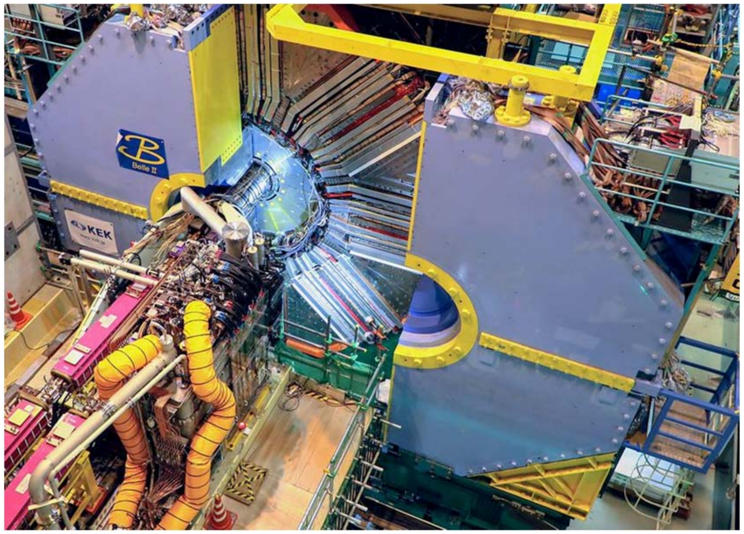
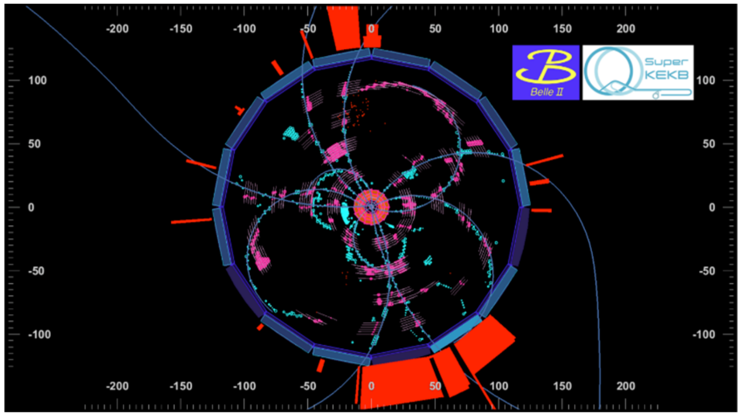
Seminar, Tel Aviv, November 2, 2020





Belle II -
first results from a new flavour physics experiment

Univerza *v Ljubljani*
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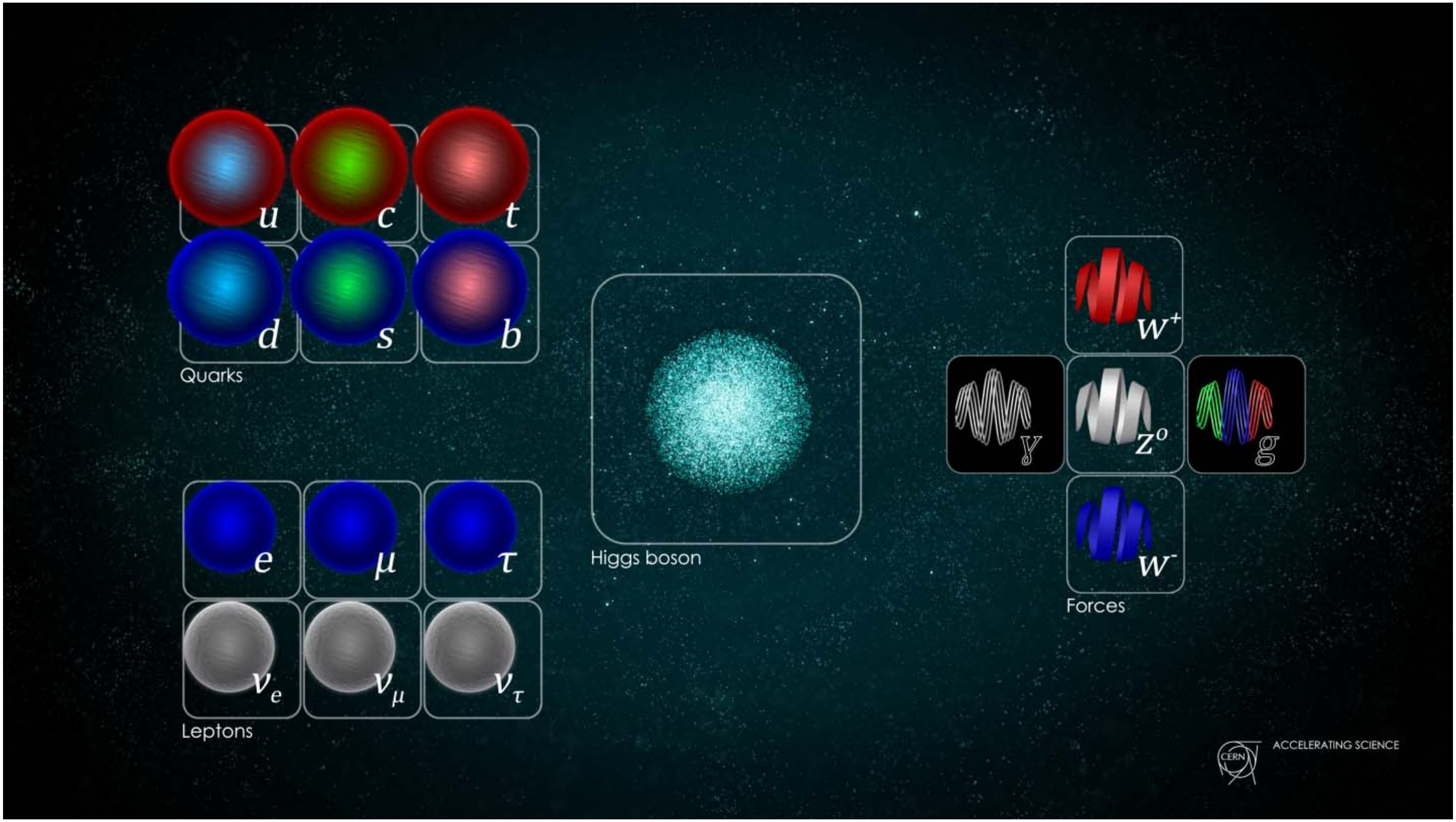
European Research Council
Established by the European Commission

Contents

- Introduction: B physics
- Why a super B factory, and how?
- SuperKEKB and Belle II
- Belle II: first results
- Outlook

Standard Model



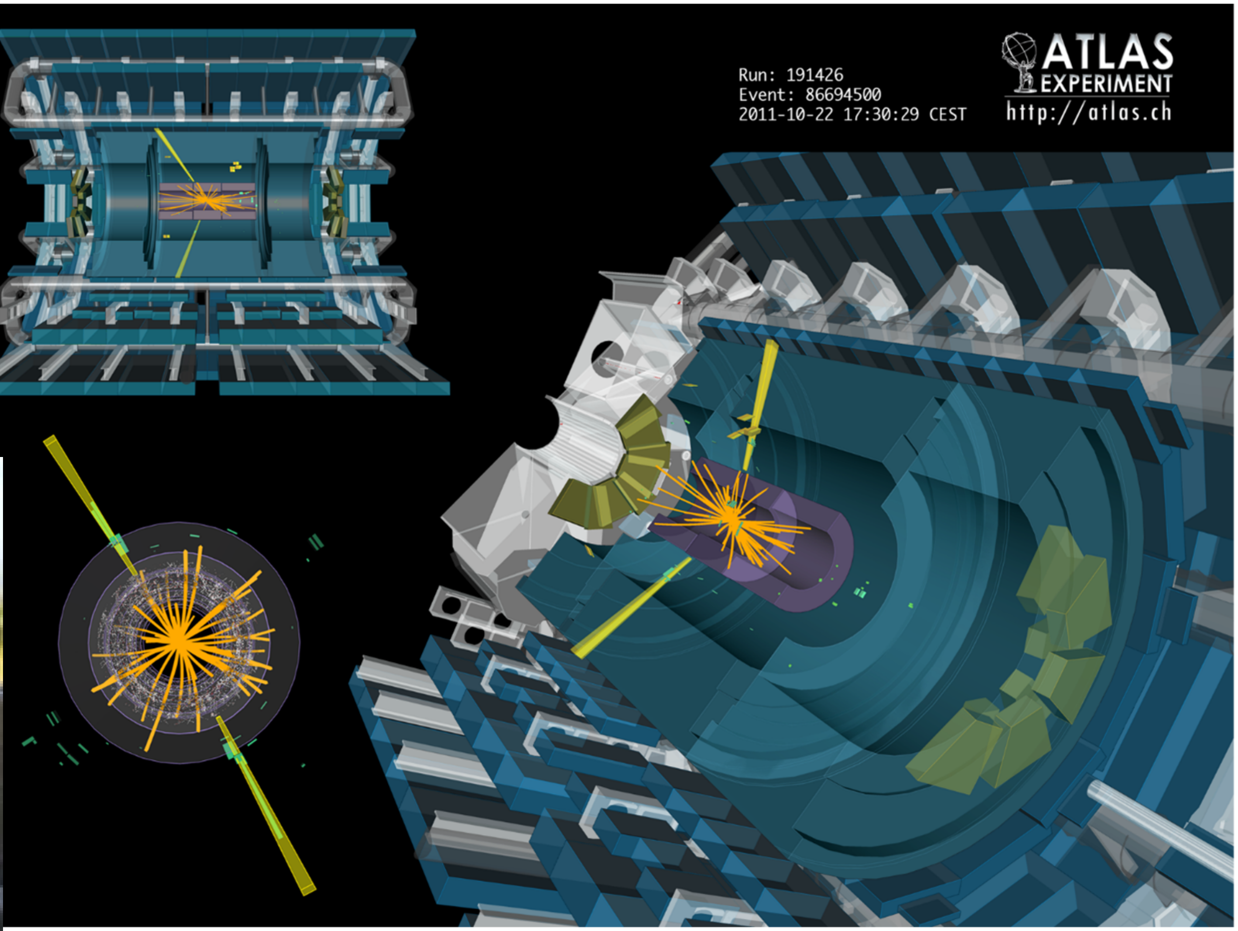
An incredibly successful theory to describe elementary particles and their interactions

The cherry on the cake, the last missing piece of the Standard Model puzzle: Higgs boson discovery in 2013

Nobel prize 2013!

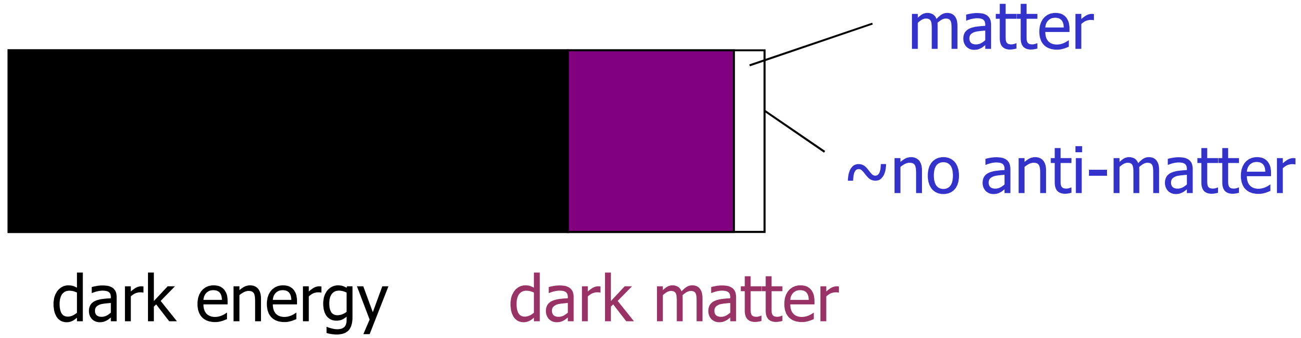
Francois Englert in Peter W. Higgs

Higgs boson decay to two high-energy gamma rays, H → $\gamma\gamma$, as seen in the ATLAS detector



However…

- However, the CP violation mechanism of the Standard model is by far too small to account for the asymmetry between matter and anti-matter in the Universe (falls short by 10 orders of magnitude !)
- SM does not contain the fourth fundamental interaction, gravitation
- Most of the Universe is made of stuff we do not understand...



Two complementary approaches to study shortcomings of the Standard Model and to search for the so far unobserved processes and particles (so called New Physics, NP). These are the **energy frontier** and the **intensity frontier** .

Energy frontier : direct search for production of unknown particles at the highest achievable energies.

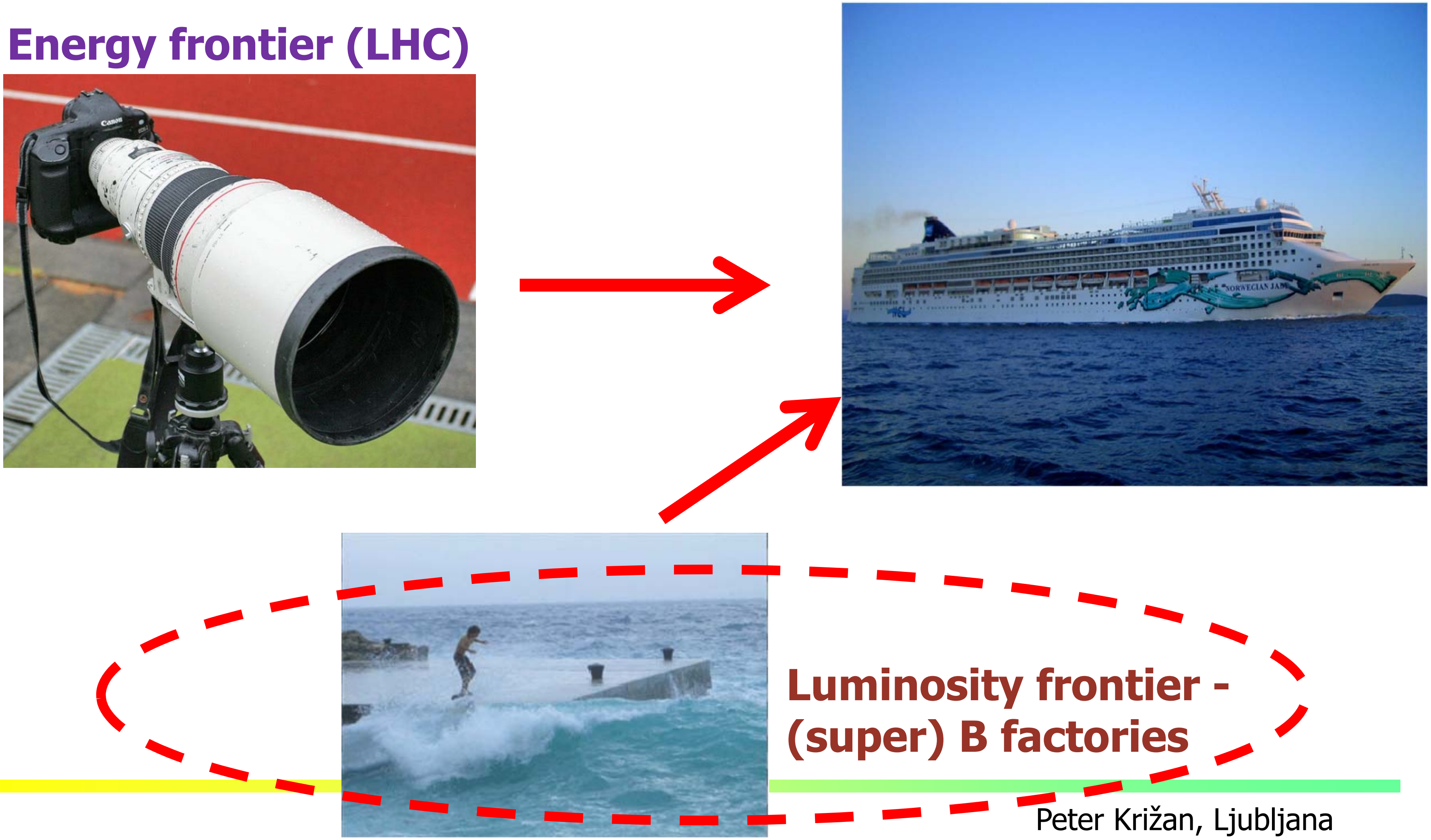
Intensity frontier : search for rare processes, deviations between theory predictions and experiments with the ultimate precision.

→for this second kind of studies, one has to investigate a very large number of reactions (˝events˝) → need accelerators with ultimate **intensity** (˝luminosity˝)

Comparison of **energy** /**intensity** frontiers

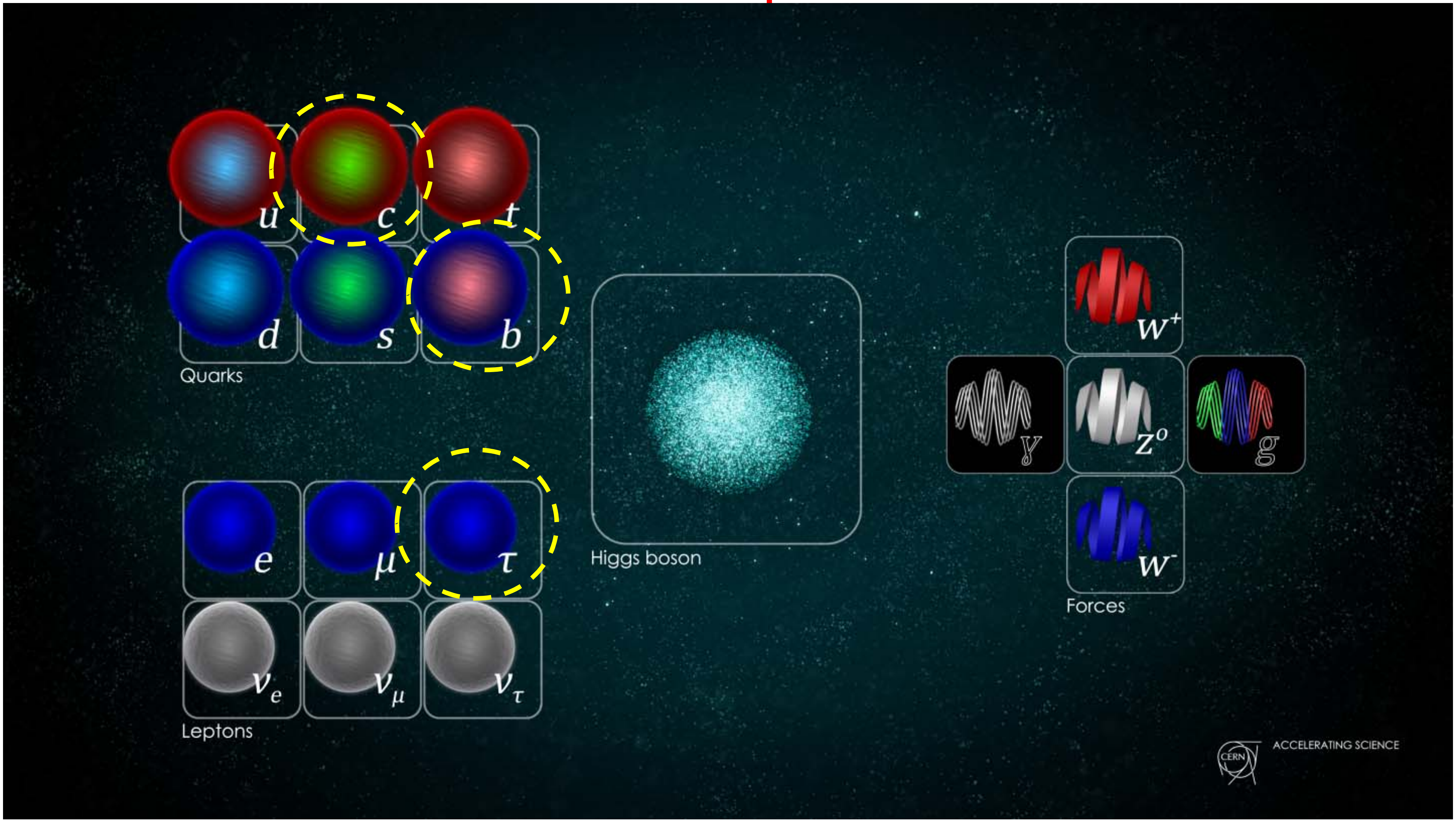
To observe a large ship far away one can either use **strong binoculars** or observe **carefully the direction and the speed of waves** produced by the vessel.

Energy frontier (LHC)



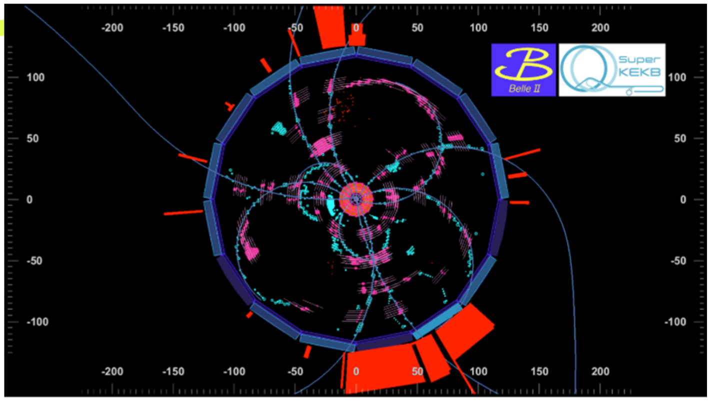
Luminosity frontier - (super) B factories

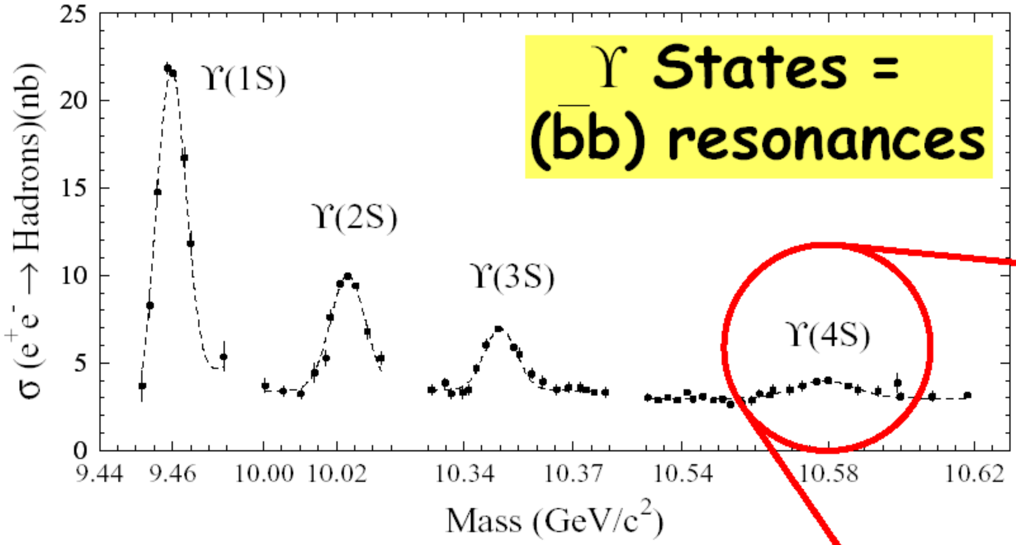
Heavy flavour physics: physics of b and c quarks and tau leptons



One of the most important avenues of the intensity frontier.

B meson production in $e^+e^- \to \Upsilon(4S) \to BB$

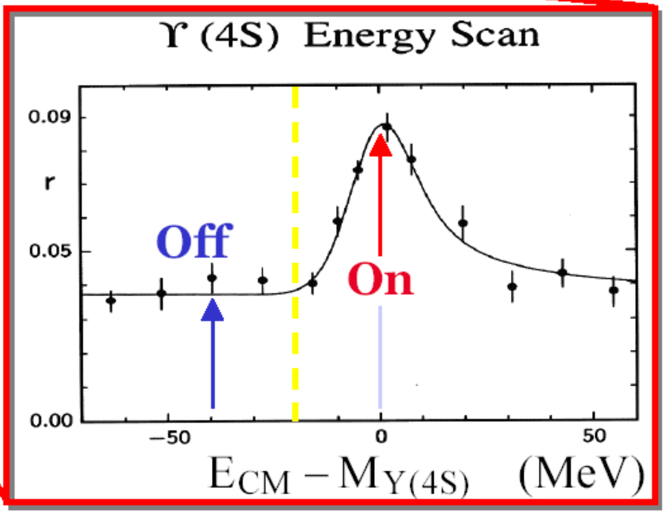




Υ States =
$(b\bar{b})$ resonances

Cross Sections at $\Upsilon(4S)$:

$b\bar{b} \sim 1.1$ nb
$c\bar{c} \sim 1.3$ nb
$d\bar{d}$, $s\bar{s} \sim 0.3$ nb
$u\bar{u} \sim 1.4$ nb



$e^+e^- \to \Upsilon(4S) \to B\bar{B}$
$L = 1$ state

B factories

Systematic studies of B mesons at Υ(4S)

80s-90s: two very successful experiments:

- ARGUS at DORIS (DESY)
- CLEO at CESR (Cornell)

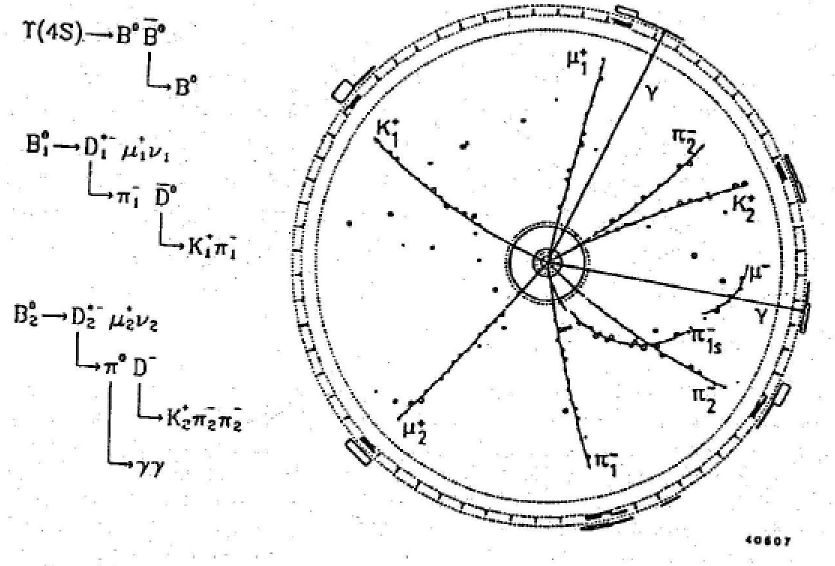
Magnetic spectrometers at e^+e^- accelerators (5.3GeV+5.3GeV beams)

Large solid angle, excellent tracking and good particle identification (TOF, dE/dx, EM calorimeter, muon chambers).

1987, one of the highlights: ARGUS discovers large $B\overline{B}$ mixing: B^0 turns into anti-B^0

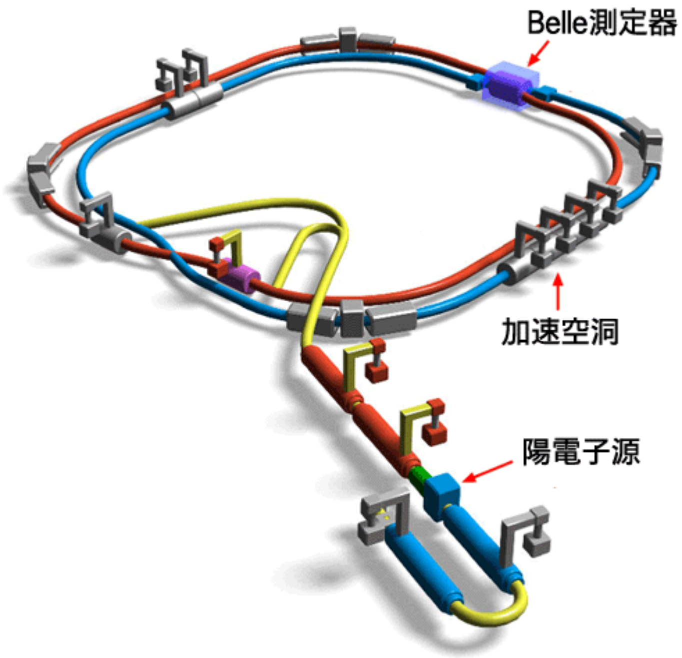
Large mixing rate → high top mass (in the Standard Model)

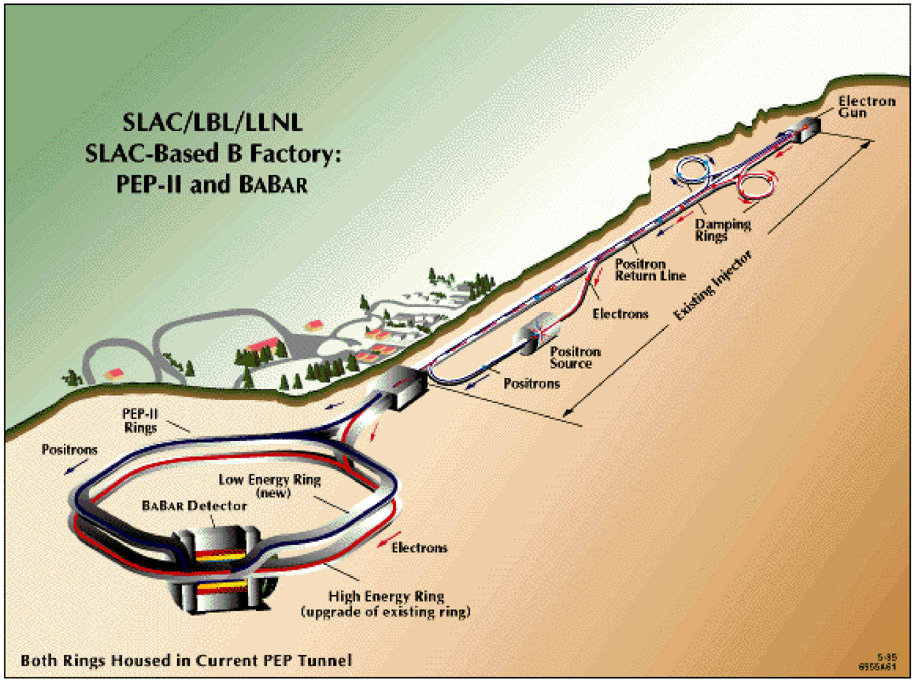
The top quark has only been discovered seven years later!



▬ Reconstructed event where a B^0 turns into anti-B^0

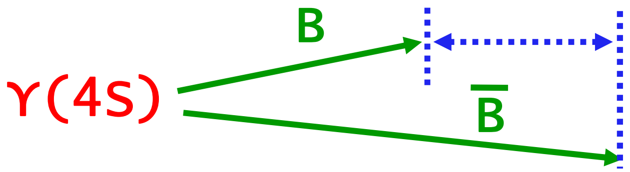
Next generation: asymmetric B factories





$\sqrt{s}=10.58$ GeV

$e^+ \longrightarrow \Upsilon(4S) \longleftarrow e^-$



$\Delta z \sim c\beta\gamma\tau_B$
$\sim 200\mu m$

BaBar	$p(e^-)=9$ GeV	$p(e^+)=3.1$ GeV	$\beta\gamma=0.56$
Belle	$p(e^-)=8$ GeV	$p(e^+)=3.5$ GeV	$\beta\gamma=0.42$

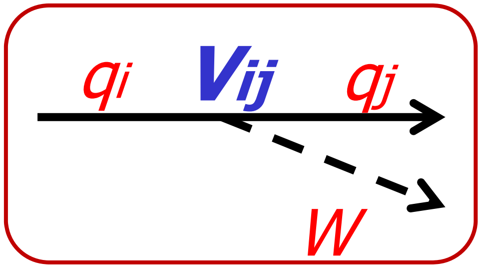
Asymmetric beam energies→B mesons are boosted, needed for studies of time evolution

Physics of B mesons at asymmetric B factories

Played a central role in particle physics from 2001 to 2010

Established the complex unitary Cabbibo-Kobayashi-Maskawa (CKM) quark transition matrix as the source of CP violati

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

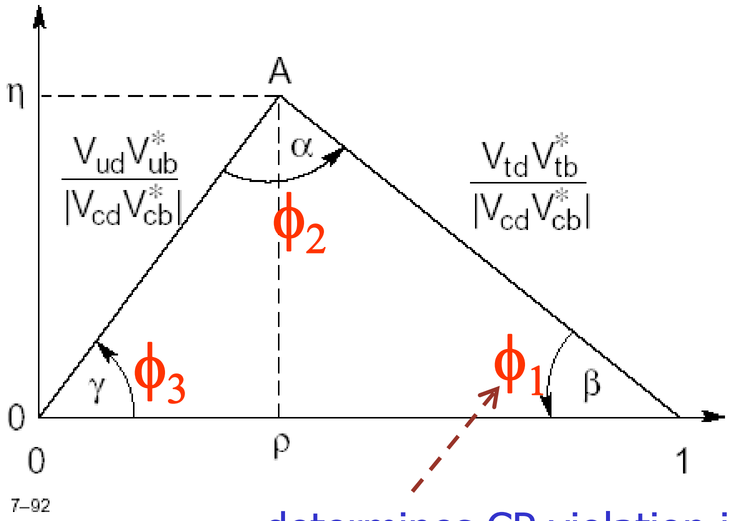


CKM: unitary matrix

→relations of the type

$$V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0$$

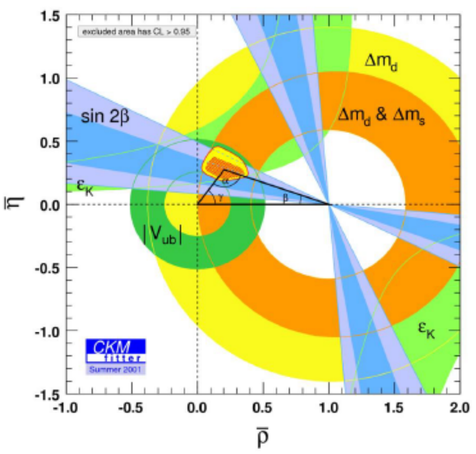
triangles in the complex plane



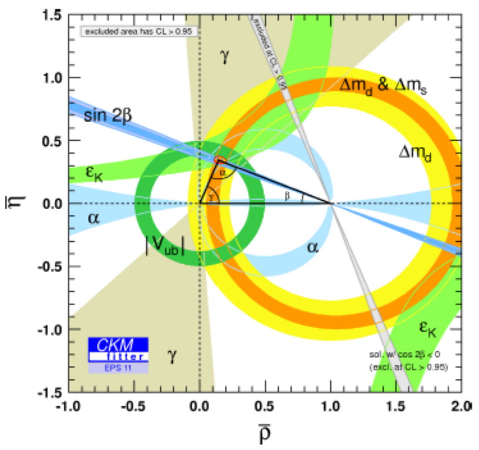
determines CP violation in $B \to J/\psi\ K_S$ decays

Physics of B mesons at asymmetric B factories

CP violation in B system: from the discovery (2001) to a precision measurement

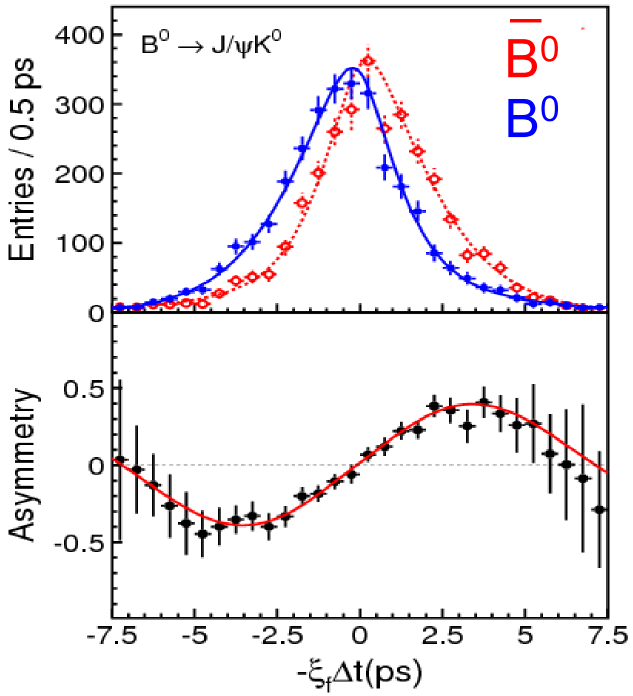


EPS 2001



EPS 2011

Time evolution of B mesons



Constraints from measurements of angles and sides of the unitarity triangle

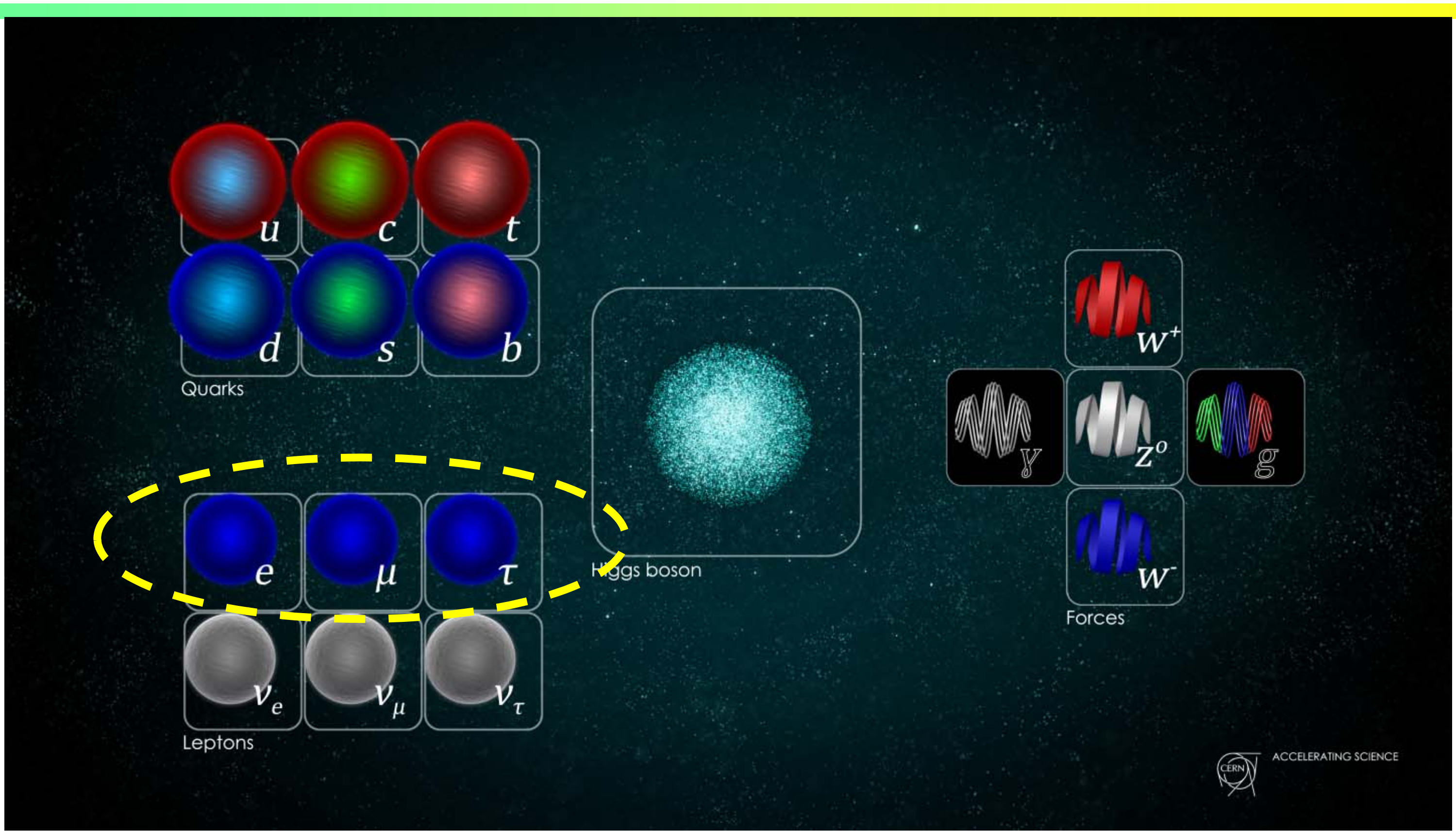
→ Remarkable agreement

→ Nobel prize for Kobayashi and Maskawa (2008)

B factories: a success story

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decay modes (e.g., $B\rightarrow\tau\nu$, $D\tau\nu$)
- $b\rightarrow s$ transitions: probe for new sources of CPV and constraints from the $b\rightarrow s\gamma$ branching fraction
- Study forward-backward asymmetry (A_{FB}) in $b\rightarrow s l^+ l^-$
- First look at the possible violation of lepton flavour universality
- Observation of D mixing
- Searches for rare τ decays
- Observation of new hadrons

Standard Model: Lepton Flavour Universality

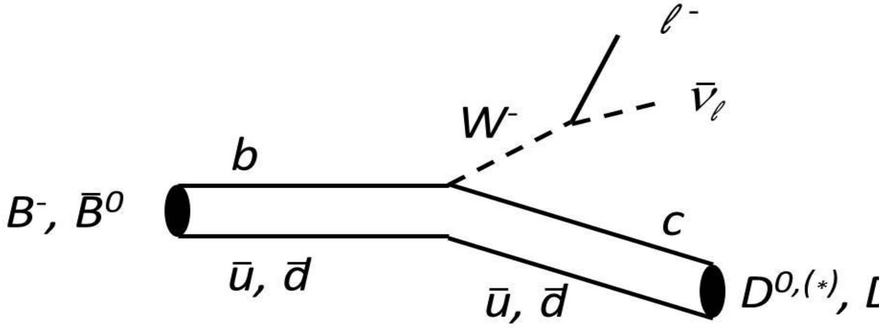


One of the cornerstones of the Standard model (verified by experiments): Lepton Flavour Universality (LFU) - interactions of leptons do not depend on their flavour

= **e^-**, μ^-, τ^- should behave in the same way

Anomalies in $B \rightarrow D^*\tau\nu$

Diagrams for the transition, mediated by the charged SM weak interaction



LFU → the rate for the transition (corrected for available phase space) should not depend on the lepton flavour

→ Same for electrons, muons and tau leptons

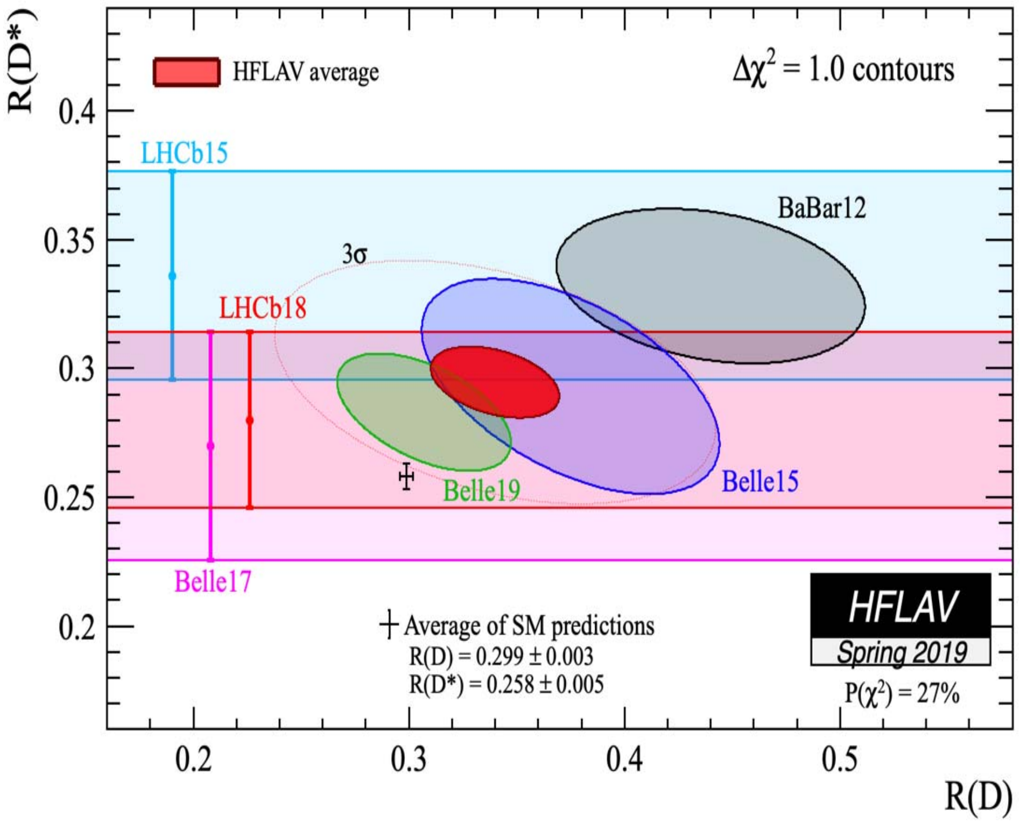
Compare the final state with a τ to the one with e or μ

Check the ratio of branching fractions $R(D^*) = Br(B \rightarrow D^*\tau\nu) / Br(B \rightarrow D^*l\nu)$

SM: $R(D^*) = 0.258 \pm 0.005$ vs. Experiment: $R(D^*) = 0.295 \pm 0.011 \pm 0.087$

(combined value of measurements of BaBar, Belle and LHCb collaborations)

Anomalies in $B \rightarrow D(*)\tau\nu$ decays



Measurements of R(D) and R(D*) compared to the SM predictions

Measurements of BaBar, Belle and LHCb collaborations

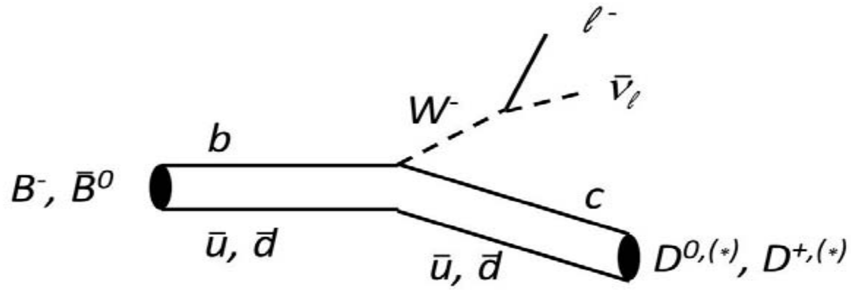
Similarly, for a D meson in the final state $R(D) = Br(B \rightarrow D\tau\nu) / Br(B \rightarrow Dl\nu)$

SM: $R(D) = 0.299 \pm 0.003$ vs. Experiment: $R(D) = 0.340 \pm 0.027 \pm 0.013$

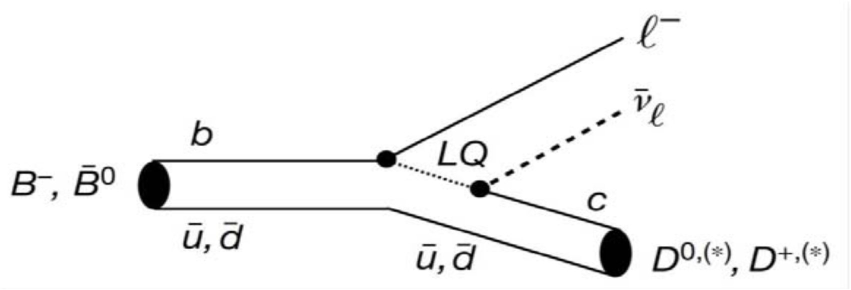
Need more data!

If not a statistical fluctuation, what are possible interpretations?

Diagrams for the *B* → *D(*)τν* transition:



mediated by the charged SM weak interaction



In addition:

a non-SM decay process involving leptoquarks

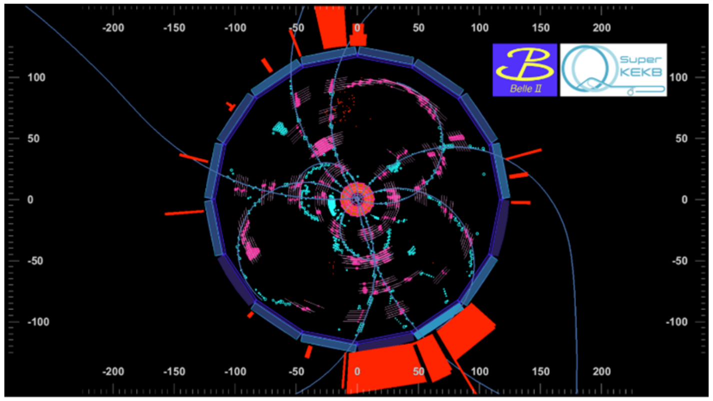
Other possibilities: an additional charged Higgs boson, and others

Need more data for any further conclusions! → the ball is on the experimental side.

Advantages of a B factory in the LHC era

Fantastic performance of the LHCb experiment at LHC with many interesting results!

Still, an e^+e^- machine running at (or near) Y(4S) is complementary to LHCb in several aspects.



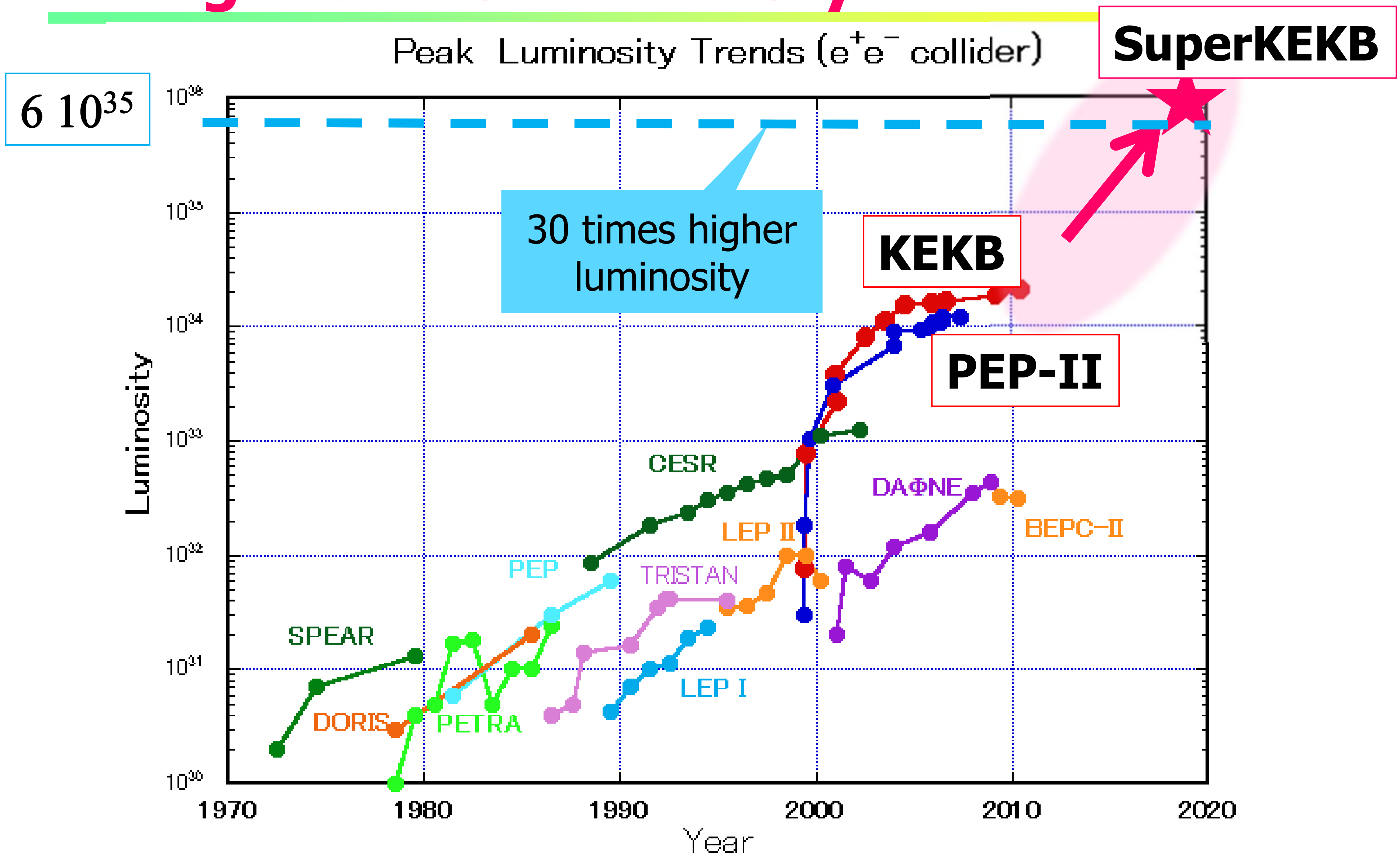
Unique capabilities of a B factory:

→ Exactly two B mesons produced
→ High flavour tagging efficiency
→ Detection of gammas, π^0s, K_Ls
→ Very clean detector environment (decays with several neutrinos in the final state, tau physics, dark sector)

Physics potential summarized in Belle II Theory Interface Platform (B2TiP) 'physics book' PTEP 2019 (2019) 12, arXiv:1808.10567

However, need a two-orders-of-magnitude larger data sample!

Need O(100x) more data →Next generation B-factory



$6\ 10^{35}$

SuperKEKB

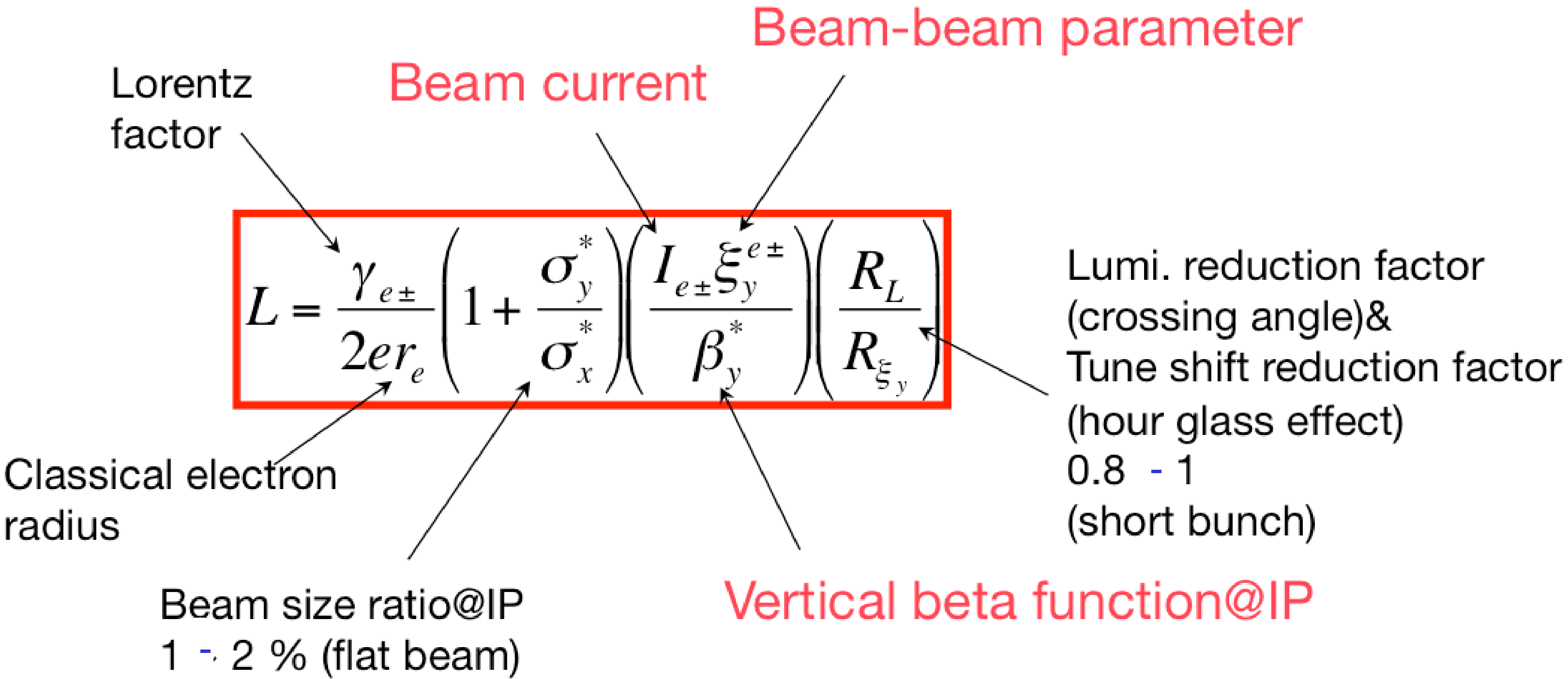
30 times higher luminosity

KEKB

PEP-II

N.B. KEKB peak L: 2.11 10^{34} cm^{-2} s^{-1}

How to increase the luminosity?



$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

Beam-beam parameter

Lorentz factor

Beam current

Lumi. reduction factor (crossing angle)&
Tune shift reduction factor (hour glass effect)
0.8 - 1
(short bunch)

Classical electron radius

Beam size ratio@IP
1 - 2 % (flat beam)

Vertical beta function@IP

(1) Smaller β_y^*

(2) Increase beam currents

(3) Increase ξ_y

"Nano-Beam" scheme

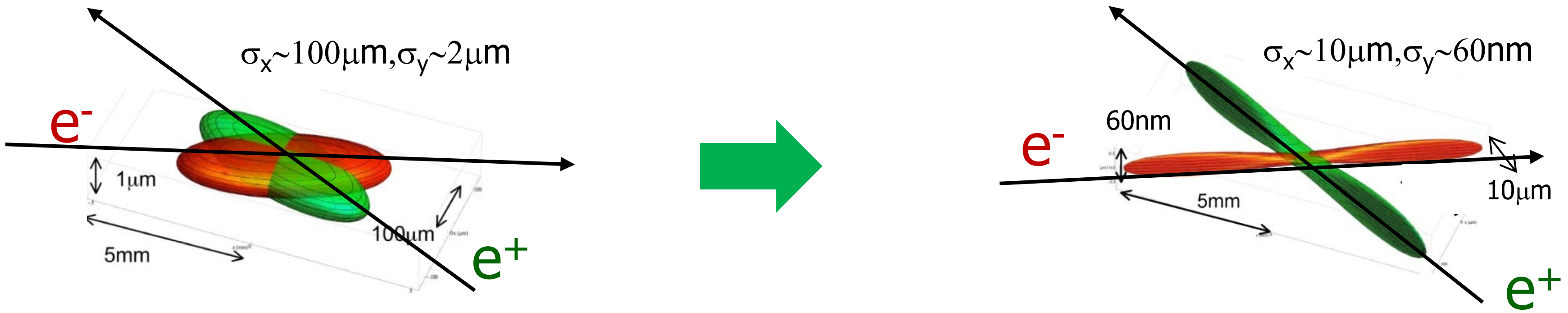
Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

How big is a nano-beam ?

How to go from an excellent accelerator with world record performance – KEKB – to a 30x times better, more intense facility?

In KEKB, colliding electron and positron beams were already much thinner than a human hair...

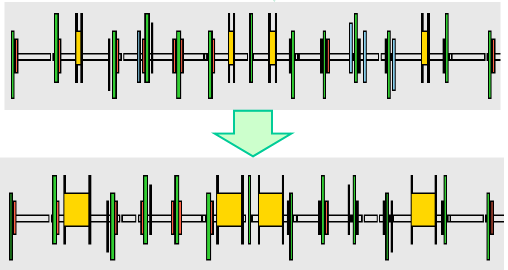


... For a 30x increase in intensity you have to make the beam as thin as a few x100 atomic layers!

To get x30 higher luminosity

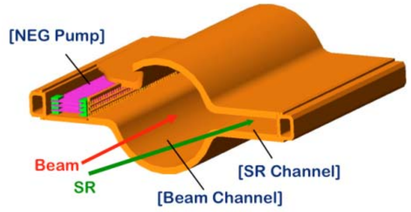
KEKB → SuperKEKB

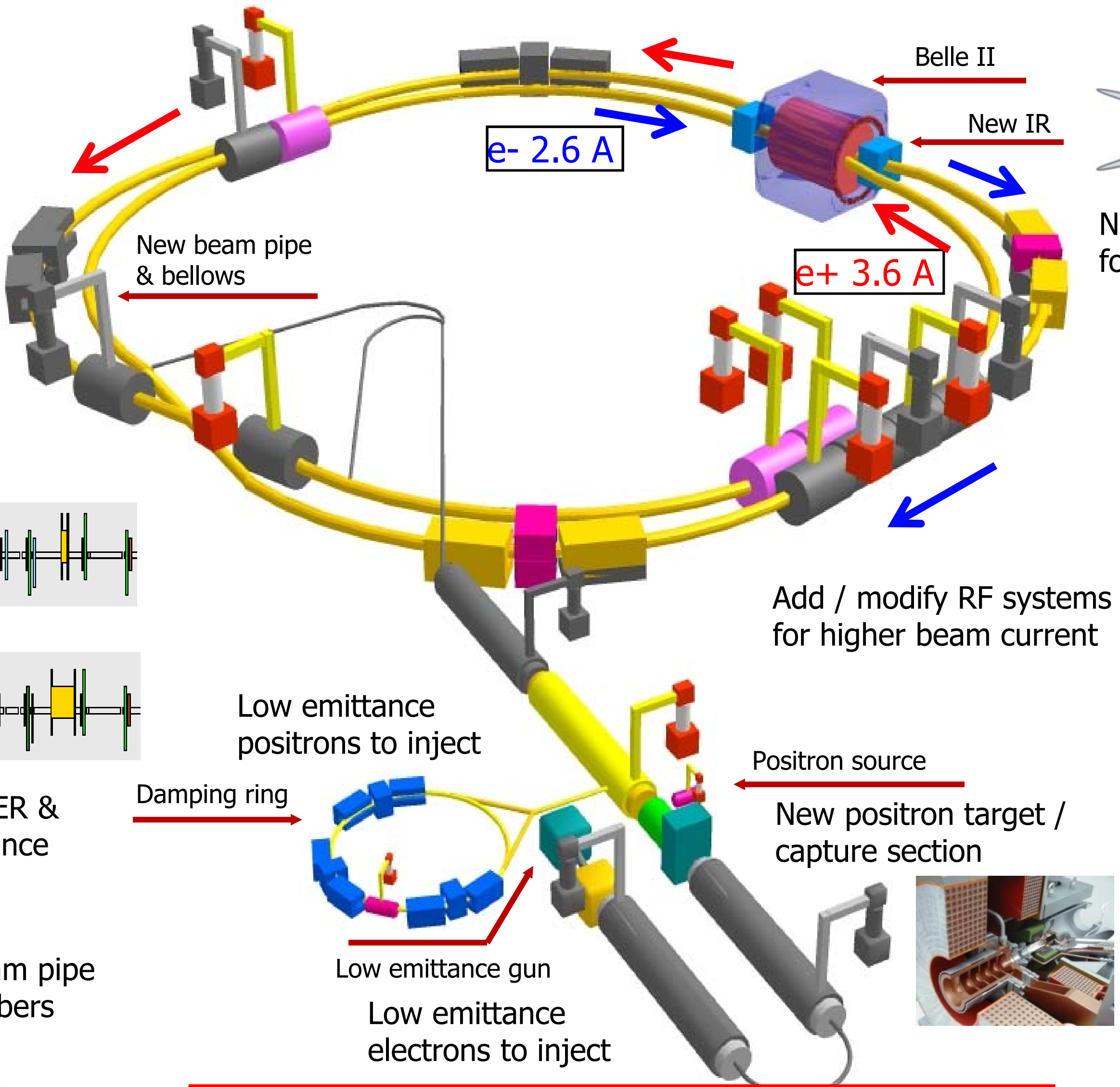
Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance

TiN-coated beam pipe with antechambers





Belle II

New IR

e- 2.6 A

e+ 3.6 A

New beam pipe & bellows

Low emittance positrons to inject

Damping ring

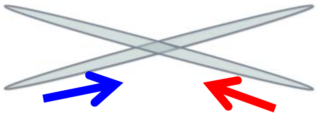
Positron source

New positron target / capture section

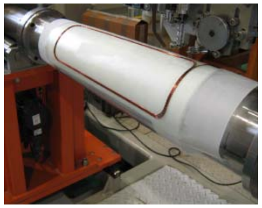
Low emittance gun

Low emittance electrons to inject

Colliding bunches



New superconducting final focusing quads near the IP



Add / modify RF systems for higher beam current

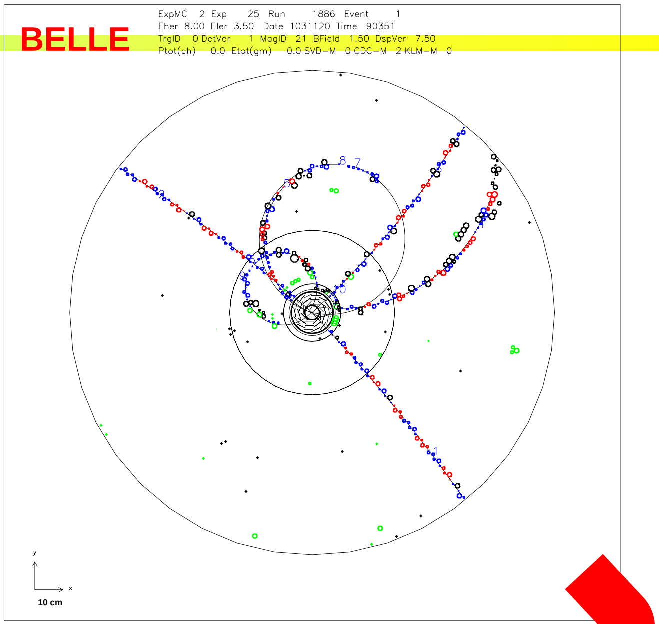
SuperKEKB, the first new collider in particle physics since the LHC

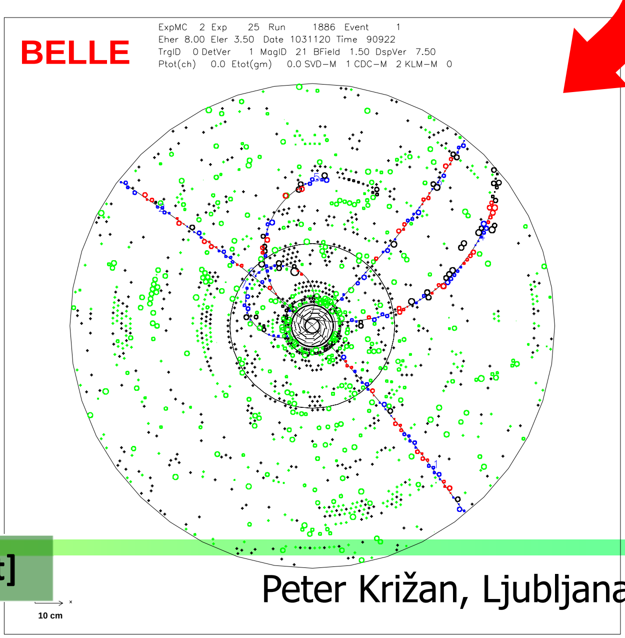
Super KEKB
uest for BSM

Requirements for the Belle II detector

Critical issues at L= 6 x 10^{35}/cm^2/sec

- **Higher background (×10-20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low *p* μ identification ← sμμ recon. eff.
  - hermeticity ← ν “reconstruction”



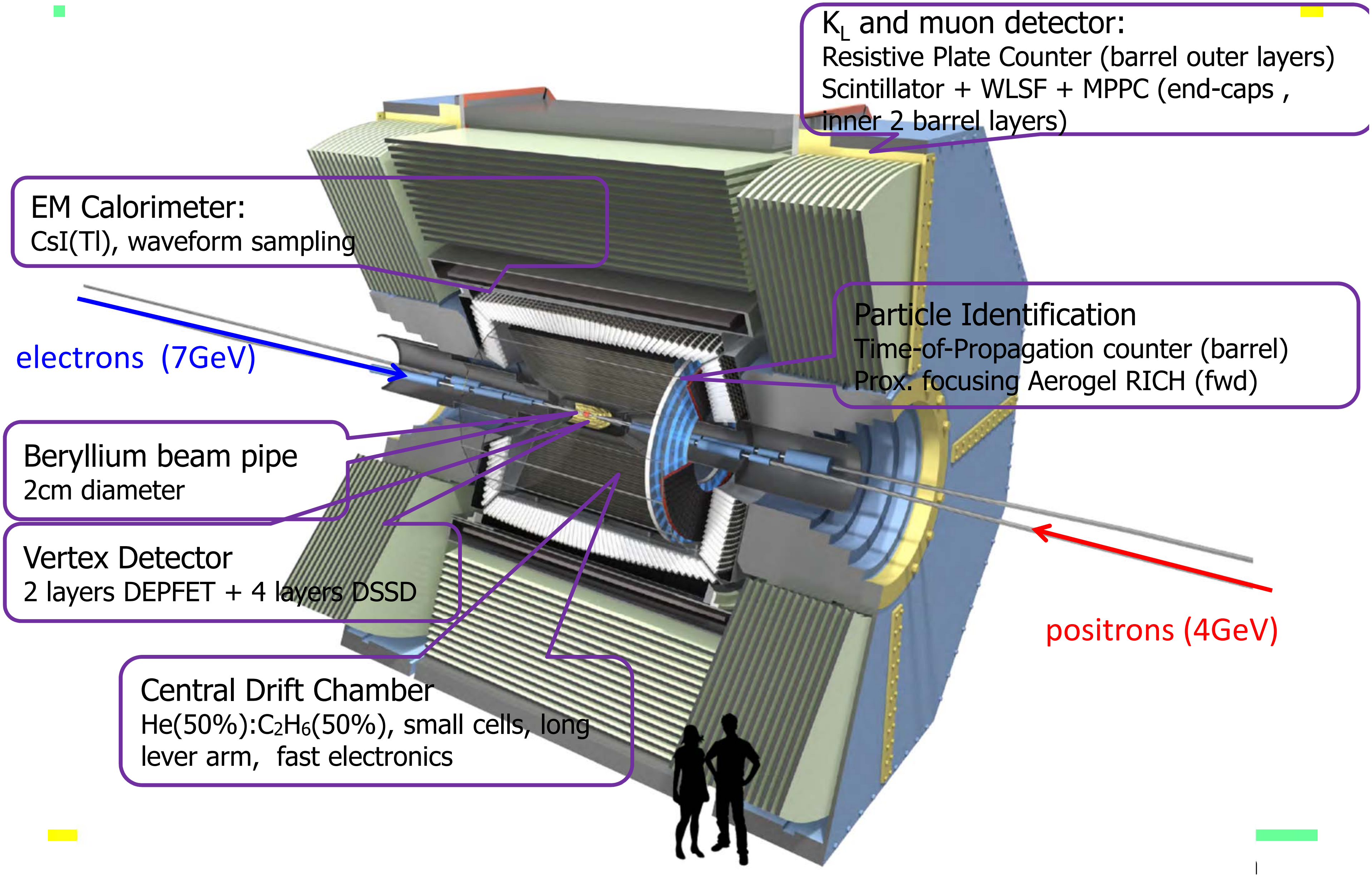


Solutions:

- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace part of endcap calorimeter crystals
- Faster readout electronics and computing system.

NIMA 907 (2018) 46-59; Belle II TDR, arxiv:1011.0352v1[physics.ins-det]

Belle II Detector



K_L and muon detector:
Resistive Plate Counter (barrel outer layers)
Scintillator + WLSF + MPPC (end-caps , inner 2 barrel layers)

EM Calorimeter:
CsI(Tl), waveform sampling

electrons (7GeV)

Particle Identification
Time-of-Propagation counter (barrel)
Prox. focusing Aerogel RICH (fwd)

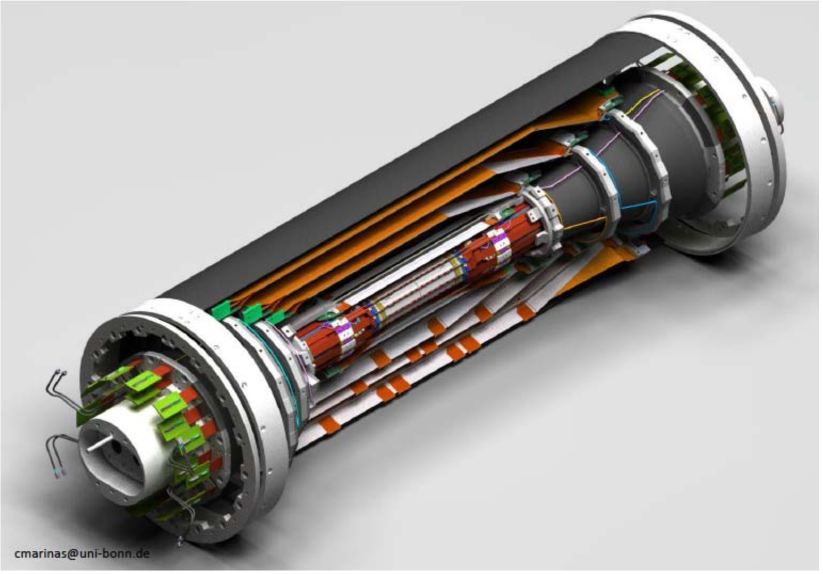
Beryllium beam pipe
2cm diameter

Vertex Detector
2 layers DEPFET + 4 layers DSSD

positrons (4GeV)

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

Vertexing/Inner Tracking



Beampipe r= 10 mm (Japan)

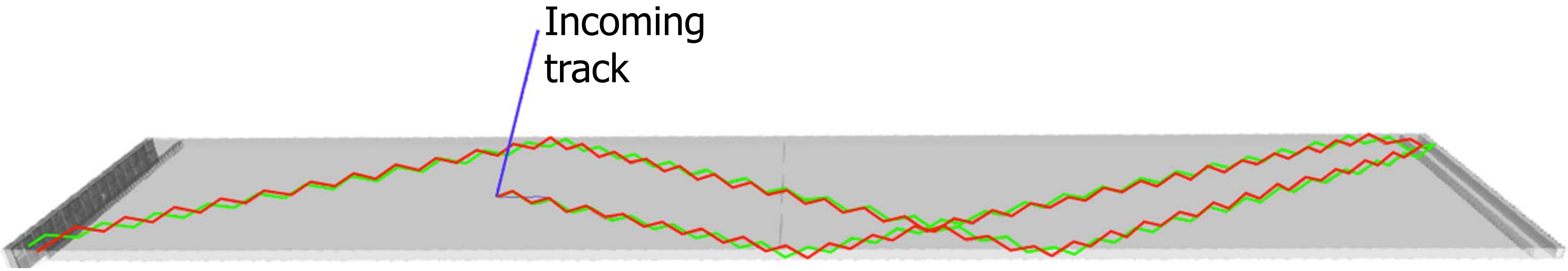
DEPFET pixels (Germany, Czech Republic,
Spain, China, Poland)
Layer 1 r=14 mm
Layer 2 r= 22 mm

DSSD (double sided silicon detectors)
Layer 3 r=38 mm (Australia)
Layer 4 r=80 mm (India)
Layer 5 r=105 mm (Austria)
Layer 6 r=135 mm (Japan)
FWD/BWD (Italy)

+Poland, Korea

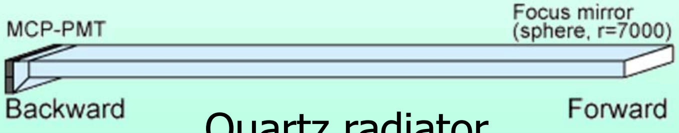
Barrel Particle Identification (uses Cherenkov radiation)

The paths of Cherenkov photons from a 2 GeV pion and kaon interacting in a TOP quartz bar. (Japan, US, Slovenia, Italy)



Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



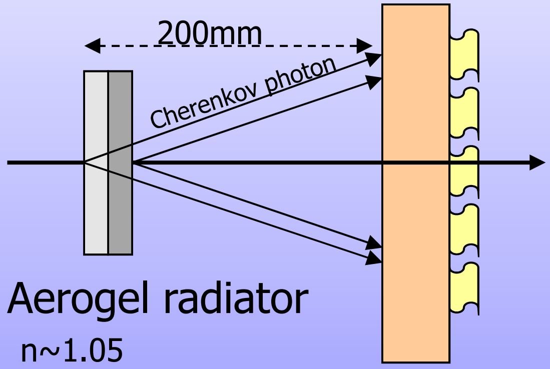
Quartz radiator

Focusing mirror

Small expansion block

Hamamatsu MCP-PMT (measure t, x and y)

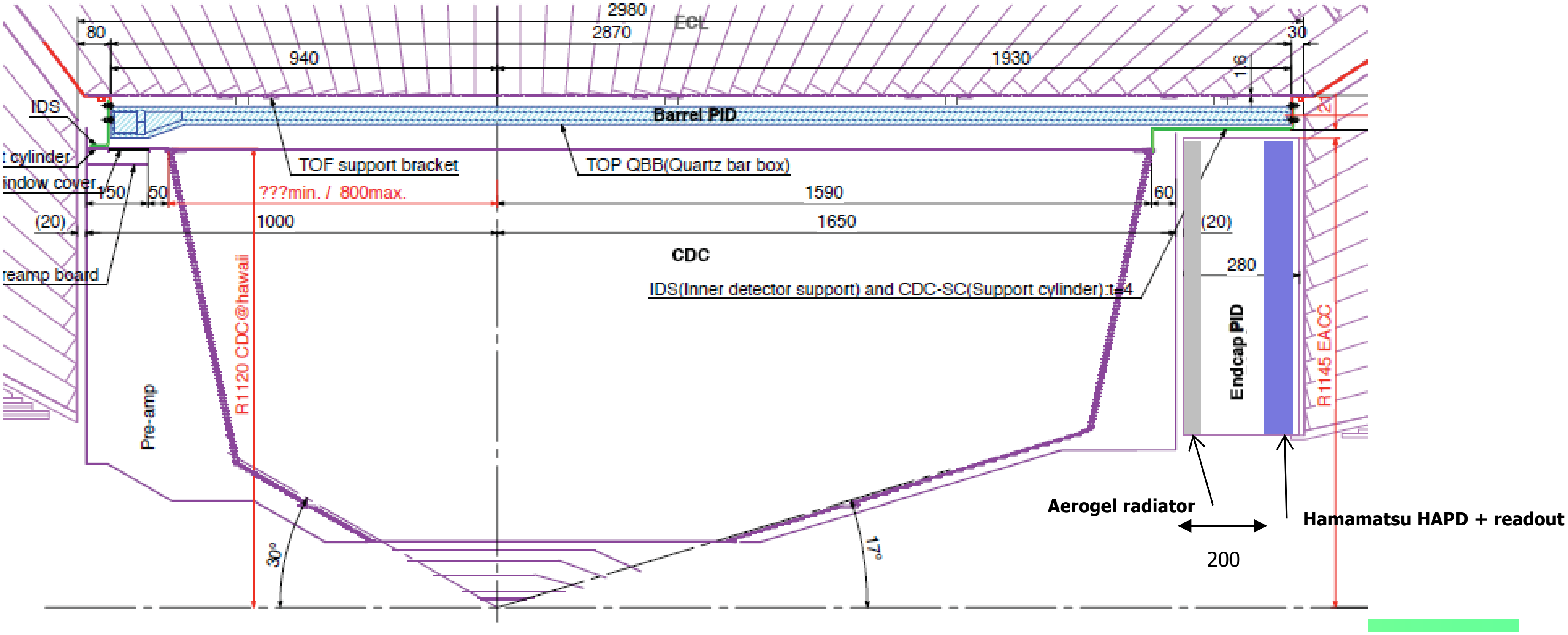
Endcap PID: Aerogel RICH (ARICH)



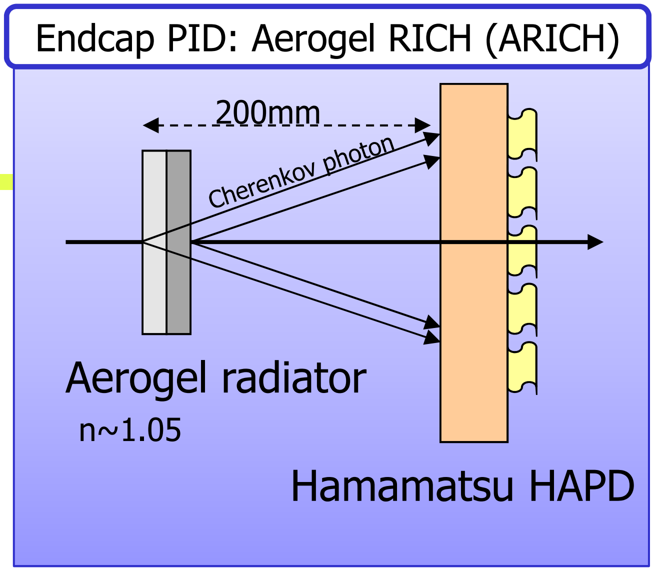
Aerogel radiator

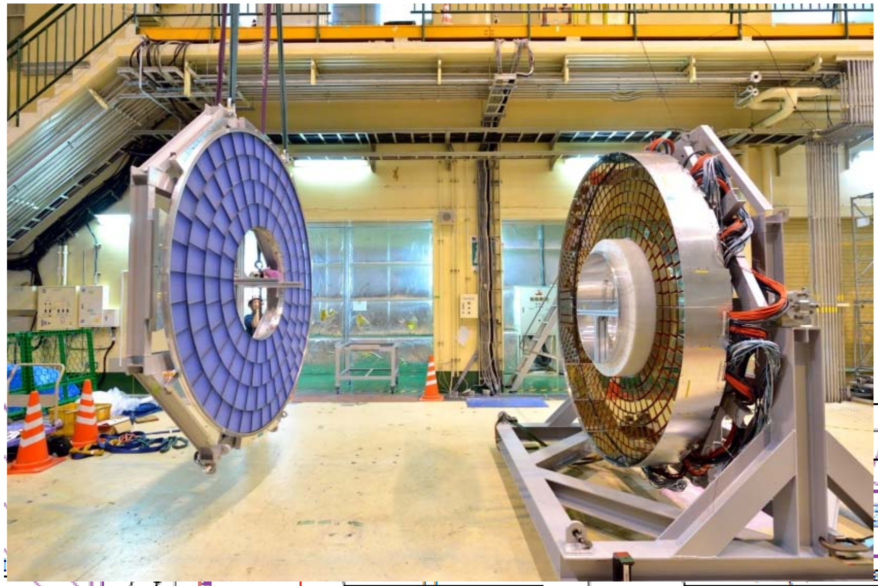
n~1.05

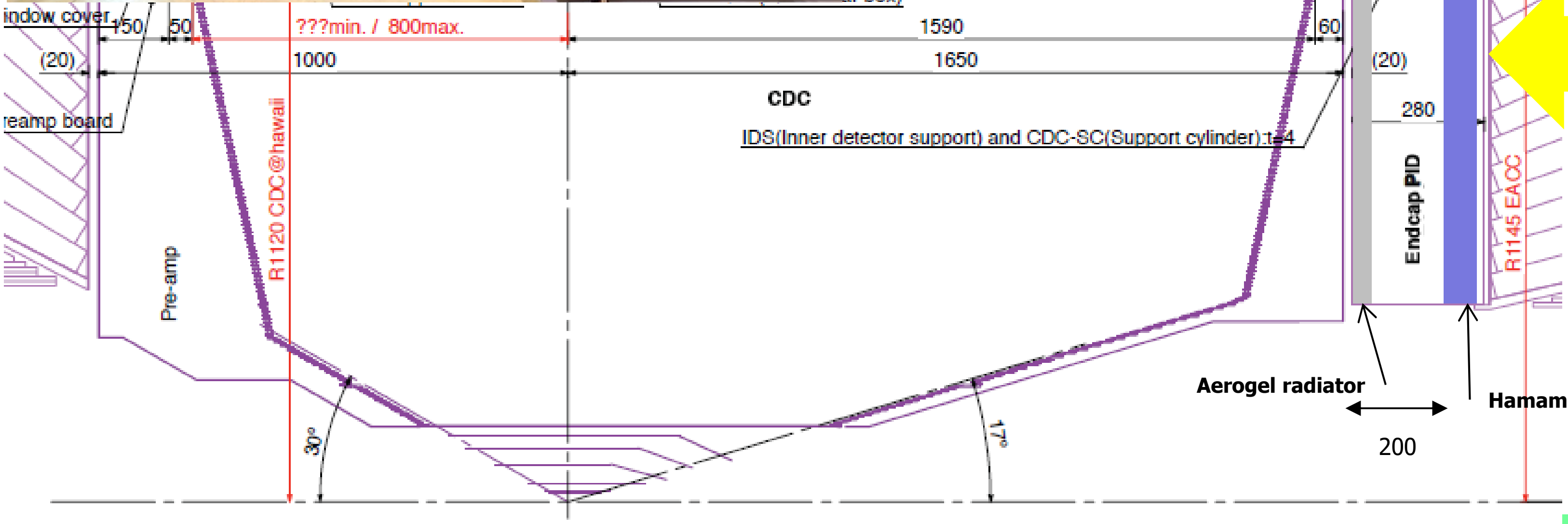
Hamamatsu HAPD



PID Devices: ARICH for endcap







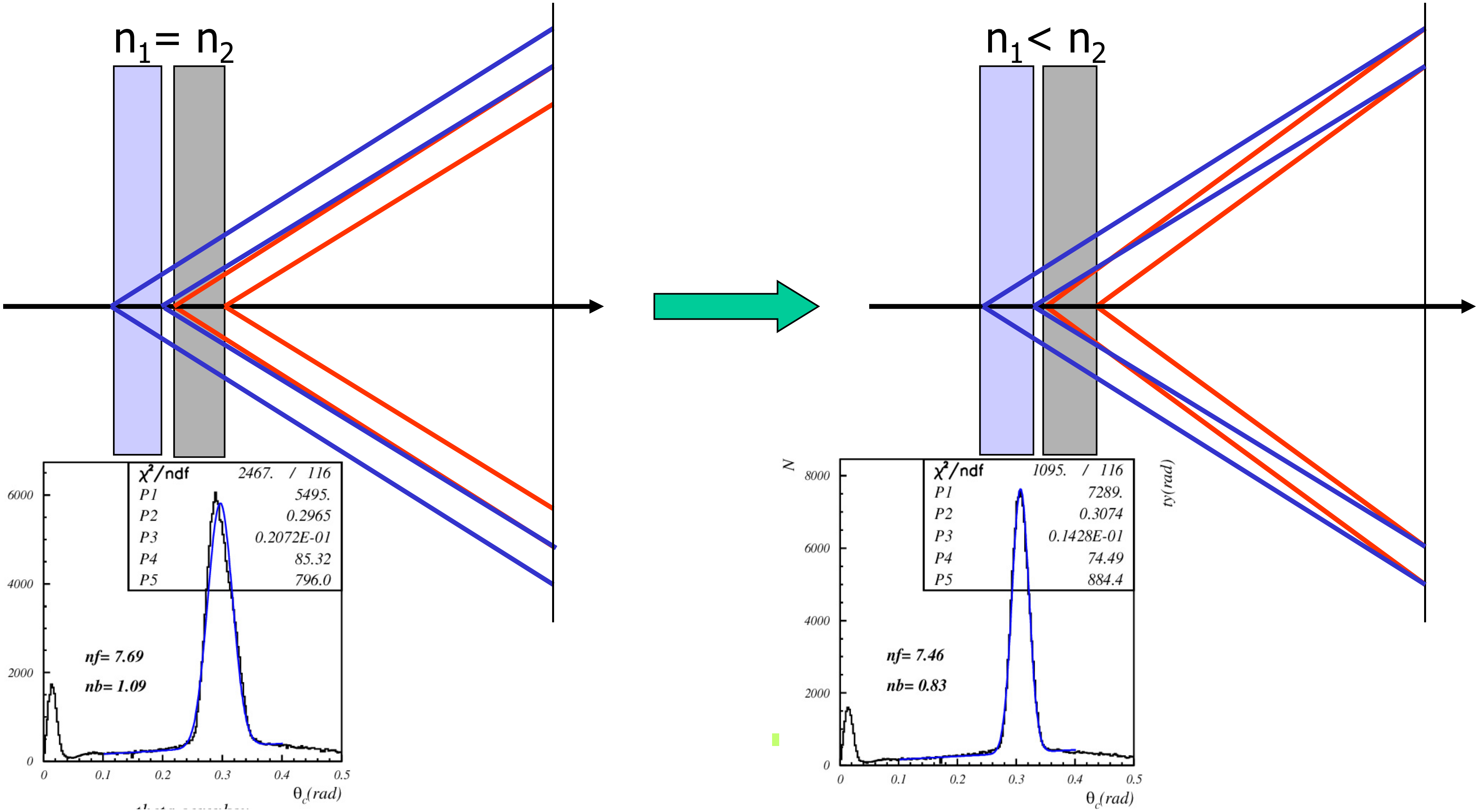
Radiator with multiple refractive indices

Small number of photons from aerogel → need a thick layer of aerogel.

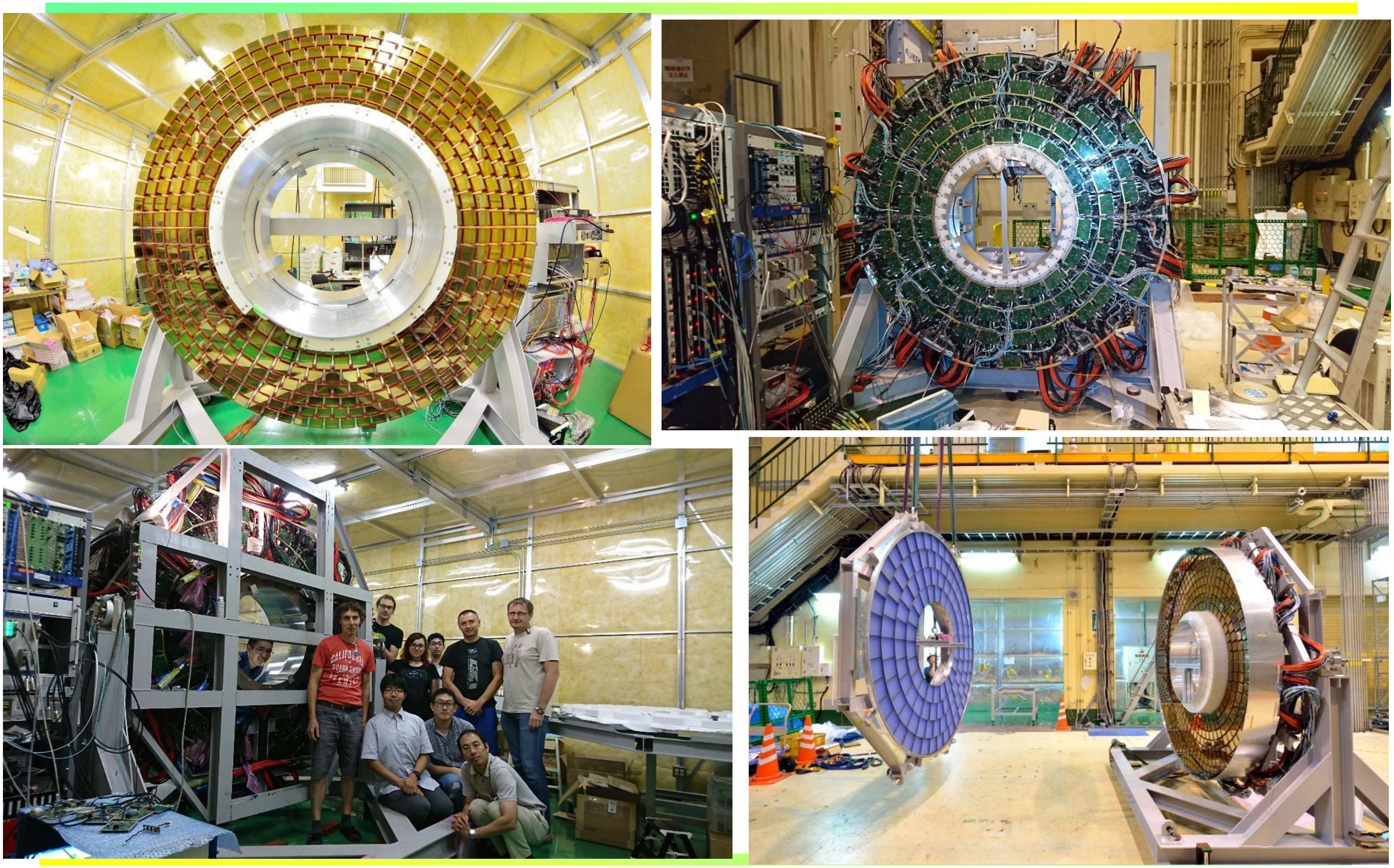
How to improve the resolution by keeping the same number of photons?

→ stack two tiles with different refractive indices:
“focusing” configuration → “focusing radiator“

normal

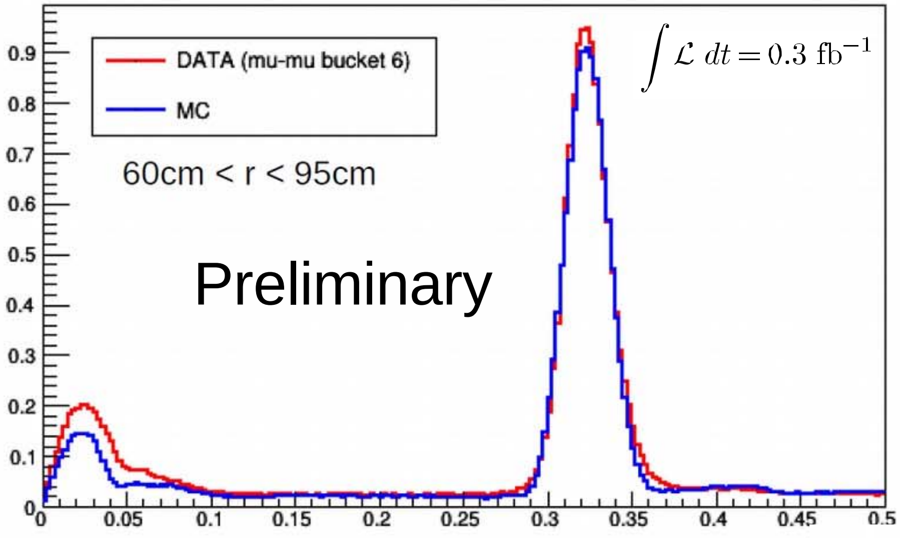


The big eye of ARICH



Performance in the early Belle II data

Cherenkov angle distribution in $e^+e^- \to \mu^+\mu^-$



DATA

$$N_{sig} = 11.38/\mathrm{track}$$

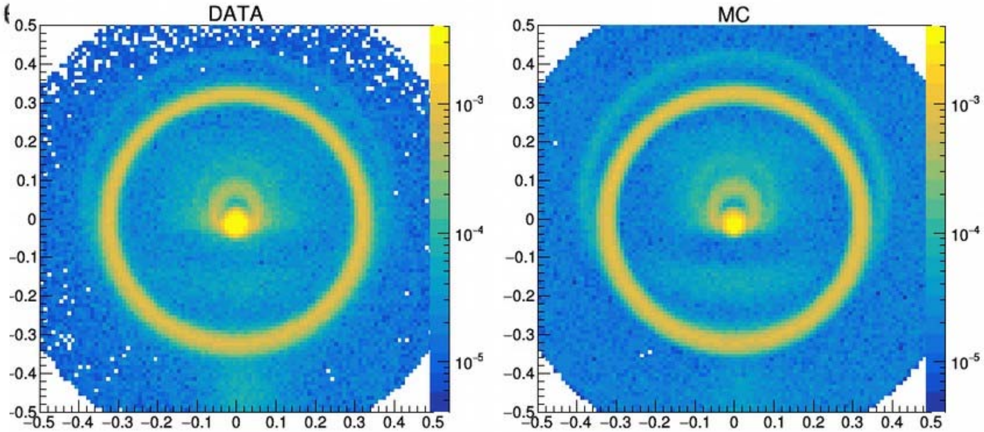
$$\sigma_c = 12.7\ \mathrm{mrad}$$

MC

$$N_{sig} = 11.27/\mathrm{track}$$

$$\sigma_c = 12.75\ \mathrm{mrad}$$

Overall a very good DATA/MC agreement !



Chrenkov ring (accumulated)

Belle II / SuperKEKB Operation phases

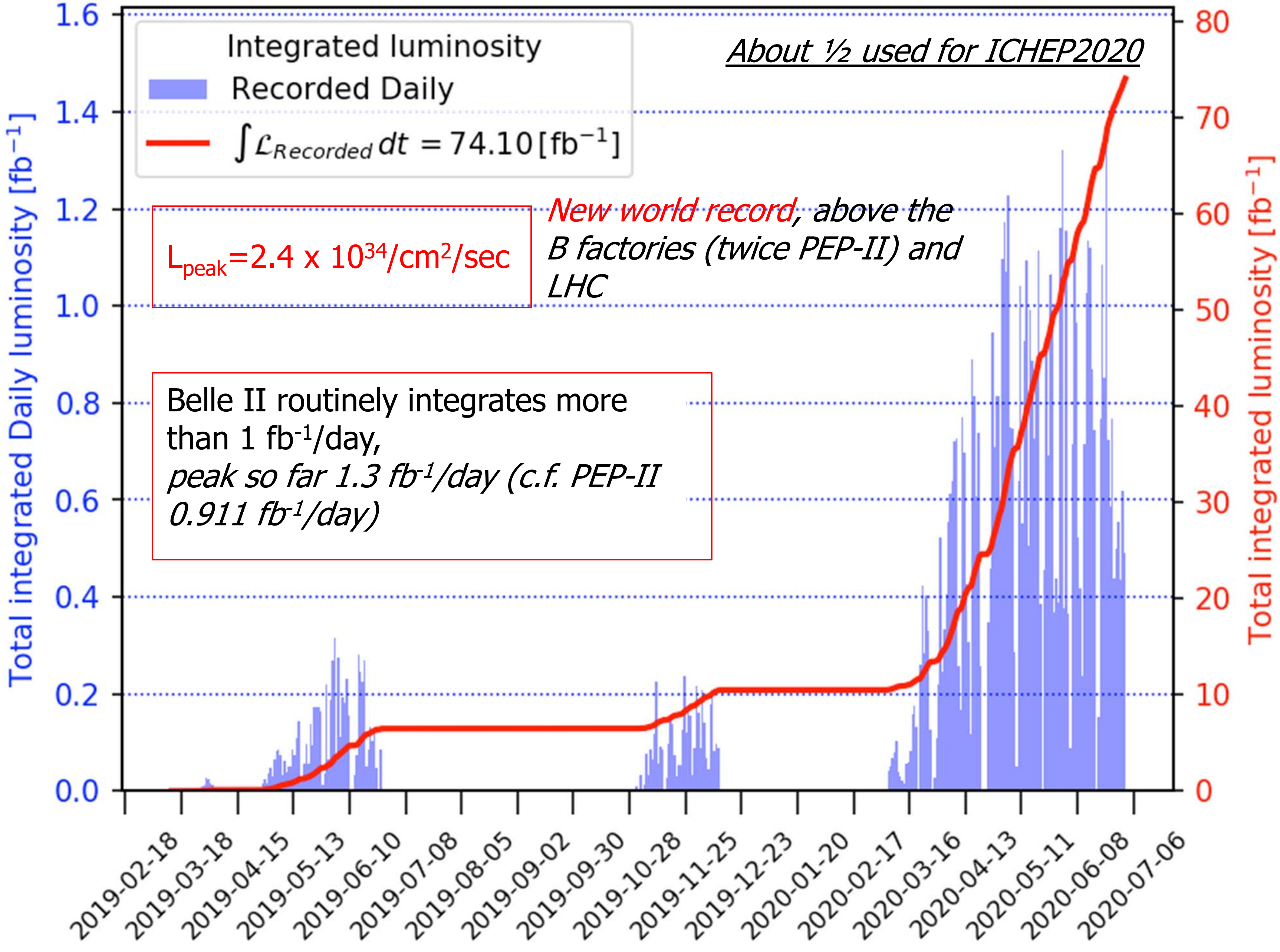
Phase 1:
Background, Vaccum Scrubbing, RF system
Feb-June 2016.
Brand new 3 km positron ring.

Phase 2: Pilot run without VXD
Superconducting Final Focus, add positron damping ring,
First Collisions on Apr. 26, 2018 (integrated luminosity 0.5 fb^{-1}).
Feb-July, 2018

Phase 3: → Physics running (spring 2019, fall 2019, spring 2020).
Have integrated a luminosity of 74 fb^{-1} so far.

N.B. Number of events = Integrated luminosity * Cross Section

Belle II Integrated Luminosity



<u>*About ½ used for ICHEP2020*</u>

L_{peak}=2.4 x 10^{34}/cm^2/sec

New world record, above the B factories (twice PEP-II) and LHC

Belle II routinely integrates more than 1 fb^{-1}/day,
peak so far 1.3 fb^{-1}/day (c.f. PEP-II 0.911 fb^{-1}/day)

Also see https://cerncourier.com/a/kek-reclaims-luminosity-record/

Major issue in the operation: fighting the backgrounds

In case of high background levels: radiation damage/ageing of detectors.

Detector lifetime (in particular TOP counter)

- To keep the MCP-PMT QE within an acceptable level until the end of the experiment (for ~10y), the accelerator generated backgrounds have to be mastered by collimators, beam tuning, additional shielding, …

→ TOP PMT hit rate could limit the luminosity.

Permanent damage on PXD and SVD by accidental huge beam loss.

Synchrotron radiation from HER beam on PXD

→ Should be carefully monitored not to irradiate PXD unnecessarily.

Spring 2020: Running an international experiment and accelerator during a global pandemic

SuperKEKB/Belle II was/is operating during the COVID-19 pandemic with protocols in place to maximize safety and minimize the risk of infection. Somewhat difficult with travel restrictions and a heavy load on a skeleton crew at KEK (~40 people).

Developed a "social distancing" scheme for on-site shifts in the Belle II and SuperKEKB control rooms. Mobilized remote shifters around the world – depend heavily on internet chat utilities for communication and monitoring.

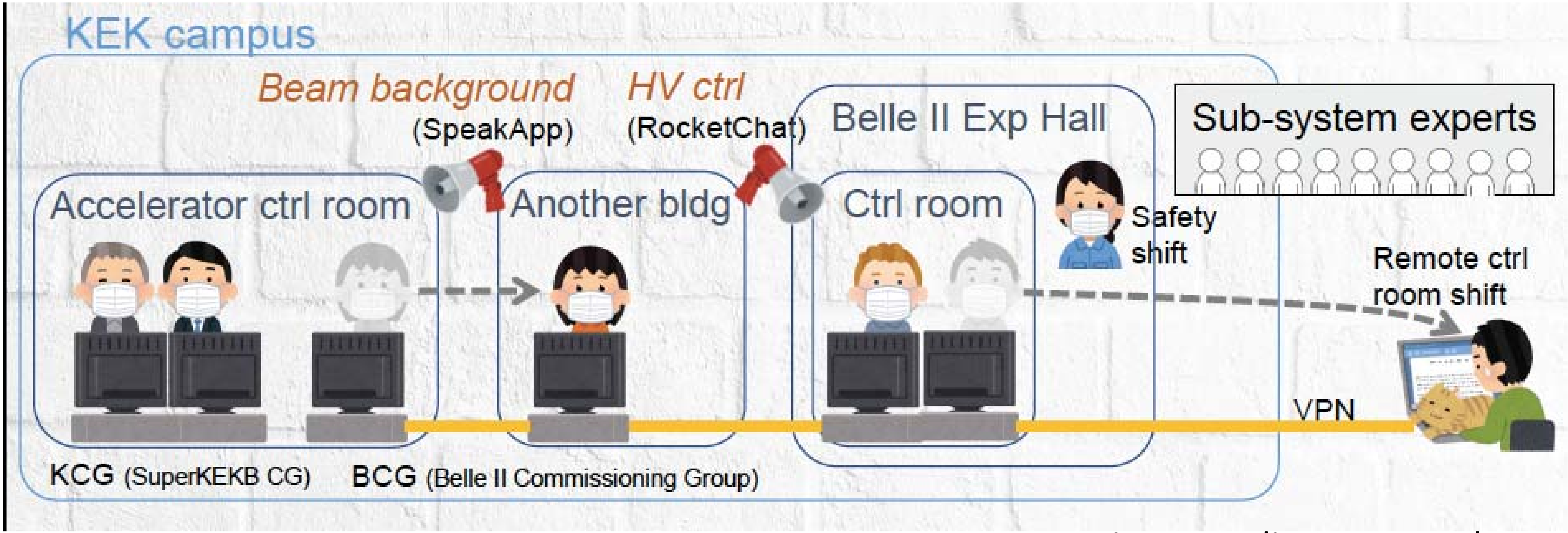
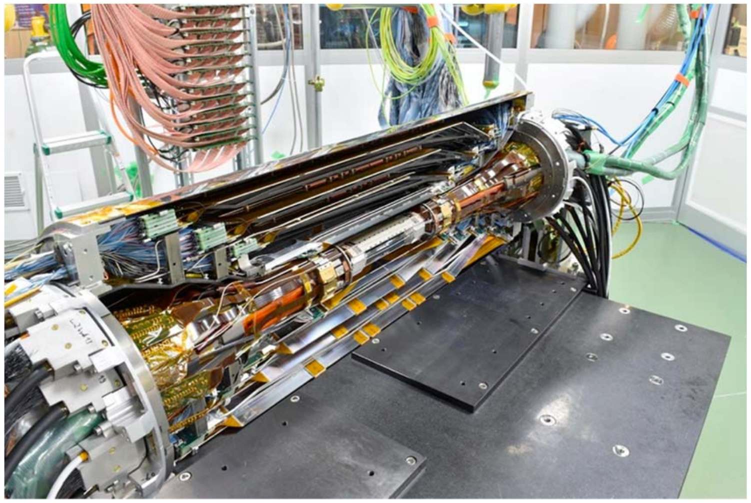


Figure credit: K. Matsuoka

Belle II/SuperKEKB Phase 3 (Physics Run) Goals

Early aims: Demonstrate SuperKEKB Physics running with acceptable backgrounds, and all the detector, readout, DAQ and trigger capabilities of Belle II including tracking, electron/muon id, high momentum PID, and especially the *ability to do time-dependent measurements needed for CP violation.*



Carry out innovative and world leading dark sector searches/measurements. Publish first papers.

Long term: Integrate the world's largest e^+e^- data samples and observe or constrain New Physics in B physics, charm physics and tau physics.

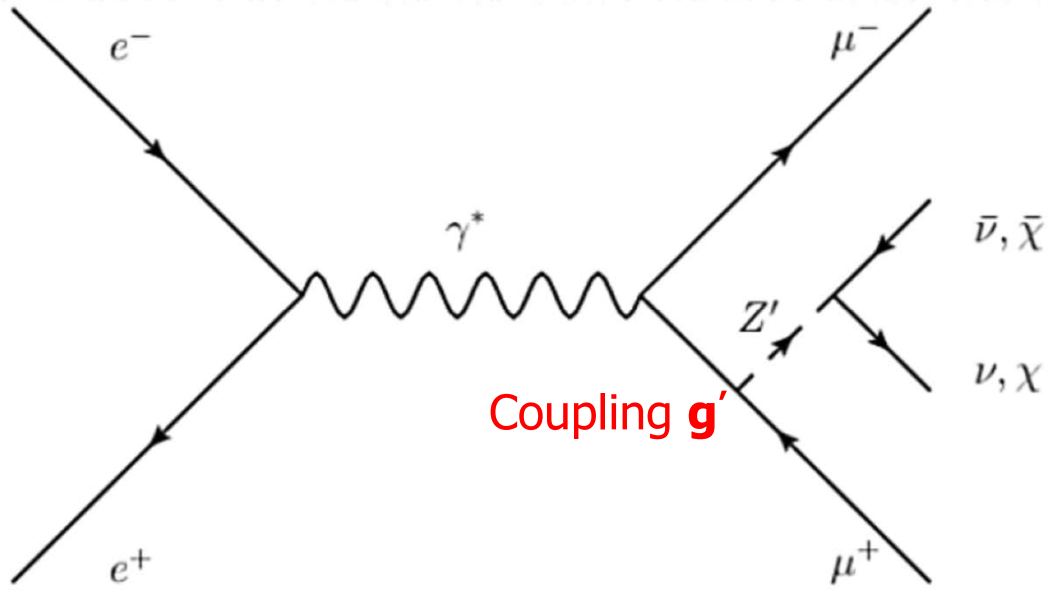
Dark Sector:

B factories: limited by triggering, QED backgrounds and theoretical imagination. *Now new possibilities of triggering, more bandwidth.*

There are a variety of possible dark sector portal particles: Vector, Scalar, Pseudo-scalars.

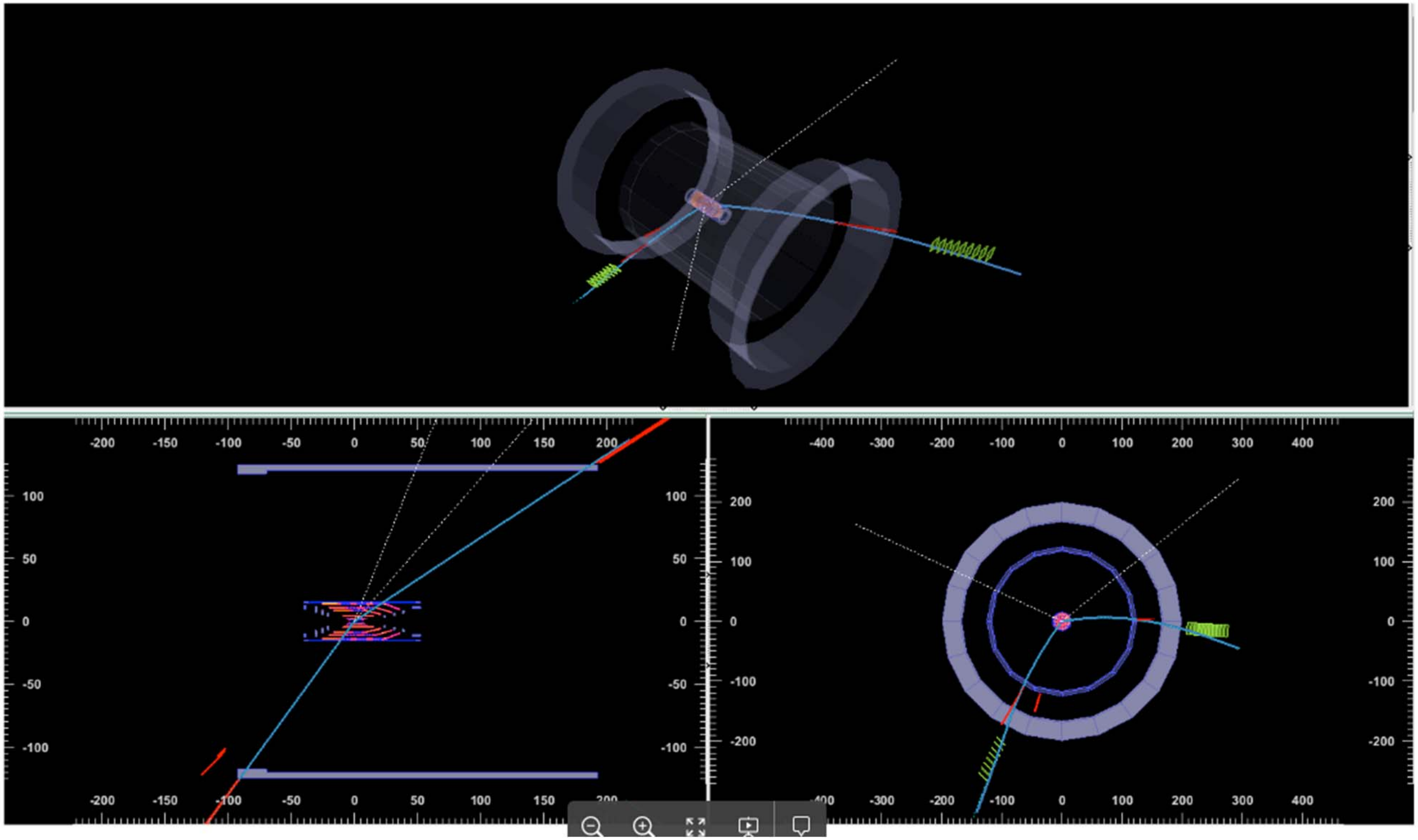
They may decay to lepton pairs, photon pairs, or Invisible particles

Belle II First Physics. A novel result on the dark sector (Z' →nothing) recoiling against di-muons *or* an electron-muon pair. *Both possibilities are poorly constrained at low Z' mass and in the first case, could explain the muon g-2 anomaly.*



Also examine a *lepton flavour violating* NP signature in the dark sector (with e+μ in the final state)

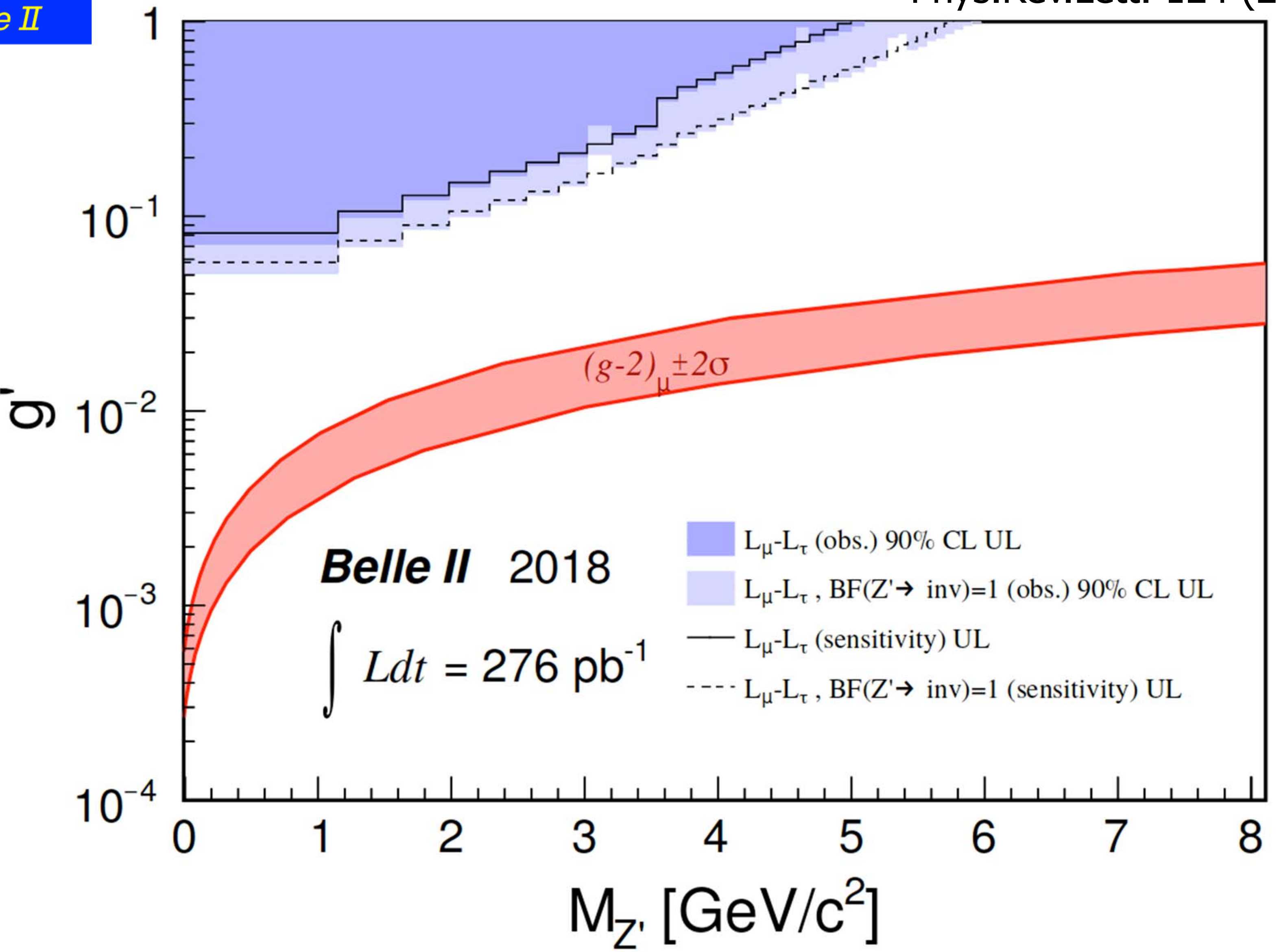
Monte Carlo simulation of a $Z' \rightarrow$ invisible



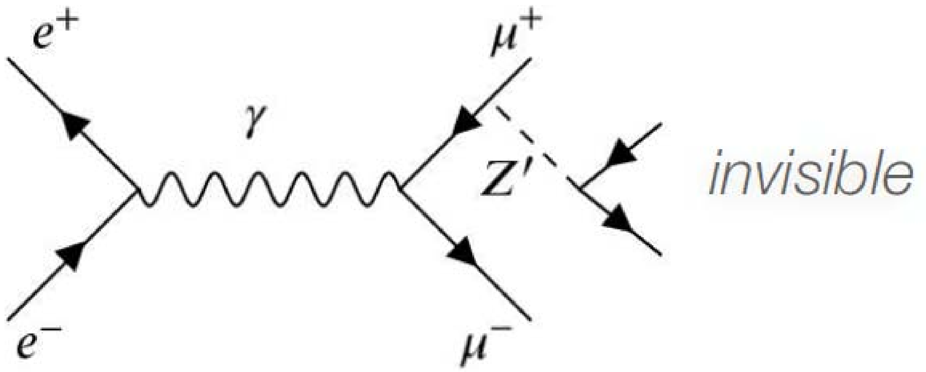
However, in data we do not find any significant excess in the recoil mass distribution.

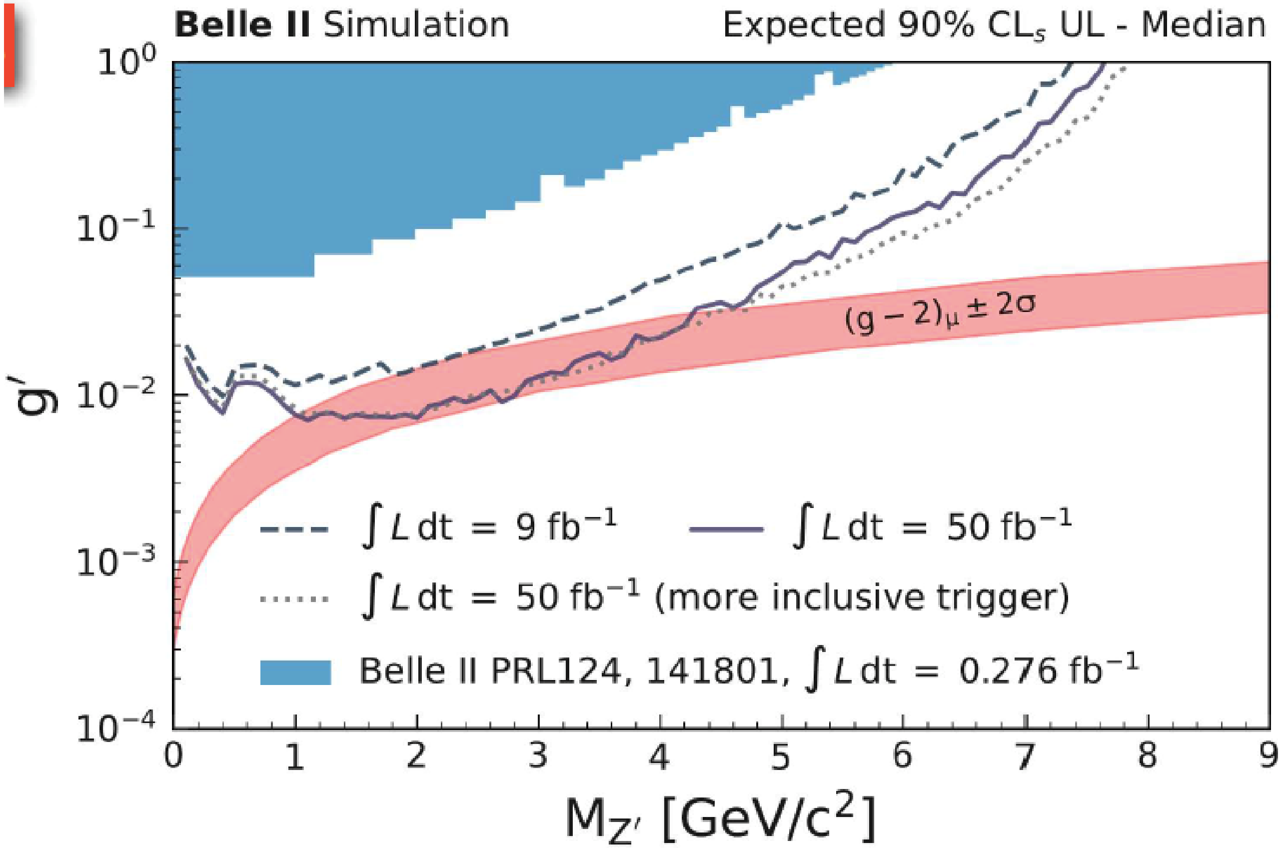
With 278 pb^{-1} from the Phase 2 pilot run

Phys.Rev.Lett. 124 (2020) 14



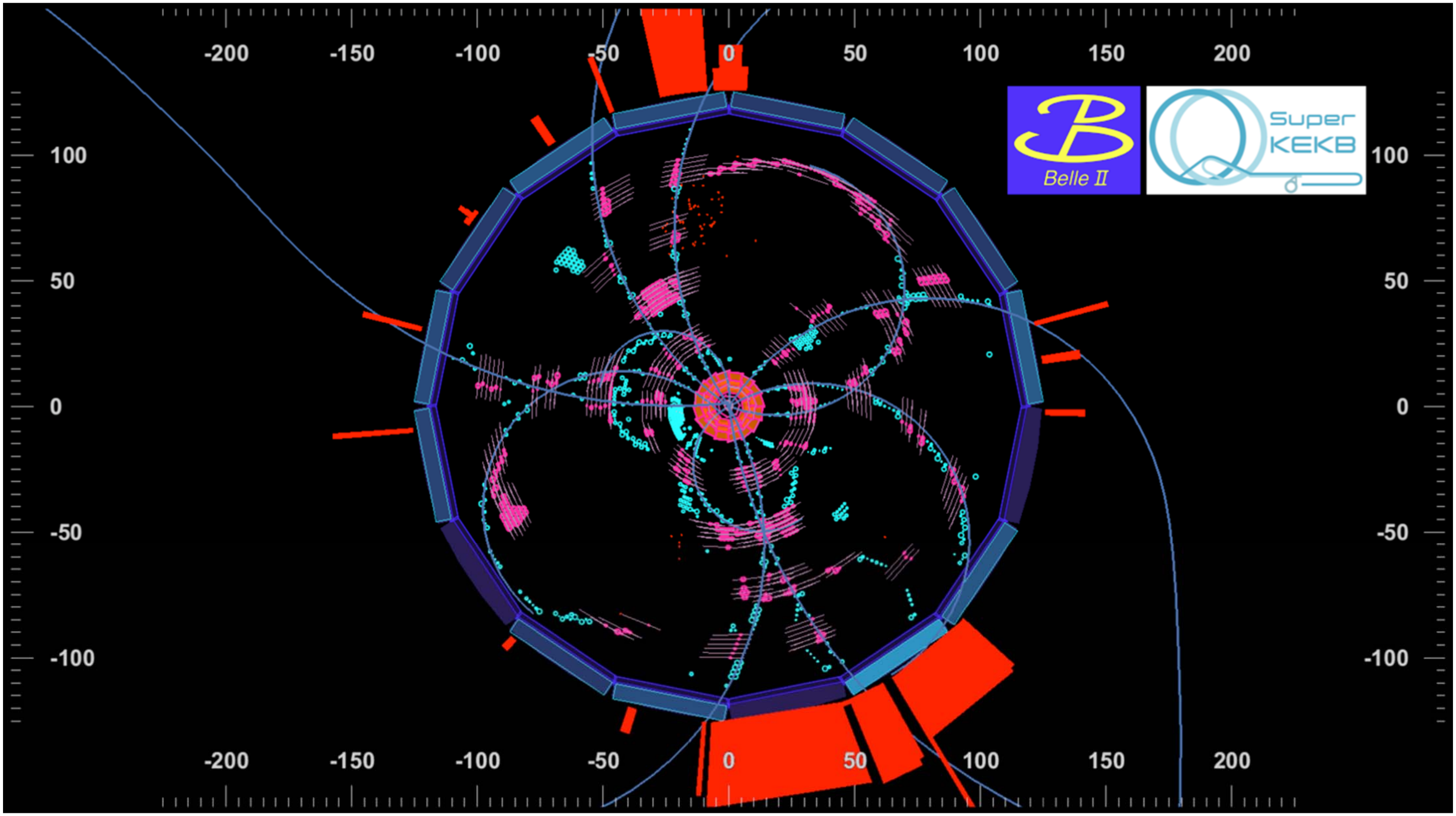
Near term prospects for Z′ →invisible





Uses Phase 3 data on tape. Adding in KLM triggers may allow us to “break through” the g-2 band.

Flavour Physics Results from the Physics Run (“Phase 3”)

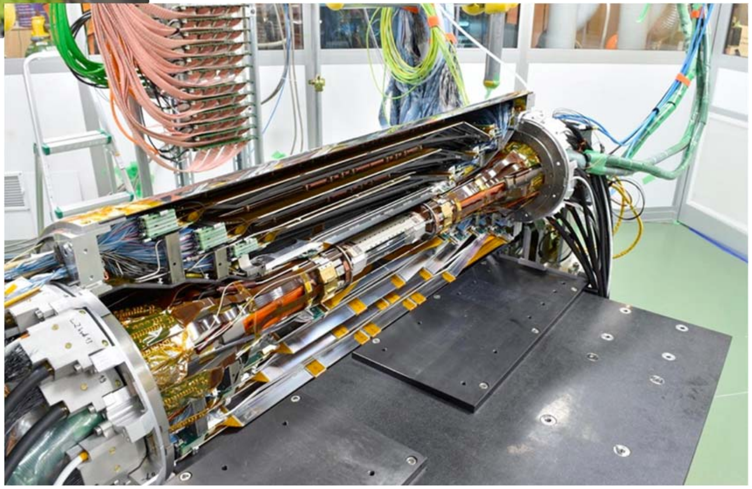


Time Dependent Measurements at Belle II

Belle II

Belle II VXD installed on Nov 21, 2018.

- PXD: L1 and two ladders of L2,
- SVD (4 layers)



Check time-dependent capabilities: Examples of D^0 lifetime results.

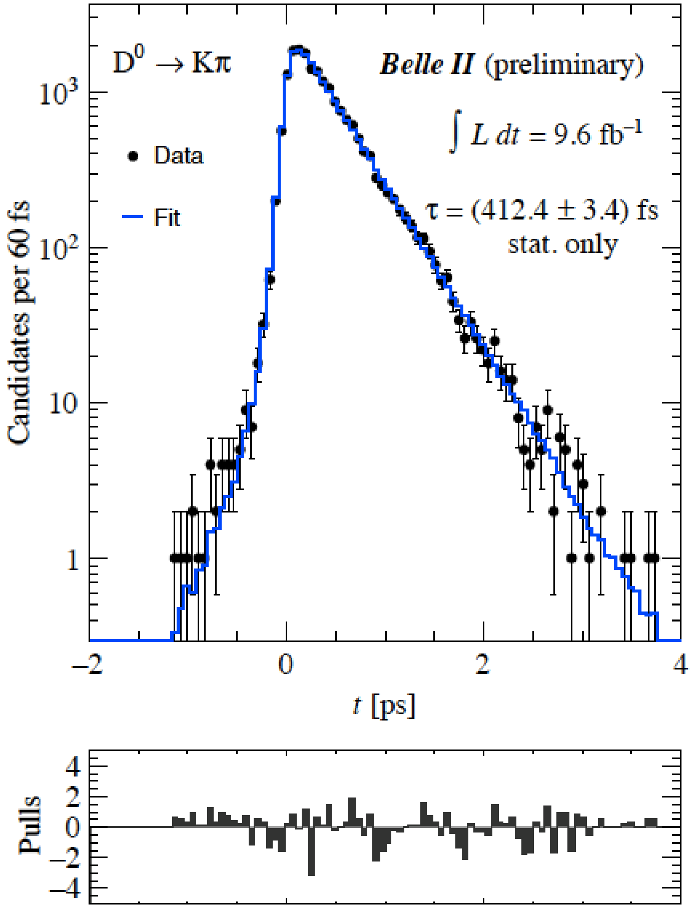
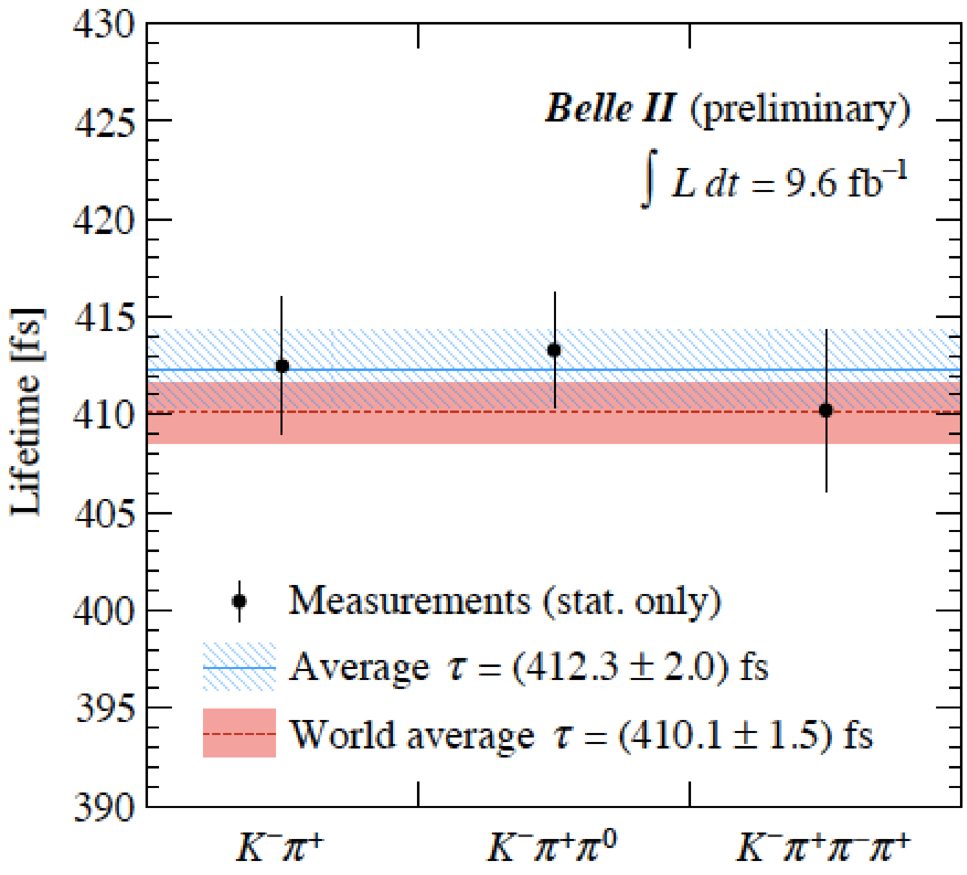
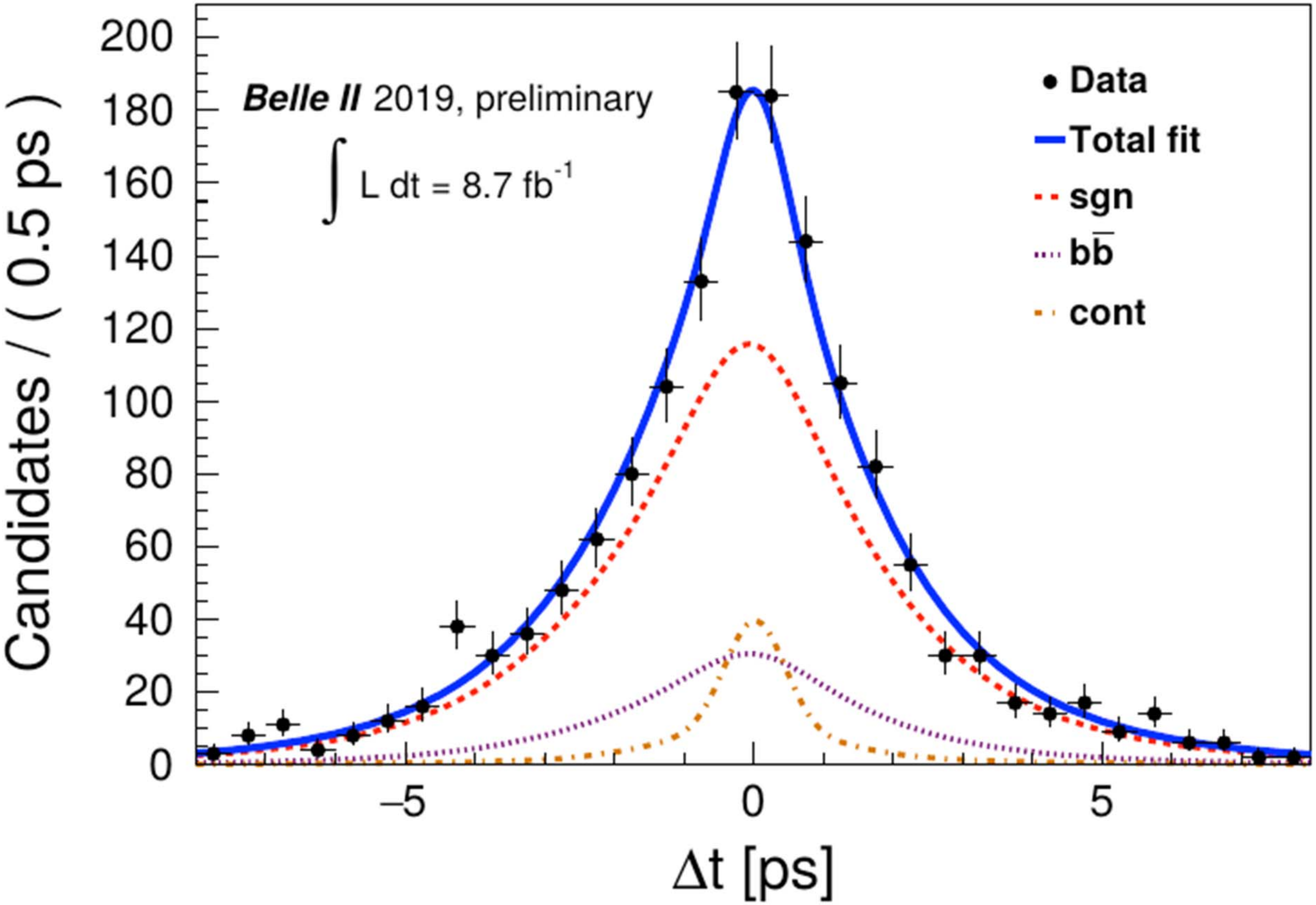


Figure 2: Fit to the proper-time distributions of D^*-tagged $D^0 \to K^-\pi^+$ candidates reconstructed with 2019 Belle II data. The extracted lifetime in this channel is (412.4 ± 3.4) fs, the estimated average proper time resolution is (97 ± 8) fs.



The addition of a pixel vertex detector (with a 1cm radius beampipe) gives a *factor of two improvement* in proper time resolution for charm lifetime measurements compared to Belle. Alignment systematics are much improved.

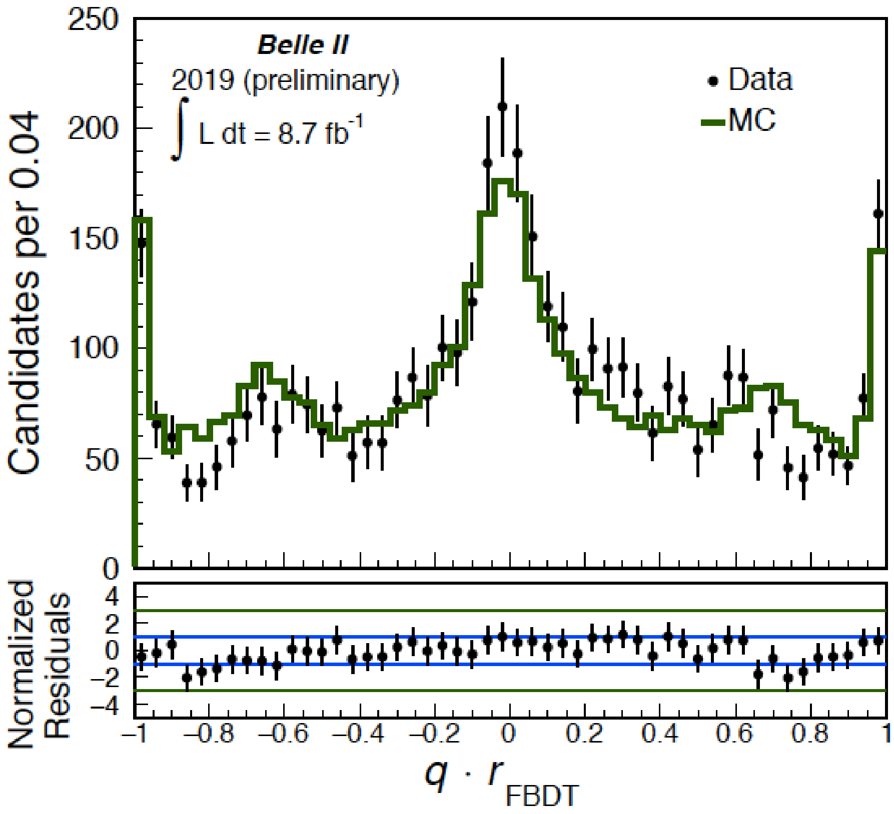
B^0 Lifetime measurement ($B \rightarrow D^{(*)} h$)



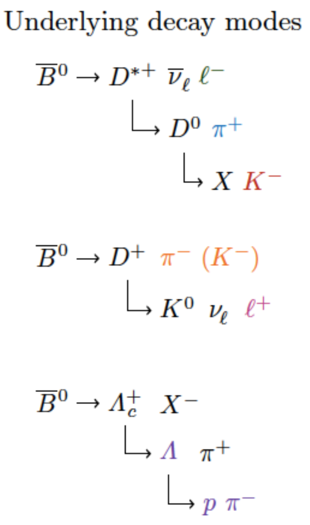
$$\tau(B^0) = 1.48 \pm 0.28 \pm 0.06\, ps$$

https://arxiv.org/pdf/2005.07507

Flavour Tagging (b quark or anti-b quark ?)



Categories	Targets for $\overline{B}^0$
Electron	e^-
Intermediate Electron	e^+
Muon	μ^-
Intermediate Muon	μ^+
Kinetic Lepton	l^-
Intermediate Kinetic Lepton	l^+
Kaon	K^-
Kaon-Pion	K^-, π^+
Slow Pion	π^+
Maximum P*	l^-, π^-
Fast-Slow-Correlated (FSC)	l^-, π^+
Fast Hadron	π^-, K^-
Lambda	Λ


Underlying decay modes

$\overline{B}^0 \to D^{*+}\,\overline{\nu}_\ell\,\ell^-$
↳ $D^0\,\pi^+$
↳ $X\,K^-$

$\overline{B}^0 \to D^+\,\pi^-\,(K^-)$
↳ $K^0\,\nu_\ell\,\ell^+$

$\overline{B}^0 \to \Lambda_c^+\,X^-$
↳ $\Lambda\,\pi^+$
↳ $p\,\pi^-$

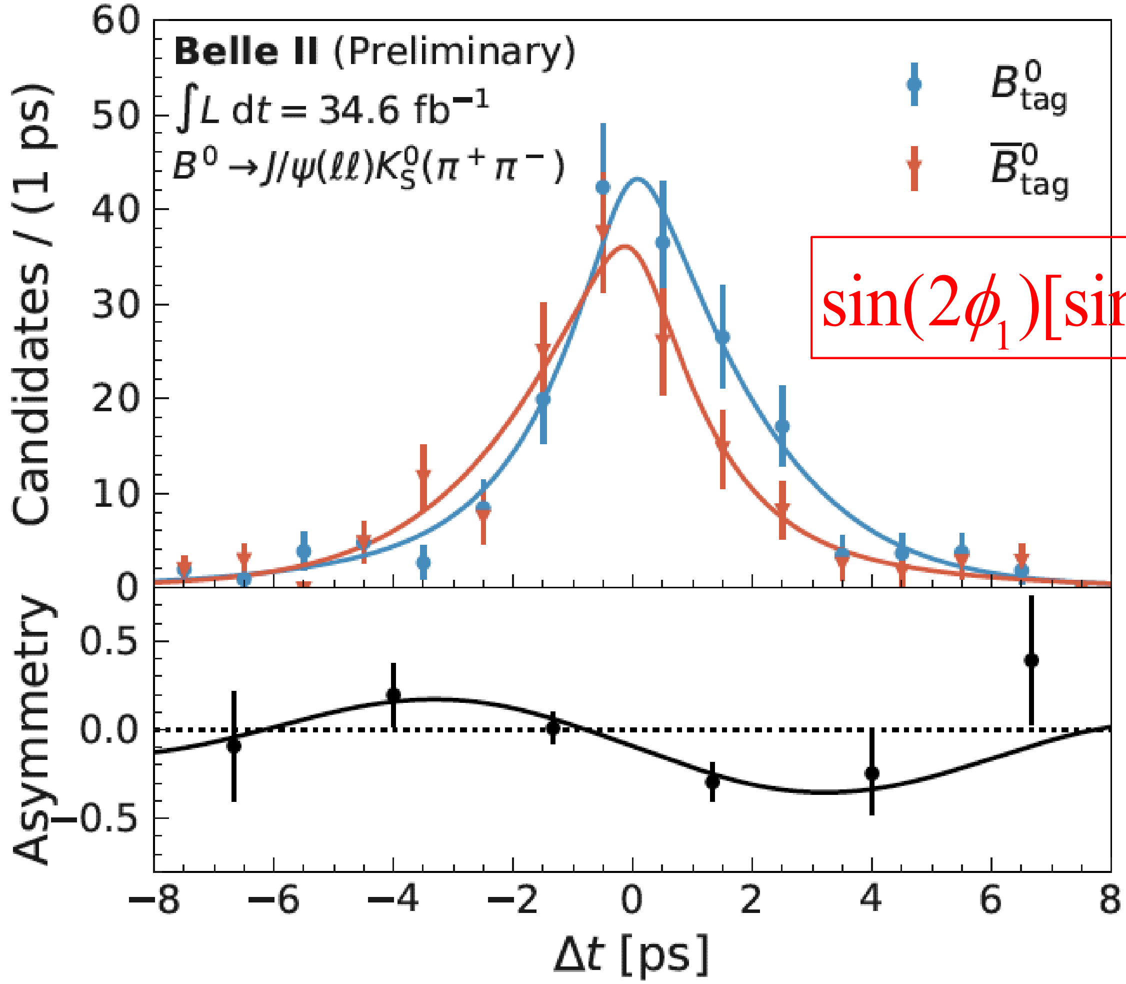
We obtain epsilon_eff = epsilon(1-2 w^2)= **33.8+-3.9%**, which is a slight improvement over the Belle result of 30.1+-0.4%

Agreement of Data and MC

arXiv:2008.02707 [hep-ex]

Hint of time-dependent CPV from Belle II (2.7σ significance)

BELLE2-NOTE-PL-2020-011



$$\boxed{\sin(2\phi_1)[\sin(2\beta)] = 0.55 \pm 0.21 \pm 0.04}$$

(WA=0.691±0.017)

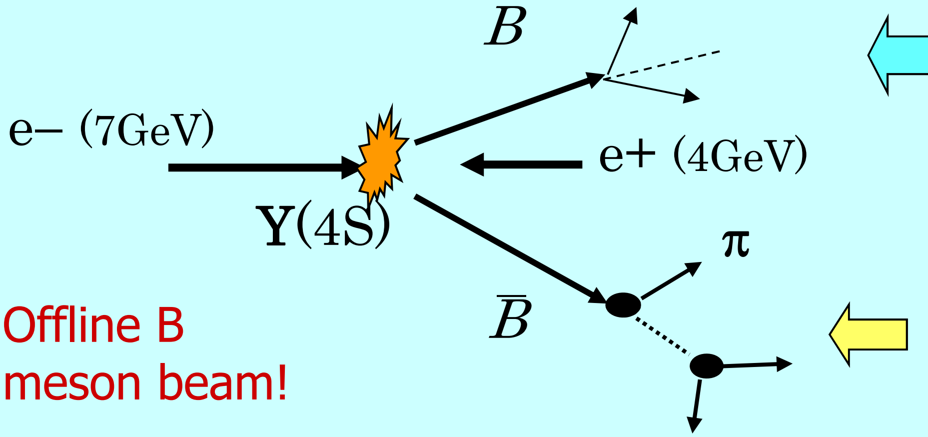
$$B^0 \to f\ ;\ B^0 \to \overline{B^0} \to f$$

$$N_{+/-} \quad \frac{\exp(-|\Delta t|/\tau)}{4\tau}\left\{1 \pm (1-2w)\sin(2\phi_1)\sin(\Delta m_d \Delta t)\right\} \otimes R(\Delta t)$$

Full Event Interpretation (FEI)

Idea: reconstruct one of the B's to tag B flavour/charge, determine its momentum, and exclude decay products of this B from further analysis

(exactly two B's produced in Υ(4S) decays)



Offline B meson beam!

Decays of interest
- $B \rightarrow X_u\, l\, \nu$, $\pi\, l\, \nu$
- $B \rightarrow K\, \nu\, \nu$
- $B \rightarrow D\tau\nu$, $\tau\nu$

full reconstruction(~0.5%):
- hadronic tagging, B→Dπ etc.

partial reconstruction (~2%):
- semileptonic tagging

Powerful tool for B decays with neutrinos

→unique feature at B factories

V_{ub}: Exclusive $B \to \pi^- l^+ \nu$ with FEI

Measurements of the BF at q^2(max) combined with lattice QCD gives $|V_{ub}|$

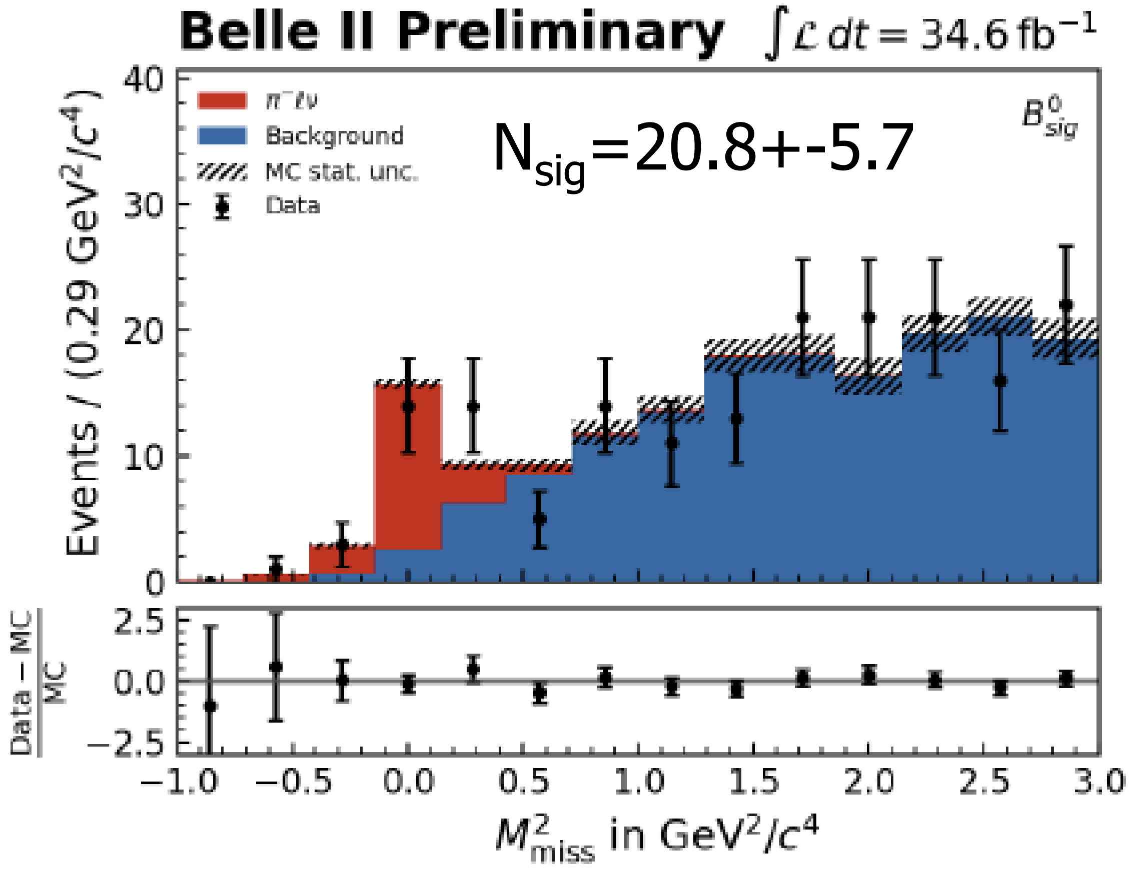
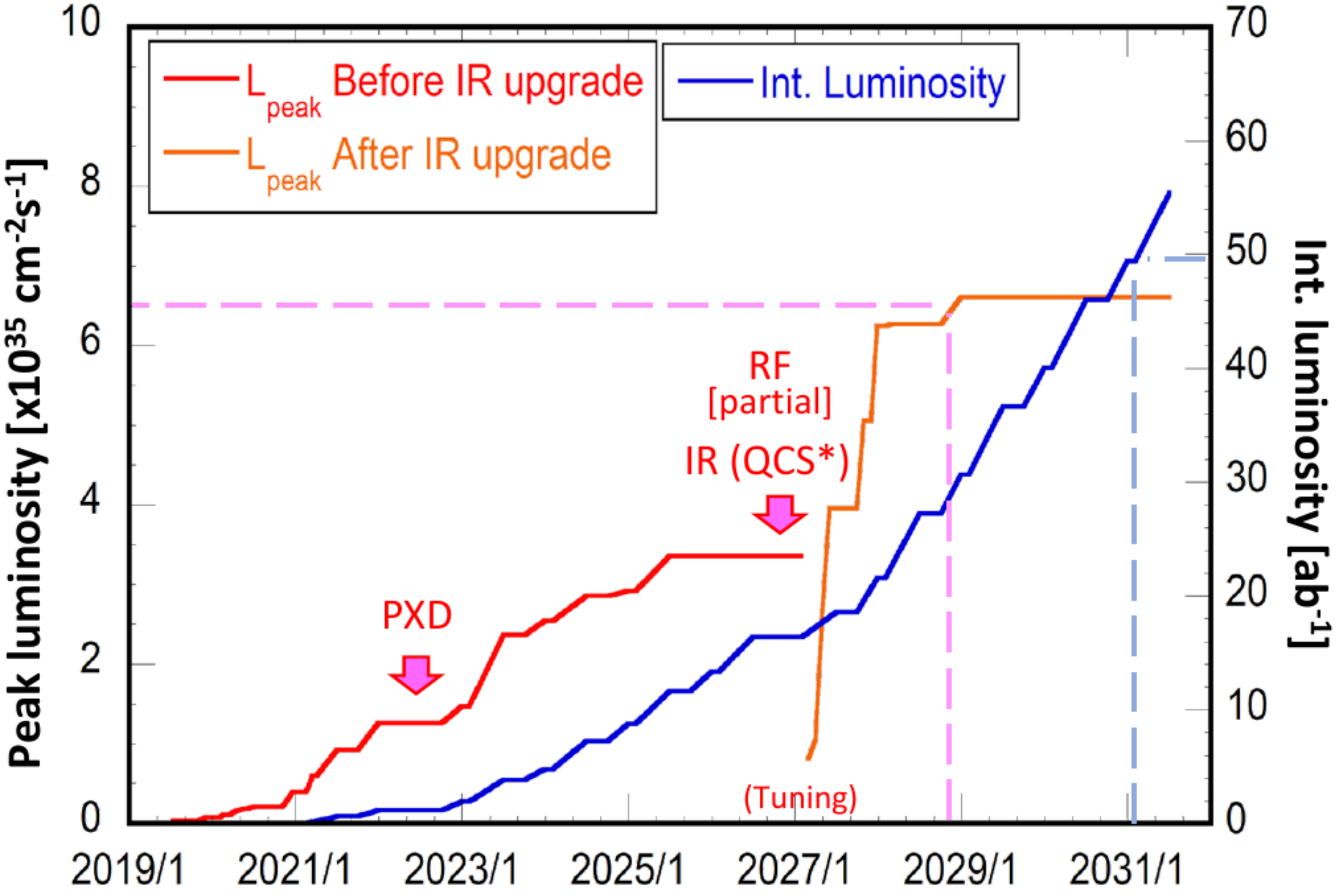


FIG. 4: Post-fit M^2_{miss} distribution in 34.6 fb^{-1} of data.

$$BF(B^0 \to \pi^- l^+ \nu) = [1.58 \pm 0.43(stat) \pm 0.07(sys)] \times 10^{-4}$$

arXiv:2008.08819 [hep-ex]

Updated plan for SuperKEKB

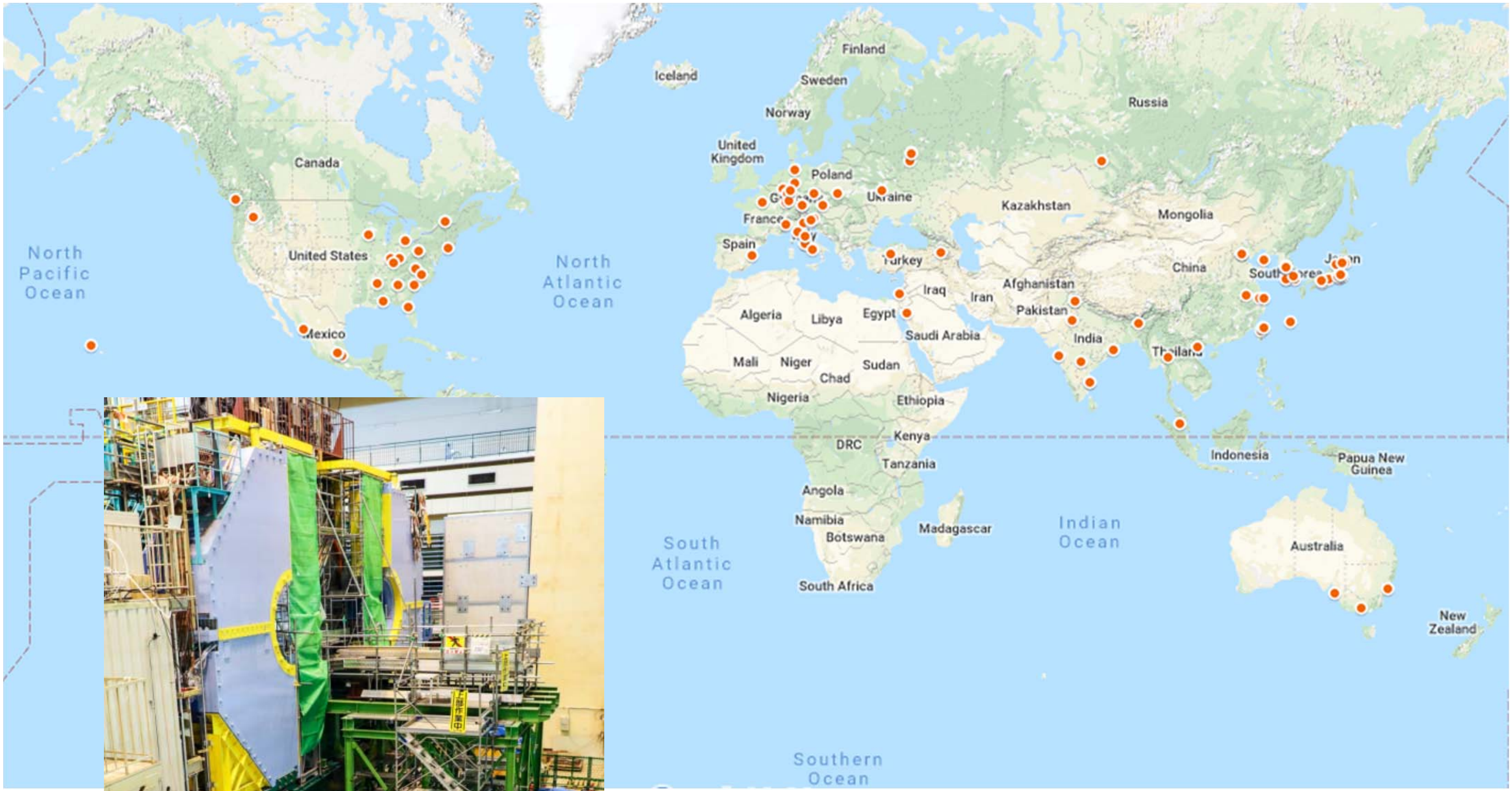


Two steps:

Intermediate luminosity (1 x 10^{35} /cm^2/sec, 5ab^{-1});

High Luminosity (6 x 10^{35}/cm^2/sec, 50 ab^{-1}) with a detector upgrade

Peter Križan, Ljubljana

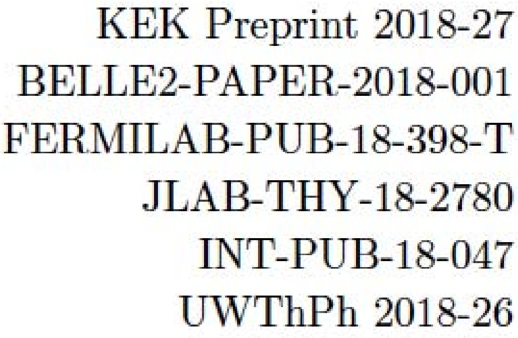


A very strong group of ~1050 highly motivated scientists from 26 countries!

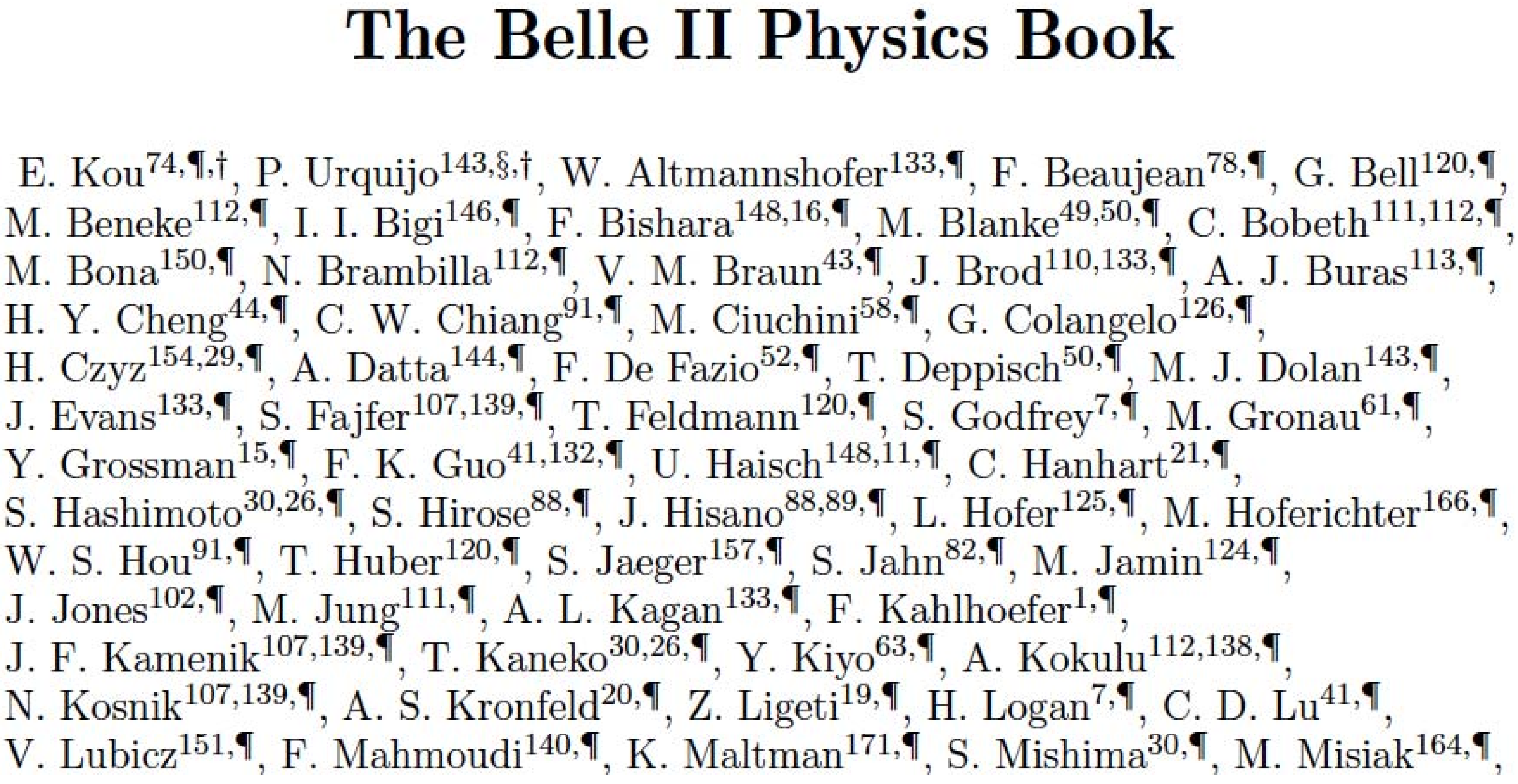
https://arxiv.org/abs/1808.10567

Outcome of the B2TIP (Belle II Theory Interface) Workshops
Emphasis is on New Physics (NP) reach.

Strong participation from theory community,
lattice QCD community and Belle II experimenters.
689 pages, published by Oxford University Press



KEK Preprint 2018-27
BELLE2-PAPER-2018-001
FERMILAB-PUB-18-398-T
JLAB-THY-18-2780
INT-PUB-18-047
UWThPh 2018-26



The Belle II Physics Book

E. Kou[74,¶,†], P. Urquijo[143,§,†], W. Altmannshofer[133,¶], F. Beaujean[78,¶], G. Bell[120,¶], M. Beneke[112,¶], I. I. Bigi[146,¶], F. Bishara[148,16,¶], M. Blanke[49,50,¶], C. Bobeth[111,112,¶], M. Bona[150,¶], N. Brambilla[112,¶], V. M. Braun[43,¶], J. Brod[110,133,¶], A. J. Buras[113,¶], H. Y. Cheng[44,¶], C. W. Chiang[91,¶], M. Ciuchini[58,¶], G. Colangelo[126,¶], H. Czyz[154,29,¶], A. Datta[144,¶], F. De Fazio[52,¶], T. Deppisch[50,¶], M. J. Dolan[143,¶], J. Evans[133,¶], S. Fajfer[107,139,¶], T. Feldmann[120,¶], S. Godfrey[7,¶], M. Gronau[61,¶], Y. Grossman[15,¶], F. K. Guo[41,132,¶], U. Haisch[148,11,¶], C. Hanhart[21,¶], S. Hashimoto[30,26,¶], S. Hirose[88,¶], J. Hisano[88,89,¶], L. Hofer[125,¶], M. Hoferichter[166,¶], W. S. Hou[91,¶], T. Huber[120,¶], S. Jaeger[157,¶], S. Jahn[82,¶], M. Jamin[124,¶], J. Jones[102,¶], M. Jung[111,¶], A. L. Kagan[133,¶], F. Kahlhoefer[1,¶], J. F. Kamenik[107,139,¶], T. Kaneko[30,26,¶], Y. Kiyo[63,¶], A. Kokulu[112,138,¶], N. Kosnik[107,139,¶], A. S. Kronfeld[20,¶], Z. Ligeti[19,¶], H. Logan[7,¶], C. D. Lu[41,¶], V. Lubicz[151,¶], F. Mahmoudi[140,¶], K. Maltman[171,¶], S. Mishima[30,¶], M. Misiak[164,¶],

Summary

- Belle II is working well and is now producing physics.
- SuperKEKB has broken the world-luminosity record and is now entering the "Super B Factory" regime.
- World-leading results already on the dark sector (Search for Z'→invisible and ALPs publications)
- Rediscovering many of the signals seen at the B factories: semileptonic decays, improving FEI, establishing "missing energy" and time-dependent capabilities, and beginning to see hints of time-dependent CP violation. Need more data to make further progress
- Expect a new, exciting era of discoveries, and a friendly competition and complementarity of Belle II and LHCb