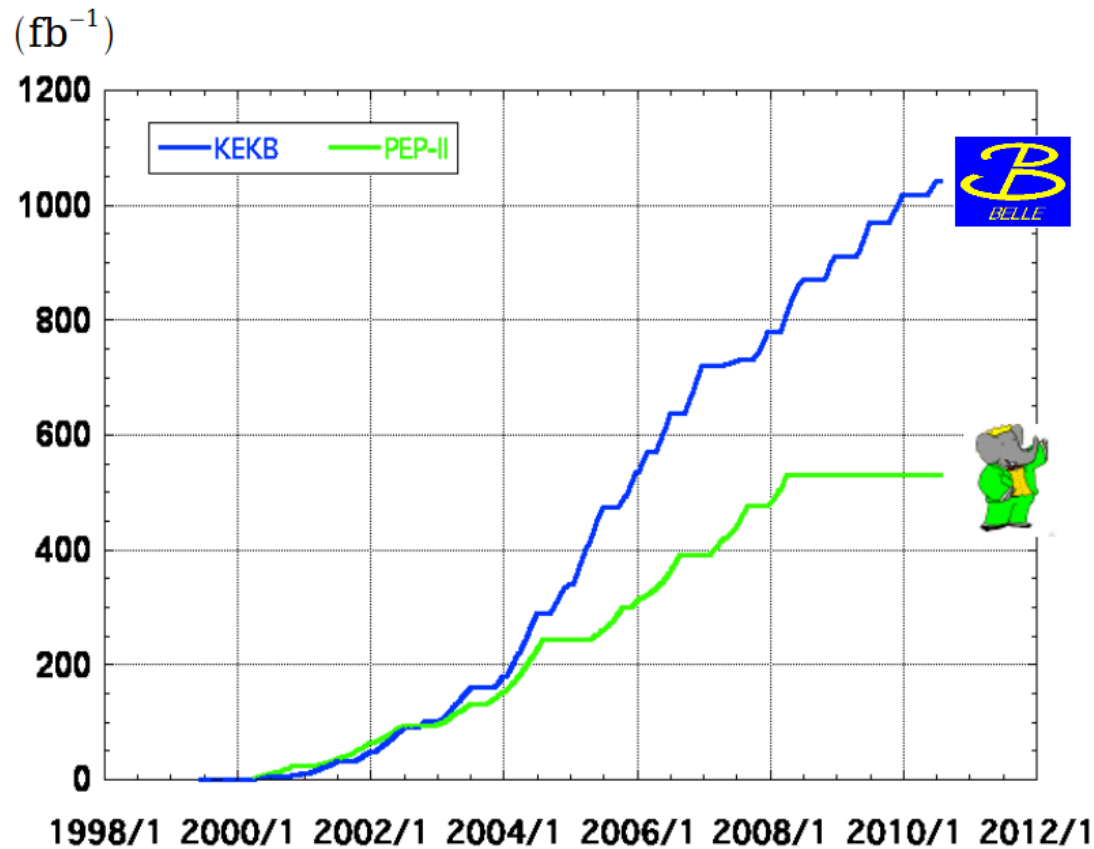# BELLE (II)

원은일
고려대학교

2019년 9월 21일
전략미팅, 대전 기초과학연구원 본원 과학문화센터

Belle 실험

- **Belle: asymmetric B meson factory, 1999-2010**
- **Main physics goal: CP violation 을 통한 물질-반물질 비대칭성 연구**

2001 sin2φ1 paper, with BaBar led 2008 Nobel prize in physics

Integrated luminosity of B factories

(fb^{-1})

KEKB PEP-II

> $1\ ab^{-1}$
On resonance:
$\Upsilon(5S)$: 121 fb^{-1}
$\Upsilon(4S)$: 711 fb^{-1}
$\Upsilon(3S)$: 3 fb^{-1}
$\Upsilon(2S)$: 25 fb^{-1}
$\Upsilon(1S)$: 6 fb^{-1}
Off reson./scan:
$\sim 100\ fb^{-1}$

$\sim 550\ fb^{-1}$
On resonance:
$\Upsilon(4S)$: 433 fb^{-1}
$\Upsilon(3S)$: 30 fb^{-1}
$\Upsilon(2S)$: 14 fb^{-1}
Off resonance:
$\sim 54\ fb^{-1}$

1998/1 2000/1 2002/1 2004/1 2006/1 2008/1 2010/1 2012/1

The Nobel Prize in Physics 2008

"for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics"

"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"

Yoichiro Nambu
1/2 of the prize
USA
Enrico Fermi Institute, University of Chicago Chicago, IL, USA
b. 1921 (in Tokyo, Japan)

Makoto Kobayashi
1/4 of the prize
Japan
High Energy Accelerator Research Organization (KEK) Tsukuba, Japan
b. 1944
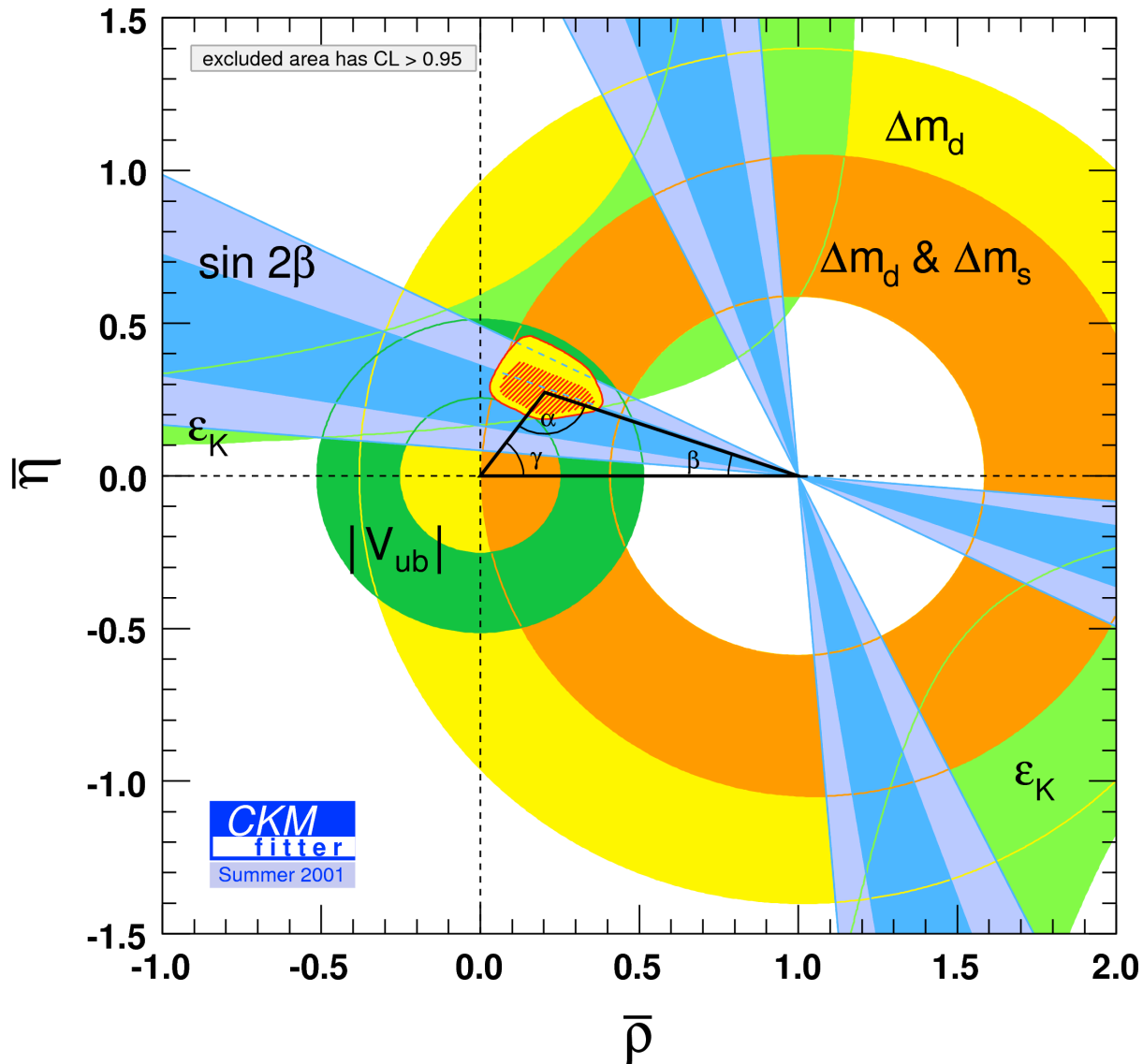
Toshihide Maskawa
1/4 of the prize
Japan
Kyoto Sangyo University; Yukawa Institute for Theoretical Physics (YITP), Kyoto University Kyoto, Japan
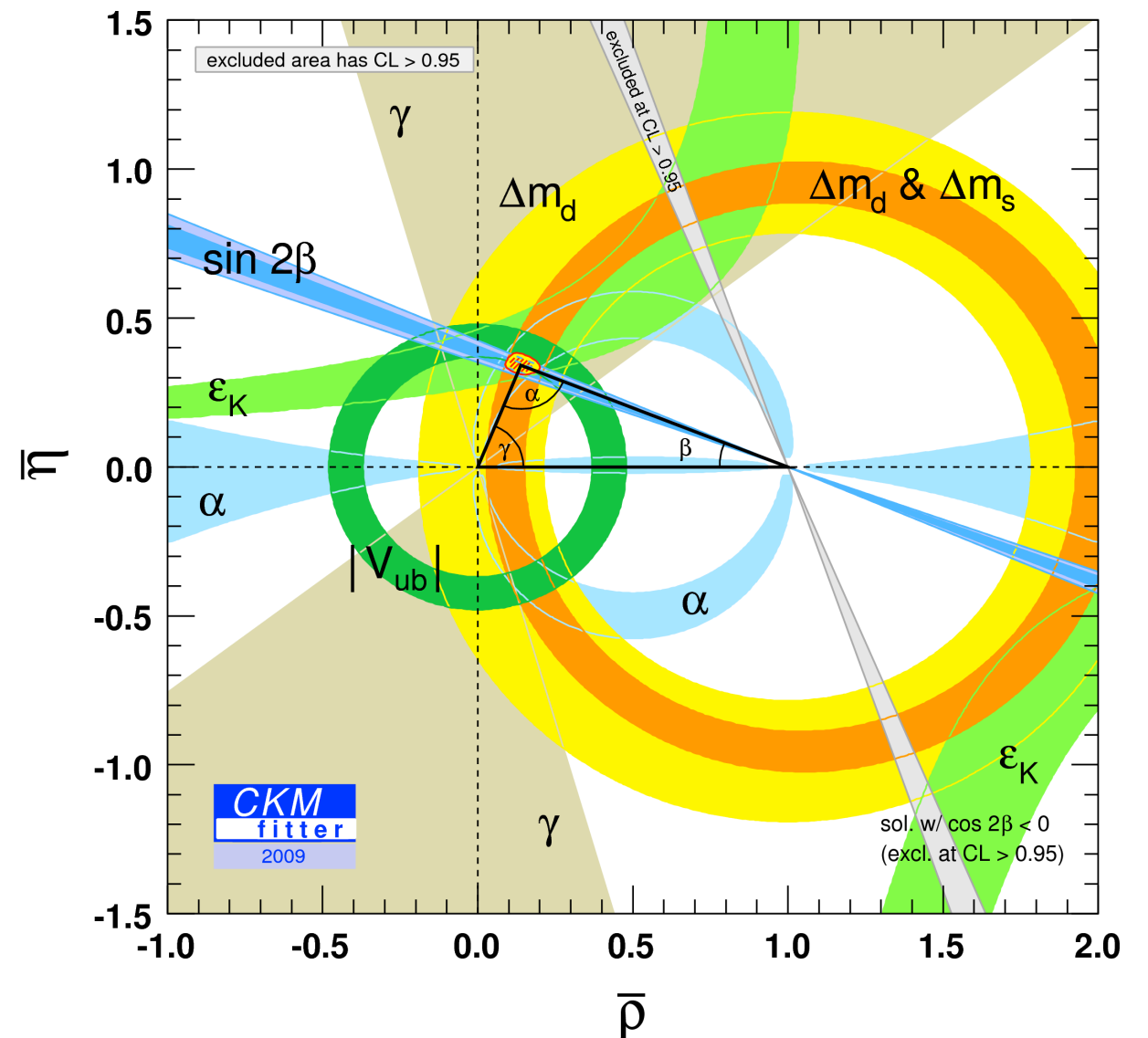b. 1940

More than 500 papers published and still going on

Belle (and BaBar) for 10 years

2001

2009

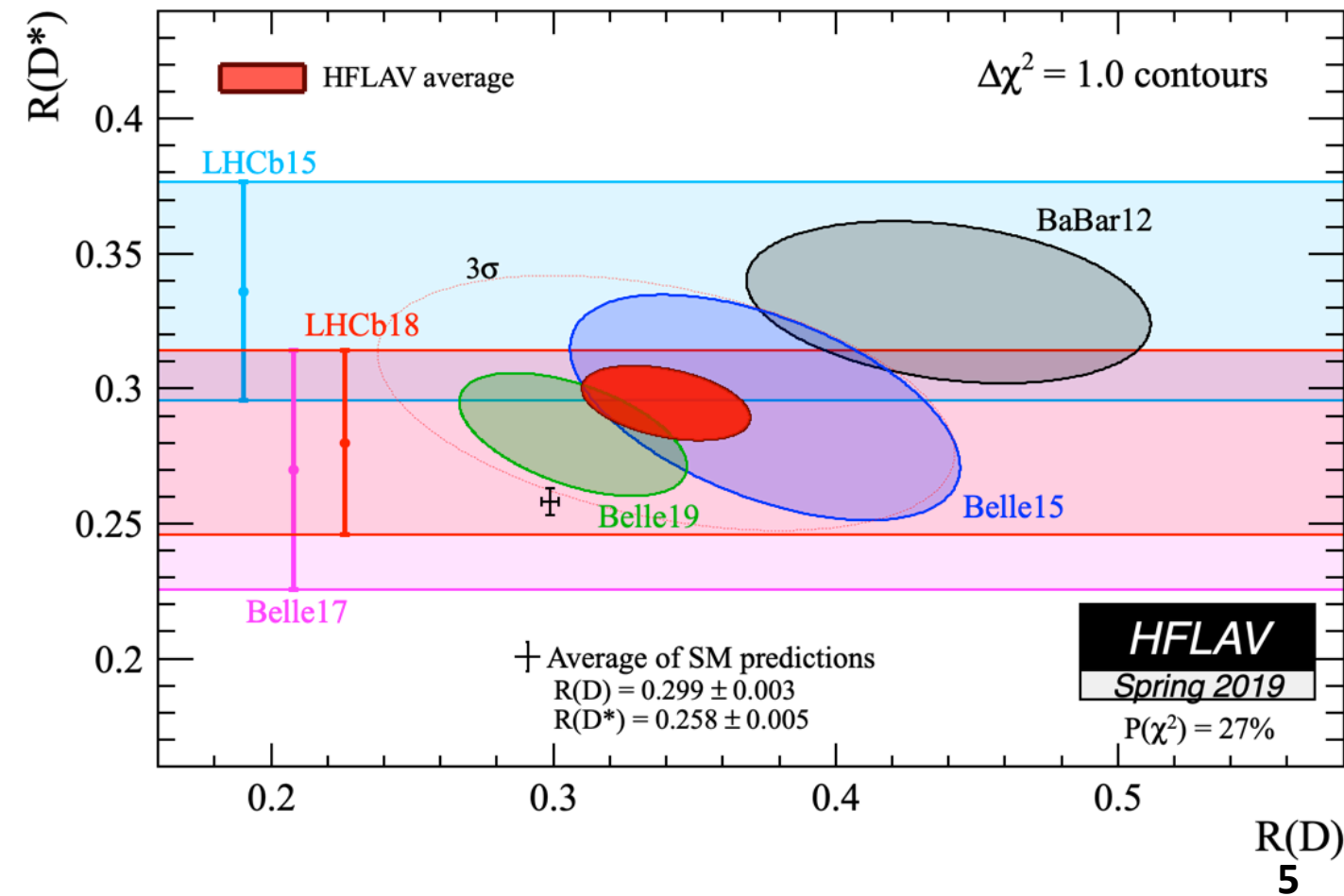- **Precision physics in the flavor sector: impressive accomplishments**
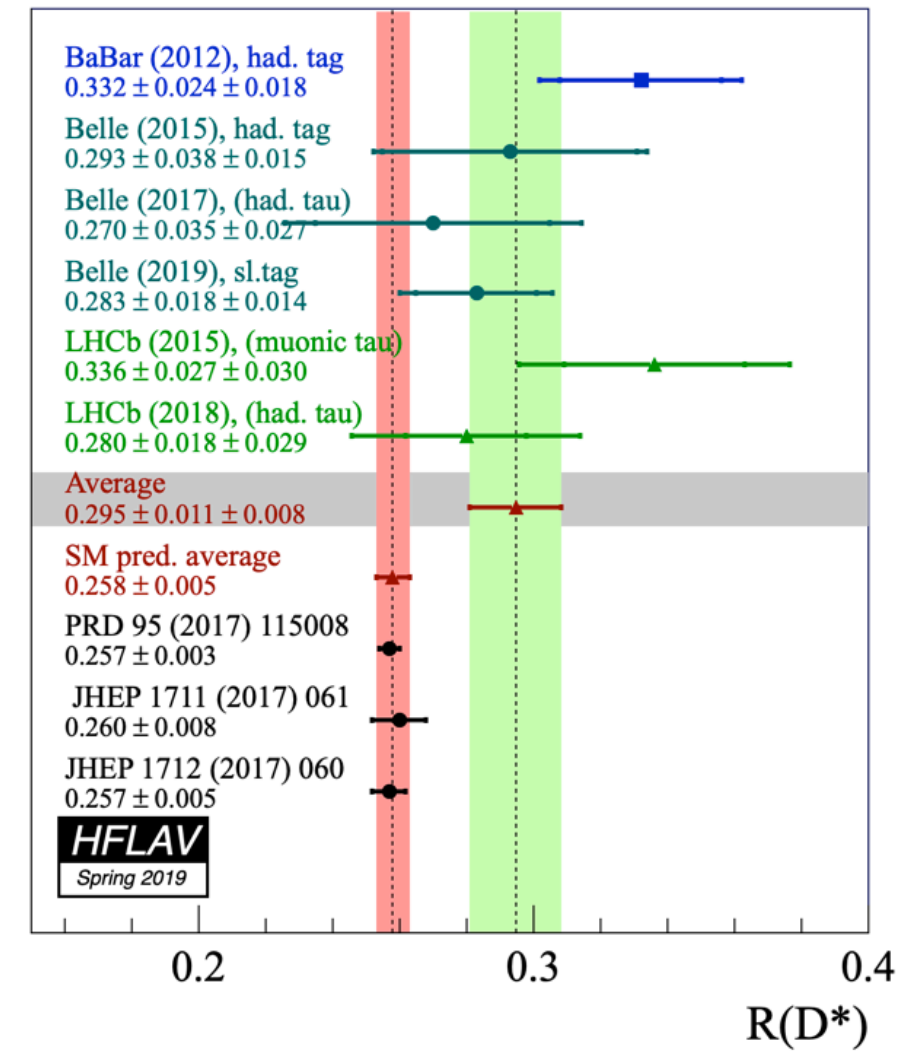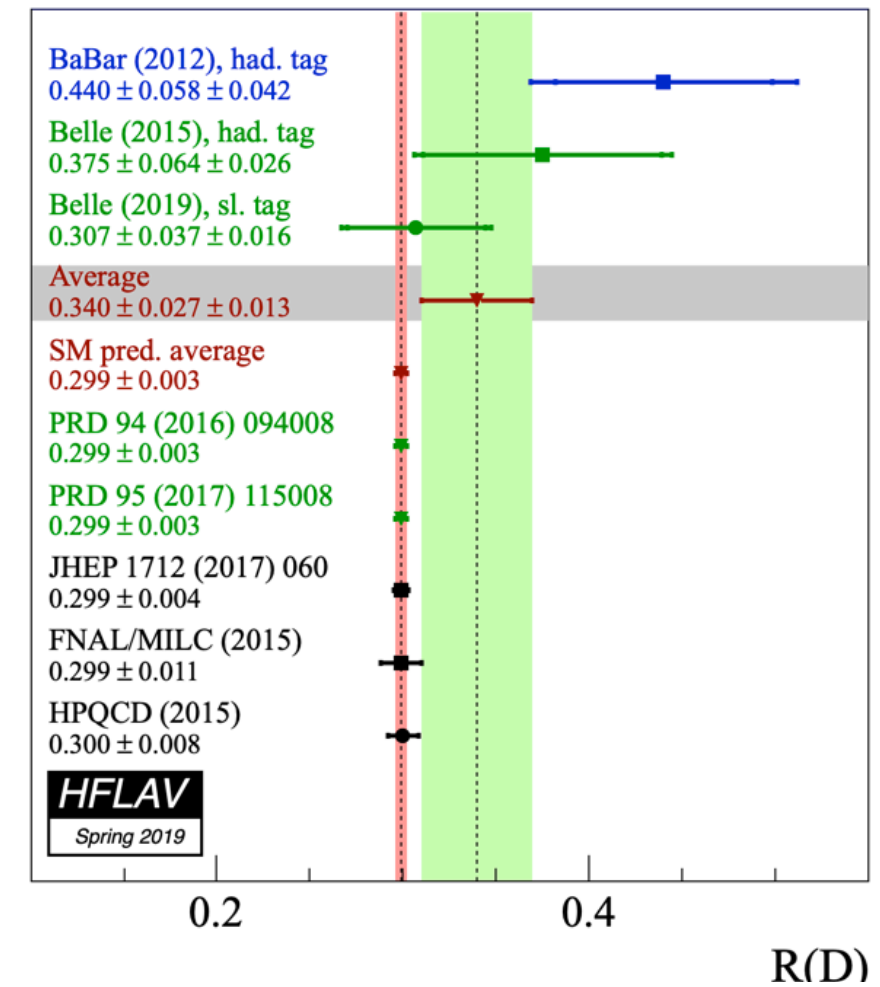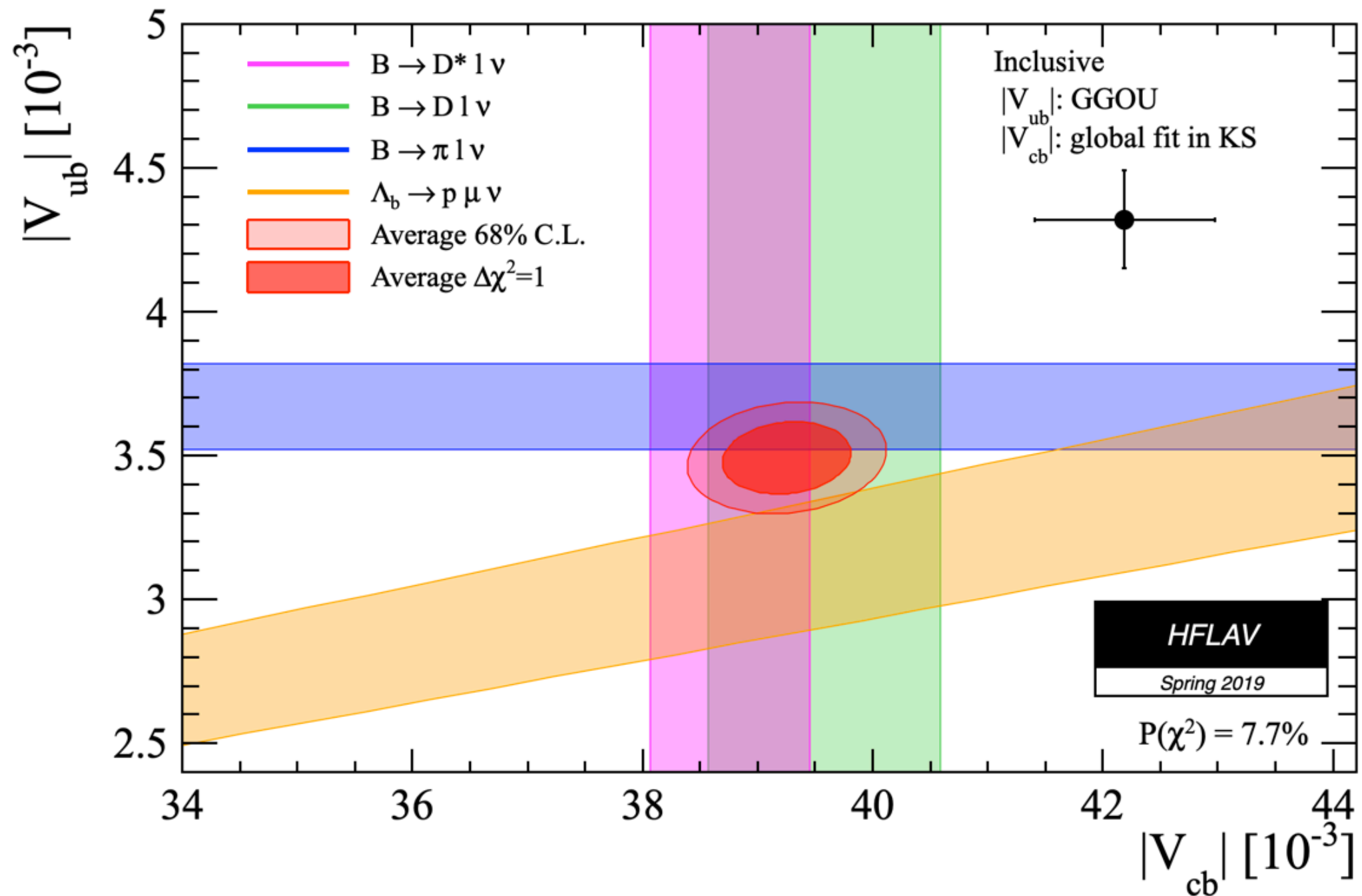- **새로운 물리현상 발견은 아직…**

Physics Highlights

R(D(*))

- Semi-tauonic decay modes are highly sensitive to new physics (ex) charged higgs)

$$R(D^{(*)}) = \frac{\mathcal{B}(B \to D^{(*)}\tau\bar{\nu}_\tau)}{\mathcal{B}(B \to D^{(*)}\ell\bar{\nu}_\ell)}$$

5

Won

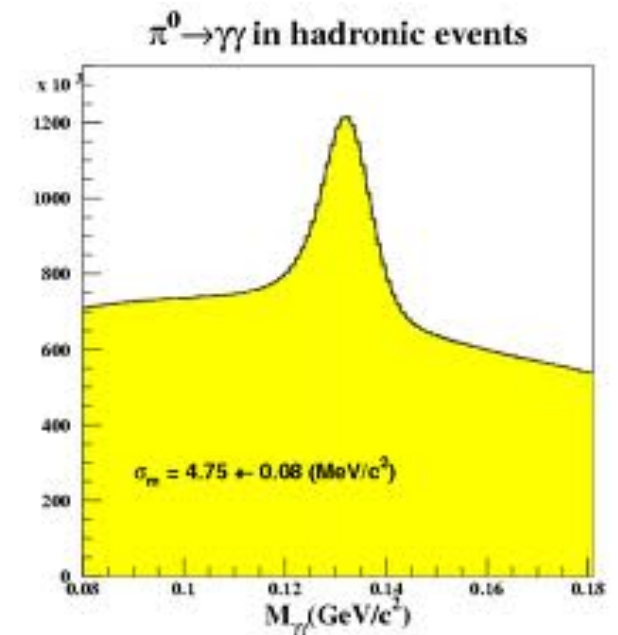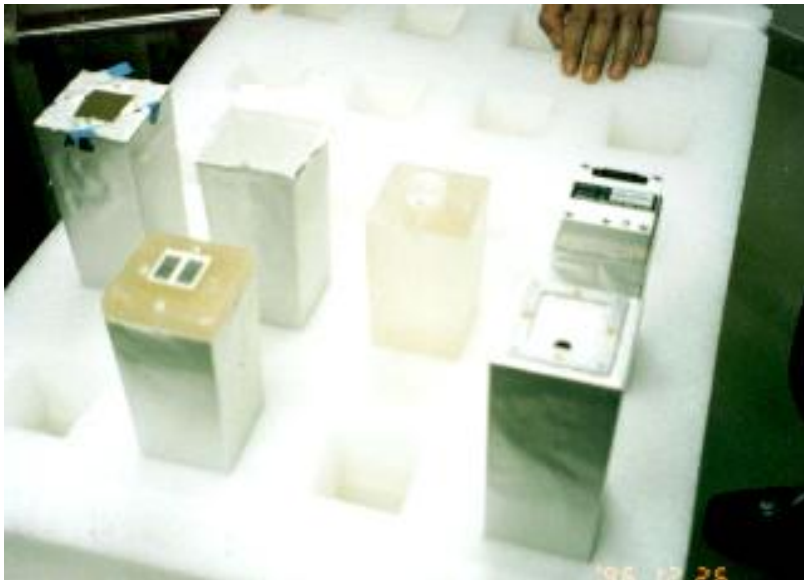# Tension in $|V_{ub}|$ & $|V_{cb}|$

Inclusive measurements of both $|V_{ub}|$ and $|V_{cb}|$ yields higher values than from exclusive measurements

Belle & Us

Belle 실험과 한국 그룹

- 한국 벨 그룹: 45인 (교수+포닥+대학원생)
- 열량계 건설
- 열량계 트리거 하드웨어 제작+cluster logics (both on/offline)

- Silicon sensor, electron ID, time of flight detector 일부 참여
- DST production/DAQ construction 참여
- 2019년 현재 총 박사 배출 실적: 29인

Belle 실험과 한국 그룹

- 500 편이 넘는 논문에서 한국 그룹은 약 40 편 정도 주저자/교신저자
- **S. Olsen and S. K. Choi: the historic X(3872) paper**
  - **Most sited paper in Belle: S. K. Choi won Hoam Prize in 2017**

73

BN #654
Authors

Observation of a narrow charmonium-like state in exclusive $B^\pm \to K^\pm \pi^+ \pi^- J/\psi$ decays

Journal:	PRL **91**, 262001 (2003) hep-ex/0309032 (1657 citations)
Contacts:	S. L. Olsen, S.-K. Choi
Referees:	D. Marlow, P. Chang, R. Itoh
Registered:	Thu Aug 14 2003
Deadline:	Fri Sep 5 2003 (expired) (confirmed)
Submitted:	Mon Sep 8 2003 (+3 days)

- **B. R. Ko and E. Won: D0 mixing in e+e- for the first time.**

PRL **112**, 111801 (2014)   PHYSICAL REVIEW LETTERS   week ending 21 MARCH 2014

Observation of D^0-$\bar{D}^0$ Mixing in e^+e^- Collisions

B. R. Ko,[27] E. Won,[27] I. Adachi,[12] H. Aihara,[61] K. Arinstein,[4] D. M. Asner,[46] V. Aulchenko,[4] T. Aushev,[21] A. Bala,[47]

- **Leadership: Y. J. Kwon: Spokesperson 2018-2020**

SuperKEKB/Belle II
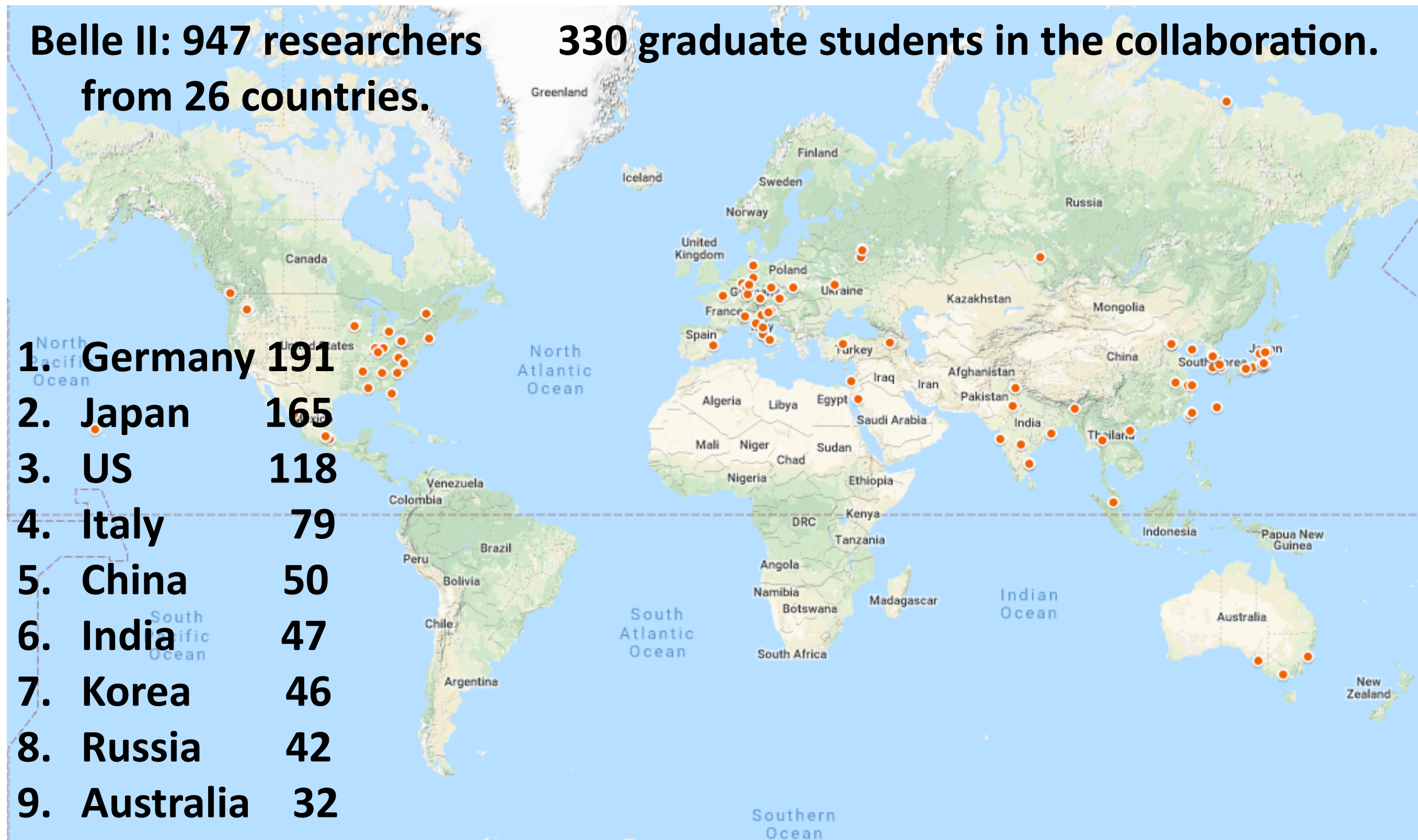
Physics Programs at Belle II

- Look for new physics through various decays

  - b —> s transitions: expected to be small in SM
  - Direct CPV in B —> Kπ (b—>s penguin contribute)
  - B—>τν
  - |Vub|, |Vcb|
  - B—>D(*)τν
  - New CPV in the quark sector?
  - FCNC beyond SM?
  - LFV?
  - Dark sector particle?
  - XYZ-like particle?

Belle II Collaboration

Belle II: 947 researchers   330 graduate students in the collaboration.
from 26 countries.

1. Germany 191
2. Japan   165
3. US   118
4. Italy   79
5. China   50
6. India   47
7. Korea   46
8. Russia   42
9. Australia   32
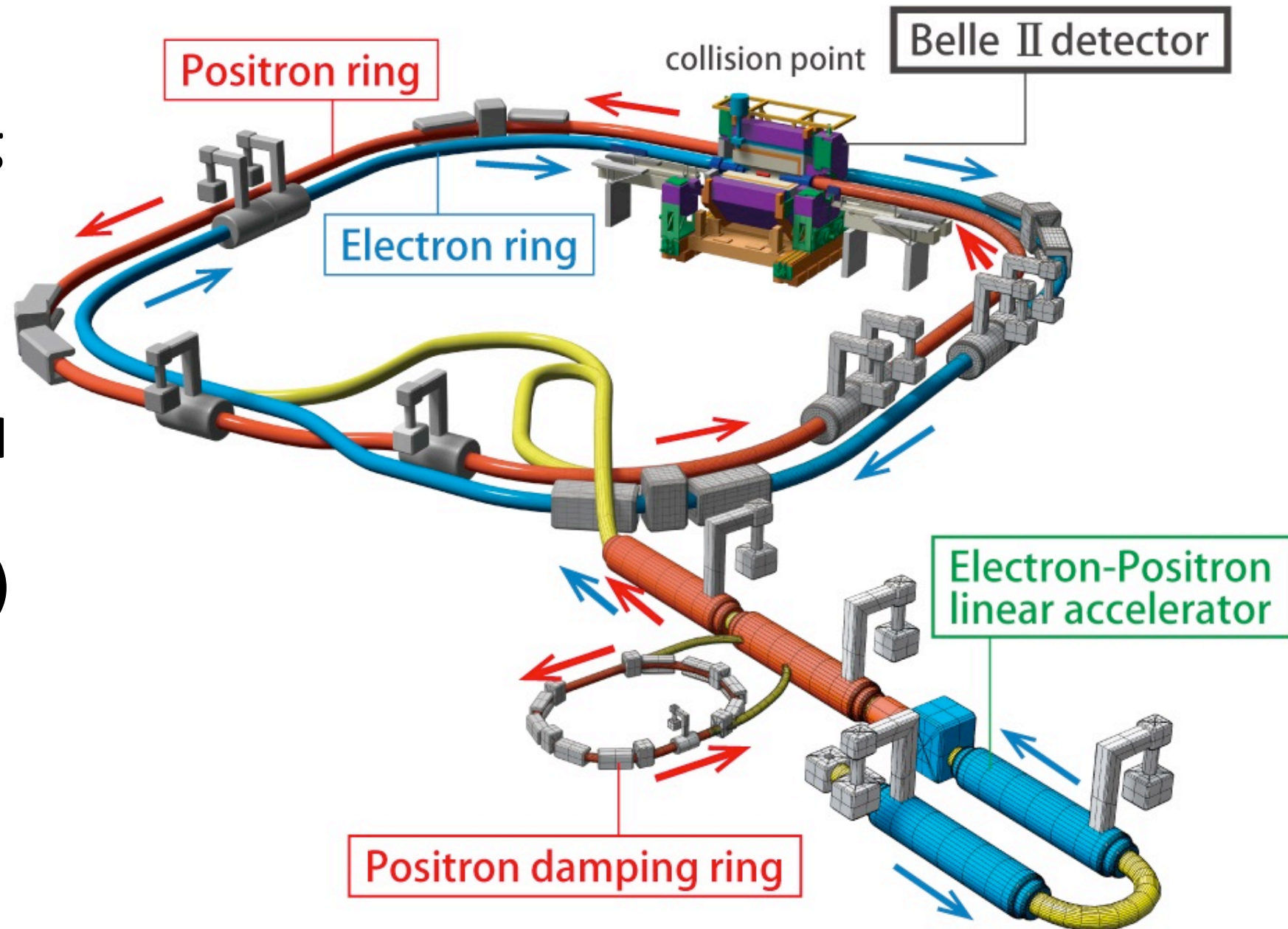
SuperKEKB

- **The first new collider since LHC.**

  - **Phase 1: background, optics commissioning (2016)**

  - **Phase 2: pilot run, superconducting final focus**
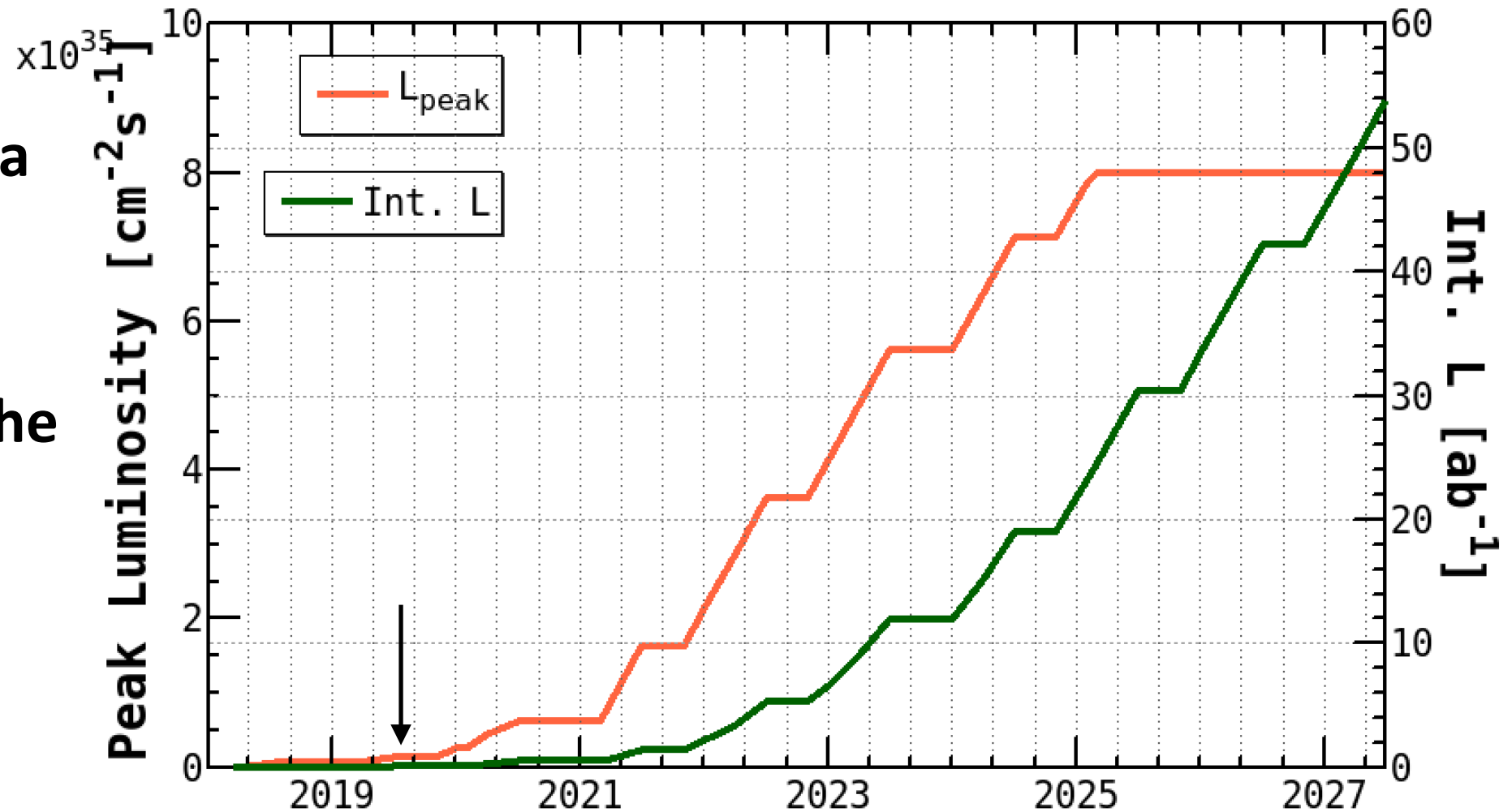   **First collision** (0.5 fb^{-1}) (April-July 2018)

  - **Phase 3: Physics run (March-June 2019)**

SuperKEKB/Belle II Luminosity projection

- **KEKB/Belle recorded ~1 ab^{-1} of data.**

- **Beam currents only a factor of two higher**

- **"nano-beams" are the key (vertical 50 nm)**

- **Target instantaneous luminosity: 8 x 10^{35} cm^{-2} s^{-1}. and it will bring 60 ab^{-1} by 2027.**

Belle II Detector

BEAST (Background commissioning detector)

KLong and muon detector:
Resistive Plate Chambers (barrel outer layers)
Scintillator + WLSF + SiPM's (end-caps , inner 2 barrel layers)

EM Calorimeter:
CsI(Tl), waveform sampling (barrel+ endcap)

electrons (7 GeV)

Particle Identification
TOP detector system (barrel)
Prox. focusing Aerogel RICH (fwd)

Beryllium beam pipe
2cm diameter

Vertex Detector
2 layers DEPFET + 4 layers DSSD

positrons (4 GeV)

Central Drift Chamber
He(50%):C_2H_6(50%), small cells, long lever arm, fast electronics (Core element)
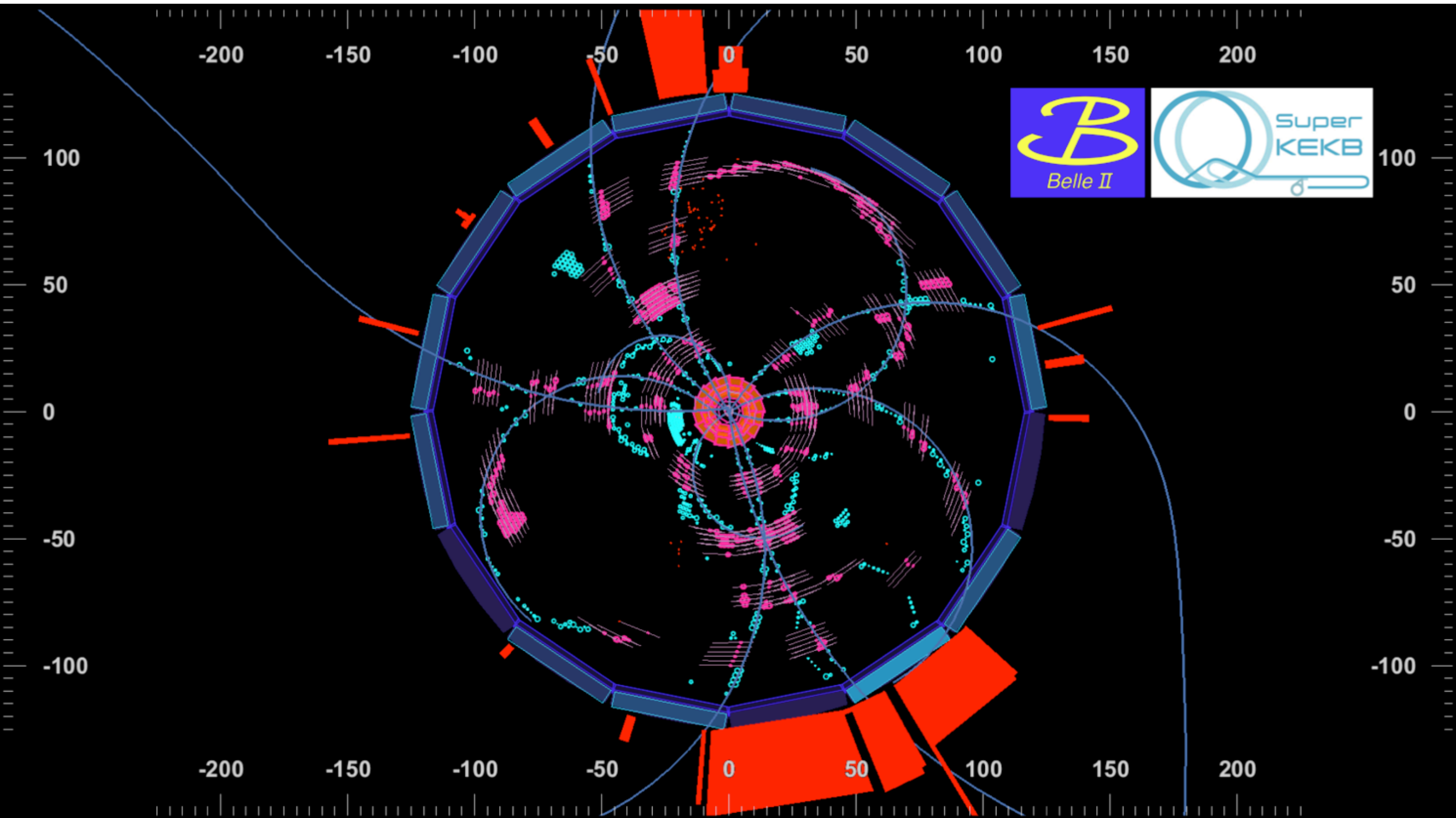
15

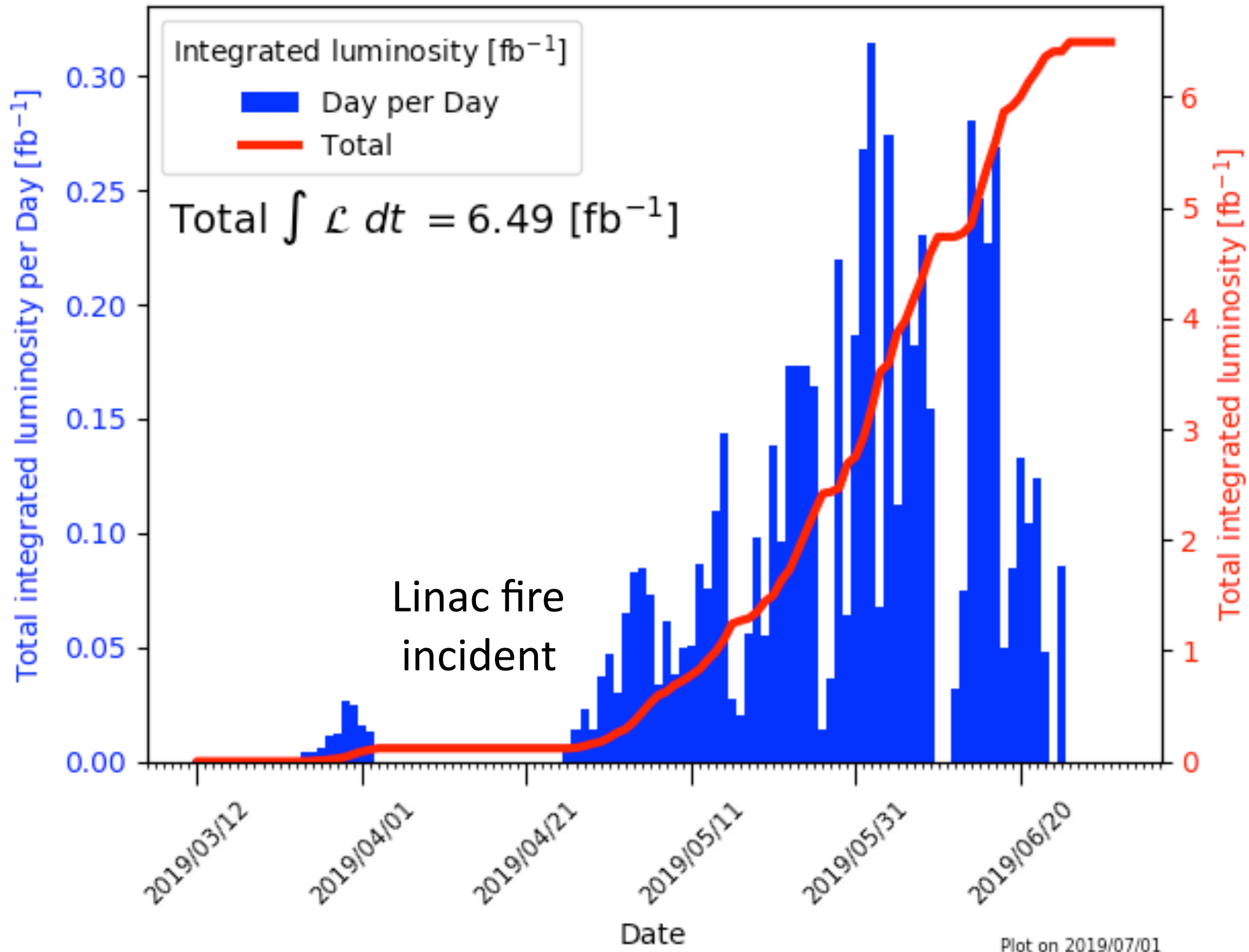# 2019: first collision with pixel detector

2019: first collision with pixel detector
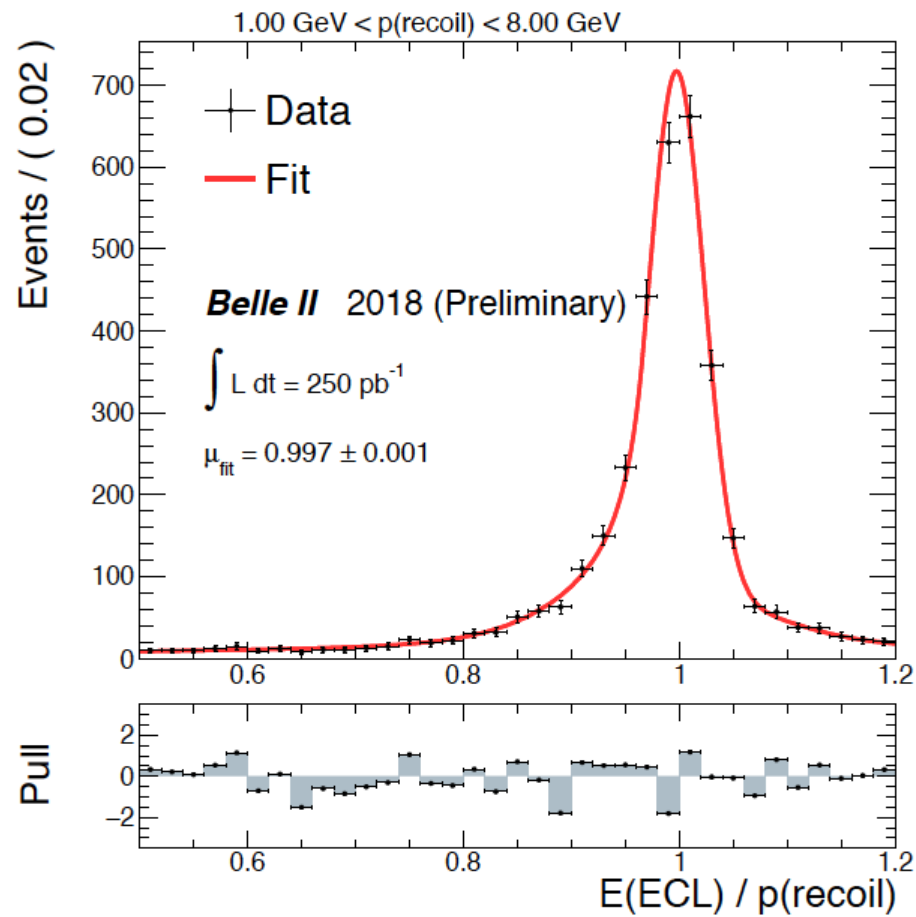
Spring 2019: physics run
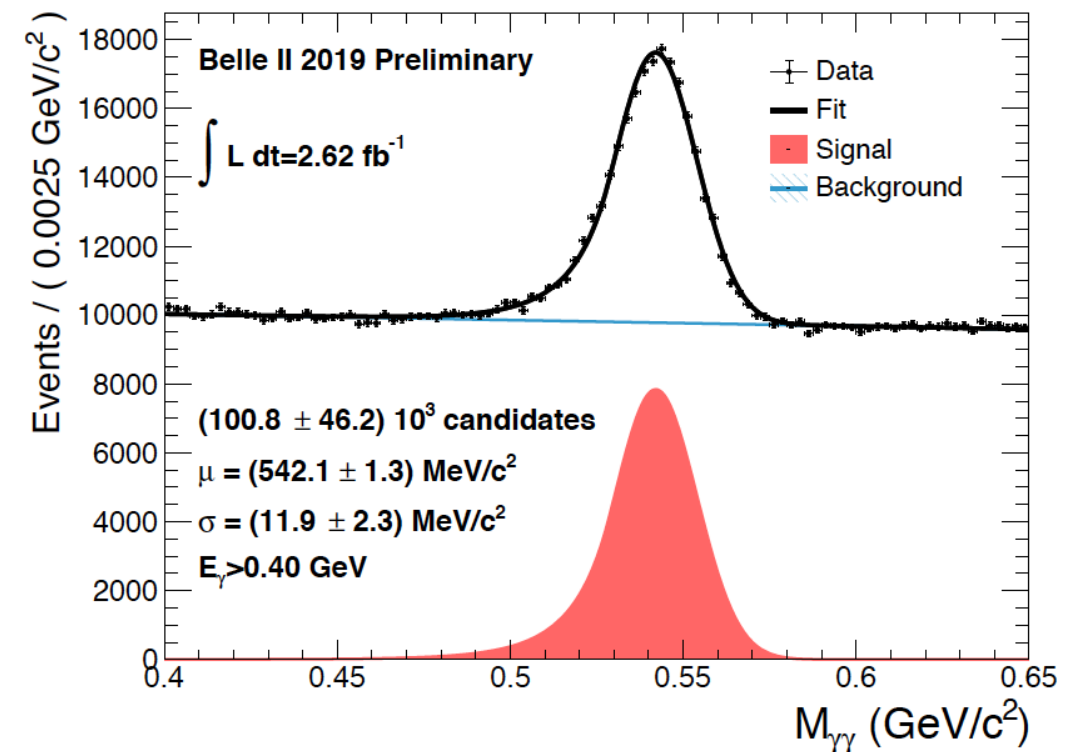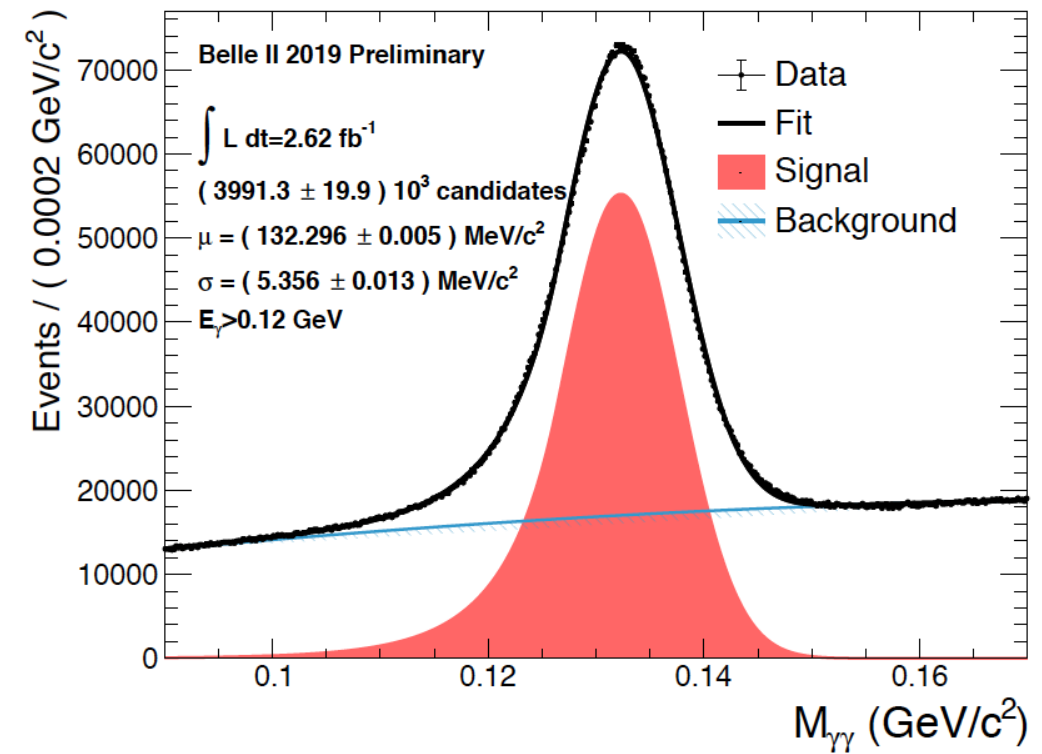

Belle II online luminosity   Exp: 7-8 - All runs

Total $\int \mathcal{L}\, dt = 6.49$ [fb^{-1}]

Linac fire incident

$L_{peak} \sim 5.5$ x10^{33}/cm^2/s)

Plot on 2019/07/01

Photons

$$e^+ e^- \to \mu^+ \mu^- \gamma$$

$$\pi^0 \to \gamma\gamma$$

$$\eta \to \gamma\gamma$$
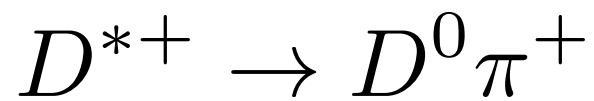
$D^{*+} \rightarrow D^0\pi^+$ Charm mesons
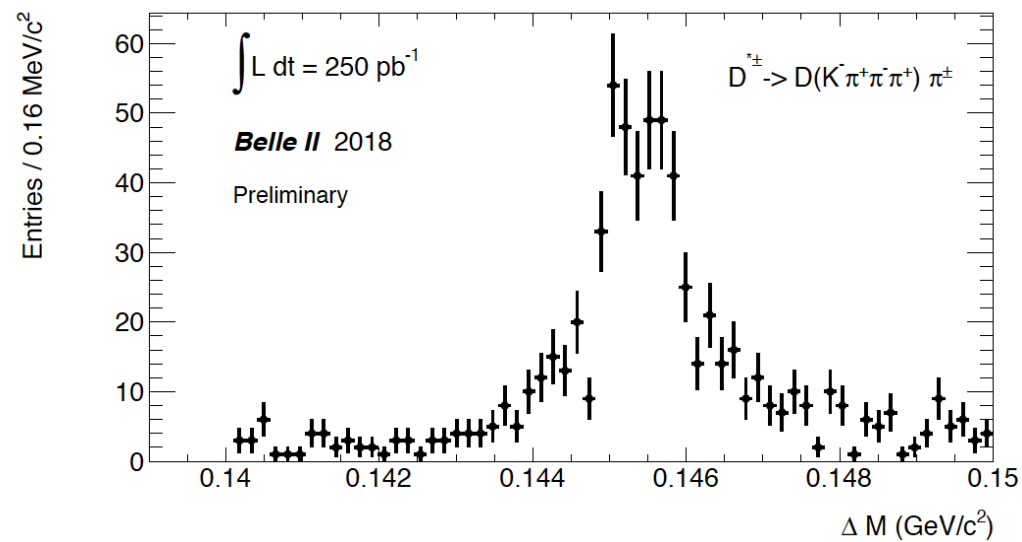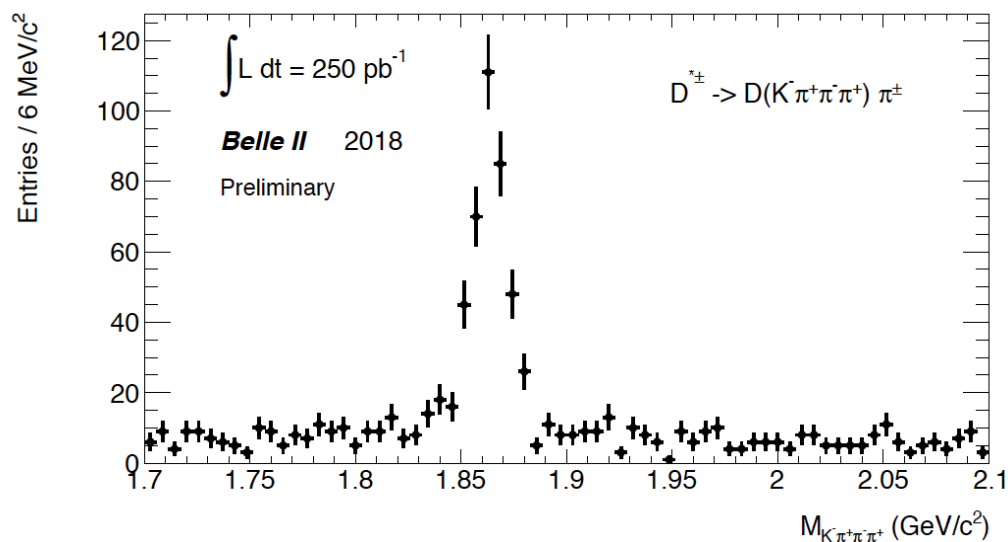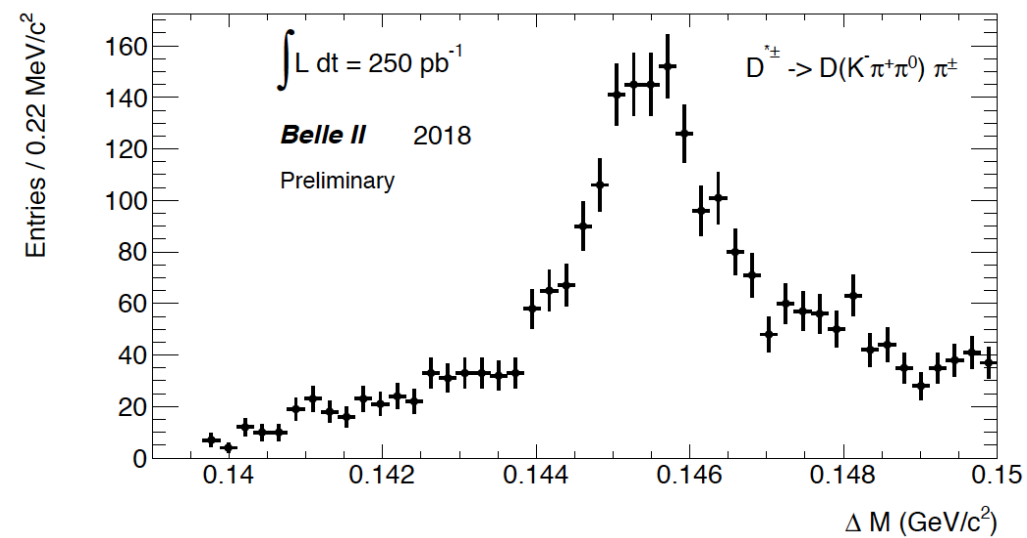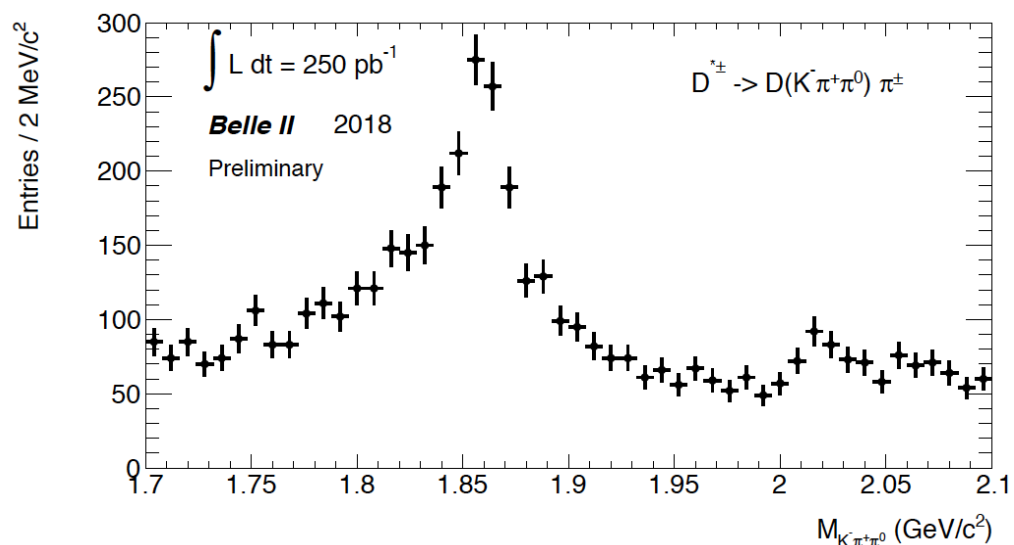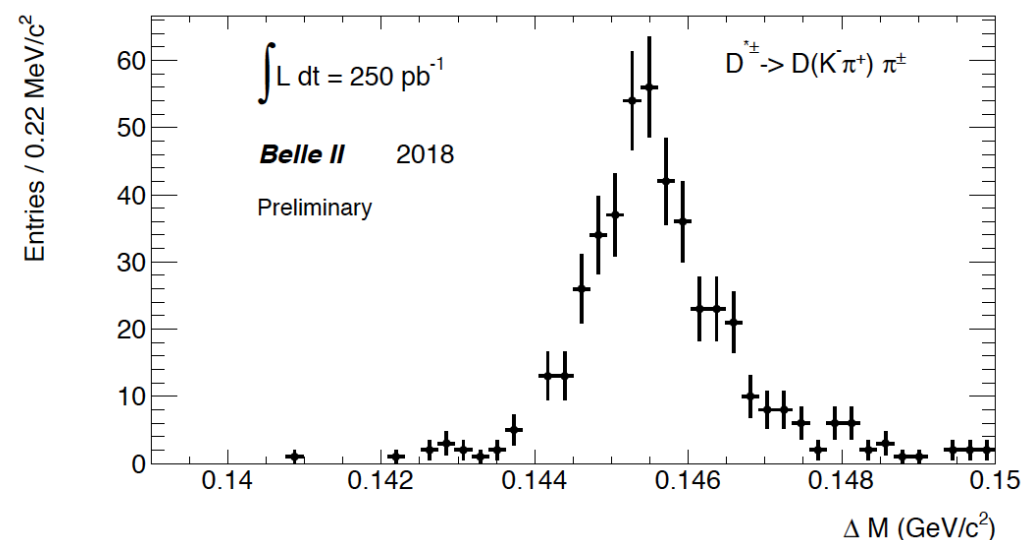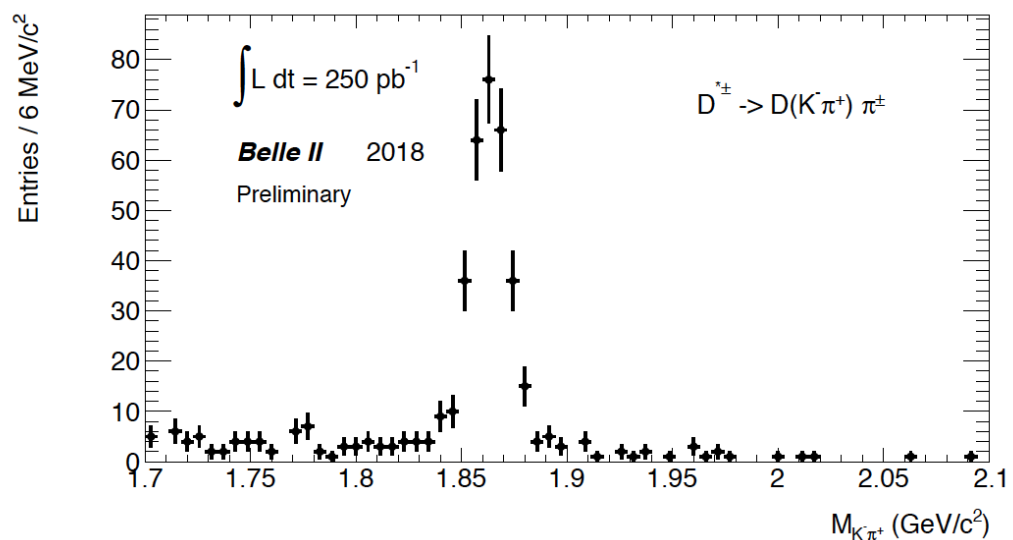
Beauty mesons

$$\Delta E = E_{cm}/2 - E_{recon}$$

$$M_{bc} = \sqrt{(E_{cm}/2)^2 - p_{recon}^2}$$
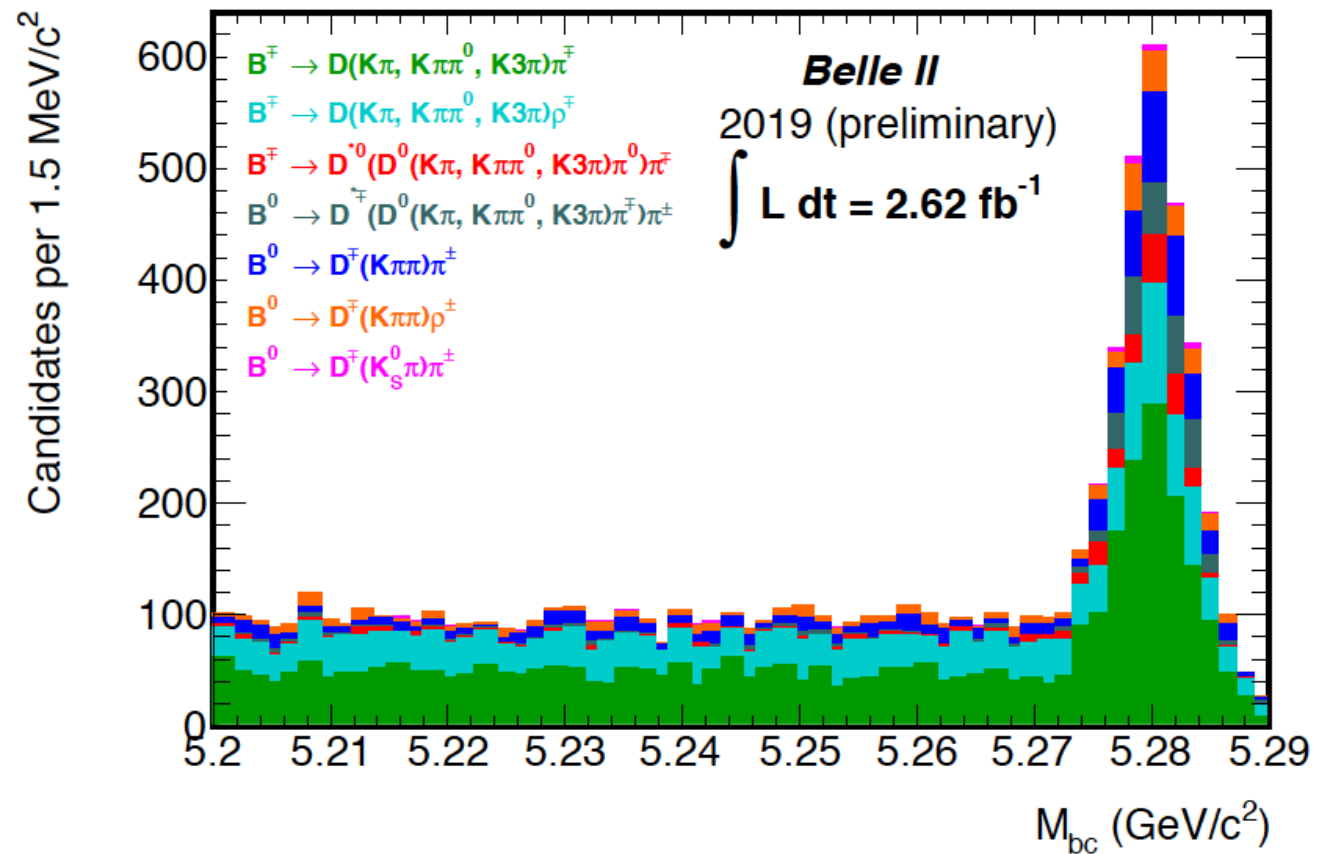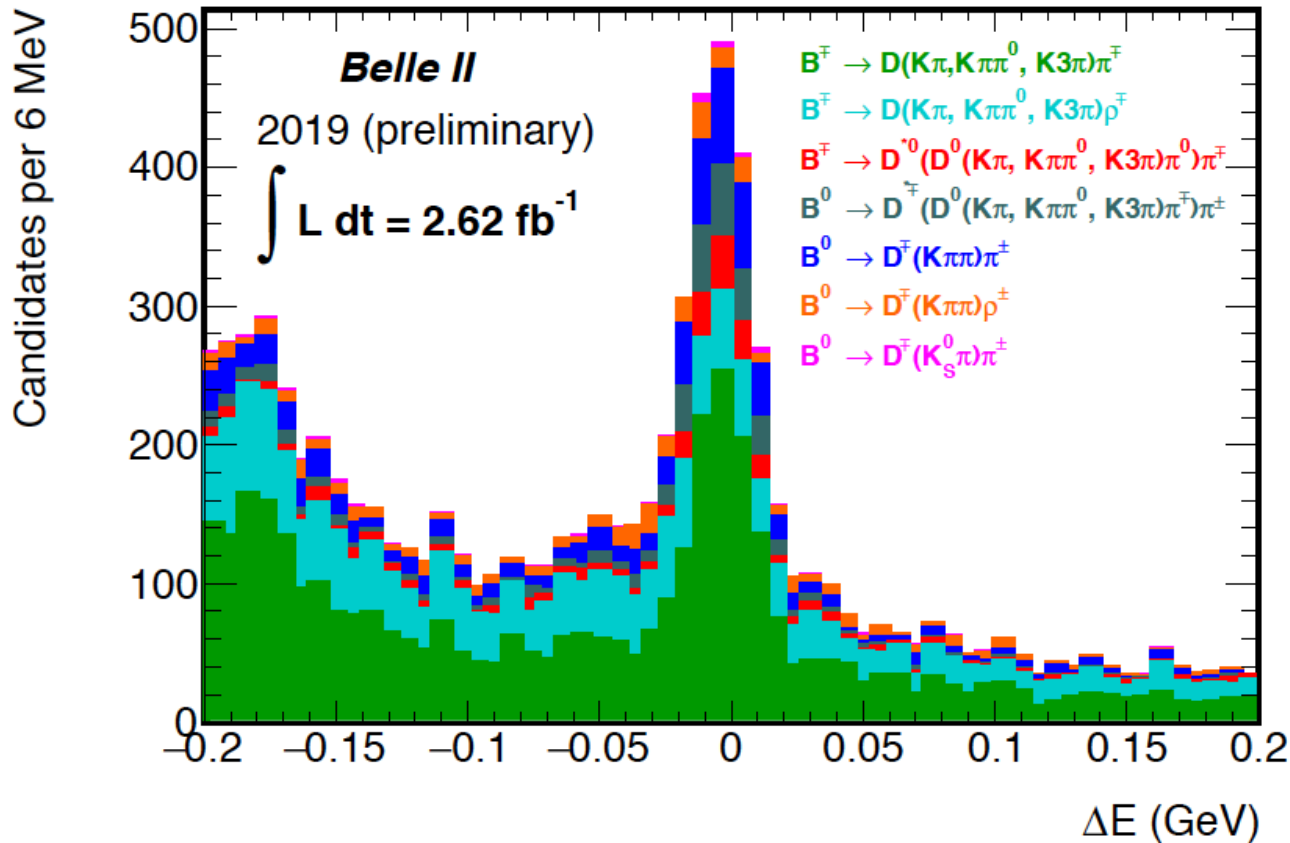
- **We have 2200 fully reconstructed hadronic B decays!**

- Demonstration of Belle II's B physics capabilities: modes with neutrals, and Ks mesons are efficiently reconstructed along with all-charged final states containing kaons and pions.

First physics @ Belle II

- **Dark sector: Z' recoiling against di-muons or electron-muon pair.**
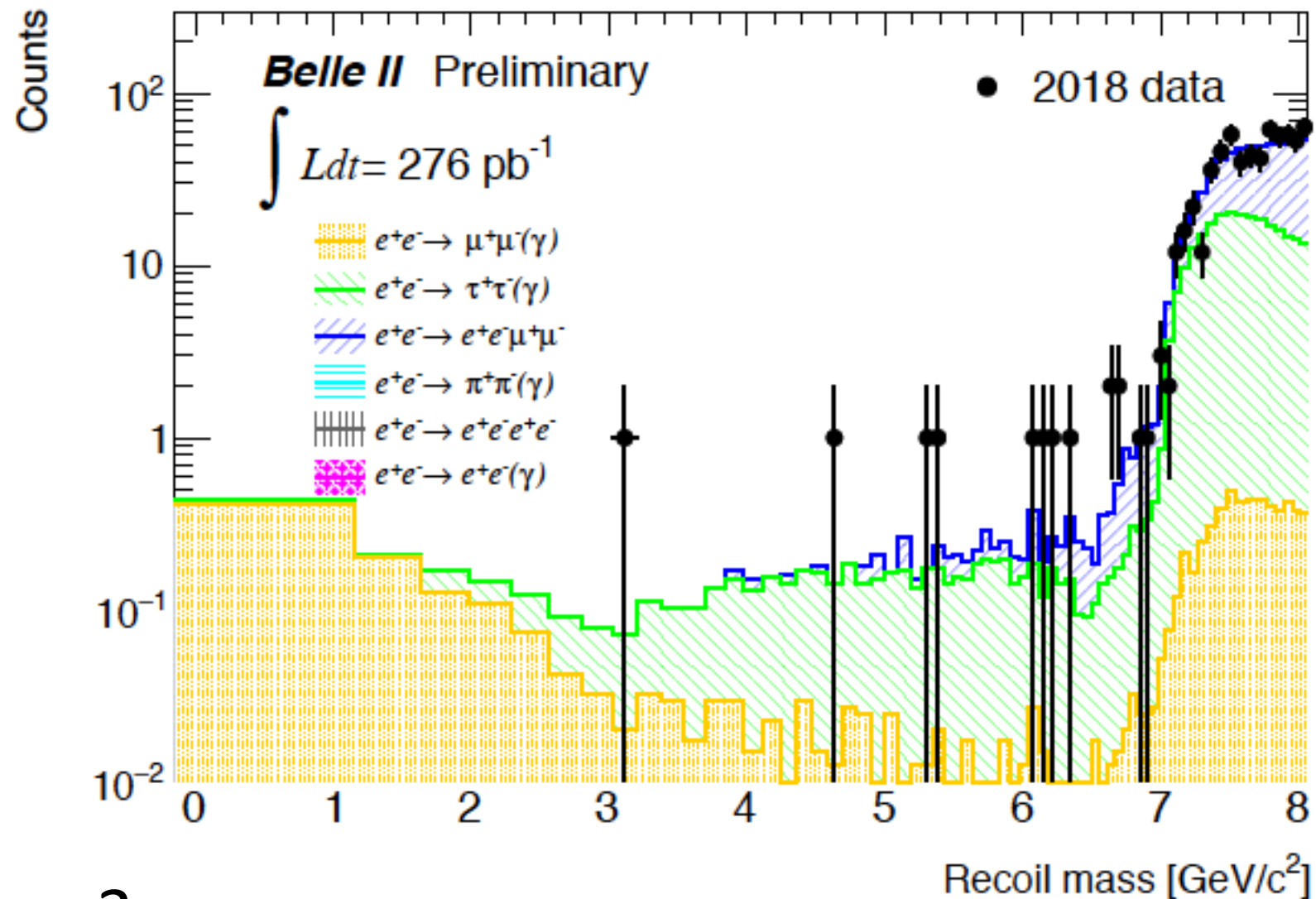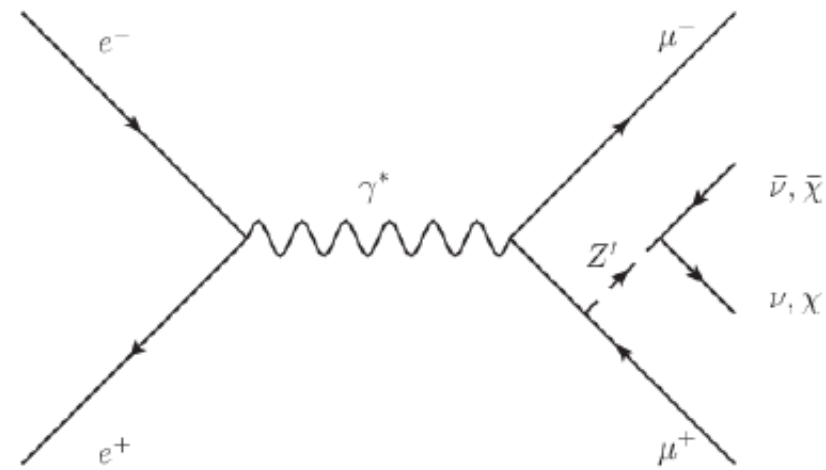
No excess above 3σ seen.

First physics @ Belle II

$$e^+e^- \to \mu^+\mu^- Z', Z' \to \text{nothing}$$

Belle II vs LHCb

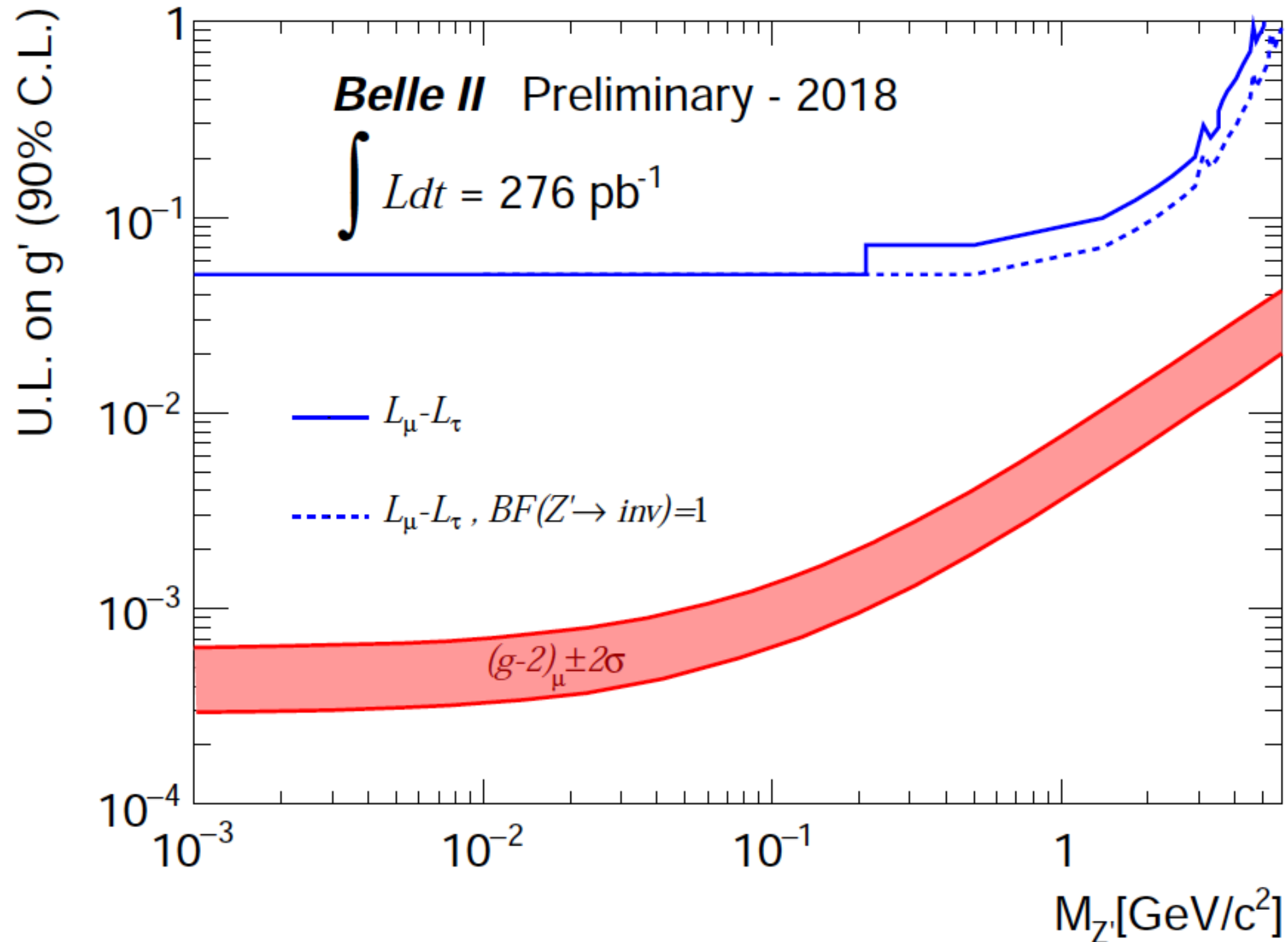| Observable	SM prediction	Theory error	Present result	Future error	Future Facility
$|V_{us}|$ $[K \to \pi \ell \nu]$	input	$0.5\% \to 0.1\%_{\text{Latt}}$	0.2246 ± 0.0012	0.1%	K factory
$|V_{cb}|$ $[B \to X_c \ell \nu]$	input	1%	$(41.54 \pm 0.73) \times 10^{-3}$	1%	Super-B
$|V_{ub}|$ $[B \to \pi \ell \nu]$	input	$10\% \to 5\%_{\text{Latt}}$	$(3.38 \pm 0.36) \times 10^{-3}$	4%	Super-B
γ $[B \to DK]$	input	$< 1°$	$(70^{+27}_{-30})°$	$3°$	LHCb
$S_{B_d \to \psi K}$	$\sin(2\beta)$	$\lesssim 0.01$	0.671 ± 0.023	0.01	LHCb
$S_{B_s \to \psi \phi}$	0.036	$\lesssim 0.01$	$0.81^{+0.12}_{-0.32}$	0.01	LHCb
$S_{B_d \to \phi K}$	$\sin(2\beta)$	$\lesssim 0.05$	0.44 ± 0.18	0.1	LHCb
$S_{B_s \to \phi \phi}$	0.036	$\lesssim 0.05$	—	0.05	LHCb
$S_{B_d \to K^* \gamma}$	few $\times 0.01$	0.01	-0.16 ± 0.22	0.03	Super-B
$S_{B_s \to \phi \gamma}$	few $\times 0.01$	0.01	—	0.05	LHCb
A^d_{SL}	-5×10^{-4}	10^{-4}	$-(5.8 \pm 3.4) \times 10^{-3}$	10^{-3}	LHCb
A^s_{SL}	2×10^{-5}	$< 10^{-5}$	$(1.6 \pm 8.5) \times 10^{-3}$	10^{-3}	LHCb
$A_{CP}(b \to s\gamma)$	< 0.01	< 0.01	-0.012 ± 0.028	0.005	Super-B
$\mathcal{B}(B \to \tau \nu)$	1×10^{-4}	$20\% \to 5\%_{\text{Latt}}$	$(1.73 \pm 0.35) \times 10^{-4}$	5%	Super-B
$\mathcal{B}(B \to \mu \nu)$	4×10^{-7}	$20\% \to 5\%_{\text{Latt}}$	$< 1.3 \times 10^{-6}$	6%	Super-B
$\mathcal{B}(B_s \to \mu^+ \mu^-)$	3×10^{-9}	$20\% \to 5\%_{\text{Latt}}$	$< 5 \times 10^{-8}$	10%	LHCb
$\mathcal{B}(B_d \to \mu^+ \mu^-)$	1×10^{-10}	$20\% \to 5\%_{\text{Latt}}$	$< 1.5 \times 10^{-8}$	$[?]$	LHCb
$A_{\text{FB}}(B \to K^* \mu^+ \mu^-)_{q_0^2}$	0	0.05	(0.2 ± 0.2)	0.05	LHCb
$B \to K \nu \bar{\nu}$	4×10^{-6}	$20\% \to 10\%_{\text{Latt}}$	$< 1.4 \times 10^{-5}$	20%	Super-B
$|q/p|_{D-\text{mixing}}$	1	$< 10^{-3}$	$(0.86^{+0.18}_{-0.15})$	0.03	Super-B
ϕ_D	0	$< 10^{-3}$	$(9.6^{+8.3}_{-9.5})°$	$2°$	Super-B
$\mathcal{B}(K^+ \to \pi^+ \nu \bar{\nu})$	8.5×10^{-11}	8%	$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$	10%	K factory
$\mathcal{B}(K_L \to \pi^0 \nu \bar{\nu})$	2.6×10^{-11}	10%	$< 2.6 \times 10^{-8}$	$[?]$	K factory
$R^{(e/\mu)}(K \to \pi \ell \nu)$	2.477×10^{-5}	0.04%	$(2.498 \pm 0.014) \times 10^{-5}$	0.1%	K factory
$\mathcal{B}(t \to cZ, \gamma)$	$\mathcal{O}(10^{-13})$	$\mathcal{O}(10^{-13})$	$< 0.6 \times 10^{-2}$	$\mathcal{O}(10^{-5})$	LHC ($100\,\text{fb}^{-1}$)

- **Belle II: clean environment: efficient detection of neutrals (γ, π^0, η)**

- **Belle II: quantum correlated $B^0\bar{B}^0$ pairs: flavor tagging is more efficient (34% vs 3%)**

- **Belle II: full reconstruction: b—>u transition**

- **LHCb: large X-section**

Belle II & Us

Belle II 실험과 한국 그룹

- 한국 벨 II 그룹: 46인 (교수+포닥+대학원생)
- 열량계 트리거 하드웨어 제작
- 3차원 전하입자 궤적 트리거 firmware development
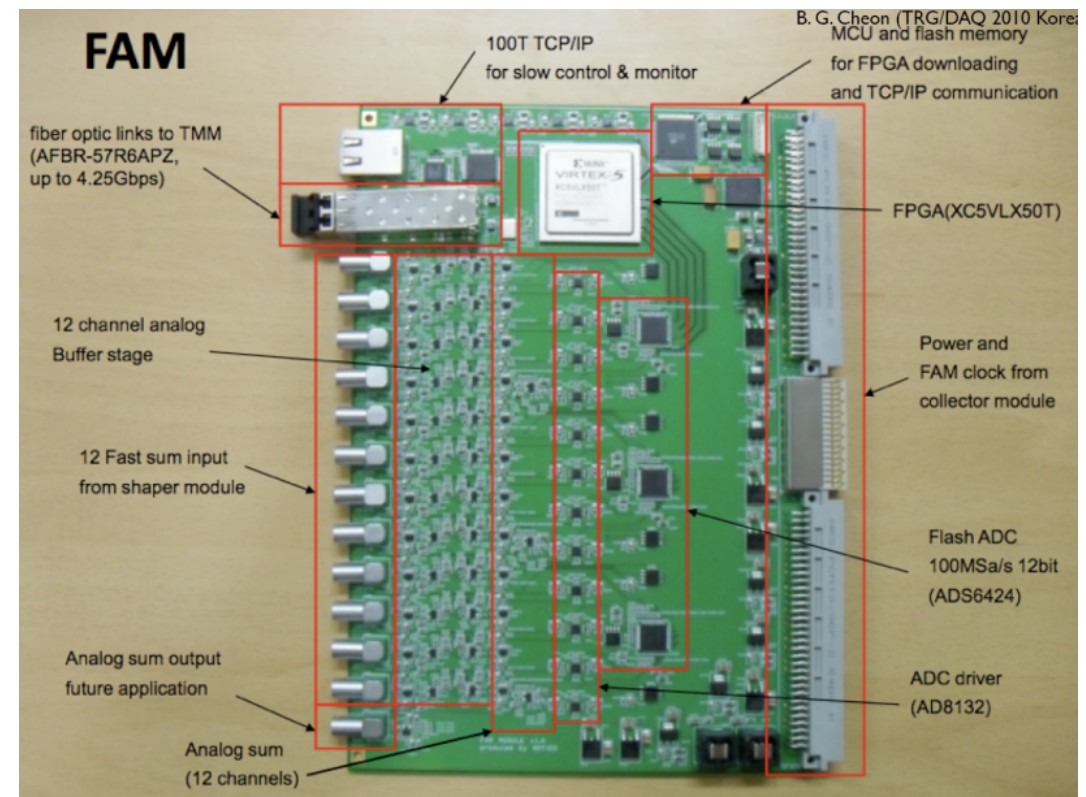
- **Belle II data handling system using AMGA (KISTI)**
- **Silicon sensor assembly**
- **DAQ construction**
- **Data production and Geant4 validation**

Belle II 실험: M&O (*)

● 벨 II 실험에서는 실험 운영을 위한 분담금 요구 (Maintenance and Operation)

● M&O Status
  - FY2013:   455,050 yen paid.
  - FY2014: 2,654,300 yen paid.   한-Jparc사업: 2013-2015
  - FY2015: 1,706,200 yen paid.

  - FY2016: 4,485,900 yen paid.
  - FY2017: 5,059,200 yen paid.   대형시설활용사업: 2016-2018
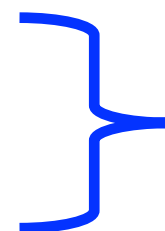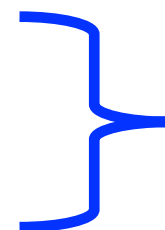 - FY2018: 6,300,000 yen paid.

  - FY2019
  - FY2020   대형시설활용사업: 2019-2021
  - FY2021

(*) 한-CERN 사업: 관측기 사용료

Belle II 실험: 예산 (*)

예상되는 1 년 한국 벨2 운영 경비

 - 7천만원 (M&O)

 - 여비: Belle II shift/Collaboration meeting/Conference

   단기 1인 200 만원 x 30 회 = 6천만원

   장기 1인 2000 만원 (6개월) x 5 인 = 1억원

 - 인건비

   포닥 5천만원 x 4 인 x 1년 = 2억원

   대학원생 1400 만원 x 15인 x 1년 = 2억 1천만원

 - 트리거 업그레이드: 2억원/년

총 8억 4천만원/년

(*) 컴퓨팅 자원 및 네트워크 자원은 KISTI 를 통하여 별도로 얻음.

건의사항

최근 10여년 동안 국내 교수충원은 LHC 실험 분야가 대부분

벨2 실험에서 한국그룹의 지속적 기여을 위한 경입자 충돌 분야 충원 필요

감사합니다.