Status and Prospects of Belle II —2019

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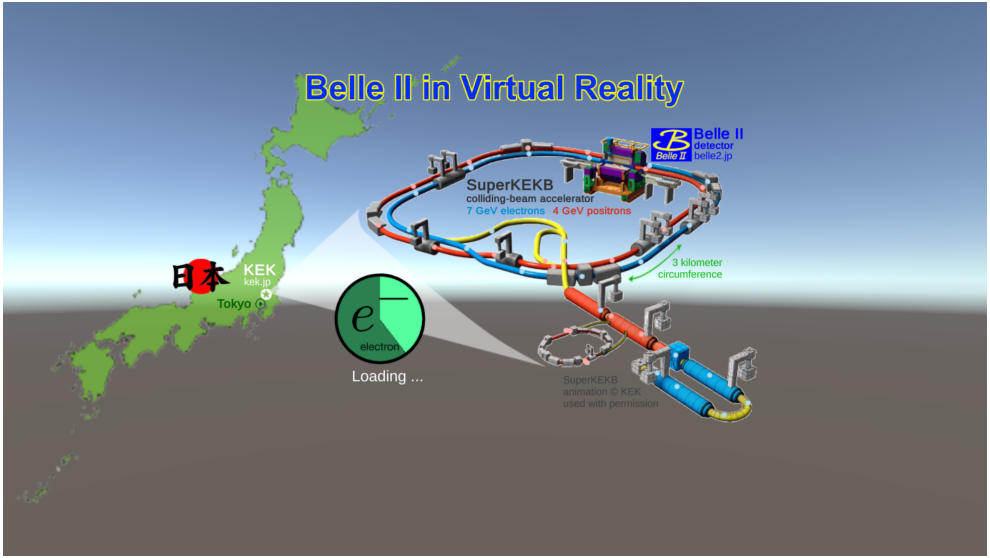
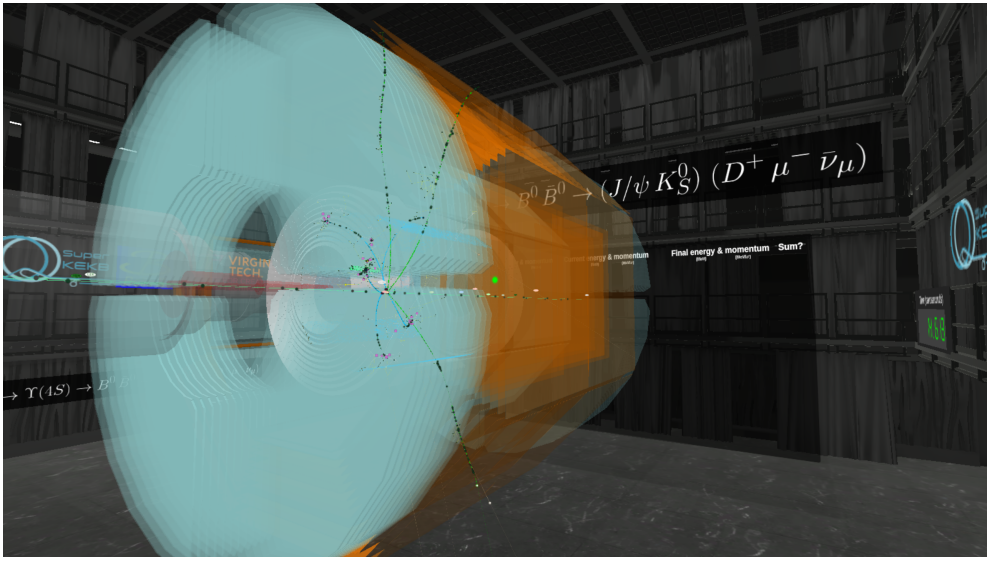
高能所→ ... →**复旦大学**

第17届重味物理和CP破坏研讨会
内蒙古大学，呼和浩特， 2019年7月31日

Belle II VR

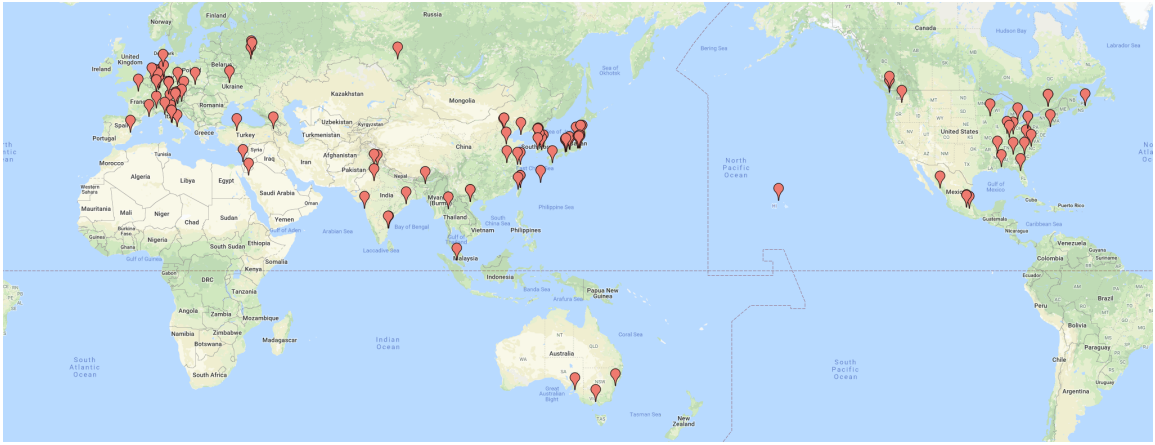

Belle II in Virtual Reality
Belle II
detector
belle2.jp
SuperKEKB
colliding-beam accelerator
7 GeV electrons 4 GeV positrons
3 kilometer
circumference
日本
KEK
kek.jp
Tokyo
e⁻
electron
Loading ...
SuperKEKB
animation © KEK
used with permission



Play with Belle II detector (virtual) and e^+e^- collisions. Easy to get Belle II VR from steam or Prof. Leo Piilonen's homepage.

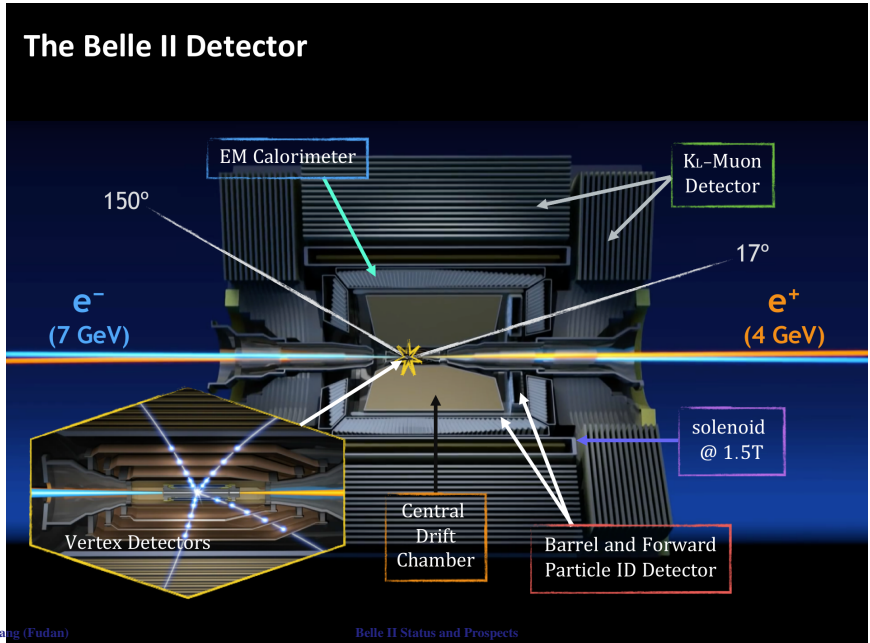

SuperKEKB 加速器
電子
(7 GeV)
Belle II測定器
(衝突点)
陽電子
(4 GeV)
1 km
電子・陽電子入射直線加速器
(ライナック)
陽電子貯蔵リング
(建設中)
高エネルギー加速器研究機構 (茨城県つくば市)

Belle II Collaboration



- Belle II Collaboration: 26 counties/regions, 116 institutions, $\sim$ 1000 collaborators.
- Belle II China Group: 高能所，中科大，北大，北航，复旦，辽宁师大，苏州大学，以及山东大学。成员约60名。

The Belle II Detector



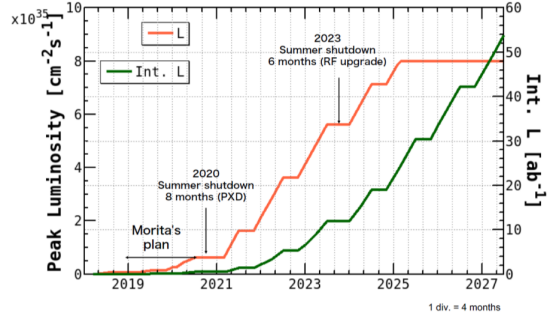
Outline after introduction

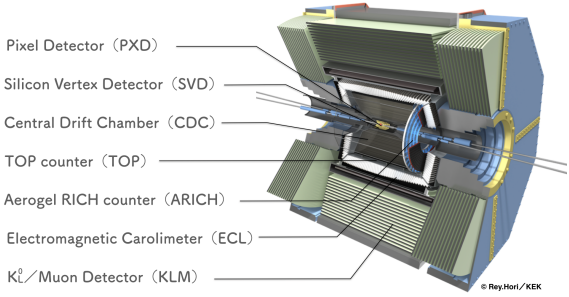
1. Phase III: Physics Run
2. China Group
3. Belle II upgrade (informal)

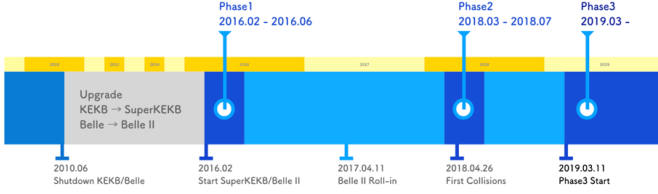
Belle II experiment

- 超大的统计量，丰富的物理内容。
- 物理取数阶段(Phase III)于今年3月11日开始。
- 近期工作重点是物理分析与实验升级。

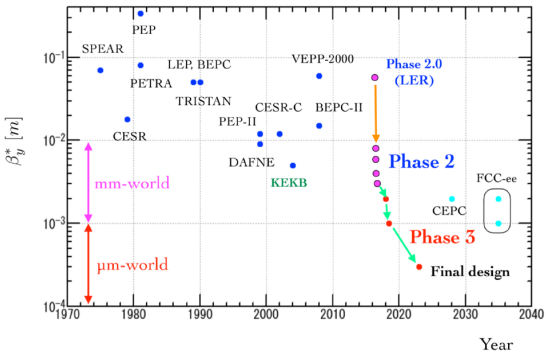
Belle II预期亮度和统计量

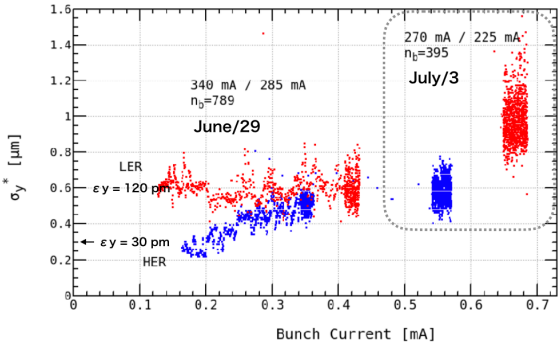






Increasing Luminosity

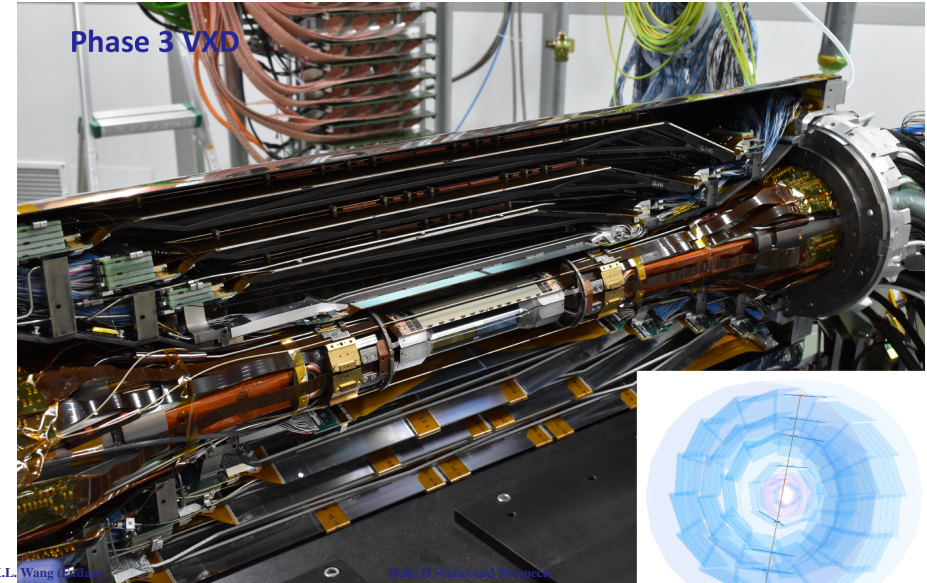


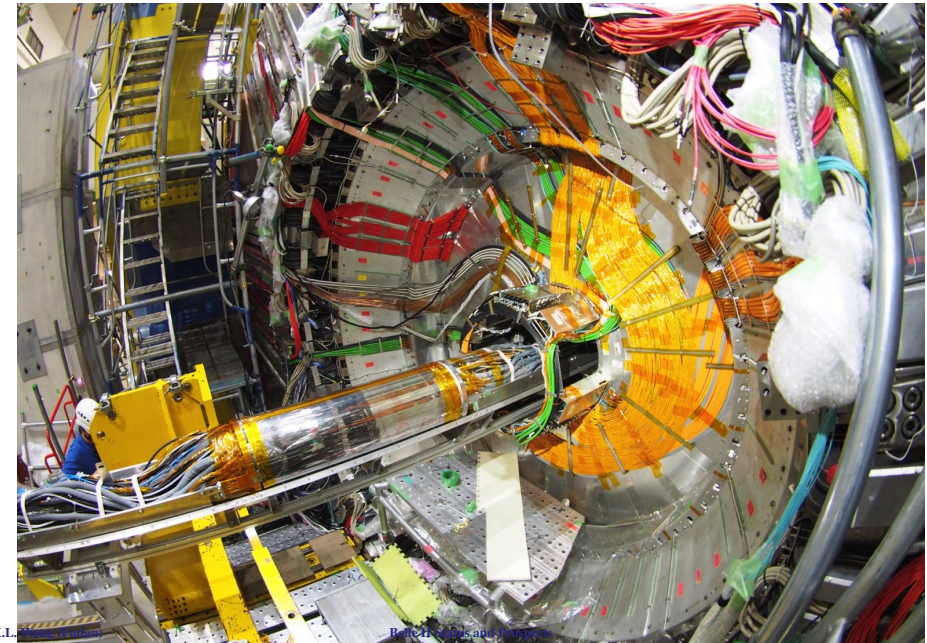


Key ingredients: Increase currents and squeeze beams at IP… but it's not that easy

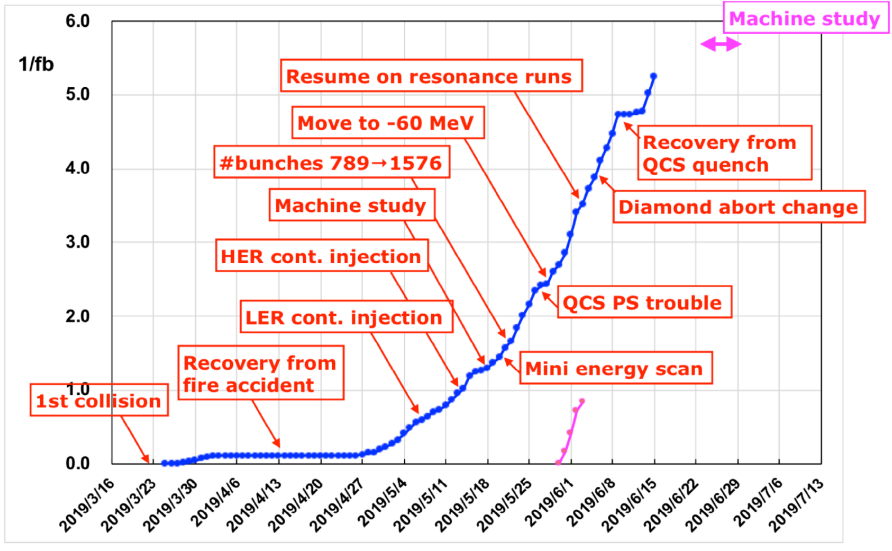
Blow up was a concern towards Phase 3, limiting the peak Luminosity achievable

VXD: Pixel detector



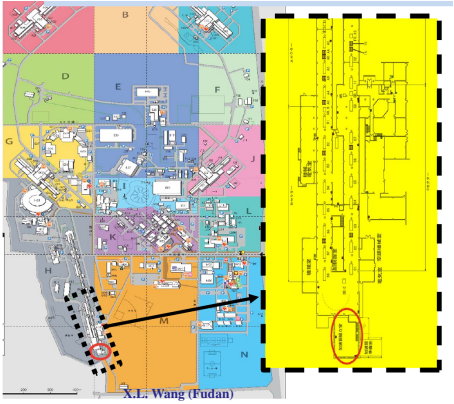


SKB operation



Fire accident

- The accident happened in the NEXTEF facility where R&D on the X-band linac is taking place.
- No injuries, no radiation leakage, fortunately.

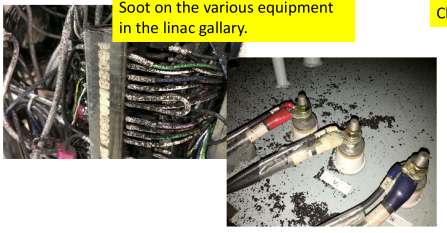


KEK
High Energy Accelerator Research Organization

Fire Incident on 3/April

- The room is separated by a wall from the injector linac used by SuperKEKB. However, soot from the fire entered the injector area via holes in the wall.
- It took 20 days to understand the impact and to clean the apparatus. The beam was back in the LINAC and was injected to the SuperKEKB on 25/April.

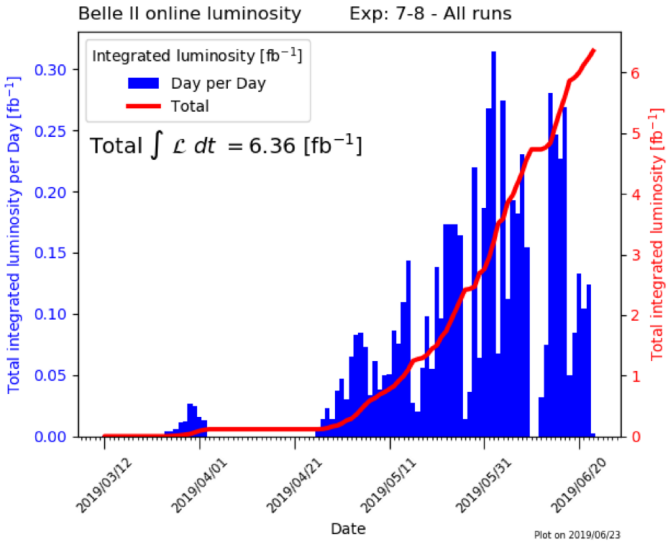
Soot on the various equipment in the linac gallary.



Cleaning work in the gallery

5

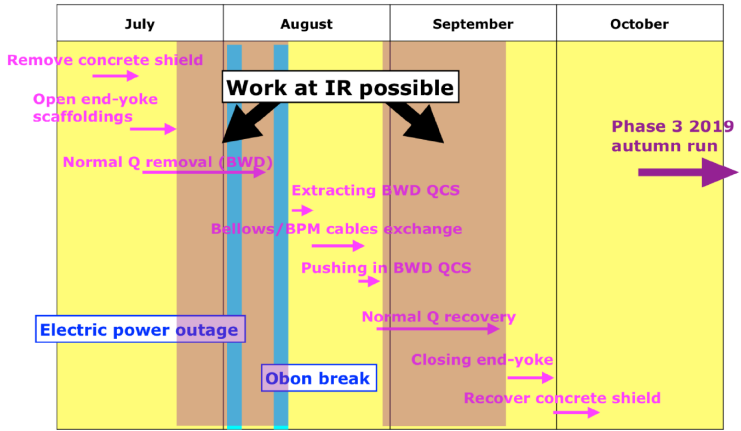
Early Phase 3 Dataset



- Physics analysis
- Rediscoveries
- Detector performance

Tracking	Efficiencies with ee →ττ, ee (γ)
	IP studies with 2-track events
Neutrals	Efficiencies and resolution with ee→ μμ (γ)
	π^0, η resolutions
Hadron ID	K/π separation with D*→ D^0(Kπ) π
	p/π separation with Λ→pπ
Lepton ID	e/π separation with ee→ llee, ee→ee(γ), J/ψ→ee, K_S→ ππ
	μ/π separation with ee→ llee, ee→μμ(γ), J/ψ→ee, ee→τ(1P)τ(hhhν)
Trigger	Efficiencies with ee →ττ
	Efficiencies with ee →ee(γ), μμ(γ)
Combined	Mass, Vertex resolutions, Yields of narrow resonances
Luminosity	ee→ ee (γ), γγ (γ)

Fall Run 2019



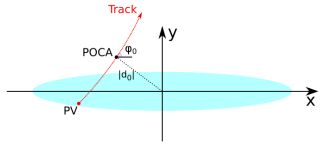
- Fall run from 15^{th} October until 12^{th} December.
- Target: 20 fb^{-1} (0.6 fb^{-1}/day) with 2 mm optics and 1 A current on HER/LER.

Transverse Impact Parameter (d_0) Resolution

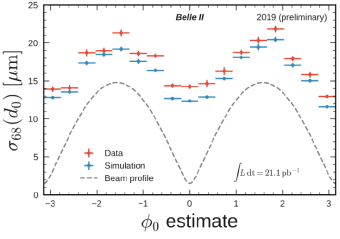
- After correcting for the beam spot position, the ϕ-dependent $\sigma(d_0)$ depends on the intrinsic VXD resolution and transverse size of the luminous region:

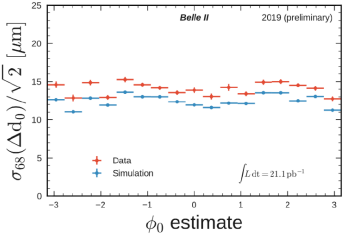
$$\sigma_{d_0} = \sqrt{\sigma_i^2 + (\sigma_x \sin\phi_0)^2 + (\sigma_y \cos\phi_0)^2}$$

- In early phase 3, σ_x = 14.8μm and σ_y = 1.5μm



- The intrinsic resolution is estimated by
  $\Delta d_0 \equiv d_0(t_-) + d_0(t_+)$,
  from 2-track (t_- and t_+) events, which are produced back-to-back.

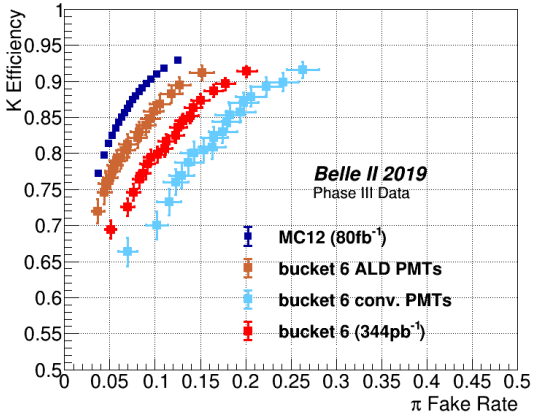


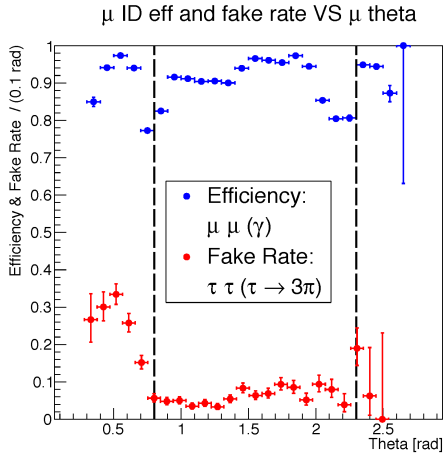


- Good agreement observed between data and MC expectation

Particle identification

K/π ID from iTOP

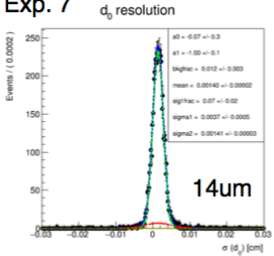


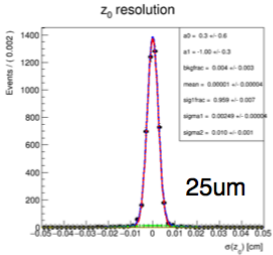


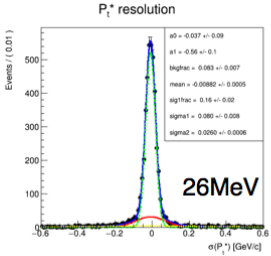
- More studies, especially calibrations, are required.
- 复旦组承担了KLM的时间刻度工作。

Tracking from CDC

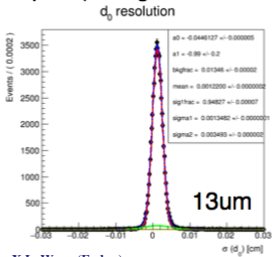
Exp. 7

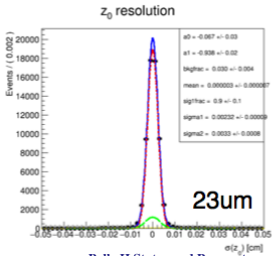


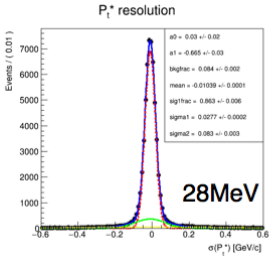




Exp. 8 (w/ higher threshold)







Belle II Physics Book

Belle II Theory Interface Platform (B2TIP)
Workshop series, 2015-2018:

WG1
Semileptonic & Leptonic B decays

WG2
Radiative & Electroweak Penguins

WG3
α/φ_2 β/φ_1

WG4
γ/φ_3

WG5
Charmless Hadronic B Decay

WG6
Charm

WG7
Quarkonium(-like)

WG8
Tau, low multiplicity

WG9
New Physics

The Belle II Physics Book
Emi Kou and Phill Urquijo, editors

689 pages
arXiv: 1808.10567
submitted to PTEP

Belle II China Group

- 合作单位：8个，另有新的单位在申请加入。
  高能所、中科大、北大、北航、复旦、辽师大、苏州大学、山东大学。
- 人员规模：约60人。
  - 高级研究人员：12名。
  - 博士后：16名。
  - 研究生：约30名。
- 参与领域：物理分析、硬件、软件、DAQ和计算系统等。
- Belle II期望中国组承担KLM和HLT的现场运行维护工作。

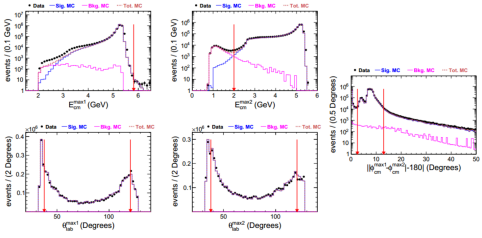
物理研究领域

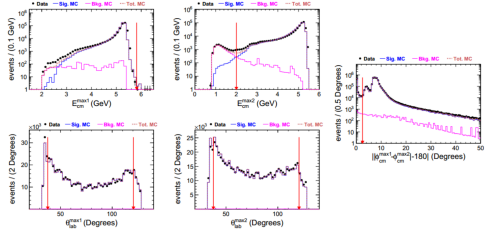
- Where China group has advantage
  - $D\bar{D}$-mixing and CPV
  - Exotics: XYZ & quarkonium, T_{cs}, T_{cc}, $D^*(2380)$,...
- New idea, new method
  - Lepton universality (R_K, R_D, R_{D^*})
  - Semileptonic decays using the B decay vertex
  - Dark sector
- What are the hot topics of heavy flavor physics? What can China group do?
- Suggestions/comments welcome!

Luminosity measurement

By 周兴玉

- Two methods used: Bhabha (I) and Digamma (II).





Systematic uncertainties (I)

Source	Uncertainty (%)
Theoretical uncertainty of the signal generator	0.1
Center and spread of the CM energy	0.5
Position of the interaction point	0.2
Location of the ECL detector	0.2
Statistics of signal MC samples	0.1
$E_{\rm cms}$ requirement in the selection criteria	0.2
$\theta_{\rm lab}$ requirement in the selection criteria	0.3
$\phi_{\rm cms}$ requirement in the selection criteria	0.1
Material effects in vertex detectors	0.1
Overlapping clusters due to material effects	0.1
Contamination of other kinds of events	0.2
Overlay of beam backgrounds	0.1
Sum	0.8

Systematic uncertainties (II)

Source	Uncertainty (%)
Theoretical uncertainty of the signal generator	0.1
Center and spread of the CM energy	0.5
Position of the interaction point	0.1
Location of the ECL detector	0.2
Statistics of signal MC samples	0.1
$E_{\rm cms}$ requirement in the selection criteria	0.2
$\theta_{\rm lab}$ requirement in the selection criteria	0.3
$\phi_{\rm cms}$ requirement in the selection criteria	0.8
Material effects in vertex detectors	0.7
Overlapping clusters due to material effects	0.1
Contamination of other kinds of events	0.5
Overlay of beam backgrounds	0.1
Sum	1.4

计算资源建设

- 复旦大学已完成服务器域名申请，很快将加入Belle II DIRAC。近期还将继续提升计算资源。
- 北航的服务器仍在提供计算任务。
- 高能所正在建设Tier 2 DIRAC site，计算中心为中国组计算方面的协调和代表单位。

存储和计算资源

- Computing
  - 640 CPU cores, 10kHS06
- Storage
  - 300 TB
- Status
  - Funding is OK
  - Currently it's calling for bid
  - Estimated to be ready at 2019/8

站点建设计划

- Goal: A Tier 2 DIRAC site
- Site type: Grid
- Computing
  - CreamCE
  - Updating to HTCondorCE in near future
  - Belle II has 55 CEs, 23 of them are CreamCE, 2 are HTCondorCE
- Storage
  - DPM SE
  - DPM is also used for ATLAS and LHCb at IHEP
  - Belle II has 26 SEs, 10 of them are DPM
- Data transfer between SEs
  - FTS, now testing at BES-DIRAC
  - Rucio, under investigation
- Software repo: CVMFS
  - IHEP has stratum 0+1 CVMFS instance
- Join Belle II-DIRAC as a grid site

Belle II Improvement program

- Short term
  - Replacement of TOP PMTs with ALD PMTs
  - Replacement of the PXD with complete detector
  - DAQ upgrade
- Medium term
  - Looking at options to make the detector more robust against background and radiation bursts
- Longer term
  - Started looking at luminosity upgrade possibilities

Upgrade info from Belle II Manager

- JAHEP (Japan Association of High Energy Physicists) is the community of Japanese high energy physicists. We discuss future HEP projects regularly at the executive committee called High Energy Committee and at its sub-committee "future project committee", but not limited to these small bodies.
- SuperKEKB/Belle II is currently supposed to continue until we accumulate 50/ab. Not much has been discussed about post-SuperKEKB plan.
- Two "recent" reports from the future project committee:
  - 2017 update (M. Ishino (chair), T. Higuchi, N. Taniguchi et al.) http://www.jahep.org/files/20170906-en.pdf
  - 2012 report on future projects(T. Mori (chair), T. Iijima, Y. Ushiroda et al.) http://www.jahep.org/office/doc/201202_hecsubc_report.pdf

> SuperKEKB will reach a milestone, namely to accumulate 50 ab^{-1} of integrated luminosity by around 2021, provided everything proceeds well. By that time, observation of various new physics phenomena or limitations on new physics are expected, however, in the case that the coupling of new physics is too small, depending on how the research develops, there may be a case for a further luminosity increase by more than a factor 10. In such an event, the feasibility of a further luminosity upgrade must be considered based on the actual experience at SuperKEKB and INFN SuperB; presently however there is no concrete idea.

- The current esitmation is $5\times$ higher.
- Belle II $\rightarrow$ Belle III???

Phase III BG predictions

H.Nakayama
Nov. 2018

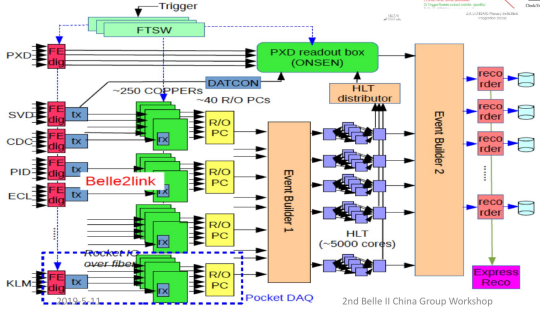
	Phase2 findings	Dangerous at early phase3?	Dangerous at final phase3?
SR	See ~10keV peaks in PXD/FANGS	+X side: OK(PXD) -X: side: FANGS analysis ongoing	Same as left
Integrated Dose	PXD, films see more than diamonds (as expected)	Rescaled MC: marginal (no injection BG included)	Rescaled MC: marginal for SVD, critical for PXD (7x reduction needed for HER BG)
PXD occupancy	See SR-like peak, but not dominant	Rescaled MC: marginal	Rescaled MC*: critical (2x more than DHP limit)
SVD occupancy	noise (or SR-like) peak at ~10keV, not dominant	Rescaled MC: marginal	Rescaled MC*: critical (10x more than limit)
CDC rates	"persistent current" is critical.	Pure MC: marginal Rescaled MC: not prepared yet	Pure MC: critical (5x than limit) Rescaled MC: not prepared yet
TOP rates	(clean) continuous injections are not a big problem for TOP	Rescaled MC: critical** (5x than limit) for short-life PMTs, which need to survive till 2020 summer	Rescaled MC: critical (2x more than limit) for ALD-type PMTs
ECL dose on crystals	-	Pure MC: OK Rescaled MC: not prepared yet	Pure MC: critical (2x than limit) Rescaled MC: not prepared yet
KLM	?	?	?
ARICH	?	?	?

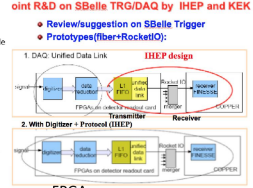
*Rescaled MC for final phase3 = (final phase3 MC) * (phase2 data/MC).
Rescaled MC for early phase3 = (final phase3 MC) * (phase2 data/MC) * ¼, or (phase2 data)* (scaling with I^2) using phase2 collimators
**At early Phase 3, background improvement will be further pursued by tuning SuperKEKB parameters and the new collimators installed

DAQ upgrade

Overview of present DAQ

- Belle II DAQ Block Diagram
- Belle2link Block Diagram(unified HW and S/FW)



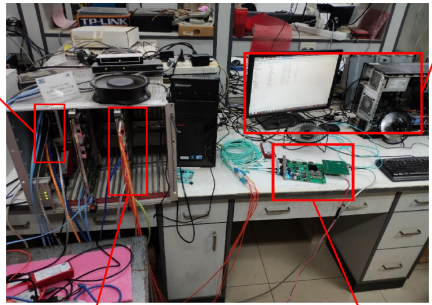


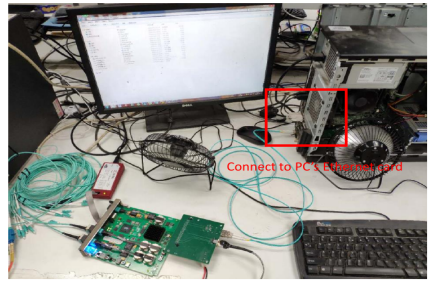
- Belle2link by IHEP, LNNU/SDU maintained by LNNU/SDU.
- Upgrade options by BNL(ATLAS), IHEP(CMS) and LAL(LHCb).

DAQ upgrade: IHEP proposal

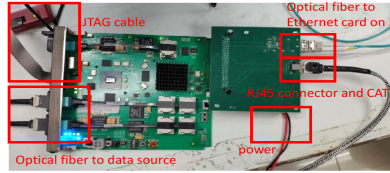
Demo system Setup at IHEP

- Photo of Full Demo System





CPPF and PC in working



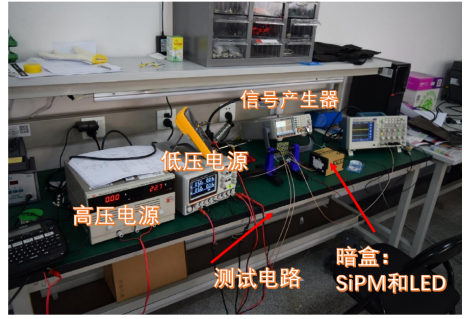
CPPF and Interface to FSTW/PC

KLM upgrade research at 复旦大学

- 从KEK获得一块KLM备用探测模板(VT建造，约150kg)，KEK免费捐赠。
- 夏威夷IDLab捐赠一套备用电子学读出系统，可同时处理150个道。
- 进展：
  - 实现信号探测，光纤通信。
  - 从电子学获得宇宙线信号。

SiPM测试系统

黄色：
SiPM信号



正在搭建更好的测试系统

Belle II - LHCb Upgrade Comparison

Belle II
Higher sensitivity to decays with photons and neutrinos (e.g. B→Kνν, μν), inclusive decays, time dependent CPV in B_d, τ physics.

LHCb
Higher production rates for ultra rare B, D, & K decays, access to all b-hadron flavours (e.g. Λ_b), high boost for fast B_s oscillations.

Overlap in various key areas to verify discoveries.

Upgrades
Most key channels will be stats. limited (not theory or syst.).
LHCb scheduled major upgrades during LS3 and LS4.
Belle II formulating a 250 ab^{-1} upgrade program post 2028.

Observable	Current Belle/ Babar	Current LHCb	Belle II (50 ab^{-1})	LHCb (23 fb^{-1})	Belle II Upgrade (250 ab^{-1})	LHCb upgrade II (300 fb^{-1})
CKM precision, new physics in CP Violation						
$\sin 2\beta/\varphi_1$ ($B\to J/\psi K_S$)	0.03	0.04	0.005	0.011	0.002	0.003
γ/φ_3	13°	5.4°	1.5°	1.5°	0.4°	0.4°
α/φ_2	4°	–	0.6°	–	0.3°	–
$\lvert V_{ub}\rvert$ (Belle) or $\lvert V_{ub}\rvert/\lvert V_{cb}\rvert$ (LHCb)	4.5%	6%	1%	3%	<1%	1%
φ_s	–	49 mrad	–	14 mrad	–	4 mrad
$S_{CP}(B\to\eta' K_S$, gluonic penguin)	0.08	○	0.015	○	0.007	○
$A_{CP}(B\to K_S\pi^0)$	0.15	–	0.04	–	0.02	–
New physics in radiative & EW Penguins, LFUV						
$S_{CP}(B_d\to K^*\gamma)$	0.32	○	0.035	○	0.015	○
$R(B\to K^* l^+l^-)$ ($1<q^2<6$ GeV$^2/c^2$)	0.24	0.1	0.03	0.03	0.01	0.01
$R(B\to D^*\tau\nu)$	6.4%	10%	1.5%	3%	<1%	1%
$Br(B\to\tau\nu)$, $Br(B\to K^*\nu\nu)$	24%, –	–	4%, 9%	–	1.7%, 4%	–
$Br(B_d\to\mu\mu)$	–	90%	–	34%	–	10%
Charm and τ						
$\Delta A_{CP}(KK\text{-}\pi\pi)$	–	8.5×10^{-4}	5.4×10^{-4}	1.7×10^{-4}	2×10^{-4}	0.3×10^{-4}
$A_{CP}(D\to\pi^+\pi^0)$	1.2%	–	0.2%	–	0.1%	–
$Br(\tau\to e\,\gamma)$	$<120\times10^{-9}$	–	$<12\times10^{-9}$	–	$<5\times10^{-9}$	–
$Br(\tau\to\mu\mu\mu)$	$<21\times10^{-9}$	$<46\times10^{-9}$	$<3\times10^{-9}$	$<16\times10^{-9}$	$<0.3\times10^{-9}$	$<5\times10^{-9}$

arXiv: 1808.08865 (Physics case for LHCb upgrade II), 1808.10567 (Belle II Physics Book)

○ Possible in similar channels, lower precision
– Not competitive.

Summary

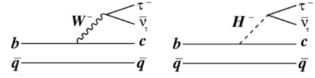
- Belle II started Physics Run on March 3rd, 2019. About 6 fb^{-1} data have been taken.
- There are good performances of the accelerator and the detector.
- The improvement/upgrade program is under consideration.
- The Belle II China Group is developing fast: 8 institutions, about 60 members, and more institutions are applying to join.
- The Belle II China Group is doing comprehensive studies in the Belle II experiment.

Thank you!

Back-up

$B \to D^{(*)} l\nu$: challenge to lepton universality

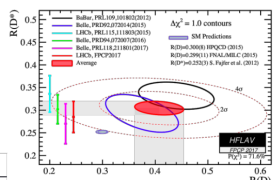
- Theoretically clean channel in SM
- Charged Higgs can contribute to the decay
- $R(D^{(*)})$ is sensitive parameter to BSM!

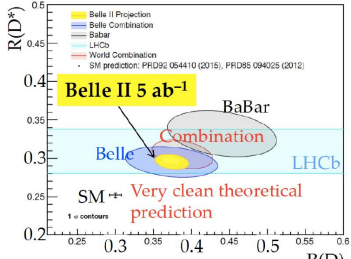


$$R(D^{(*)}) = \frac{\mathrm{Br}(B \to D^{(*)}\tau\nu)}{\mathrm{Br}(B \to D^{(*)}\mu\nu)}$$

	Exp	SM
$R(D^*)$	0.304±0.013±0.007	0.252±0.003
$R(D)$	0.407±0.039±0.024	0.300±0.008

4.1σ away from the SM

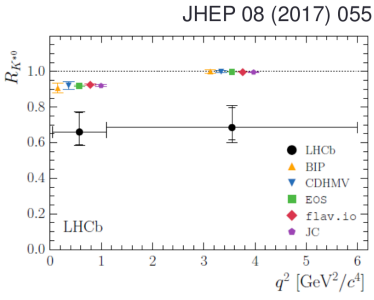




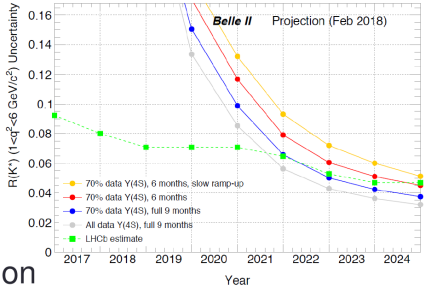
Belle II should be able to confirm the excess with ~5ab^{-1} data

$B \to K^* \ell^+ \ell^-$: yet another smoking gun

- Interesting discrepancy as well as measured in P5'



$$R(K^*) = \frac{BR(K^* \mu\mu)}{BR(K^* ee)}$$



- Belle II: good electron identification

K*ee: ~200 events/ab^{-1}
K*μμ: ~280 events/ab^{-1}

Note: LHCb value is extrapolated from run-1 result