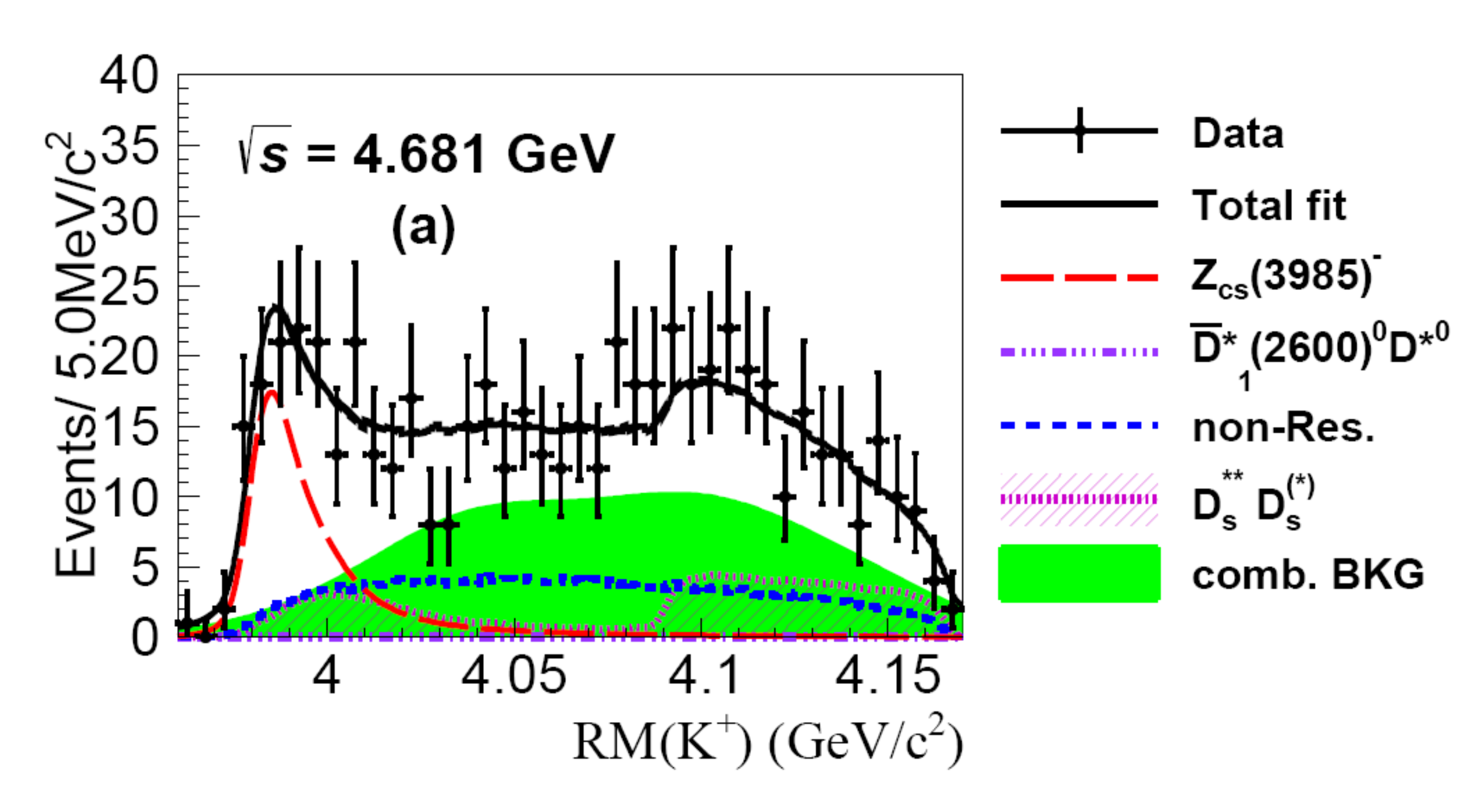
Experiment	Time (luminosity)	Expected γ uncertainty
LHCb Run-2	2019 (8 fb^{-1})	4°
LHCb Run-3,4	2030 (50 fb^{-1})	1.5°
Belle II	2029 (50 ab^{-1})	1.5°



BESIII测量结果（红色带误差棒的点）、CLEO实验结果（绿色带误差棒的方框）和BaBar&Belle 2018理论预期值（黑色空心圆）的对比。其中左侧，居中和右侧图分别是 "Equal $\Delta\delta_D$"，"Optimal" 和 "Modified Optimal" 分区间情况下得到的结果。

发现可能的Z_{cs}态

$$e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$$



1.6 fb^{-1} data

85 evts, >5.3σ

Just above D_s^*D and

D^*D_s thresholds

$$m_{\rm pole}(Z_{cs}(3985)^-) = (3982.5^{+1.8}_{-2.6} \pm 2.1)\ {\rm MeV}/c^2,$$

$$\Gamma_{\rm pole}(Z_{cs}(3985)^-) = (12.8^{+5.3}_{-4.4} \pm 3.0)\ {\rm MeV}.$$

arXiv: 2011.07855，提交Phys. Rev. Lett.

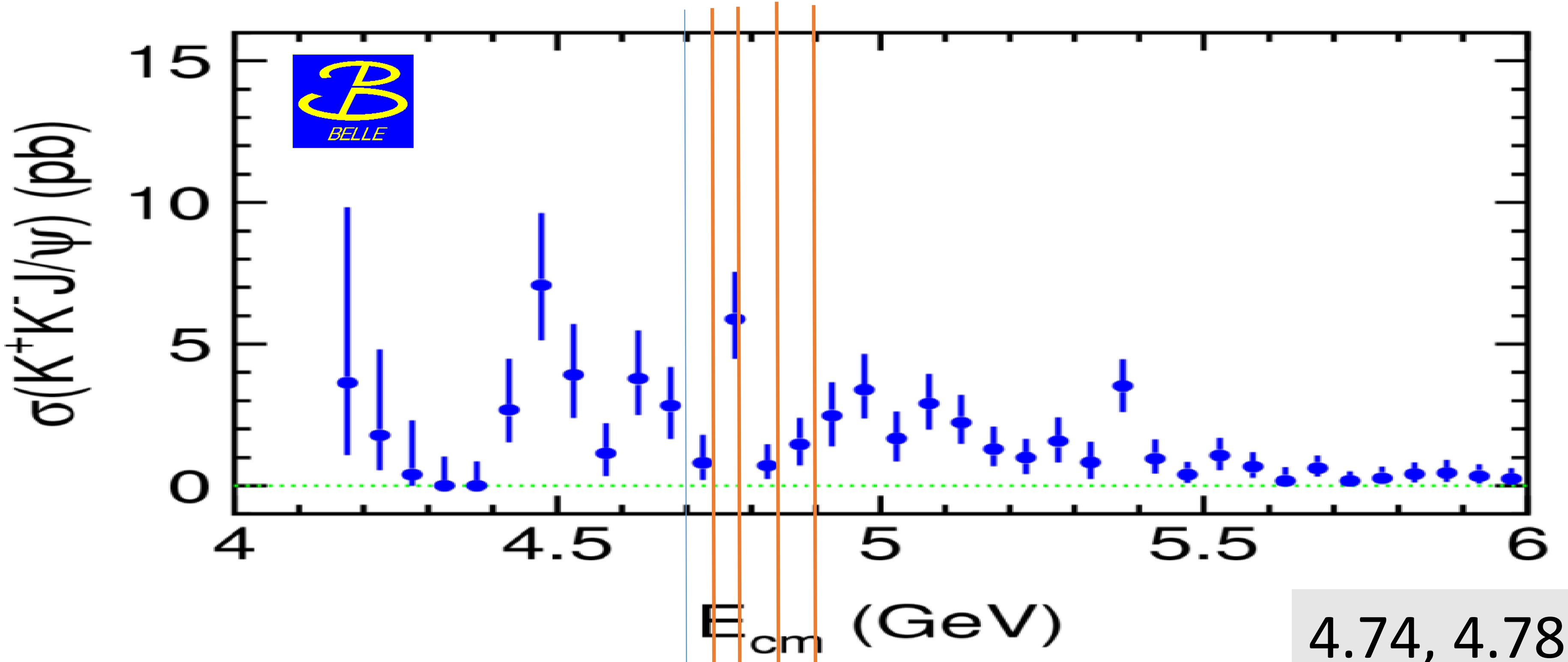
Data taking plan

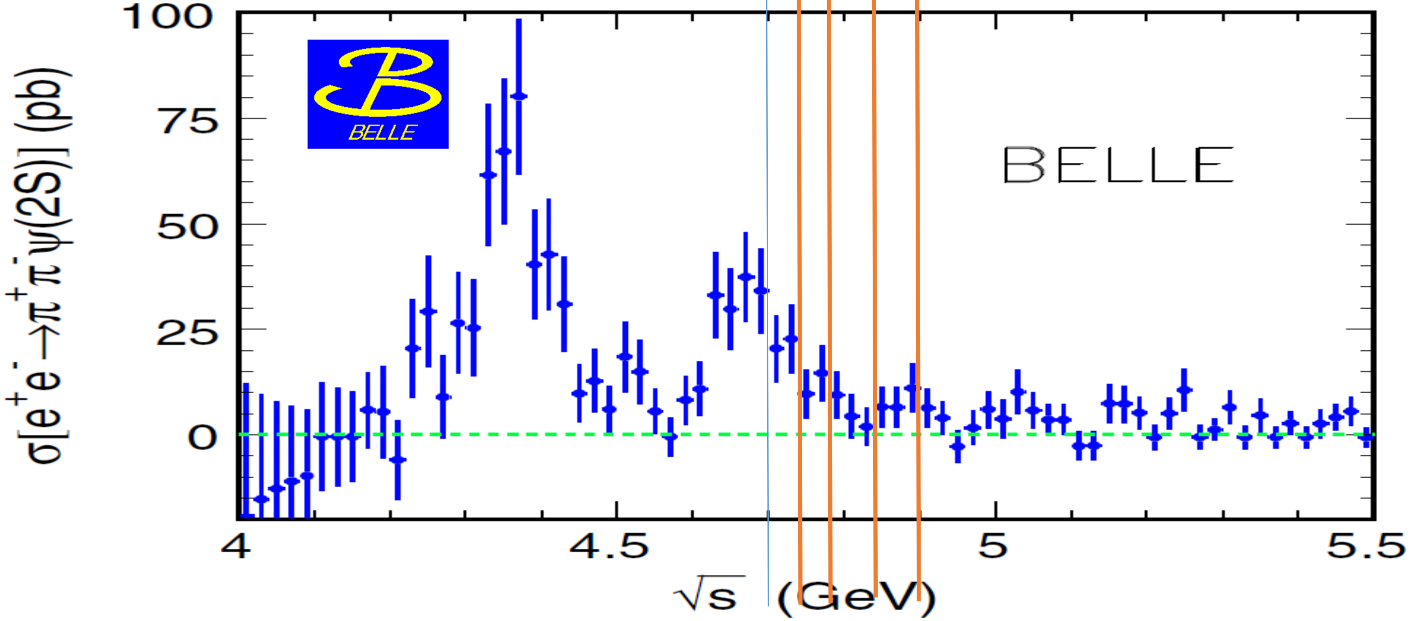
- Discussed at EB meeting, and further discussed at IB+EB meeting
- Agreed on a two-year plan (2020-22)
  - Study XYZ & charmed baryons [89 days]
    - 500 pb^{-1} per point at Ecm=4.74，4.78，4.84 GeV. [21+24+29 days]
    - 200 pb^{-1} at Ecm=4.90 GeV [15 days].
  - Take 2.55B ψ' events & 10% lum. continuum data [62 days] ➔ 3B in total
  - Take ψ(3770) data in reminder 2020-21 running year + full 2021-22 running year

    [(200-89-62)+200 = 249 days; ~16/fb]

    May try to get 15 more days for another 1/fb ψ(3770) data. ➔ 20/fb in total
- Notes:
  - BEPCII wants to run at Eb=2.35~2.45 GeV for >30% time; at Eb~1.89 GeV for >20% time in 2020-21 running year
  - Installation of CGEM in summer 2022

苑长征，BESIII合作组会报告，2020年6月

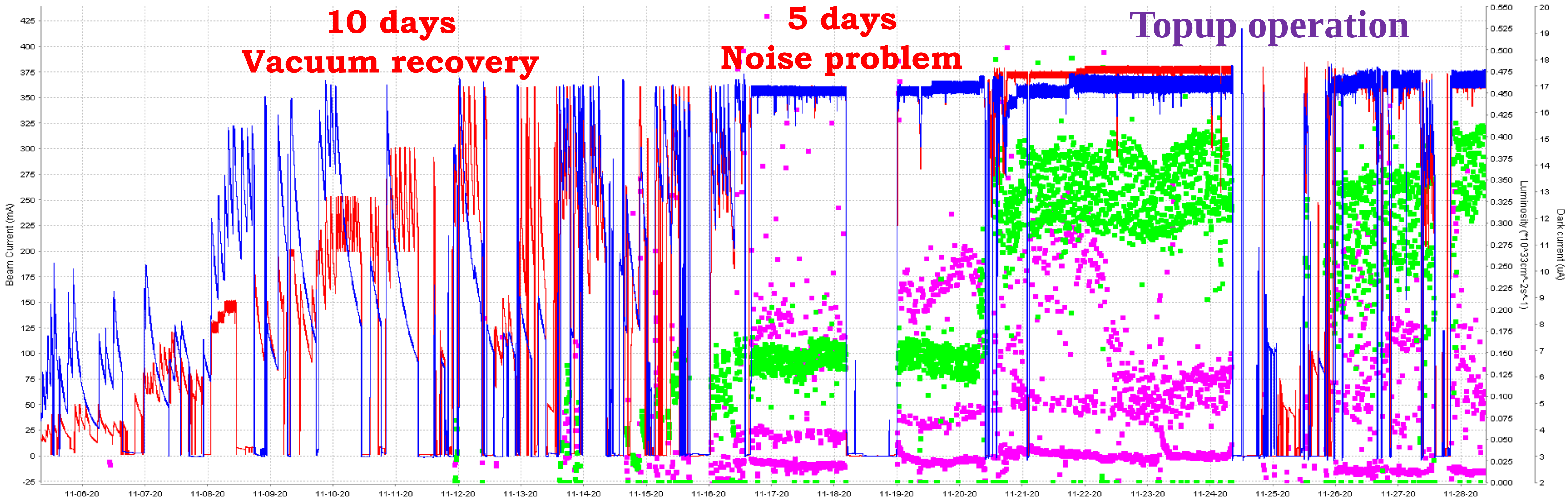




4.74, 4.78, 4.84, 4.90 GeV will make a full Y(4660) coverage and check of the jumping bin in KKJ/ψ, as well as charmed baryon & other XYZ studies.

苑长征，BESIII合作组会报告，2020年6月

Data taking at the first energy point 2.37GeV



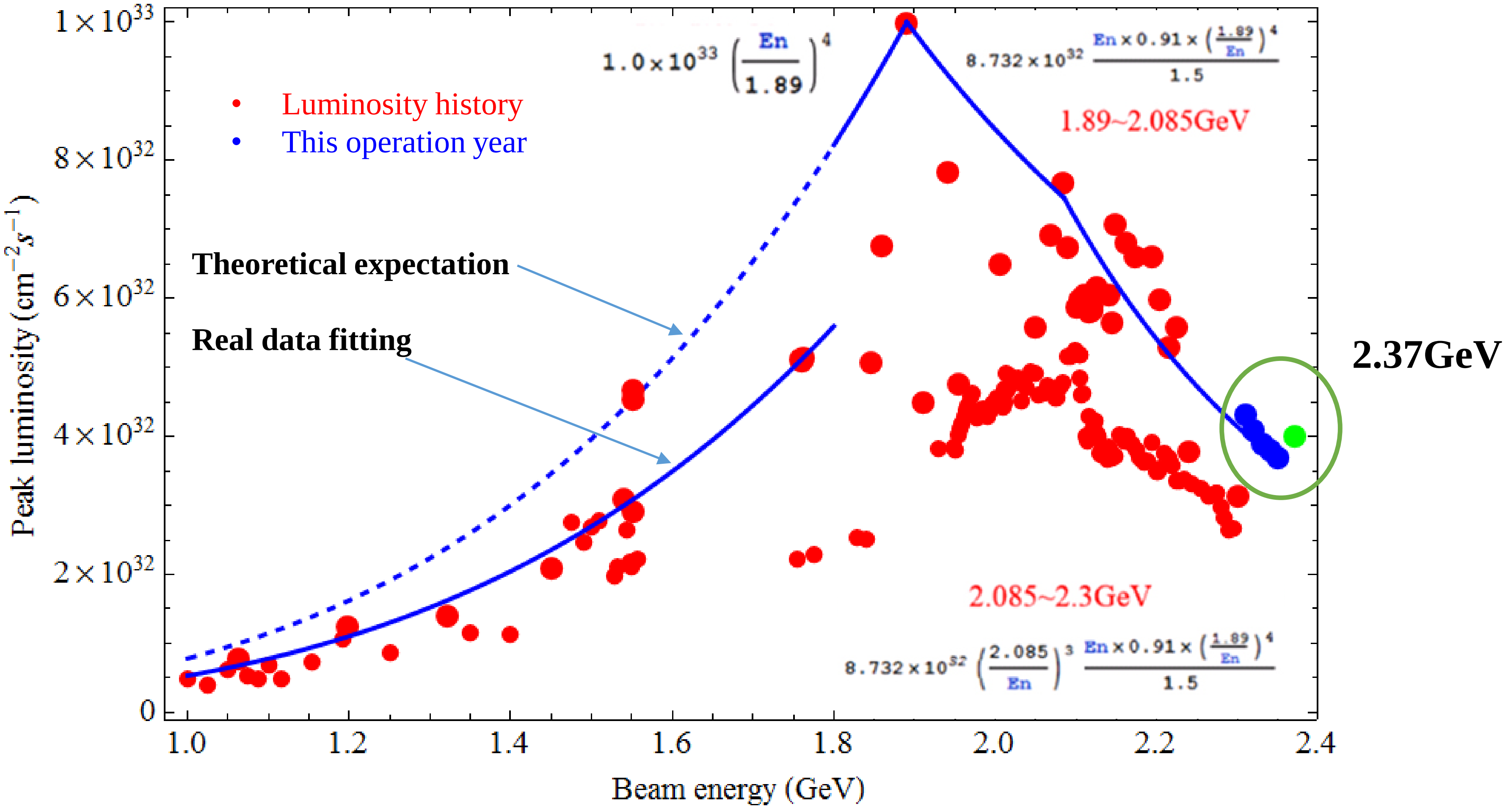
◆ Positron beam current ◆ Electron beam current ◆ Luminosity ◆ Dark current

Well beam performance & Beam power limitation & acceptable dark current and noise

- New energy record up to 2.37GeV.

于程辉，BESIII合作组会报告，2020年11月

Data taking at the first energy point 2.37GeV

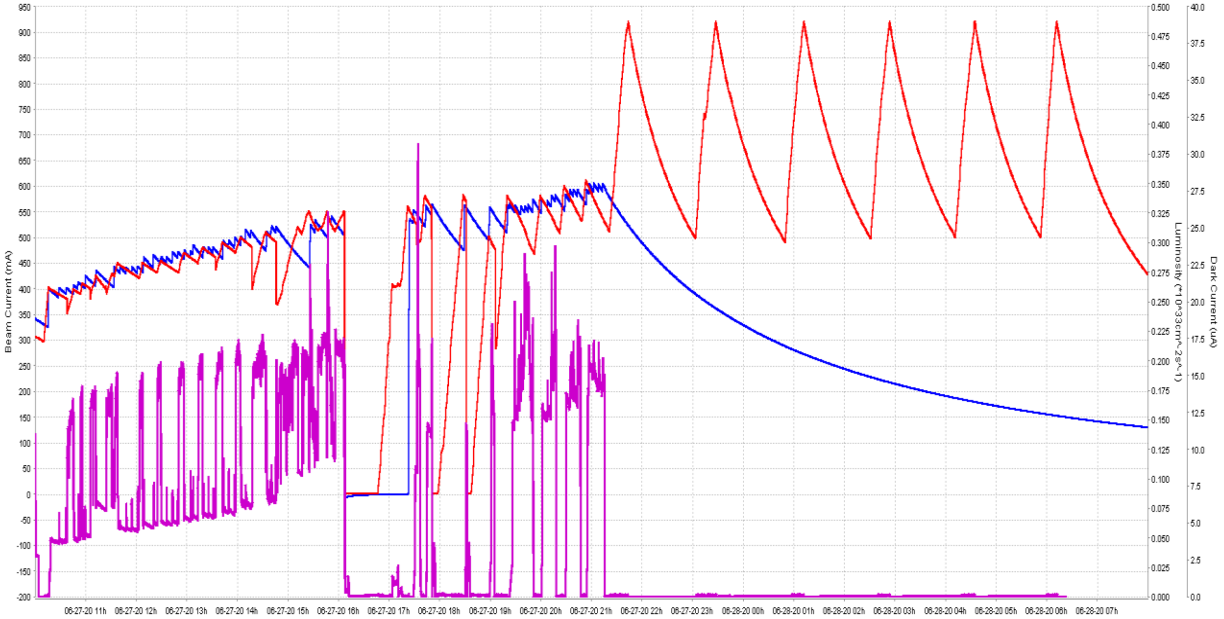


Peak luminosity **$4.0 \times 10^{32} cm^{-2}s^{-1}$** @ 360mA, beam-beam parameter **0.030**,
Peak integral luminosity per day: **$29 pb^{-1}$** on Nov. 21, 2020

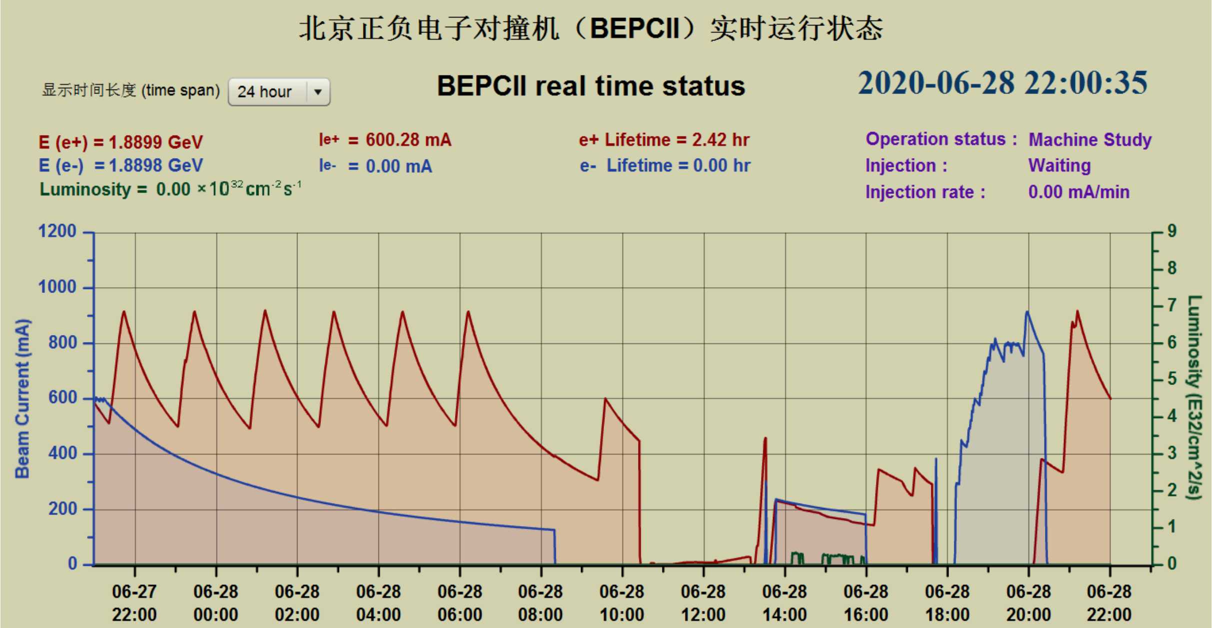
于程辉，BESIII合作组会报告，2020年11月

The preparation for the 1.89GeV

- Till now the highest record of integral luminosity per day at around 1.89GeV is **$37pb^{-1}$**. The maximum stable beam current of BEPCII is only 700mA. The main constraints are the stabilities of RF system and feedback system. Under the budget of topup operation project, RF system and feedback system were improved together.
- Detector noise and dark current background are still the strong limitations for the high beam performance.



Testing for the dark current control



Testing of high beam current 910mA

We did the machine studies at the end of last high energy physics operation

于程辉，BESIII合作组会报告，2020年11月

Data taking plan of 2020/2021

Table 7.1: List of data samples collected by BESIII/BEPCII up to 2019, and the proposed samples for the remainder of the physics program. The most right column shows the number of required data taking days in current (T_C) or upgraded (T_U) machine. The machine upgrades include top-up implementation and beam current increase.

Energy	Physics motivations	Current data	Expected final data	T_C / T_U
1.8 - 2.0 GeV	R values Nucleon cross-sections	N/A	0.1 fb^{-1} (fine scan)	60/50 days
2.0 - 3.1 GeV	R values Cross-sections	Fine scan (20 energy points)	Complete scan (additional points)	250/180 days
J/ψ peak	Light hadron & Glueball J/ψ decays	3.2 fb^{-1} (10 billion)	3.2 fb^{-1} (10 billion)	N/A
$\psi(3686)$ peak	Light hadron & Glueball Charmonium decays	0.67 fb^{-1} (0.45 billion)	4.5 fb^{-1} (3.0 billion)	150/90 days
$\psi(3770)$ peak	$D^0/D^\pm$ decays	2.9 fb^{-1}	20.0 fb^{-1}	610/360 days
3.8 - 4.6 GeV	R values XYZ/Open charm	Fine scan (105 energy points)	No requirement	N/A
4.180 GeV	D_s decay XYZ/Open charm	3.2 fb^{-1}	6 fb^{-1}	140/50 days
4.0 - 4.6 GeV	XYZ/Open charm Higher charmonia cross-sections	16.0 fb^{-1} at different $\sqrt{s}$	30 fb^{-1} at different $\sqrt{s}$	770/310 days
4.6 - 4.9 GeV	Charmed baryon/XYZ cross-sections	0.56 fb^{-1} at 4.6 GeV	15 fb^{-1} at different $\sqrt{s}$	1490/600 days
4.74 GeV	$\Sigma_c^+\bar{\Lambda}_c^-$ cross-section	N/A	1.0 fb^{-1}	100/40 days
4.91 GeV	$\Sigma_c\bar{\Sigma}_c$ cross-section	N/A	1.0 fb^{-1}	120/50 days
4.95 GeV	Ξ_c decays	N/A	1.0 fb^{-1}	130/50 days

2.37GeV， 500 pb^{-1}， 21 days
2.39GeV， 500 pb^{-1}， 24 days
2.42GeV， 500 pb^{-1}， 29 days
2.45GeV， 200 pb^{-1}， 15 days
} 1.7 fb^{-1}
psi (3686)， 3.3~4 fb^{-1}， 62 days（65 pb^{-1}/day）
psi (3770)， 1~3.2 fb^{-1}， 49 days（65 pb^{-1}/day）

> 5.0 fb^{-1}

$$8.5\times10^{32}\times(24\times60\times60)\times\frac{1}{10^{36}}\times0.8 = 59\ pb^{-1}$$

$$9.5\times10^{32}*(24*60*60)*\frac{1}{10^{36}}*0.8 = 65\ pb^{-1}$$

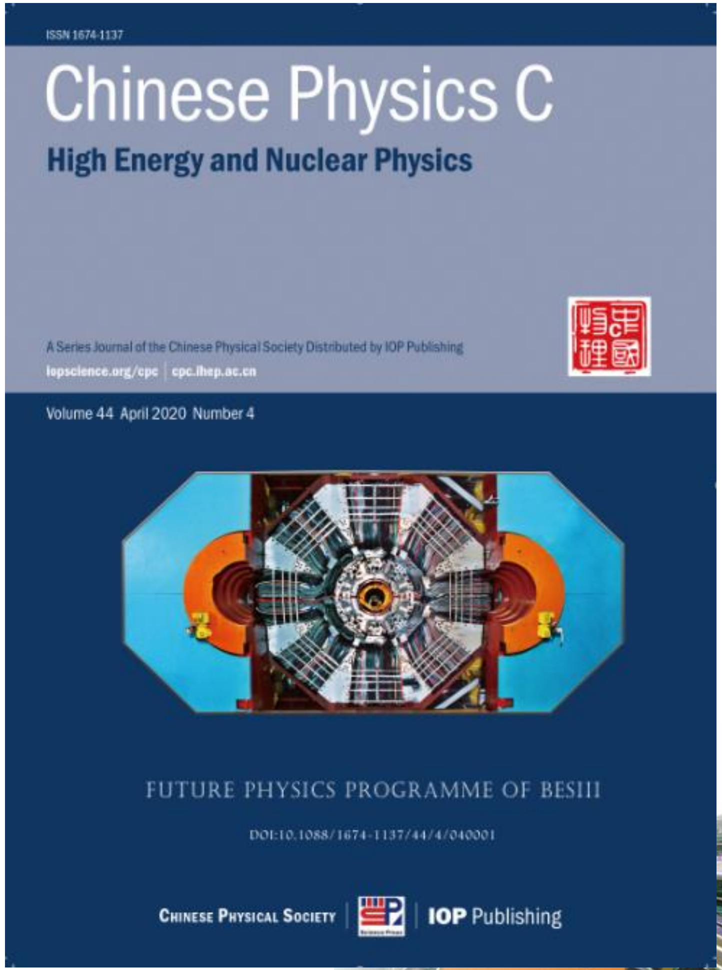
于程辉，BESIII合作组会报告，2020年11月

BEPCII is an excellent machine, and BEPCII team is an excellent team.

我们期待他们创造新的奇迹！

BESIII中长期规划

- 完成了物理白皮书的撰写，开展BEPCII亮度升级物理研究【196页】
- 国际评审委员会评审：2019年9月2-4日
- 评审报告：**2019年11月14日**
- 主要结论：
  - BESIII已经取得了丰富的物理成果，包括X(1835)、Zc(3900)、粲介子/粲重子等
  - BESIII未来物理依然非常重要
  - 加速器亮度升级非常必要，保证未来十年运行
- 白皮书发表：2020年4月



BESIII Data taking plan

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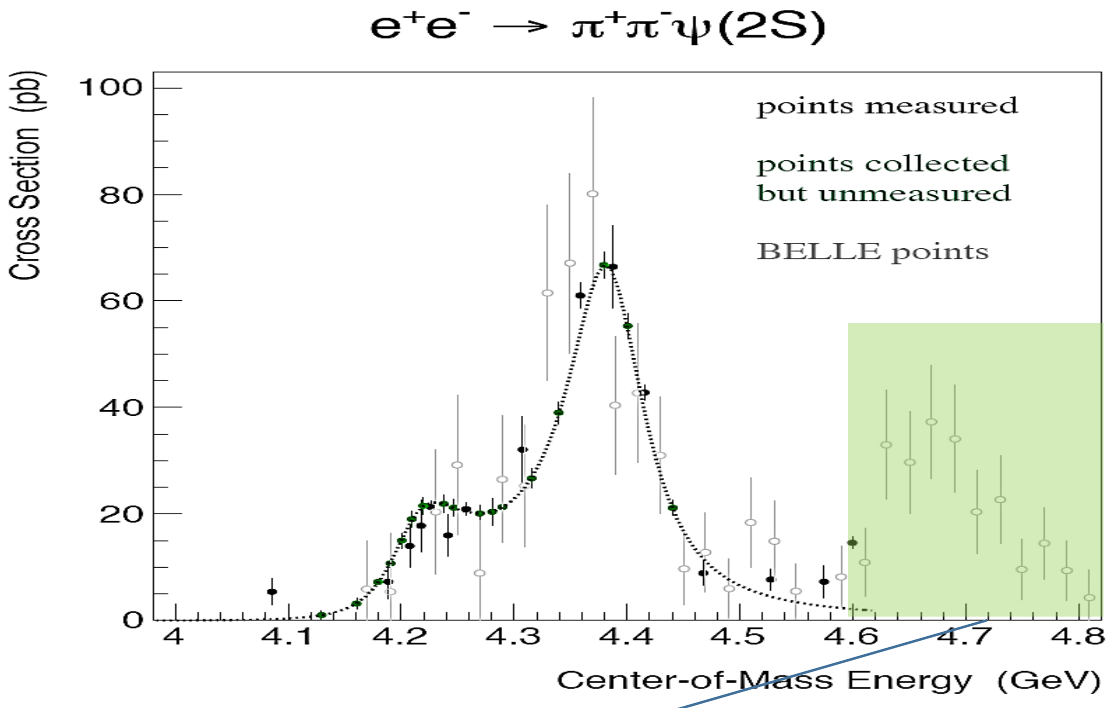

> 10 years

于程辉，BESIII物理软件研讨会报告，2020年9月

Overview of BEPCII

BEPCII upgrade programs in the recent years

- **Beam energy upgrade project (2017-2019, 5 million CNY)** was finished after 2019 summer shutdown. The beam energy can reach 2.45GeV. The optimized energy is still 1.89GeV. Data taking at the energy region 2.3~2.35GeV was smooth.

- **Top-up operation (2017-2020, 12 million CNY)** has already applied during the whole 2020 operation year.

- **Next upgrade project is BEPCIII (200 million CNY).** The optimized energy is 2.35GeV with luminosity 3 times higher than BEPCII.

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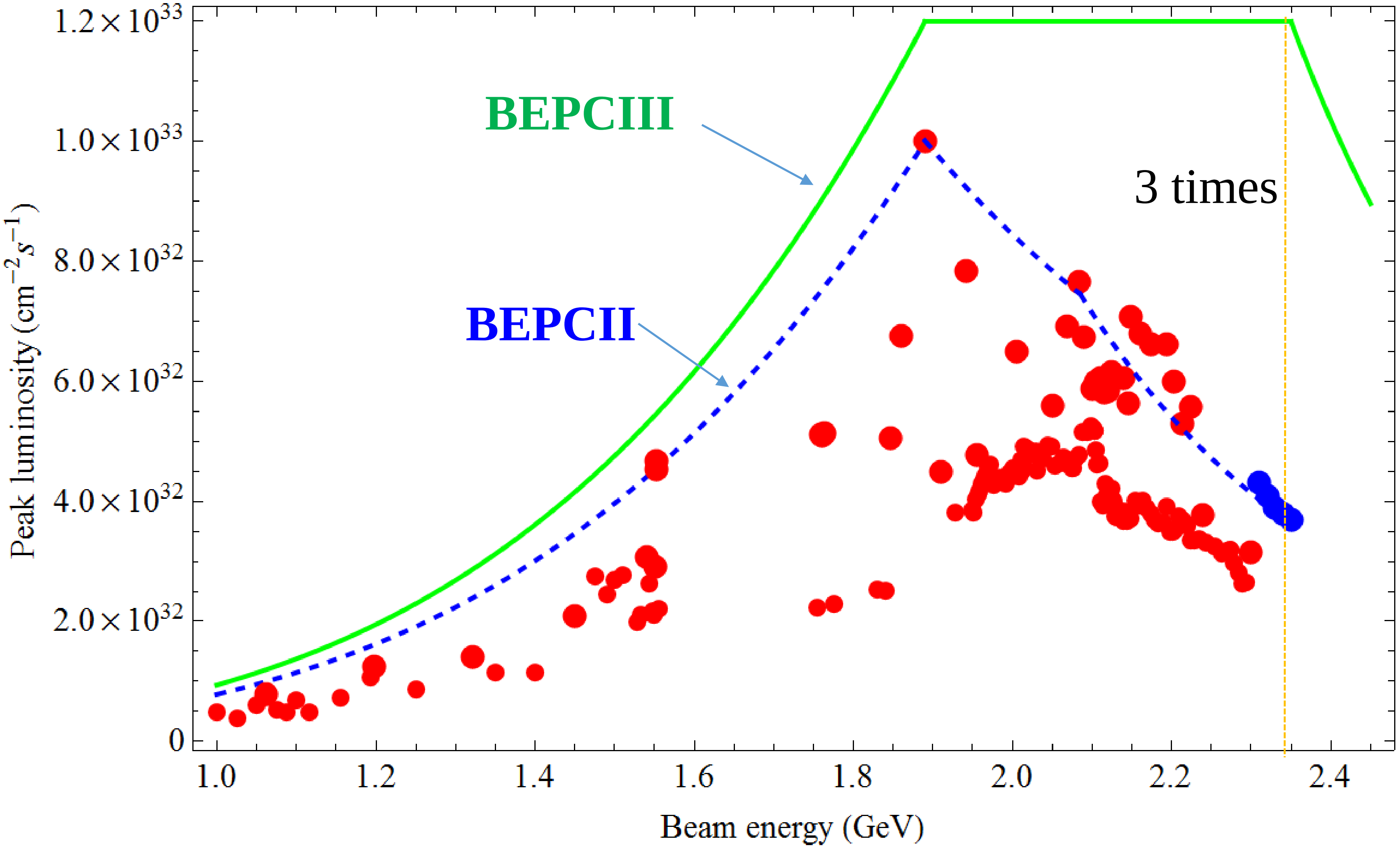
BEPCIII project



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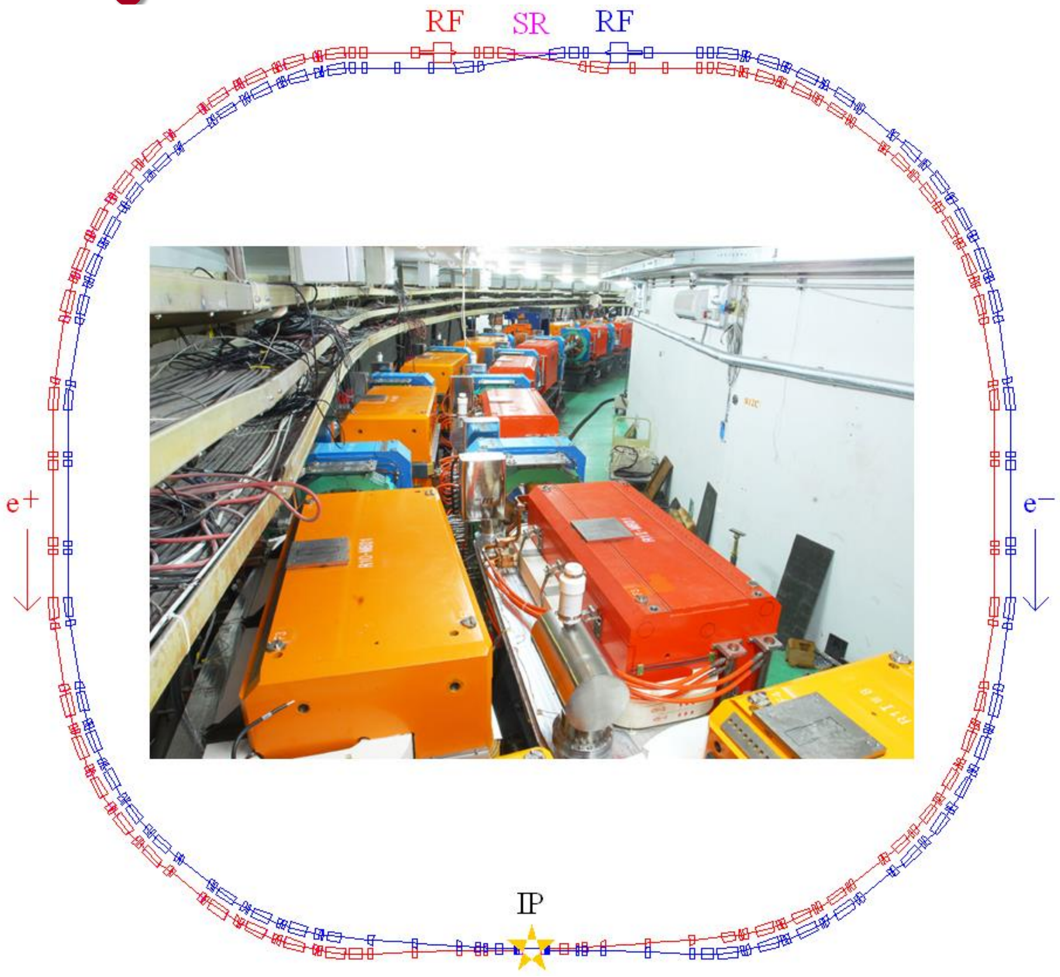
BEPCIII project

	BEPCII	BEPCIII
Lum. [$10^{33}cm^{-2}s^{-1}$] @2.35GeV	**0.35**	**1.2**
β_y^* [cm]	**1.5**	**1.35**
Bunch current	7.1 mA	7.5 mA
Bunch number	56	120
SR Power [kW]	**110**	**250**
$\xi_{y,\mathrm{lum}}$	**0.029**	**0.039**
Emittance [nmrad]	**138**	**120**
Coupling [%]	**0.53**	**0.40**
Bucket Height	0.0069	0.091
$\sigma_{z,0}$ [cm]	1.54	1.24
σ_z [cm]	**1.69**	**1.39**
RF voltage	**1.6MV**	**3.5MV**

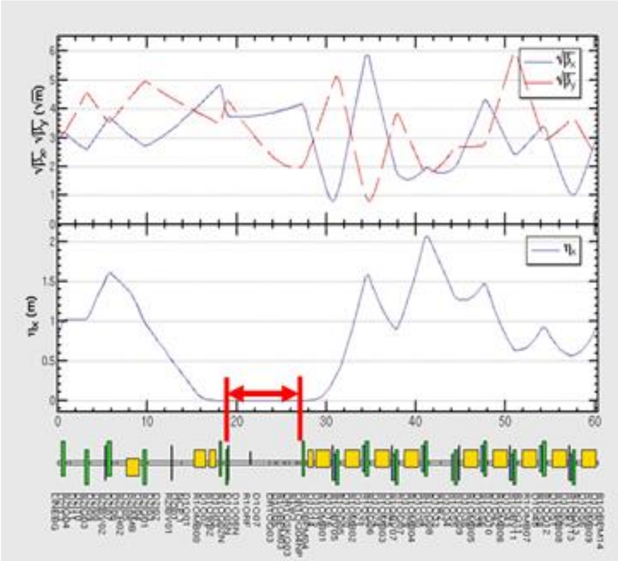


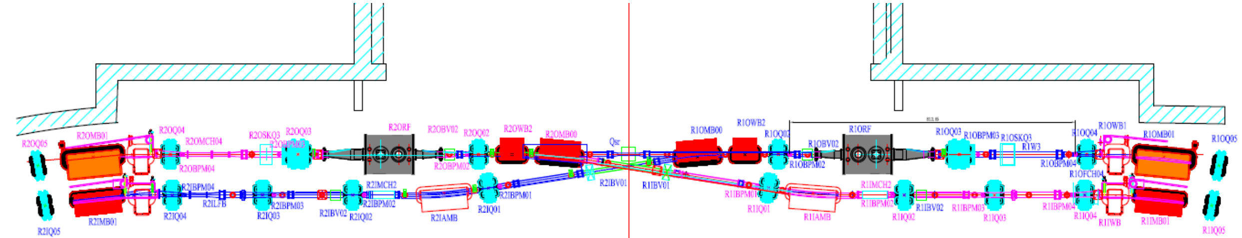
Major modification
- RF region
- Vacuum chamber
- Beam parameters

于程辉，BESIII物理软件研讨会报告，2020年9月

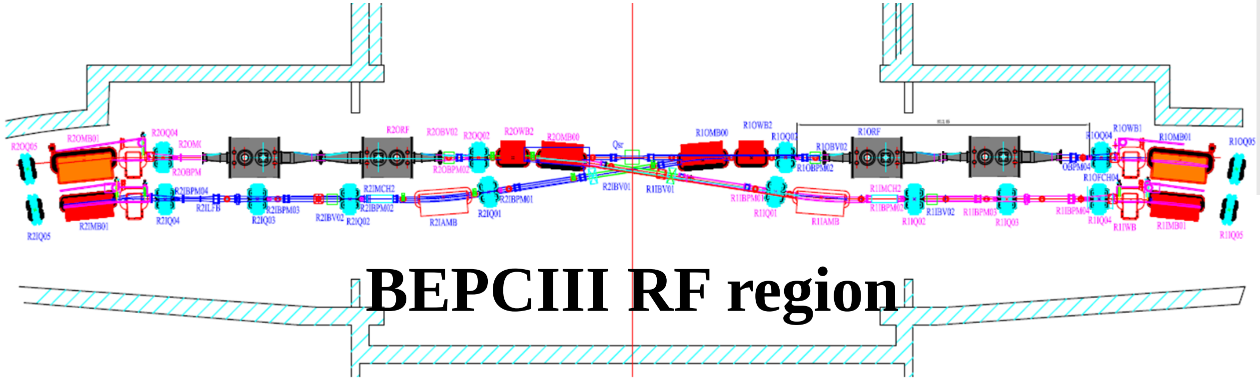
BEPCIII project

Keep the survey of BEPCIII same as BEPCII

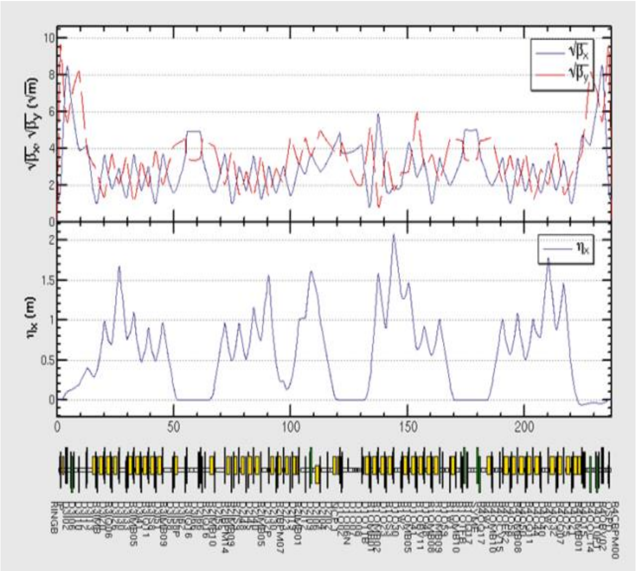




BEPCII RF region



BEPCIII RF region

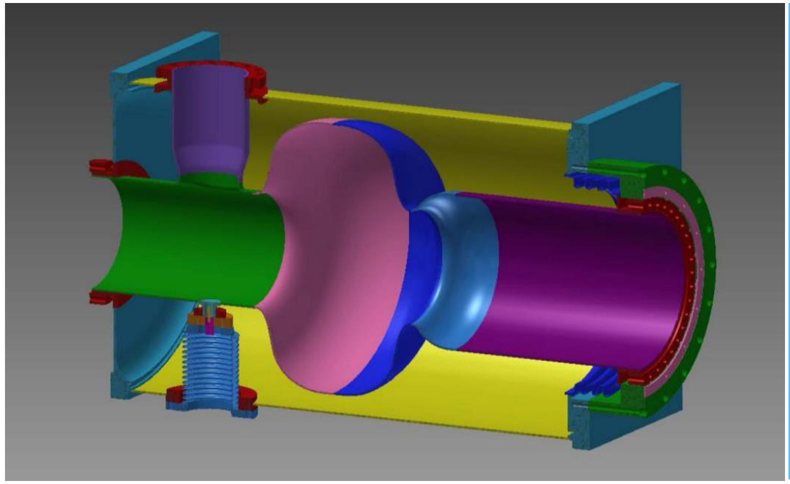


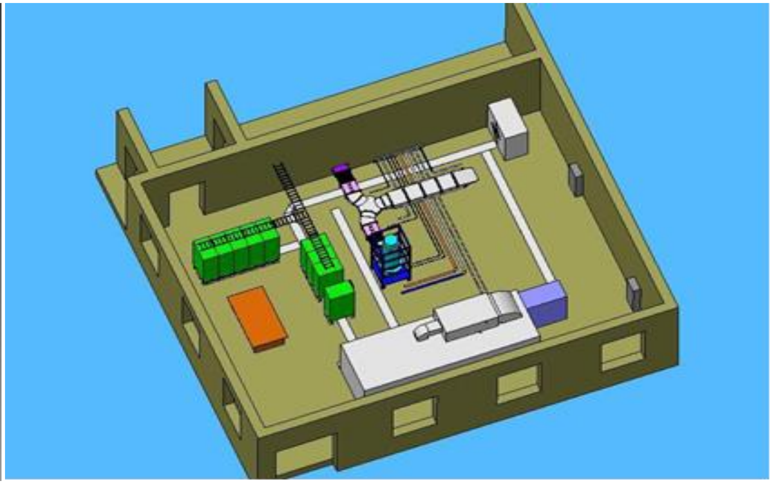
2+1 BEPCII RFC & 2+1 New type RFC

于程辉，BESIII物理软件研讨会报告，2020年9月

BEPCIII project

Specification	Device	No.
2.0～2.5MV **150kW/Cavity**	500MHz RFC	2+1
	150kW Klystron	2
	Low level system	2





We will develop the new RF cavity in China

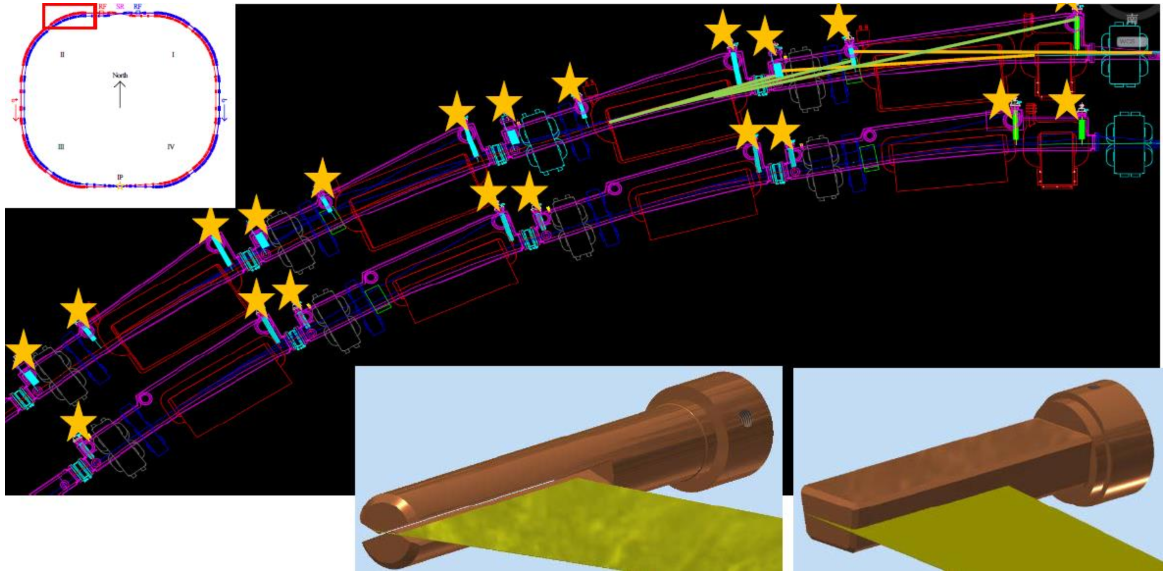
Key techniques

- High performance RF cavity
- Cryogenic system
- Photon absorber
- General supporting department
- LINAC energy upgrade up to 2.45GeV

BEPCIII project

The SR power of BEPCIII is 500kW (3 times BEPCII)

After careful deliberation, it was agreed to abandon the SR dedicated operation.



16	AB-O1-CR-460	R1O-17	*AbO1-C460	1	1W1	62.5±0.05	$9.7_0^{+0.1}$	3270	66	×
17	AB-O4-CR1-501M	R4O-11/15	*AbO4-C501	2	4B7/4B9	123.9±0.05	$8.2_0^{+0.1}$	5013	77	×
17	AB-O4-CR1-501M	R4O-13	*AbO4-C501A	1	4B8	60.7±0.05	$13.2_0^{+0.1}$	5013	77	×
18	AB-O4-CR2-501M	R4O-08	*AbO4-C501B	1	4W2	85±0.2	12±0.2	2110	77	×
40	AB-O4-RR-327	R4O-07	*AbO4-R327	1	4W2	79.1±0.05	$11_0^{+0.1}$	923	53	√
41	AB-O1-RR-345	R1O-05	*AbO1-R345	1	1B3	77.7±0.05	$5.8_0^{+0.1}$	3414	41	√
43	AB-O4-RR-427	R4O-18	*AbO4-R427	1	4W1	99.3±0.05	$8.7_{-0.1}^{0}$	3779	50	√
44	AB-O1-RR1-543M	R1O-09	*AbO1-R543	1	1B5	87.5±0.05	$12.4_0^{+0.1}$	3854	37	√
45	AB-O1-RR-589	R1O-01	*AbO1-R589	1	1W3	124.8±0.05	13.6±0.05	4450	41	√
					1B1	77.7±0.05	$5.8_0^{+0.1}$			

Main challenges

<u>Real performance of RF cavity </u>vs 2.0～2.5MV 150kW/Cavity

<u>High beam intensity and SR power lead to the heating and beam instabilities</u>

<u>Background from both loss particle and photon</u>

<u>Electromagnetic interference</u>

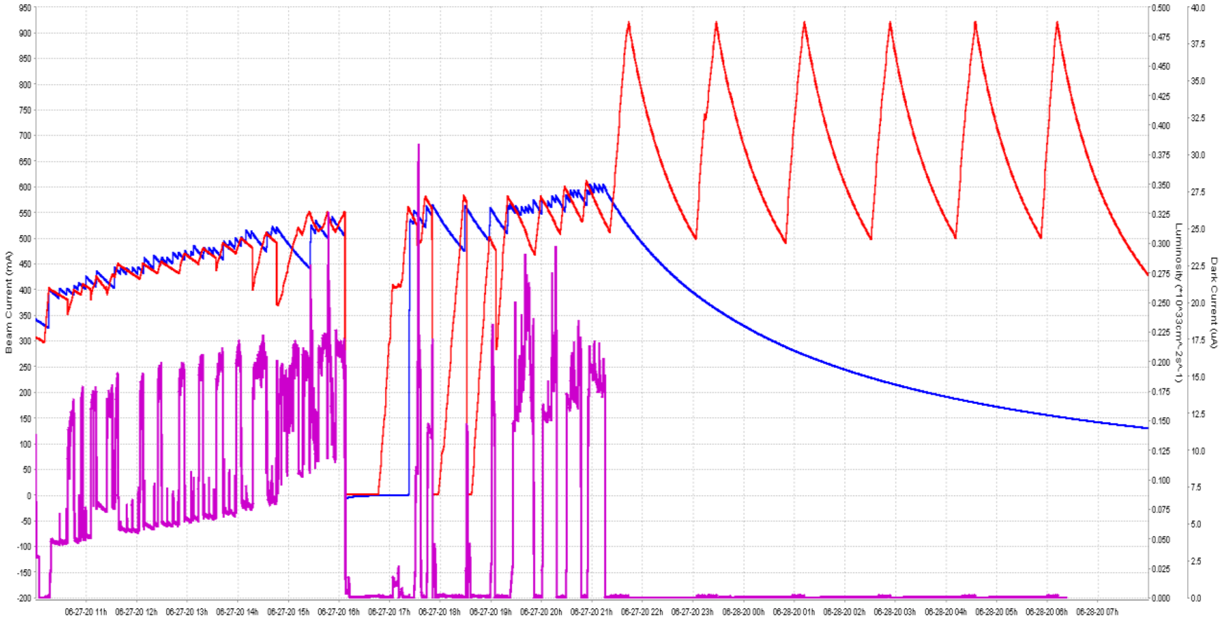
<u>Some hardware limitations which still exist in BEPCII</u>

BEPCII is an upgrade project based on BEPC. Lots of 30 years old BEPC devices will keep on working in BEPCIII

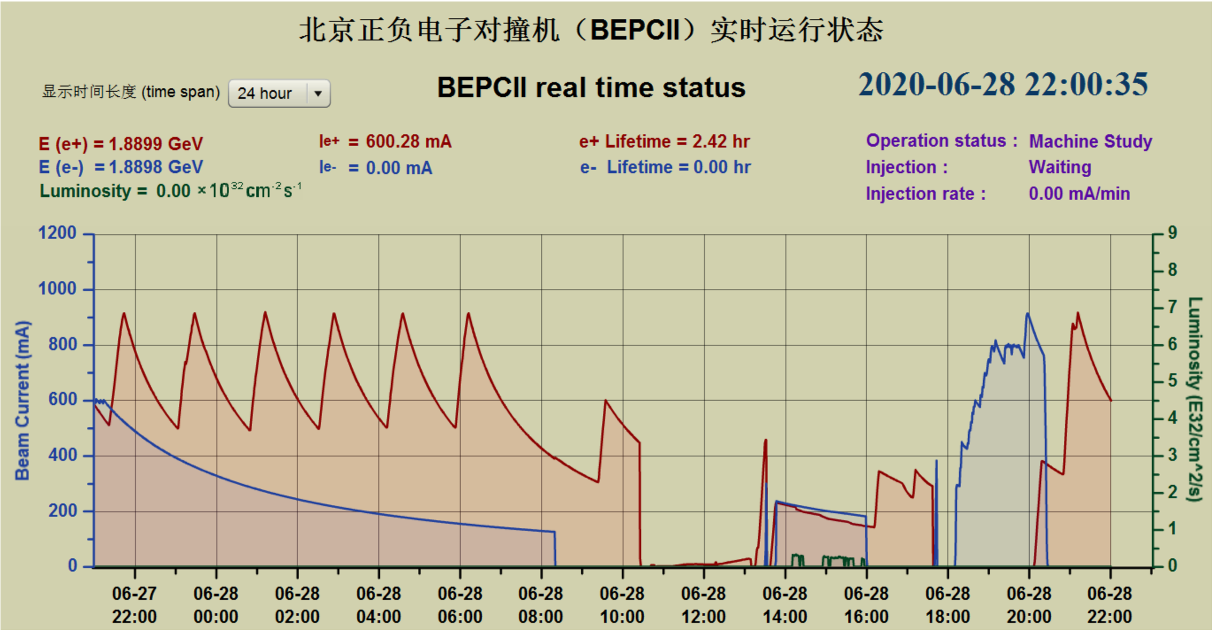
于程辉，BESIII物理软件研讨会报告，2020年9月

Main challenges

- The main constraints for the high beam current are the stabilities of RF system and feedback system.
- Under the budget of topup operation project, RF system and feedback system were improved together.
- Dark current caused by both circulating beam and injected beam is not acceptable right now.



Testing for the dark current control



Testing of high beam current 910mA

Lots of machine studies related to BEPCIII should be done in BEPCII in the following 1~2 years

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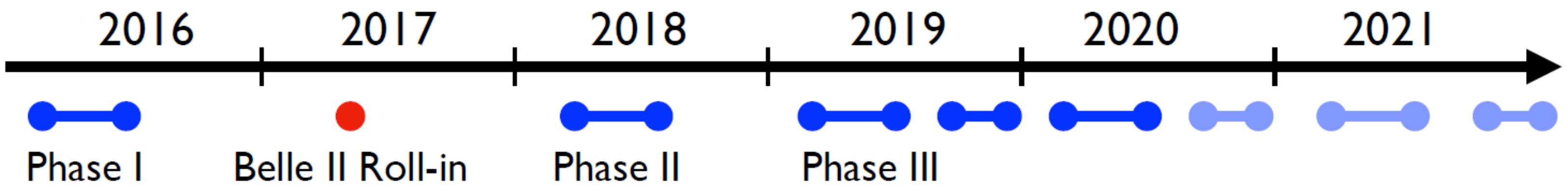
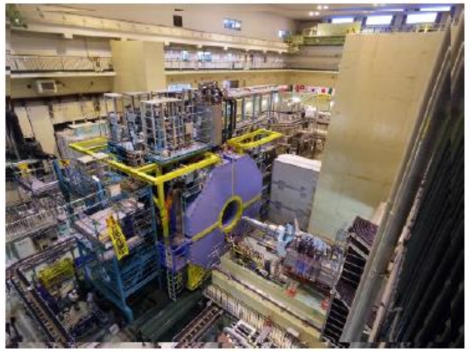
Belle II

SuperKEKB/Belle II 运行历史

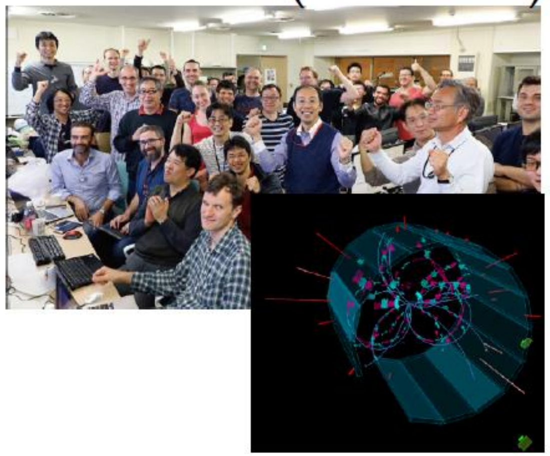


- Phase I (w/o QCS/Belle II)
  - 加速器束流调试
- Phase II (w/ QCS/Belle II, but no VXD)
  - 验证 “纳米束流(nano-beam)方案”
  - 研究束流本底
  - 取数→刻度/调试探测器
- Phase III (w/ full detector)
  - 物理取数（2019.3.25~）
  - 2020年，创造对撞亮度新的世界纪录
- 预计运行时间：> 10年



Belle II roll-in (2017.4.17)

1st collision (2018.4.26)



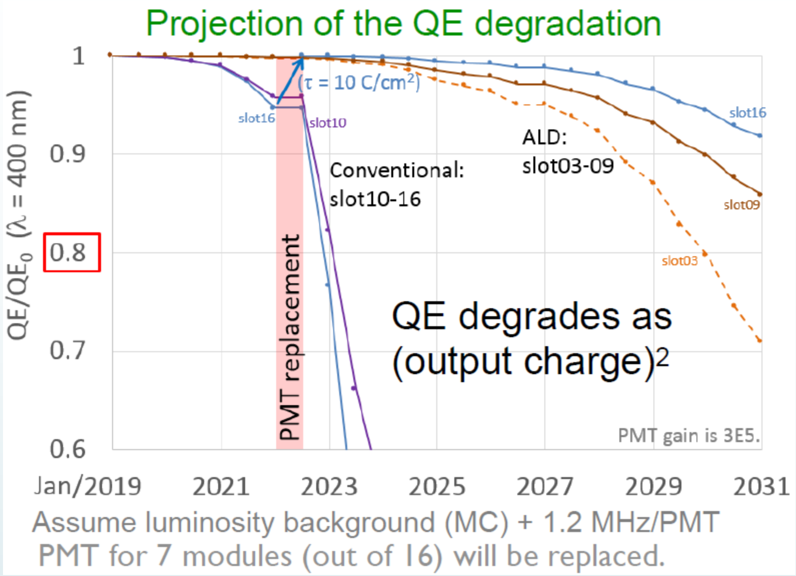
Installation of VXD

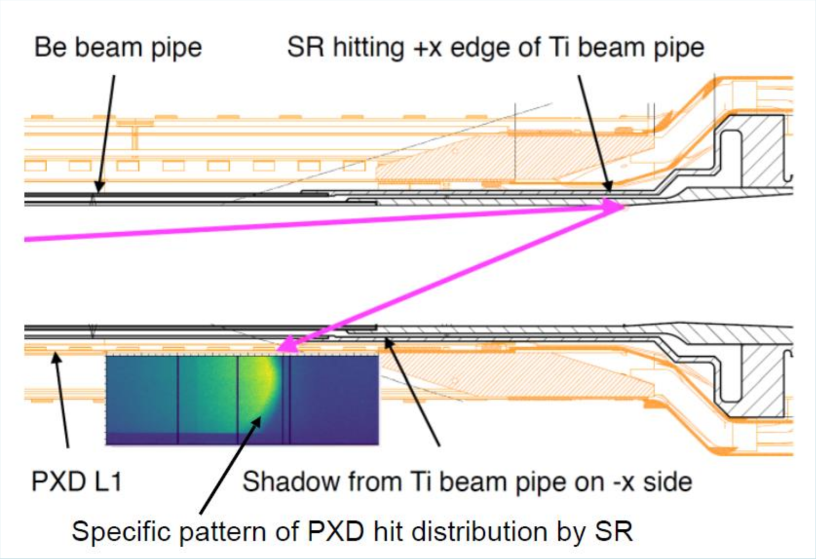
Phase 3 physics run (2019.3.25~)

王小龙，Belle II中国组研讨会报告，2020年10月

Belle II运行的主要问题

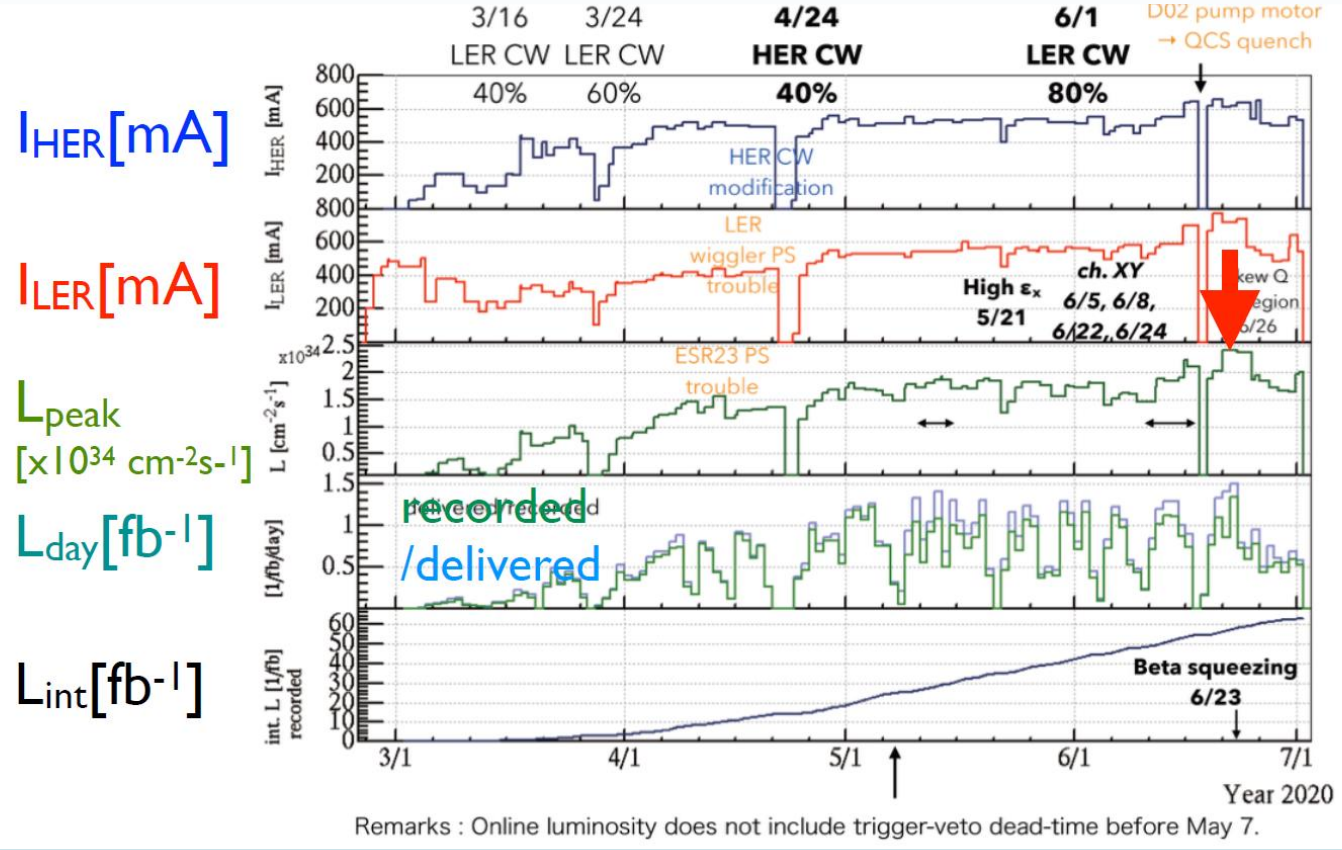
- 探测器寿命，特别是iTOP
  - 需要维持MCP-PMT的量子效率：$\frac{QE}{QE_0} > 80\%$ 直到获取50 ab^{-1}的数据；
  - 但是，Touschek和束流本底随I_{beam}^2增加，
  - 需要采取的措施：准直系统(collimators)，束流调试，更多的束流屏蔽(shielding)
- Accidental huge beam loss对PXD和SVD造成的永久损害
- 高能环(HER)同步辐射对PXD造成的辐射损伤
- Belle II设立了探测器升级研究组(Upgrade Working Group, UWG)，正在研究各种升级和改进方案。





2020年上半年的取数：2020a,b

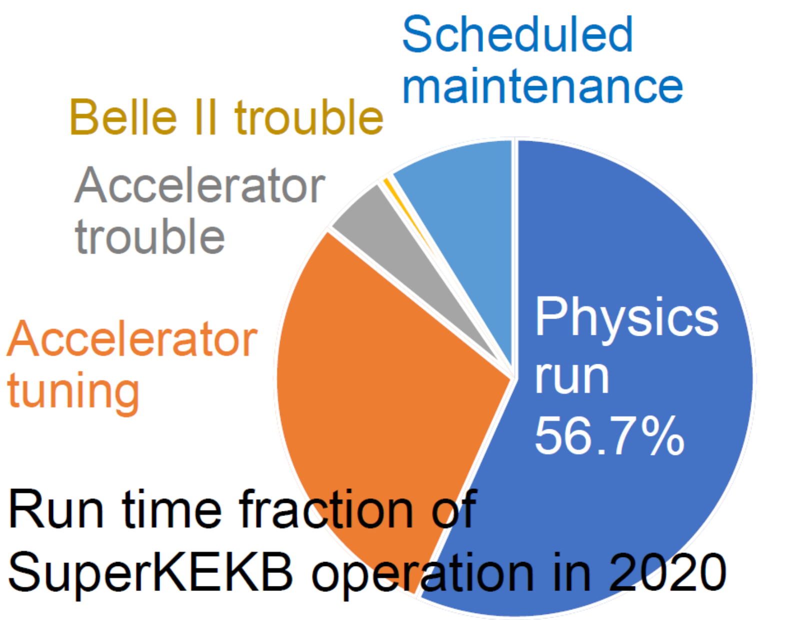
- Max current = $\frac{770mA(LER)}{660mA(HER)}$
- $L_{peak} = 2.4 \times 10^{34}\ cm^{-2}s^{-1}$(world highest)
  - KEKB record:
    - $L_{peak} = 2.11 \times 10^{34}\ cm^{-2}s^{-1}$
    - $L_{day}^{rec} = 1.48\ fb^{-1}$
- LER: $\frac{\beta_x^*}{\beta_y^*} = \frac{80\ mm}{1\ mm} \to \frac{60\ mm}{0.8\ mm}$
- HER: $\frac{\beta_x^*}{\beta_y^*} = \frac{60\ mm}{1\ mm} \to \frac{60\ mm}{0.8\ mm}$



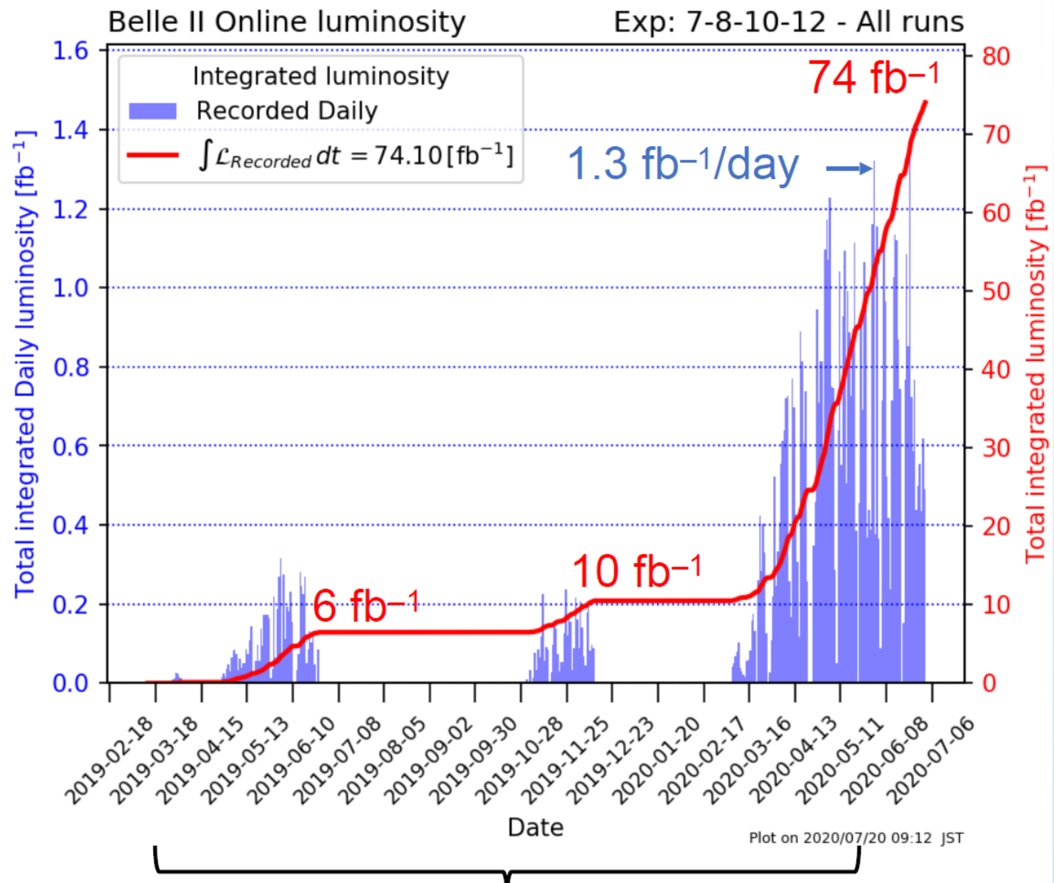
KEKB性能：$\beta_y^* = 5.9\ mm$
设计指标：$\beta_y^* = 0.3\ mm$

Belle II状态以及数据样本

- 数据获取效率提升到84%.
  - DAQ出错概率减小，并且故障排除更快。
  - ELK(Elasticsearch Logstash Kibana)对故障的分析和监控。
  - 更多有经验的值班人员
  - 降低注入的死时间



Run time fraction of SuperKEKB operation in 2020

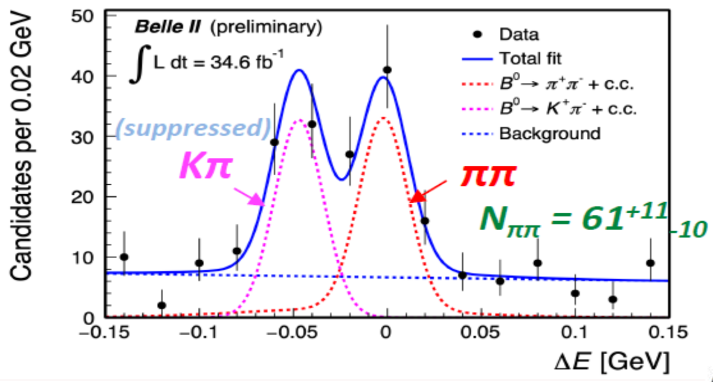


ICHEP2020 dataset
34.6(3.2) fb^{-1} on-(off-)resonance

王小龙，**Belle II中国组研讨会报告，2020年10月**

Toward ϕ_1, ϕ_2, ϕ_3 measurements

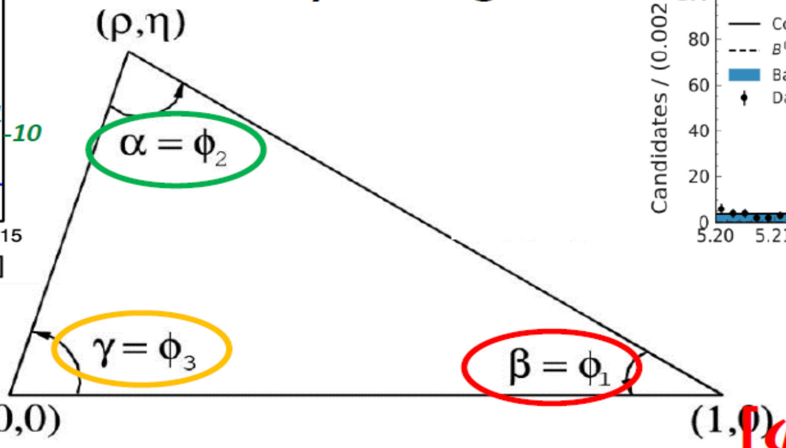
$B^0 \to \pi^\pm\pi^\mp$ **[φ_2]**



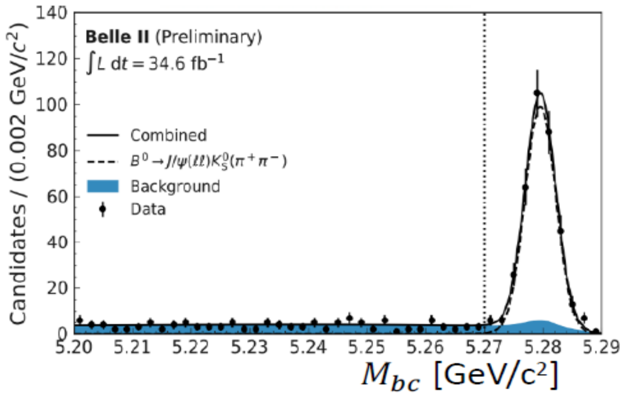
$Br = (5.6^{+1.0}_{-0.9} \pm 0.3) \times 10^{-6}$

CKM

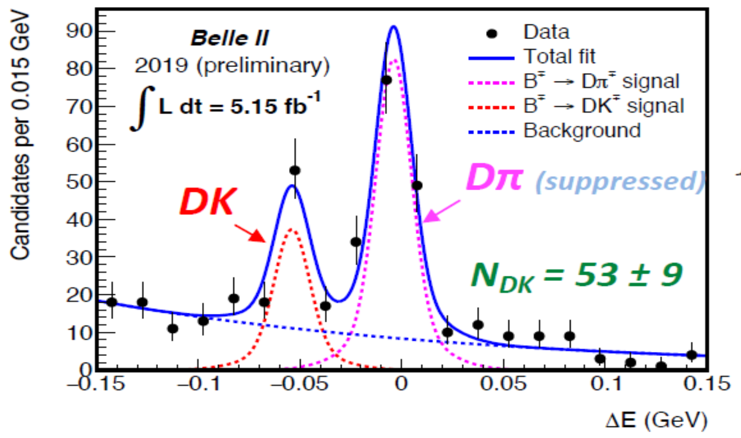
Unitarity triangle



[φ_1] $B^0 \to J/\psi\, K_s$



$B^\pm \to D^0 K^\pm$ **[φ_3]**

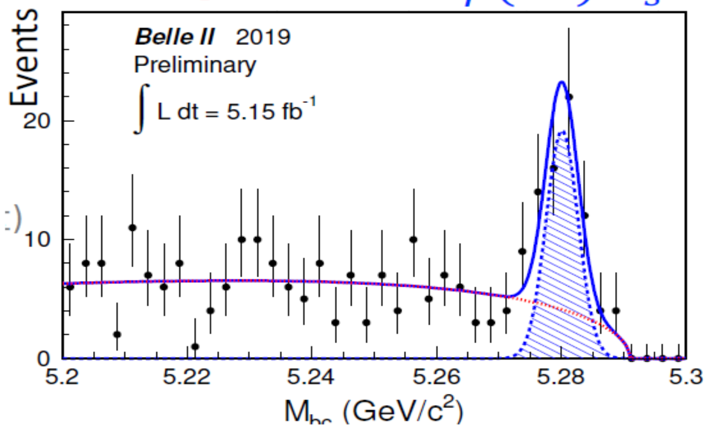


Beam energy constrained mass

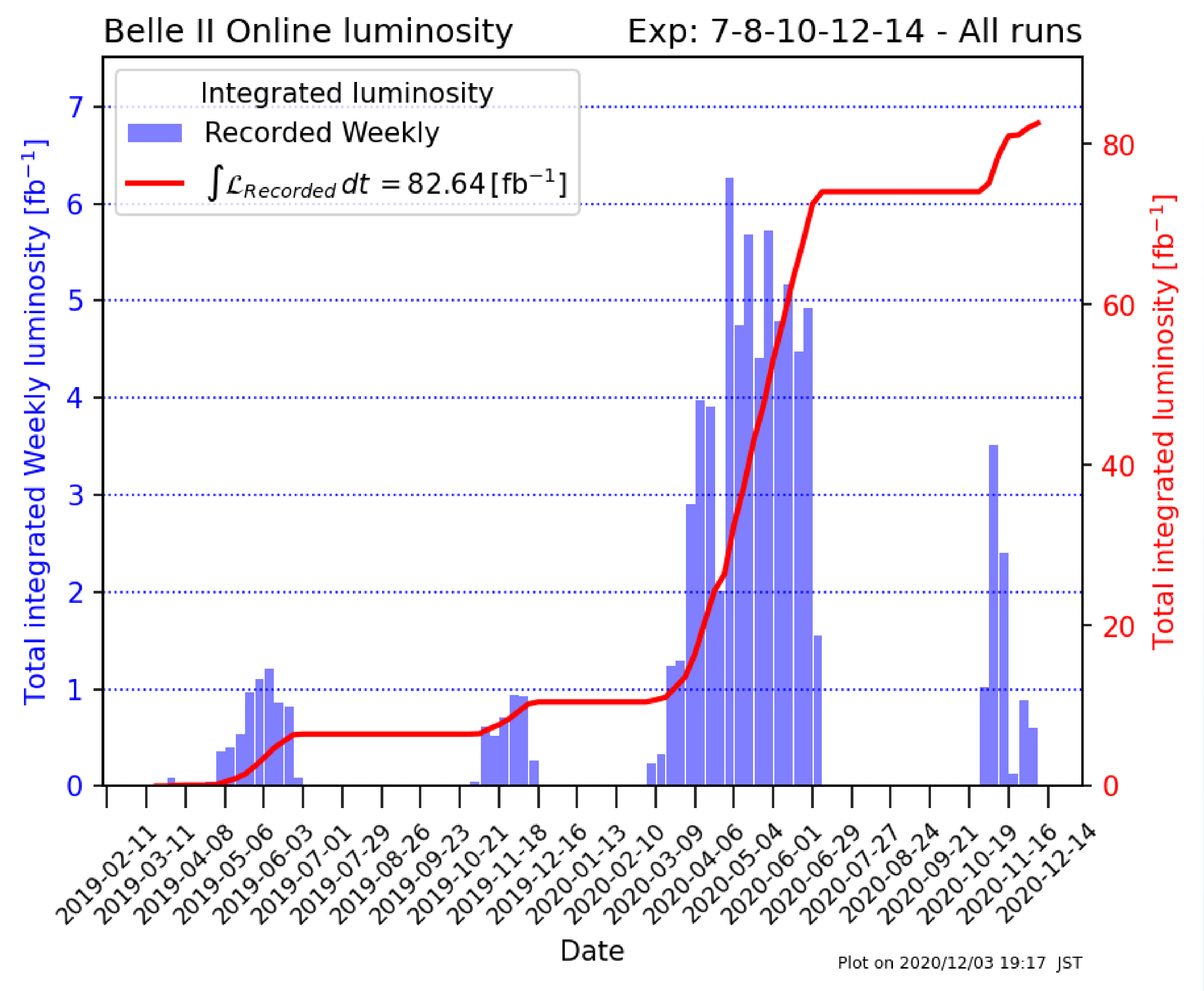
$$M_{\rm bc} \equiv \sqrt{E^{*2}_{\rm beam} - p^{*2}_B}$$

$$\Delta E \equiv E^*_B - E^*_{\rm beam}$$

[φ_1] $B^0 \to \psi(2S)\, K_s$

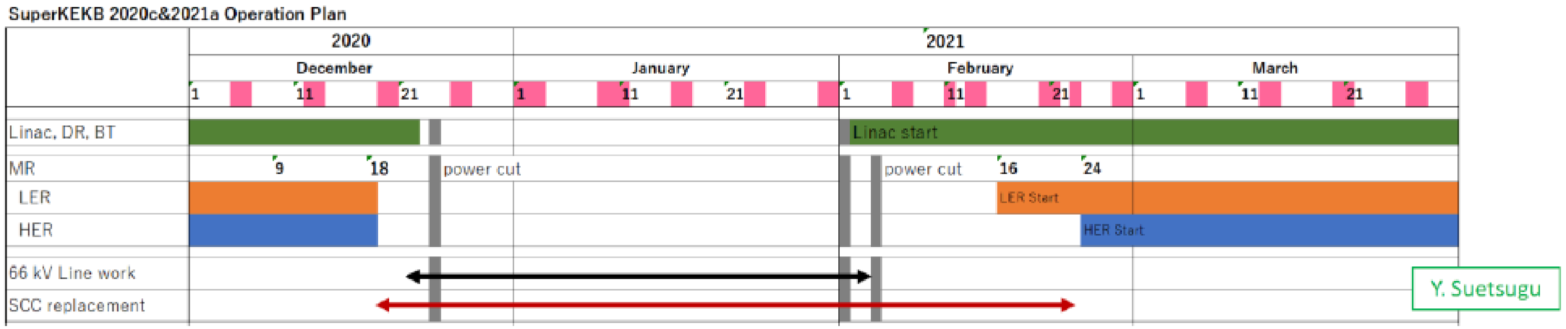


2020c run in progress

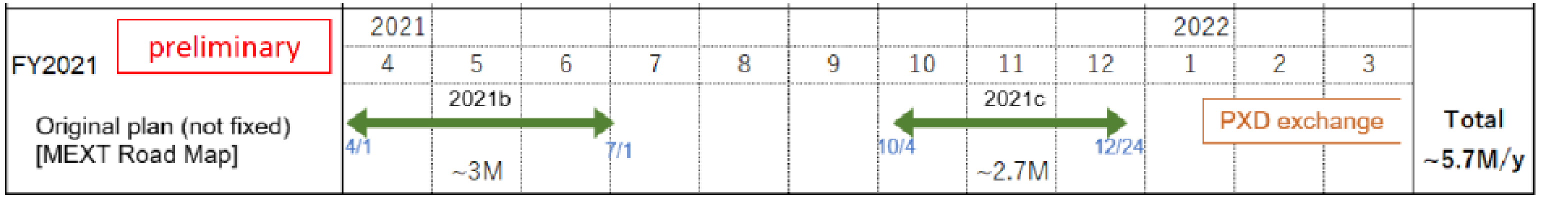


Run plan in 2021

- Winter shutdown (Dec.18 - Feb.16)
  - Replacement of SCC D11D
  - Replacement of 66kV high-voltage power supply lines
- 2021a (Feb.16 - Mar.31)
  - Operation cost will be covered with an extra budget from KEK-DG.
  - LER operation starts from Feb.16.
  - HER operation starts from Feb.24.
    - depending on D11D replacement work.



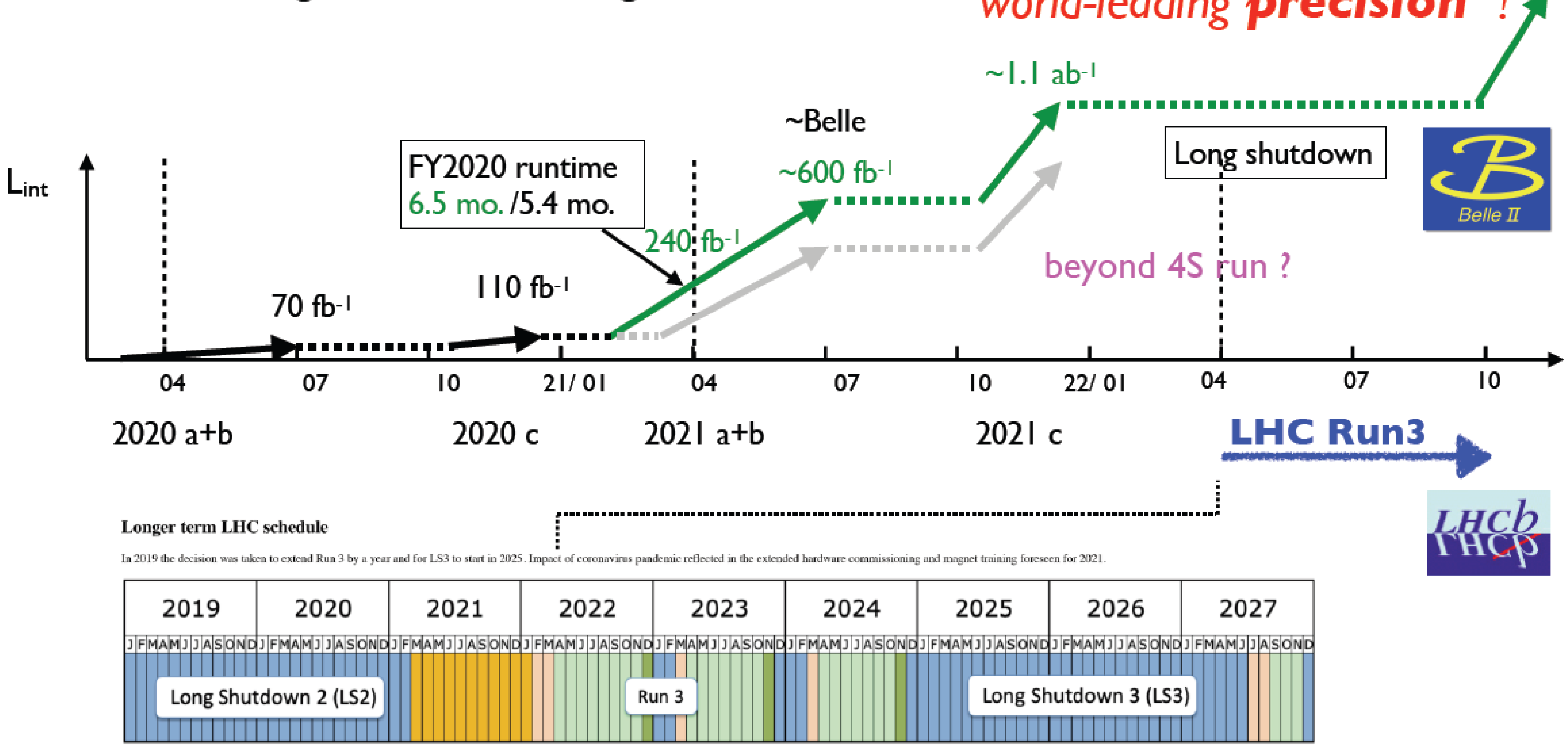
- JFY2021 runplan
  - JFY2021 budget request is ongoing (aligned to the plan in the MEXT Roadmap2020).



Belle II plan

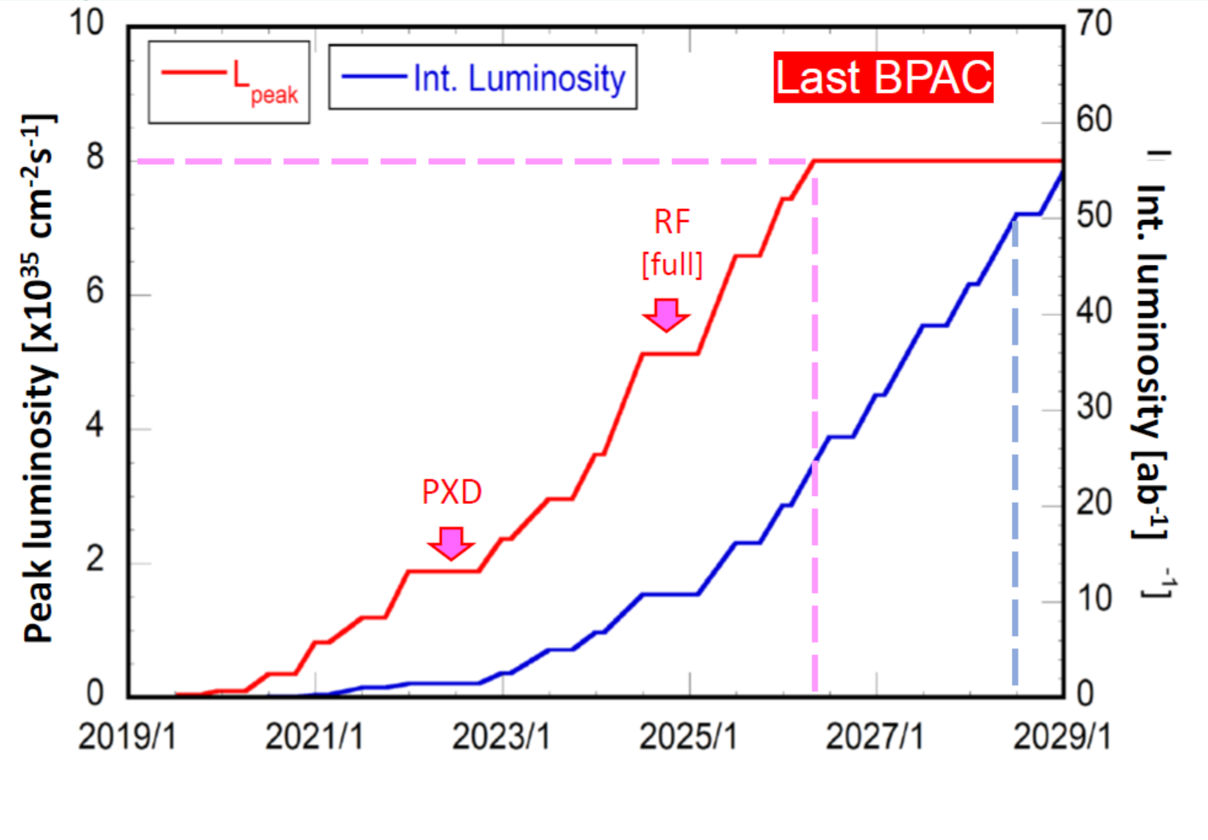
- Belle II is ready to accumulate more data (as endorsed by the BPAC review)
  - Good prospect for 6.5mo. operation in JFY2020
  - Comparable to Belle by 2021 summer
  - $>1 ab^{-1}$ target before the long shutdown.

*Many many results with "world-leading **precision**"!*



Previous plan on data taking

- Previous plan
  - Proposed in last BPAC, 2019
  - Updaged based on the results until Phase-2



- Peak luminosity： $8 \times 10^{35} cm^{-2} s^{-1}$ in ~2026
- Integrated luminosity 50 ab^{-1} in ~2028
- $\beta_y^* = 0.3\ mm$ in 2021
- PXD exchange in 2021~2022
- RF full upgrade (4 stations) in 2024
- Max. beam currents: LER 3.6 A, HER 2.6 A (~2500 bunches) in 2026
- Basically, 8 months' operation per year

- Inverstment in equipment
  - Full-scale RPF-power upgrade (add 4 stations)
  - Beam collimator upgrade
  - Linac upgrade
  - Belle II upgrade!!!

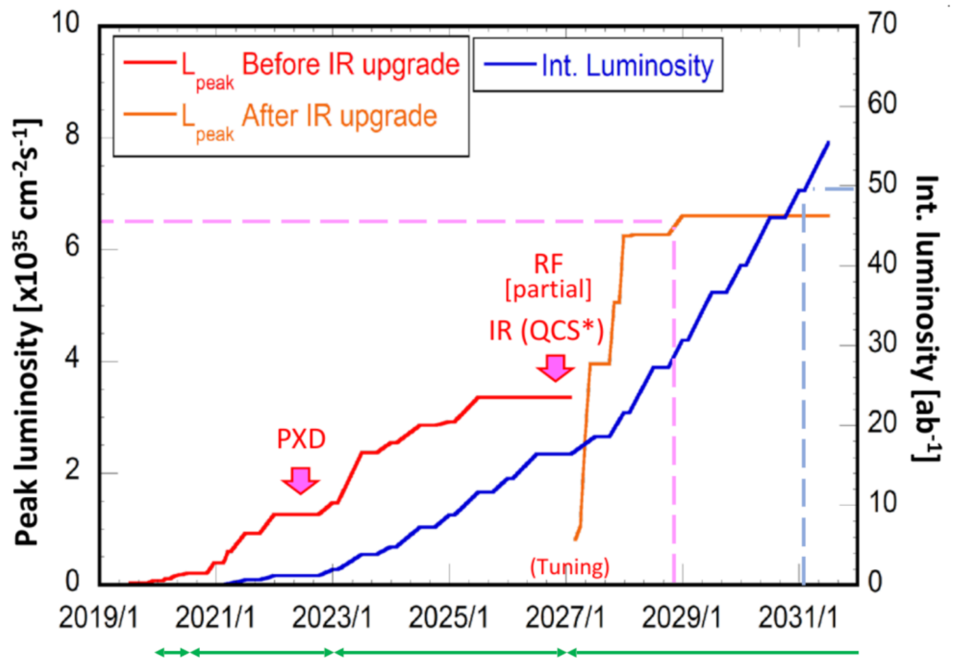
王小龙，**Belle II中国组研讨会报告，2020年10月**

中长期取数和探测器升级计划

- **Intermediate luminosity** (1 x 10^{35}, 5 ab^{-1})
- **Design/high luminosity** (0.6 x 10^{36}, 50 ab^{-1})
- **Polarization and luminosity upgrades** (up to 4 x 10^{36}, 200 ab^{-1})

$L_{design} \times 5$!!!

- < 2025 Intermediate lumi (maybe 2 x 10^{35} ?)
- 2026 – 2031 Design/High lumi
- > 2032 Polarization and luminosity upgrades



System	Limits understood ?	Upgrade activities and time scale
VXD	Reasonably well	Several options on different time scales (CMOS, DEPFET, Strips, SOI, …)
CDC	Not clear	Electronics
TOP	Reasonably well	STOP, MCPMT, SiPM on different time scales
ARICH	Reasonably well	Photon detectors on 2030 timescale
ECL	Reasonably well	Crystals, Photodiode, Preshower on long(?) timescale
KLM	Yes	Scintillators, readout electronics, TOF possibly on short time scale (?)
DAQ	Yes	Ongoing – ballistic

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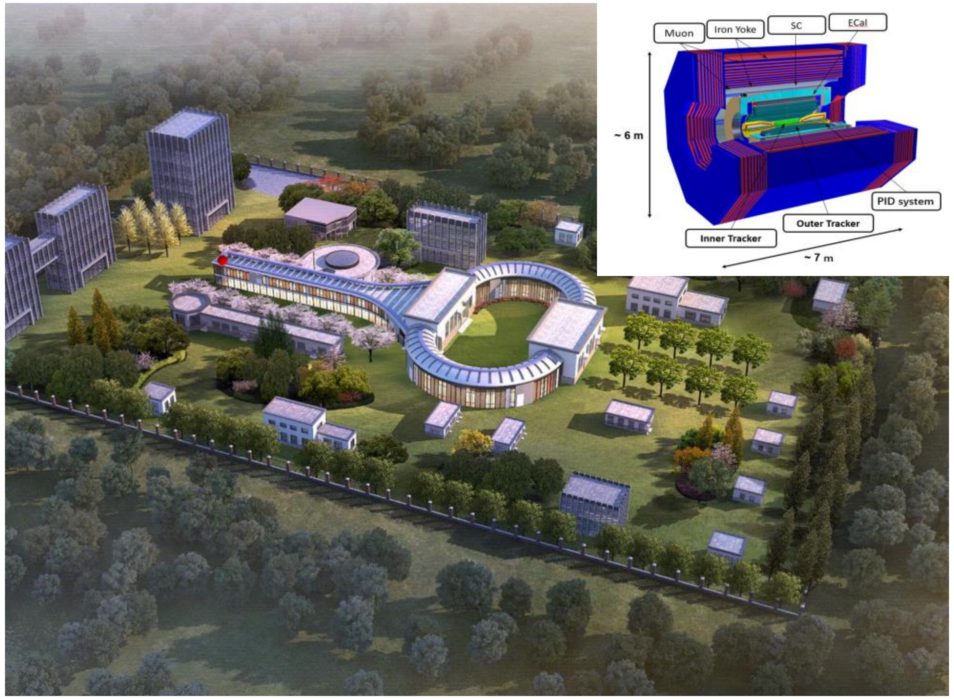
STCF

Super tau-charm Facility in China

- **Peaking luminosity 0.5×10^{35} $cm^{-2}s^{-1}$ at 4 GeV**
- **Potential to increase luminosity and realize beam polarization**
- **Energy range E_{cm} = 2-7 GeV**
- **A nature extension and a viable option for China accelerator project in the post BEPCII/BESIII era**



Expected data with 1ab^{-1}

CME (GeV)	No. of Events
3.097	3 T J/ψ
3.686	500 B ψ'
3.77	3.6 B D^0 2.8 B D^+
4.009	0.2 B Ds
4.23	1 B Y(4260) 100 M Zc 5 M X(3872) 3.6 M tau
4.63	0.5 B Λ_c
>5	fine scan

Table 1: The expected numbers of events per year at different energy points at STCF

CME (GeV)	Lumi (ab^{-1})	samples	σ(nb)	No. of Events	remark
3.097	1	J/ψ	3400	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}	
		$\tau^+\tau^-$	2.5	2.5×10^{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	$\gamma D^0\bar{D}^0$	0.40	4.0×10^{6}	$CP_{D^0\bar{D}^0}=+1$
		$\pi^0 D^0\bar{D}^0$	0.40	4.0×10^{6}	$CP_{D^0\bar{D}^0}=-1$
		$D_s^+D_s^-$	0.20	2.0×10^{8}	
		$\tau^+\tau^-$	3.5	3.5×10^{9}	
4.180	1	$D_s^{+*}D_s^-$+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	$J/\psi\pi^+\pi^-$	0.085	8.5×10^{7}	
		$\tau^+\tau^-$	3.6	3.6×10^{9}	
		$\gamma X(3872)$			
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			

Huge data samples ➔ a broad physics program.

Opportunities at STCF:

- To study the known vector states and Z_c in much more detail
- For J^{++} excited states, BESIII observed X(3872) in $e^+e^- \to \gamma X(3872)$, s far no signal for other J^{++} states with masses around 3.8-4 GeV.

  At STCF, hadronic channels:

  $$E \gtrsim 4.7\ \mathrm{GeV}, e^+e^- \to \omega X(J^{++})$$

- To study the heavier PC=++ states observed in $\phi\, J/\psi$

  $$E > 5\ \mathrm{GeV}, e^+e^- \to \phi X(J^{++})$$

- $E > 5\ \mathrm{GeV}$, to reveal expected rich phenomena due to charm baryon-antibaryon thresholds
- To establish the hidden-charm spectrum far beyond 4 GeV
- Open-charm mesons with different sensitivity to quantum numbers
- E> 6 GeV, two ccbar pair???

2. Physics of charmed hadrons

Competitions from Belle II and LHCb in study of charmed hadrons.
But STCF has certain advantages.

A comparison:

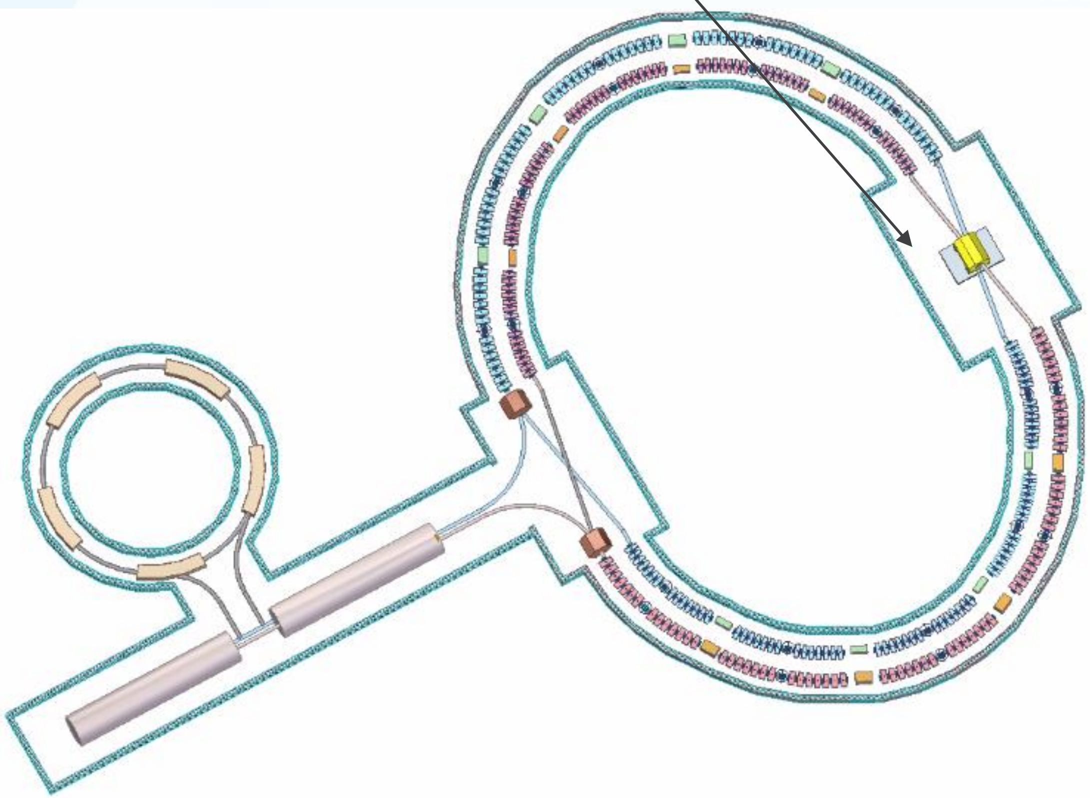
	STCF	Belle(-II)	LHCb
Production yields	★★	★★★★	★★★★★
Background level	★★★★★	★★	★★
Systematic error	★★★★★	★★★	★★
Completeness	★★★★★	★★★	★
(Semi)-Leptonic mode	★★★★★	★★★	★
Neutron/K_L mode	★★★★★	★★	☆
Photon-involved	★★★★★	★★★★★	☆
Absolute measurement	★★★★★	★★★	☆

- Most are precision measurements, which are mostly dominant by the systematic uncertainty
- STCF has overall advantage

	BESIII	STCF	Belle II
Luminosity	2.92 fb^{-1} at 3.773 GeV	1 ab^{-1} at 3.773 GeV	50 ab^{-1} at $\Upsilon(nS)$
$\mathcal{B}(D^+ \to \mu^+\nu_\mu)$	$5.1\%_{\rm stat.}$ $1.6\%_{\rm syst.}$ [8]	$0.28\%_{\rm stat.}$	–
f_{D^+} (MeV)	$2.6\%_{\rm stat.}$ $0.9\%_{\rm syst.}$ [8]	$0.15\%_{\rm stat.}$	–
$\lvert V_{cd}\rvert$	$2.6\%_{\rm stat.}$ $1.0\%^{*}_{\rm syst.}$ [8]	$0.15\%_{\rm stat.}$	–
$\mathcal{B}(D^+ \to \tau^+\nu_\tau)$	$20\%_{\rm stat.}$ $10\%^{\dagger}_{\rm syst.}$ [9]	$0.41\%_{\rm stat.}$	–
$\frac{\mathcal{B}(D^+ \to \tau^+\nu_\tau)}{\mathcal{B}(D^+ \to \mu^+\nu_\mu)}$	$21\%_{\rm stat.}$ $10\%^{\dagger}_{\rm syst.}$ [9]	$0.50\%_{\rm stat.}$	–
Luminosity	3.2 fb^{-1} at 4.178 GeV	1 ab^{-1} at 4.009 GeV	50 ab^{-1} at $\Upsilon(nS)$
$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu)$	$2.8\%_{\rm stat.}$ $2.7\%_{\rm syst.}$ [10]	$0.30\%_{\rm stat.}$	$0.8\%_{\rm stat.}$ $1.8\%_{\rm syst.}$
$f_{D_s^+}$ (MeV)	$1.5\%_{\rm stat.}$ $1.6\%_{\rm syst.}$ [10]	$0.15\%_{\rm stat.}$	–
$\lvert V_{cs}\rvert$	$1.5\%_{\rm stat.}$ $1.6\%_{\rm syst.}$ [10]	$0.15\%_{\rm stat.}$	–
$f_{D_s^+}/f_{D^+}$	$3.0\%_{\rm stat.}$ $1.5\%_{\rm syst.}$ [10]	$0.21\%_{\rm stat.}$	–
$\mathcal{B}(D_s^+ \to \tau^+\nu_\tau)$	$2.2\%_{\rm stat.}$ $2.6\%^{\dagger}_{\rm syst.}$	$0.24\%_{\rm stat.}$	$0.6\%_{\rm stat.}$ $2.7\%_{\rm syst.}$
$f_{D_s^+}$ (MeV)	$1.1\%_{\rm stat.}$ $1.5\%^{\dagger}_{\rm syst.}$	$0.11\%_{\rm stat.}$	–
$\lvert V_{cs}\rvert$	$1.1\%_{\rm stat.}$ $1.5\%^{\dagger}_{\rm syst.}$	$0.11\%_{\rm stat.}$	–
$\overline{f}^{\mu\&\tau}_{D_s^+}$ (MeV)	$0.9\%_{\rm stat.}$ $1.0\%^{\dagger}_{\rm syst.}$	$0.09\%_{\rm stat.}$	$0.3\%_{\rm stat.}$ $1.0\%_{\rm syst.}$
$\lvert\overline{V}^{\mu\&\tau}_{cs}\rvert$	$0.9\%_{\rm stat.}$ $1.0\%^{\dagger}_{\rm syst.}$	$0.09\%_{\rm stat.}$	–
$\frac{\mathcal{B}(D_s^+ \to \tau^+\nu_\tau)}{\mathcal{B}(D_s^+ \to \mu^+\nu_\mu)}$	$3.6\%_{\rm stat.}$ $3.0\%^{\dagger}_{\rm syst.}$	$0.38\%_{\rm stat.}$	$0.9\%_{\rm stat.}$ $3.2\%_{\rm syst.}$

General Description of the facility

Interaction Region: Large Piwinski Angle Collision + Crab Waist



Parameters	Phase 1	Phase 2
Circumference/m	~700	~700
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

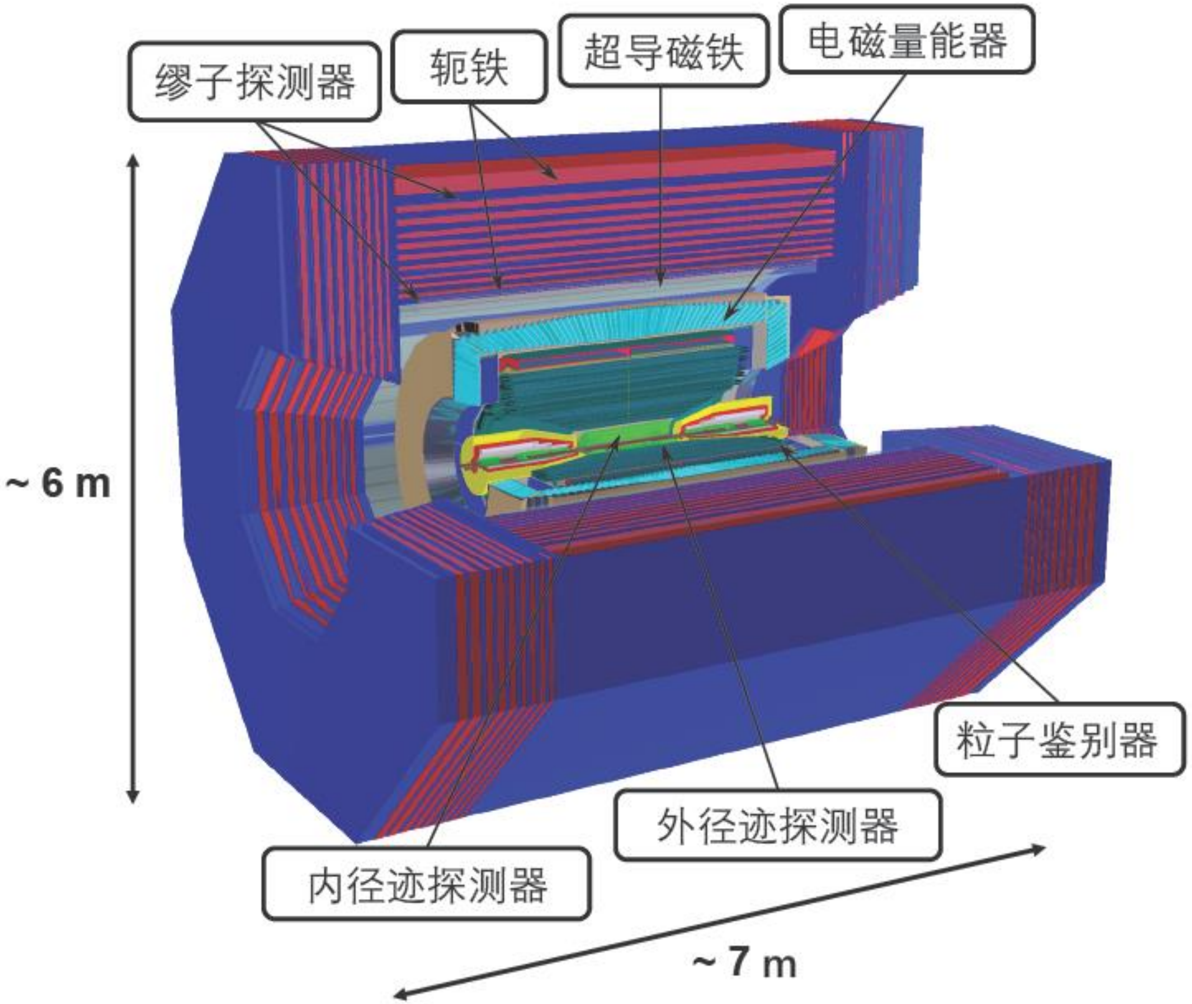
Status

- Last Year
  - Accelerator parameters and basic linear lattice is given.
  - Polarization, beam-beam and other accelerator physics work is underway.
  - Several key technologies have been developed.
  - All works above are finished by a very small team (6 people, part-time).
- This Year
  - Preliminary lattice is given.
  - Injector and its positron/electron sources have been designed.
  - Several beam instrumentation technologies have been developed. .

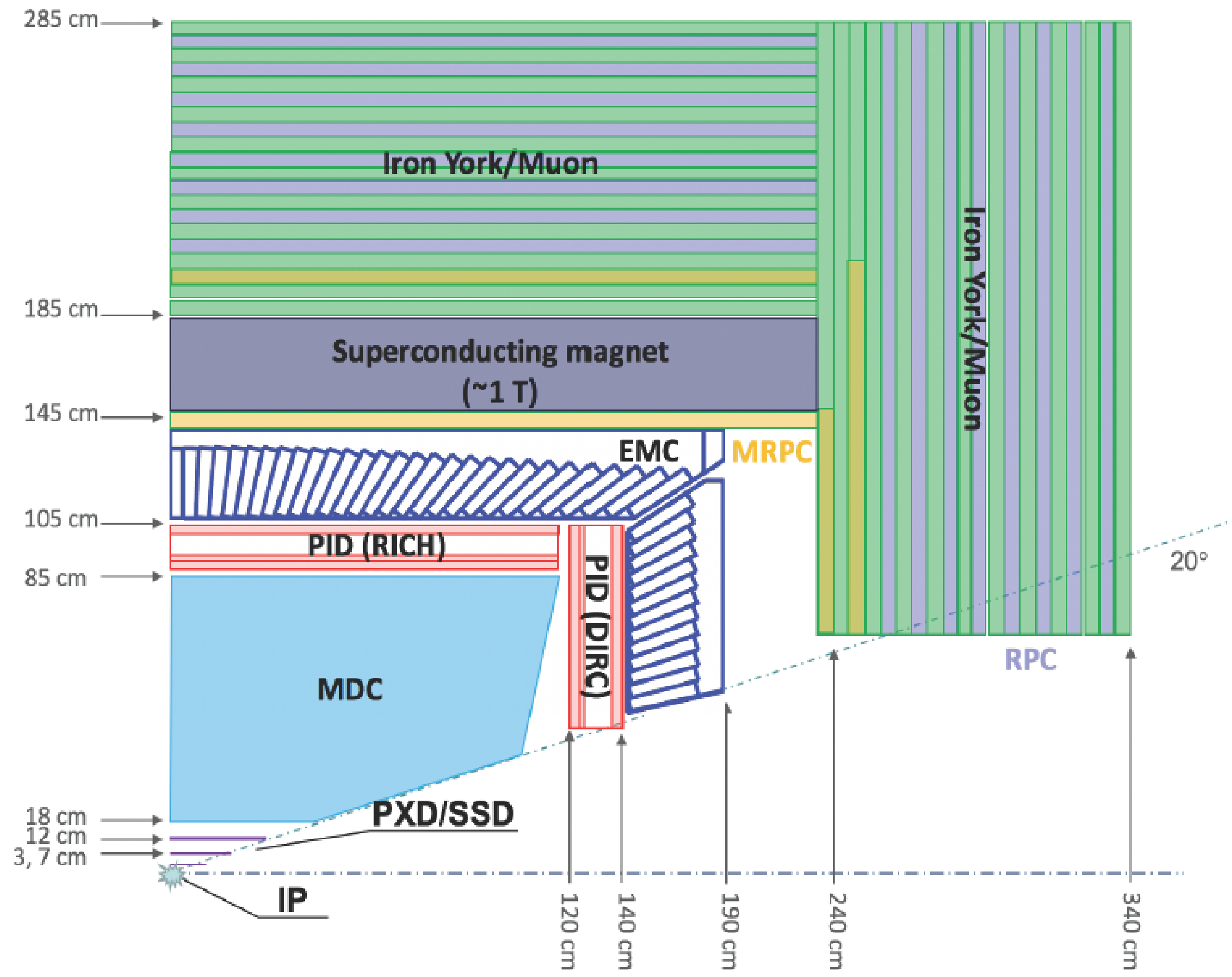
Future Plan

- Accelerator Physics
  - Complete a reasonable lattice
    - By beam dynamic study; also, using intelligent optimization algorithm
  - Collaboration with colleagues
    - For lattice design and beam-beam simulation
- Accelerator Technologies
  - Set up bench tests for instrumentations
  - Develop superconducting magnets and cavities

STCF探测器概念设计



刘建北，STCF研究进展研讨会，2020年8月



PXD

- ~$<0.25\% X_0$ / layer
- $\sigma_{xy} < 130\ \mu m$

MDC

- $\sigma_{xy} < 130\ \mu m$
- $\sigma_p/p \sim 0.5\%$ @ 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

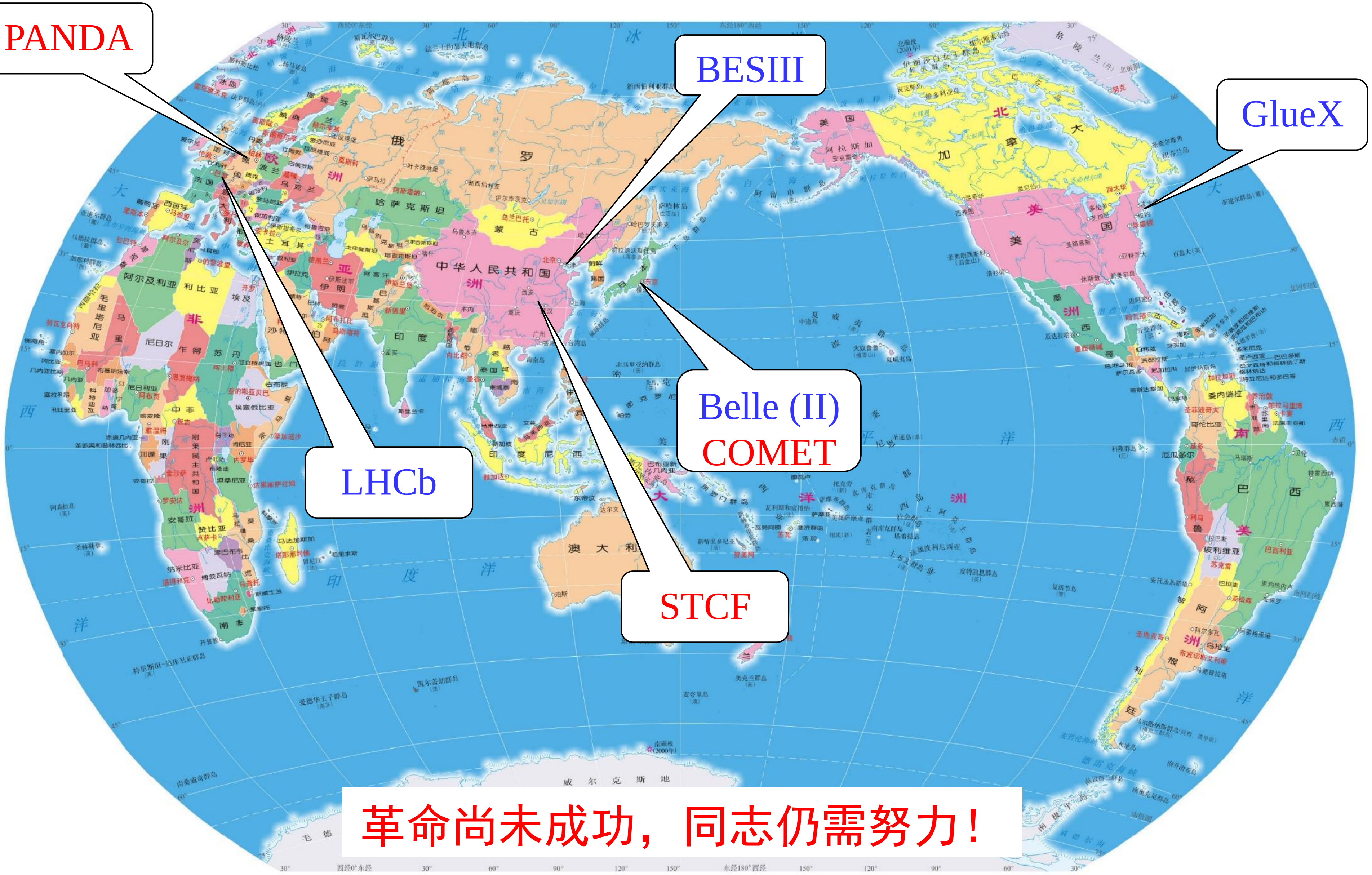
Endcap: 4

Pos. Res. : ~ 4 mm

MUD

- 0.4 - 1.8 GeV
- π suppression >30

总 结



革命尚未成功，同志仍需努力！

Thanks