

Belle & Belle II Experiment

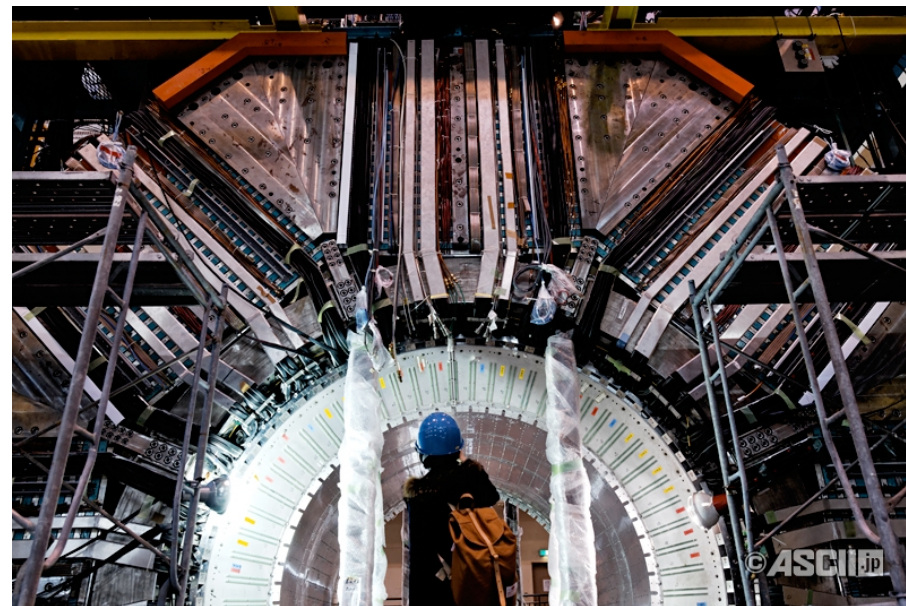
High intensity e^+e^- colliders
@KEK Japan → “Flavour factories”

Professor Elisabetta Barberio

Associate Professor Martin Sevier

Professor Geoffrey Taylor

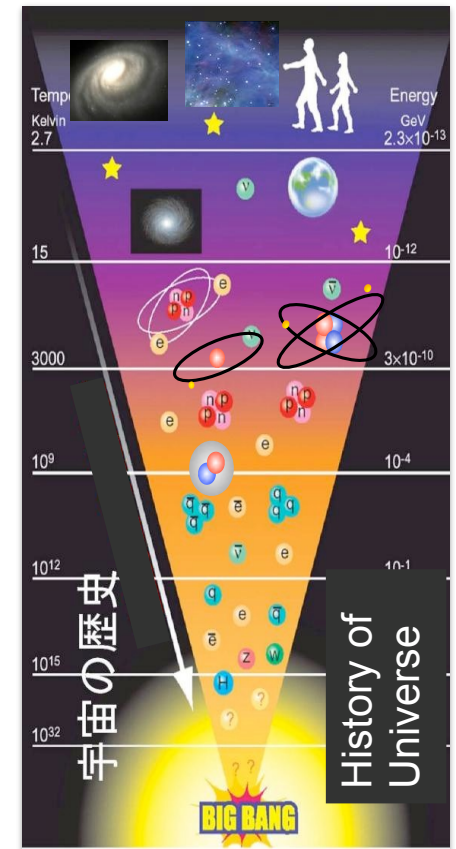
Dr Phillip Urquijo* (Belle II Physics Coordinator)



The case for new physics @ Belle (II)

Issues (addressable at a Flavour factory)

- 19 free parameters that need to be measured
→ Extensions of SM relate some, (GUTs)
- CP asymmetry from cosmological observations.
- Quark and Lepton family flavour & mass hierarchy/spectrum
- No candidates for Dark Matter
- Finite neutrino masses.



Flavour phenomena & possible absence of new physics at LHC point to existence of new symmetries at energies beyond the LHC.

Flavour in the Standard Model

	leptons	quarks	strong	E&M	weak	Higgs
1st generation	e^-	u	g	γ	W^\pm	H
	ν_e	d			Z^0	
2nd generation	μ^-	c				
	ν_μ	s				
3rd generation	τ^-	t				
	ν_τ	b				

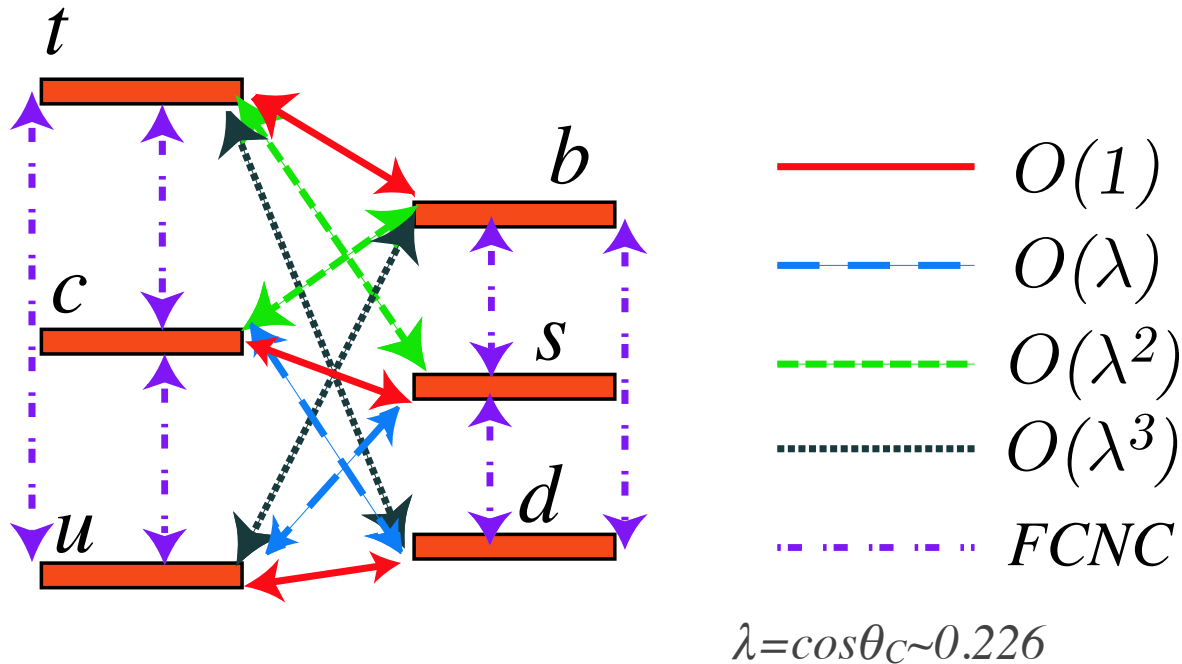
It turns out there are two “extra” copies of particles

- Why 3 sets (= generations) of particles?
 - How do they differ?
 - How do they interact with each other?
 - Are there only 3?

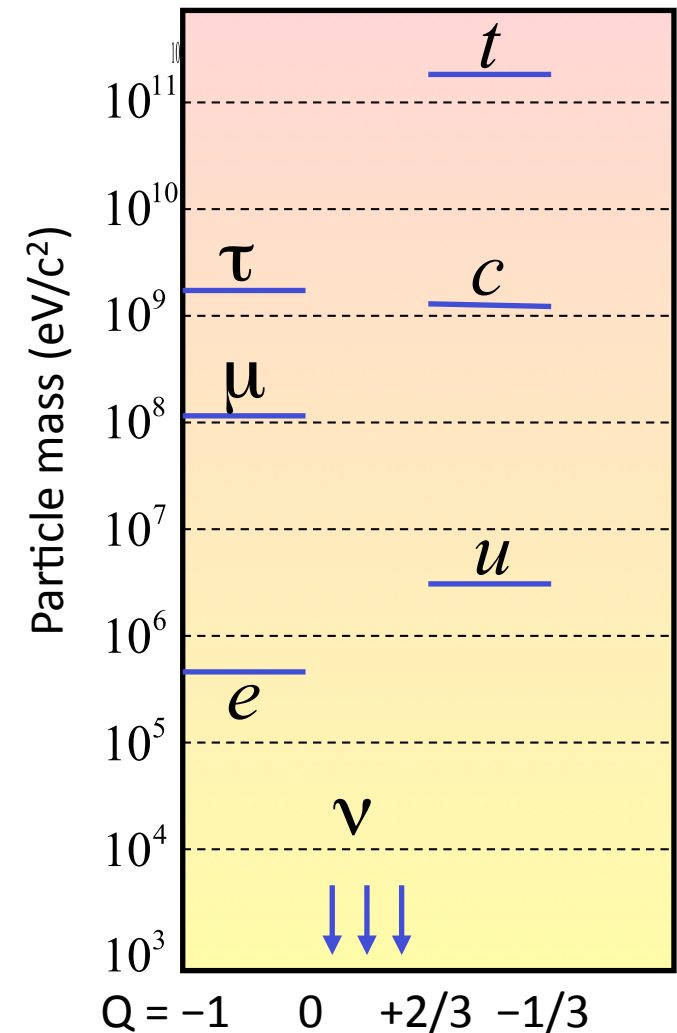


Cabibbo-Kobayashi-Maskawa matrix

$$\mathcal{L}_W \sim g V_{ij} \bar{u}_{Li} d_{Lj} W^-$$

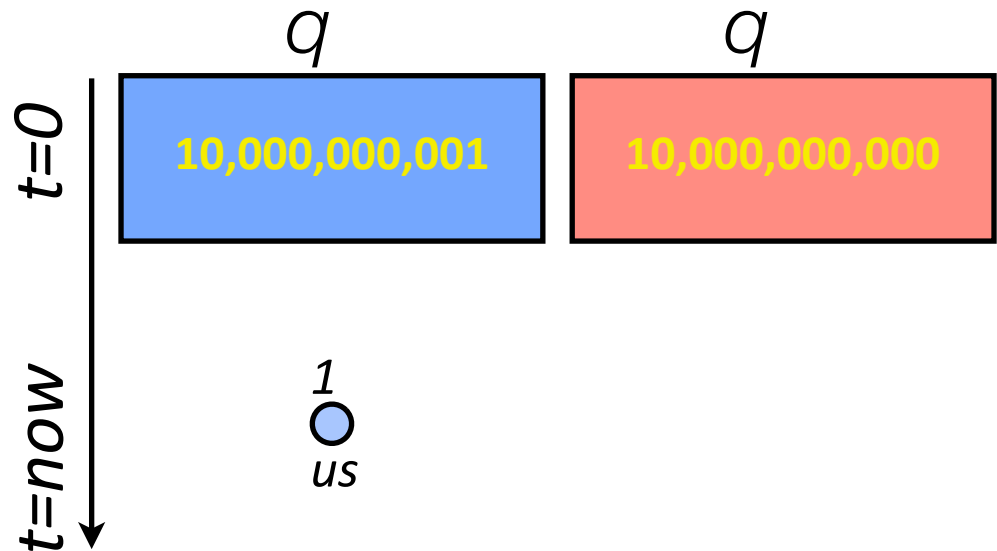


New particles governing transitions analysed through quantum effects! - Uncertainty principle.



Matter-AntiMatter Asymmetry

- Abundance of matter over antimatter, Why?
 $(N_{\text{baryon}} - N_{\text{antibaryon}}) / N_{\gamma} \sim 10^{-10}$



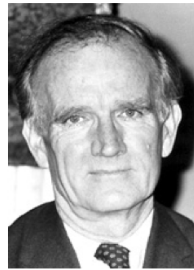
- The *Only* CP violating phase in SM leads to $10^{-17} \Delta N_B / N_{\gamma}$.
 - We should not be here!
 - Solution? extend the SM

C	Charge Conjugation	particle \leftrightarrow anti-particle
P	Parity	$x \rightarrow -x, y \rightarrow -y, z \rightarrow -z$
T	Time Reversal	$t \rightarrow -t$

Brief Flavour physics History



James Watson
Cronin



Val Logsdon Fitch

1964 Fitch and Cronin discover **CP violation** (indirect CP in K)

1970 $\Gamma(K^0 \rightarrow \mu\mu) \ll \Gamma(K^+ \rightarrow \mu\nu)$ Glashow-Iliopoulos-Maiani: No tree level FCNC \Rightarrow **Charm** inferred

1973 CPV in K due to **3rd generation**: Kobayashi & Maskawa (not a new force)

1987 Argus (DESY) B mixing $\Delta m_B \Rightarrow m_t \gg m_W$



Photo: Kyodo/Reuters
Makoto Kobayashi



Photo: Kyoto University
Toshihide Maskawa

2002 BABAR/Belle establish indirect CP violation in B_d mesons, **confirming KM theory**

U. Melbourne's role in Flavour Physics



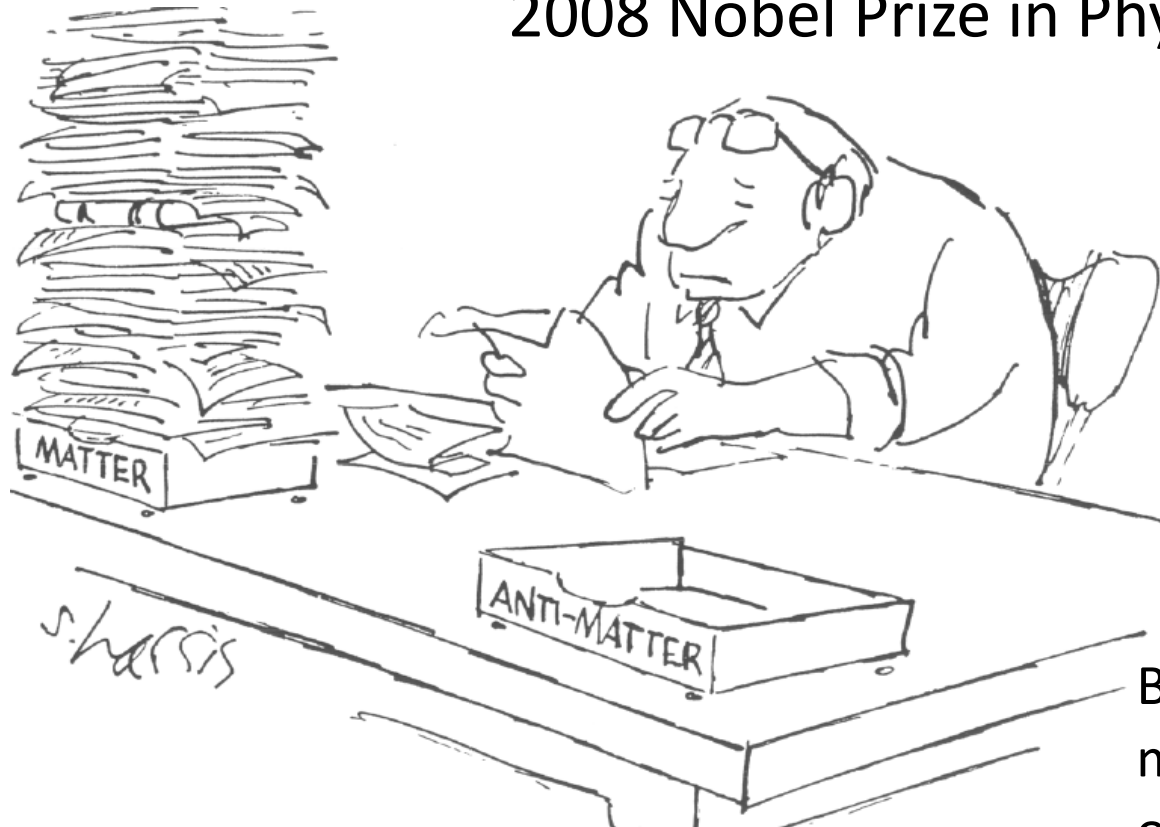
2008 Nobel Prize

Critical Role of the B factories in the verification of the KM hypothesis was recognised and cited by the Nobel Foundation

A single irreducible phase in the weak interaction matrix accounts for most of the CPV observed in kaons and B's.

Are we done ?

(Didn't the B factories accomplish their mission, recognized by the 2008 Nobel Prize in Physics ?)



BAU: Kobayashi-Maskawa mechanism still short by 10 orders of magnitude !!!

New physics amplitudes 10-20% the size of the Standard Model contributions allowed by data



Из записки С. Окубо
при большой температуре
для Вселенной с нуля
по ее кривой фигуры

НАРУШЕНИЕ СР-ИНВАРИАНТНОСТИ, С-АСИММЕТРИЯ
И БАРИОННАЯ АСИММЕТРИЯ ВСЕЛЕННОЙ

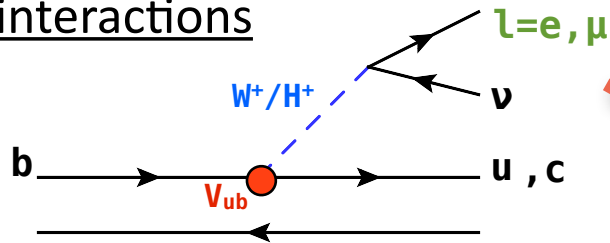
А.Д.Сазаров

Теория расширяющейся Вселенной, предполагающая сверхплотное начальное состояние вещества, по-видимому, исключает возможность макроскопического разделения вещества и антивещества; поэтому следует

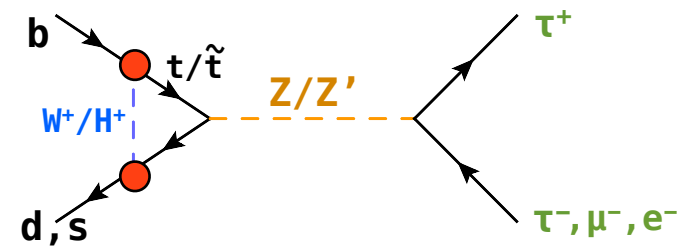
New Phenomena “DNA”

Different models predict different sets of quantum numbers/
masses/couplings.

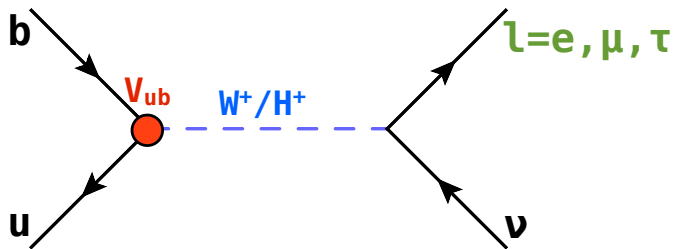
Precision tests of quark interactions



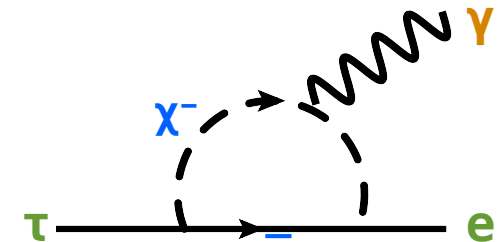
Flavour Changing Neutral Current Interactions



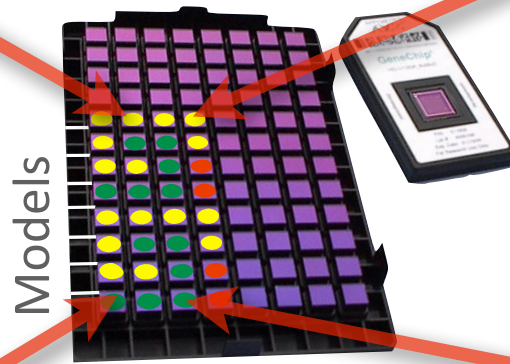
New Phenomena in rare decay processes



Search for lepton flavour violation (neutrino mass...)



New Physics
“DNA Chip”



Models

Test Analyses

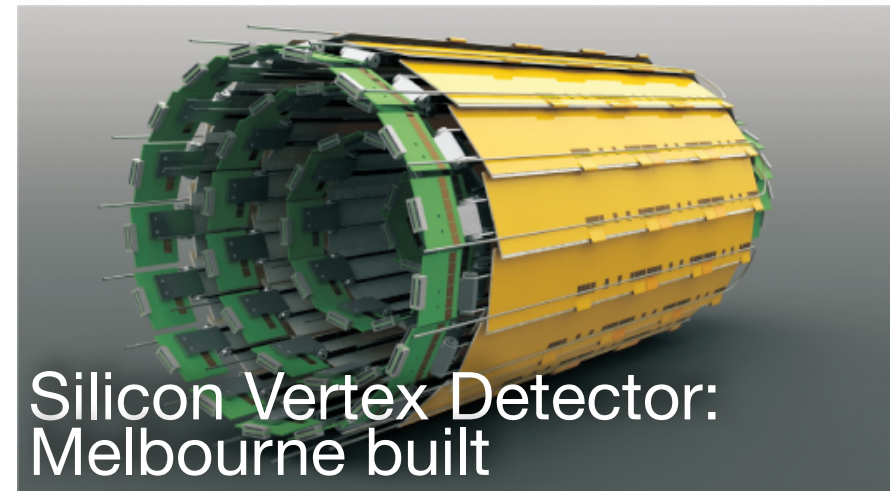
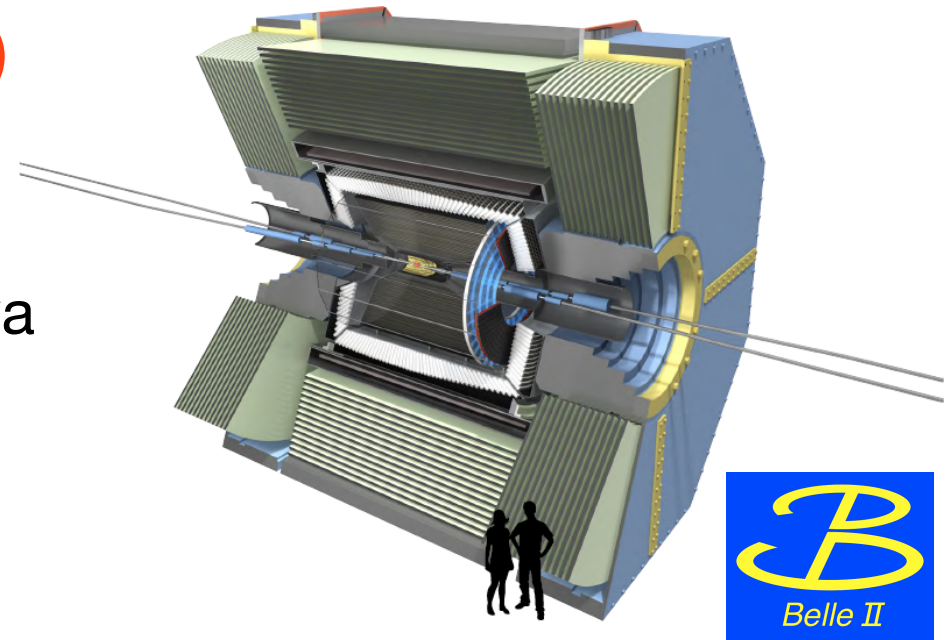
Belle → Belle II Experiment

- **Belle** experiment@KEKB (1999-2010)
 - B & D mesons, & τ leptons.
 - Discovered CP violation in B:
Nobel Prize to Kobayashi & Maskawa
2008

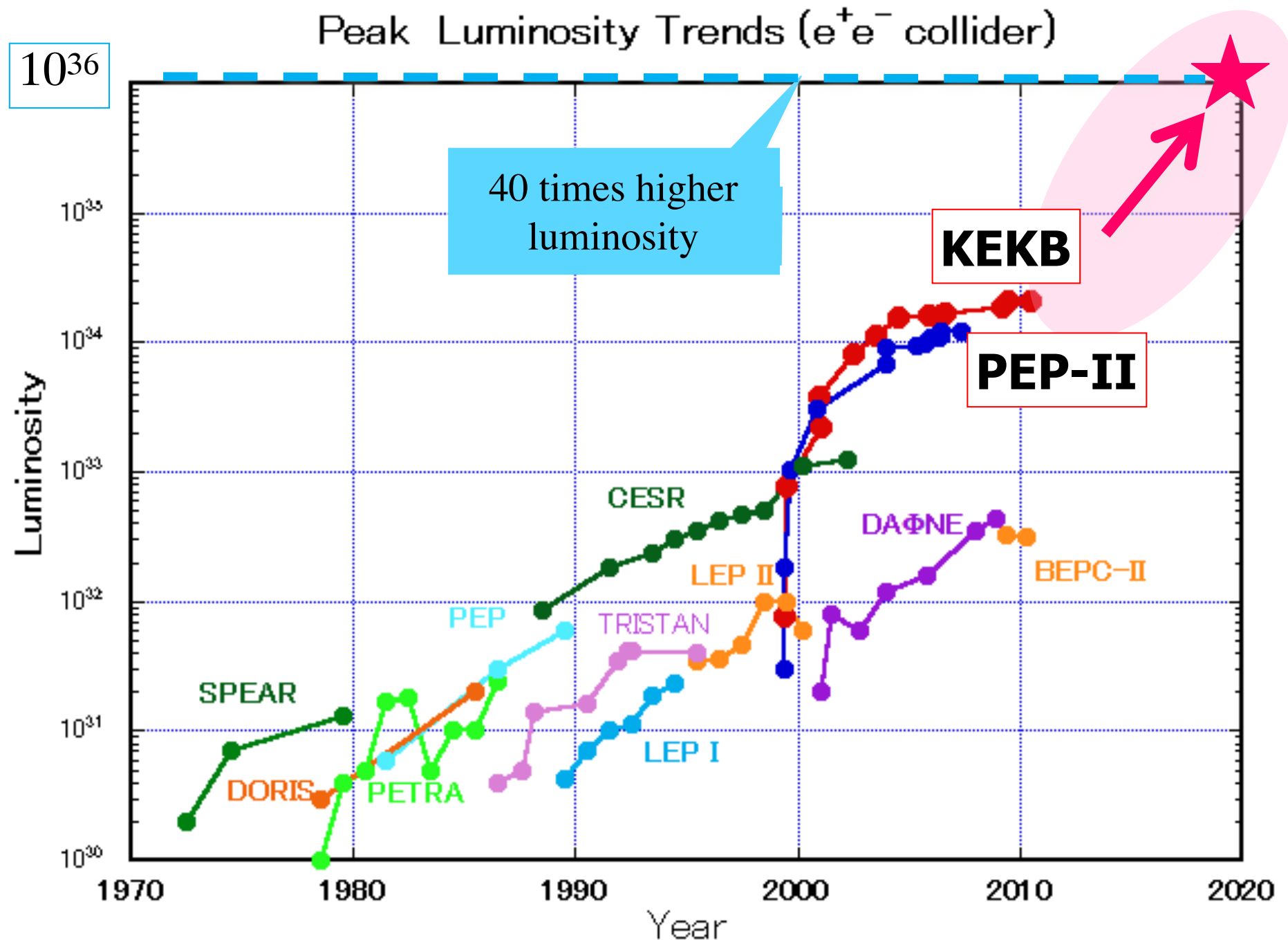
[400 collaborators, 15 nations]

- **Belle II** experiment@SuperKEKB
(commissioning from 2015, first
physics in 2017)
 - **40x** collision rate
 - New detector technology.
 - **Premier flavour experiment** of the
decade.

[600+ collaborators, 23 nations/regions]



Belle II is the e^+e^- intensity frontier



Melbourne team

Academics

Professor Elisabetta Barberio
Associate Professor Martin Sevier
Professor Geoffrey Taylor
Dr Phillip Urquijo*

PostDocs

Dr Chunhua Li
Dr Matteo Volpi

Urquijo group PhD Students

Luis Pesantez
Eiasha Waheed
Alexander Ermakov

Belle and Belle II Physics

- **Semileptonic and Leptonic B-meson Decays**

SM metrology: CKM Quark mixing matrix elements, b-quark mass

New physics: Charged Higgs, Right Handed Currents

- **CP Violation (Matter-Antimatter Asymmetries in the Quark sector)**

New sources of CP violation and Right Handed currents in loop decays of $b \rightarrow d\gamma$ and $b \rightarrow s\gamma$, and hadronic $b \rightarrow d$ transitions

- **Dark sector**

Kinetic mixing to dark photons and production of dark matter @ 0.1 - 10 GeV

- **Tau Leptons (Symmetry violation in the Lepton sector)**

Lepton Flavour and CP Violation, sensitive to GUT scale heavy neutrinos

- **CKMFitter**

Full phenomenological analysis of the quark sector and key areas with striking anomalies.

Belle II Development

- **Trigger and Data acquisition system**

World's highest luminosity accelerator, 30 kHz readout - data volume \sim LHC experiments. Only about 2% of all events will be of interest.

- **Physics Implications of the Silicon Vertex Detector**

Commission and analyse the first data for precision CP analyses. (Melbourne-built.)

- **Data mining and Grid-based physics data analysis**

Design of sophisticated data-mining and analysis techniques to be undertaken on the world-wide Belle II grid.

- **Feasibility studies for New physics discoveries**

Prepare for Belle II, and reveal exactly what Belle II can tell us about new physics.