The 4th KMI International Symposium (KMI 2019)
Quest for the Origin of Particles and the Universe

Looking at Particle - AntiParticle asymmetry with Heavy Flavors

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NAGOYA UNIVERSITY

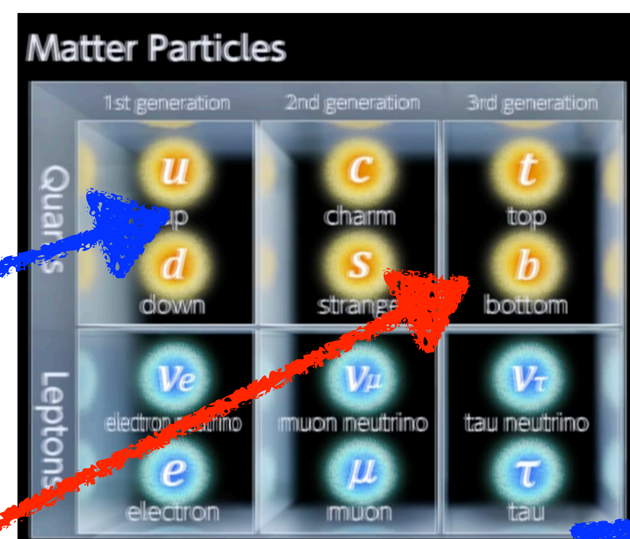
February 18, 2019

Kobayashi-Maskawa Institute
for the Origin of Particles and the Universe

Talk Outline

- Topical session focused on "Mysteries of the matter-antimatter asymmetry in the Universe".
- Introductory overview for the 2nd KMI school.

- Introduction
- CP violation in the SM
  - Flavor changing quark interaction
- Approaching New Physics with heavy flavors
  - LHC and B experiments
- Summary



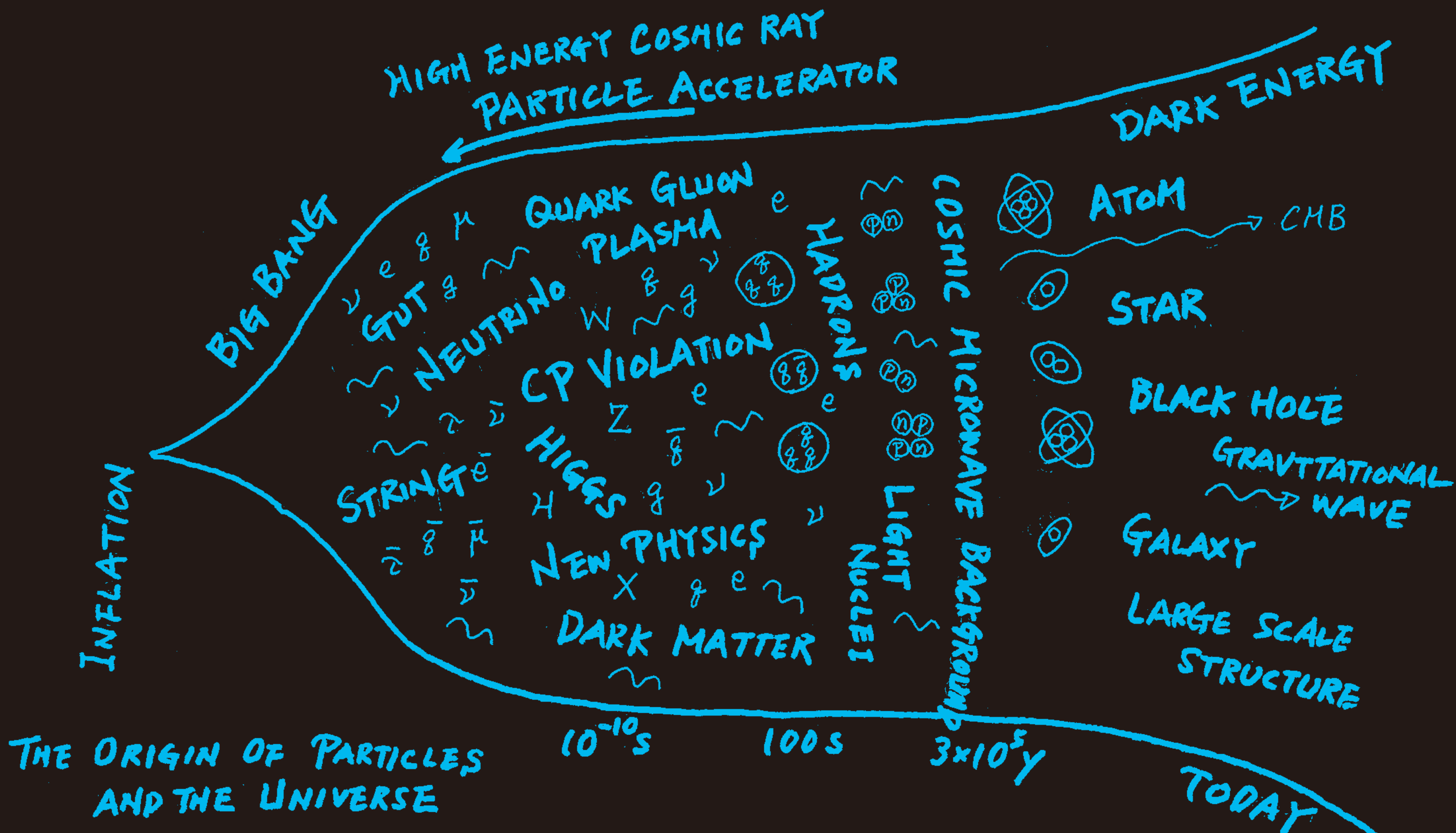
Strong CP
(M.Ramsey-Musolf)

Neutrino
(F. di. Lodovico)

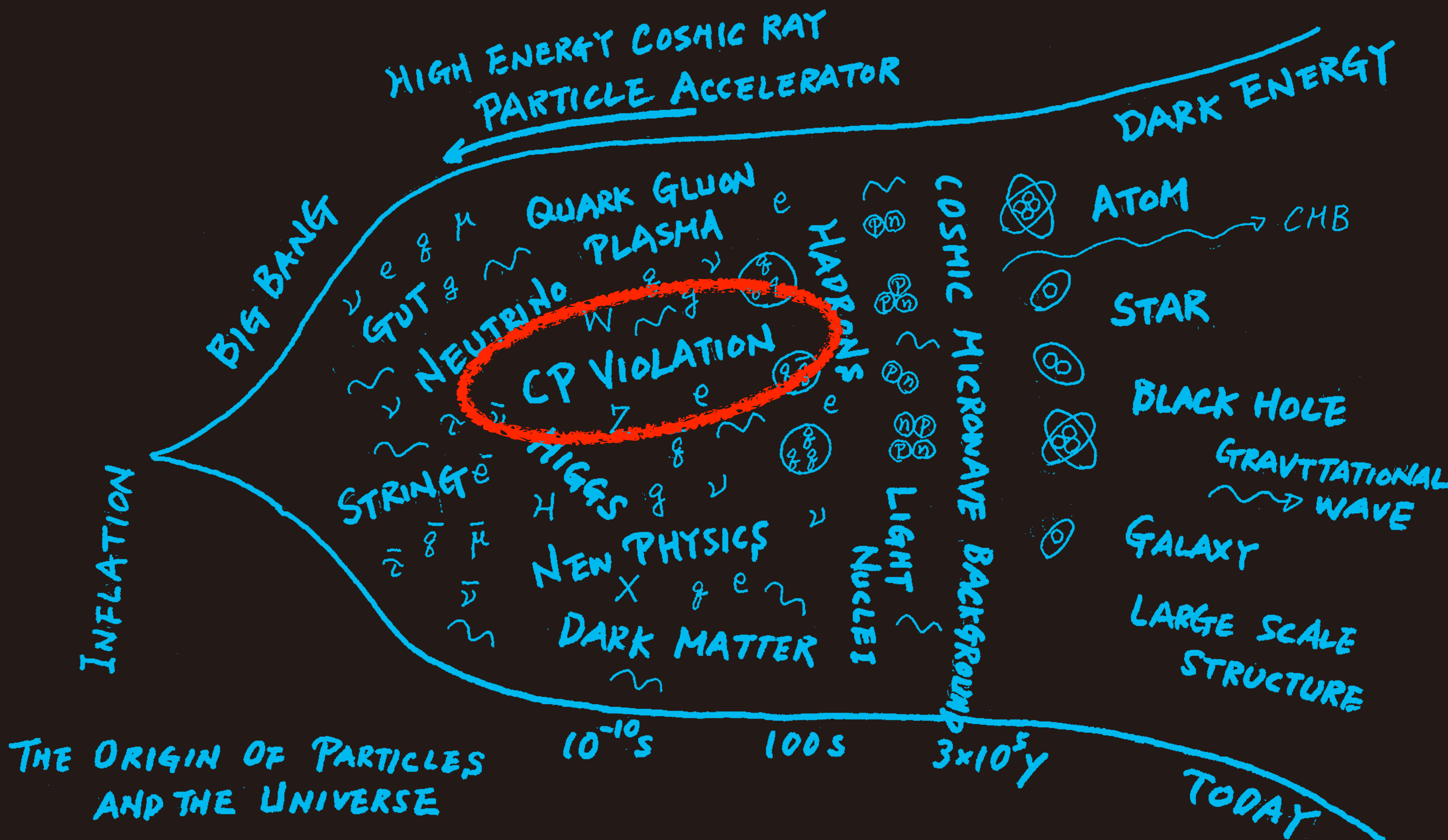
Charged leptons
(K. Hayasaka)

Cosmic ray research
(S. Haino)

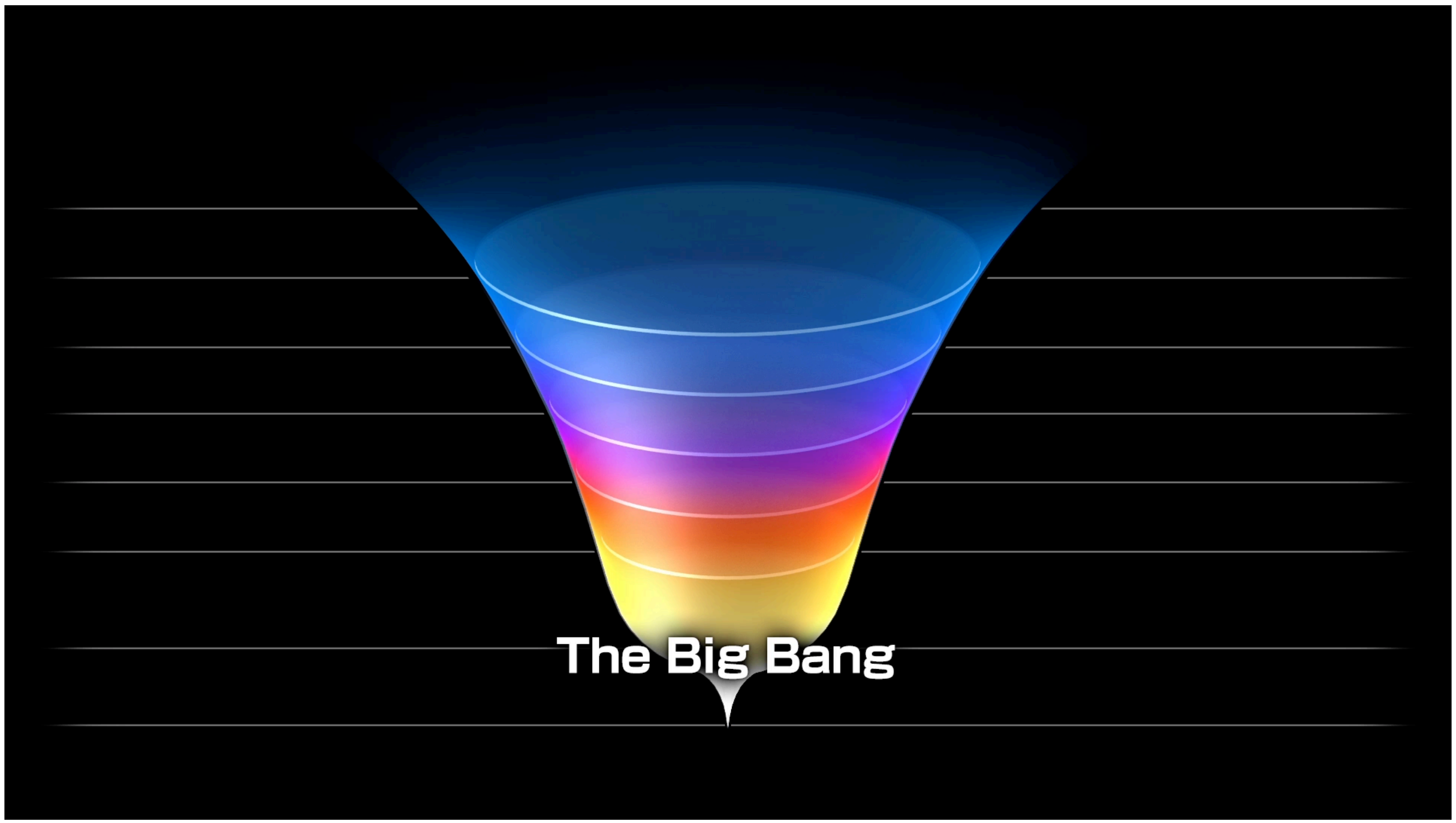
History of the Universe



History of the Universe

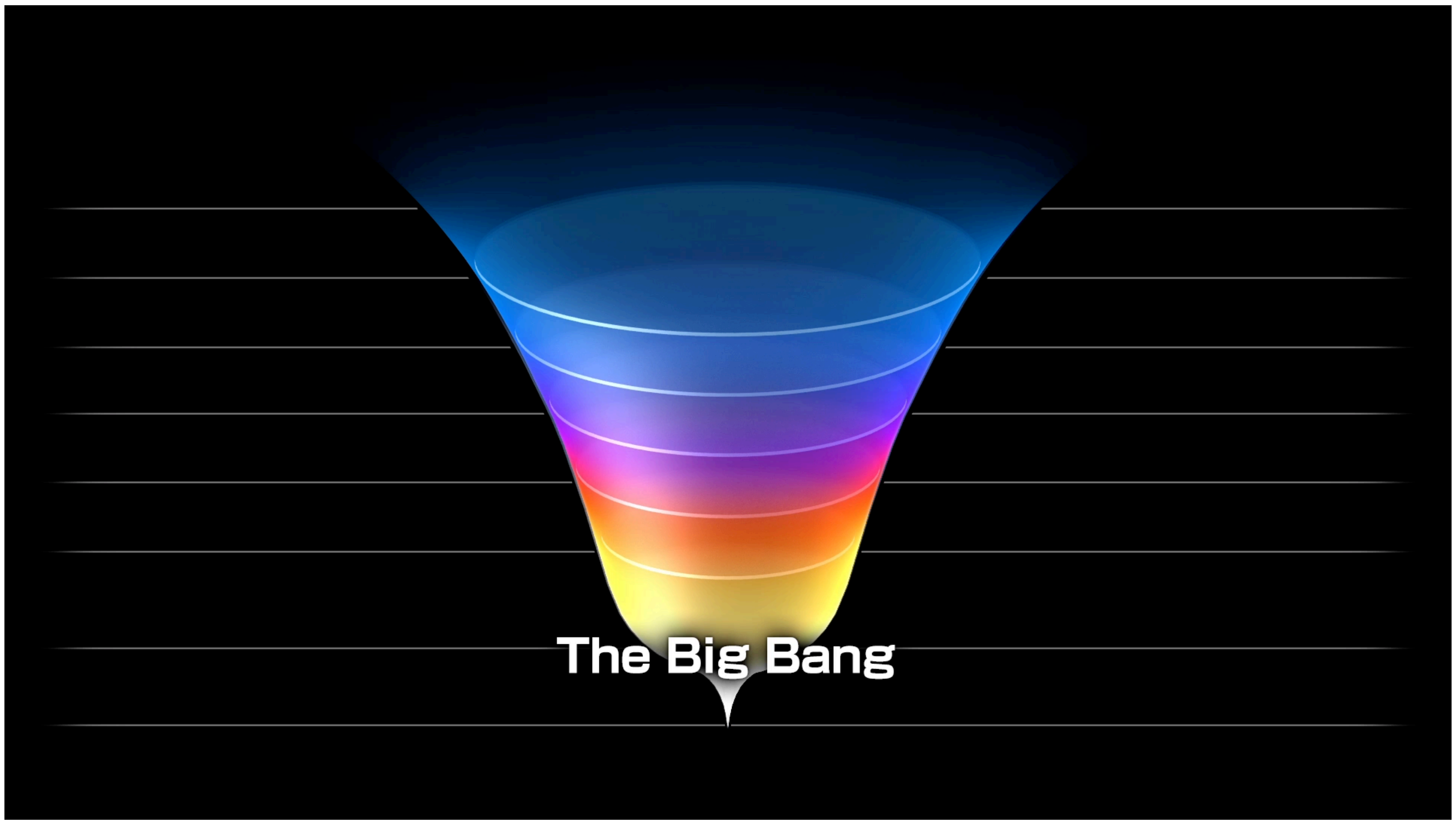


Mystery of Anti-matter Disappearance



Physicists believe that equal number of particles and anti-particles are produced from Big Bang. However, anti-particles disappeared somehow, and the present Universe is dominated by matters. Why ?

Mystery of Anti-matter Disappearance



Physicists believe that equal number of particles and anti-particles are produced from Big Bang. However, anti-particles disappeared somehow, and the present Universe is dominated by matters.
Why ?

CP Violation

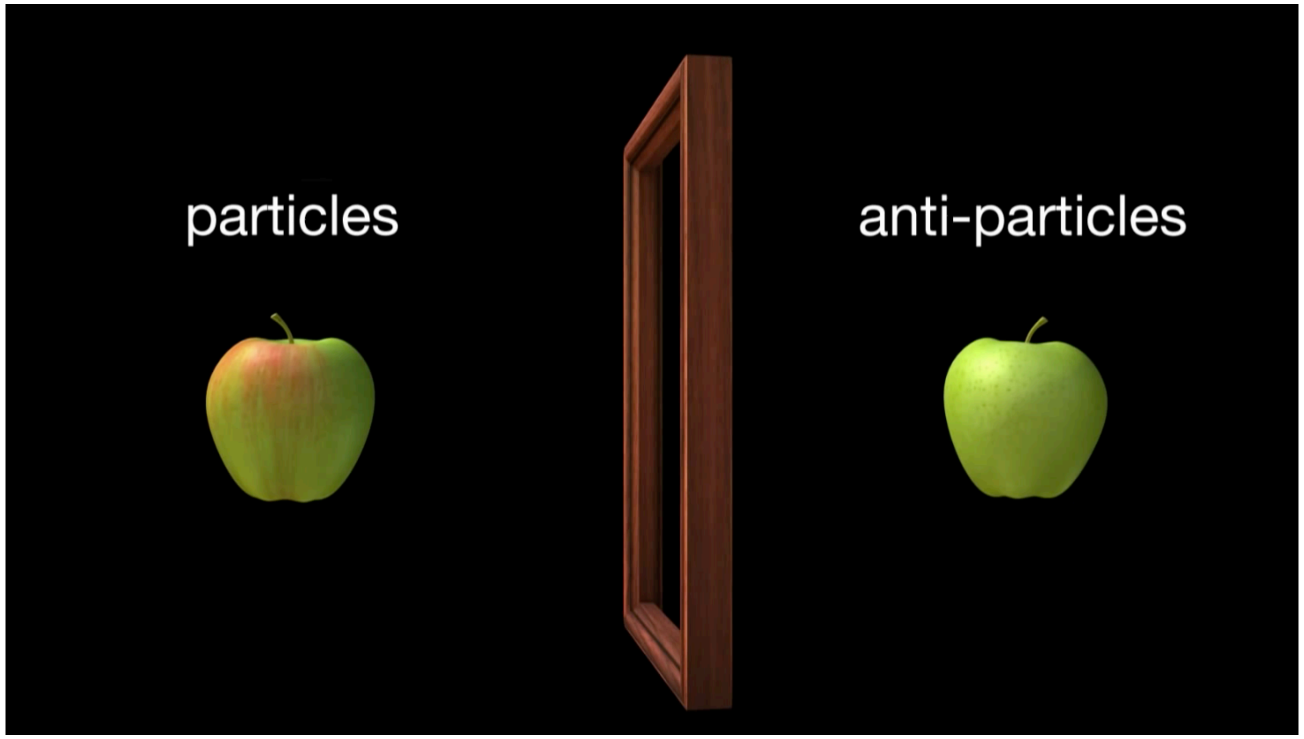
To make the matter dominated Universe, we need

I. Baryon number violation

II. CP violation

III. Loss of thermal equilibrium

[Sakharov's 3 conditions]



Discovery of CPV (1964)

- V. Fitch, J. Cronin et al.

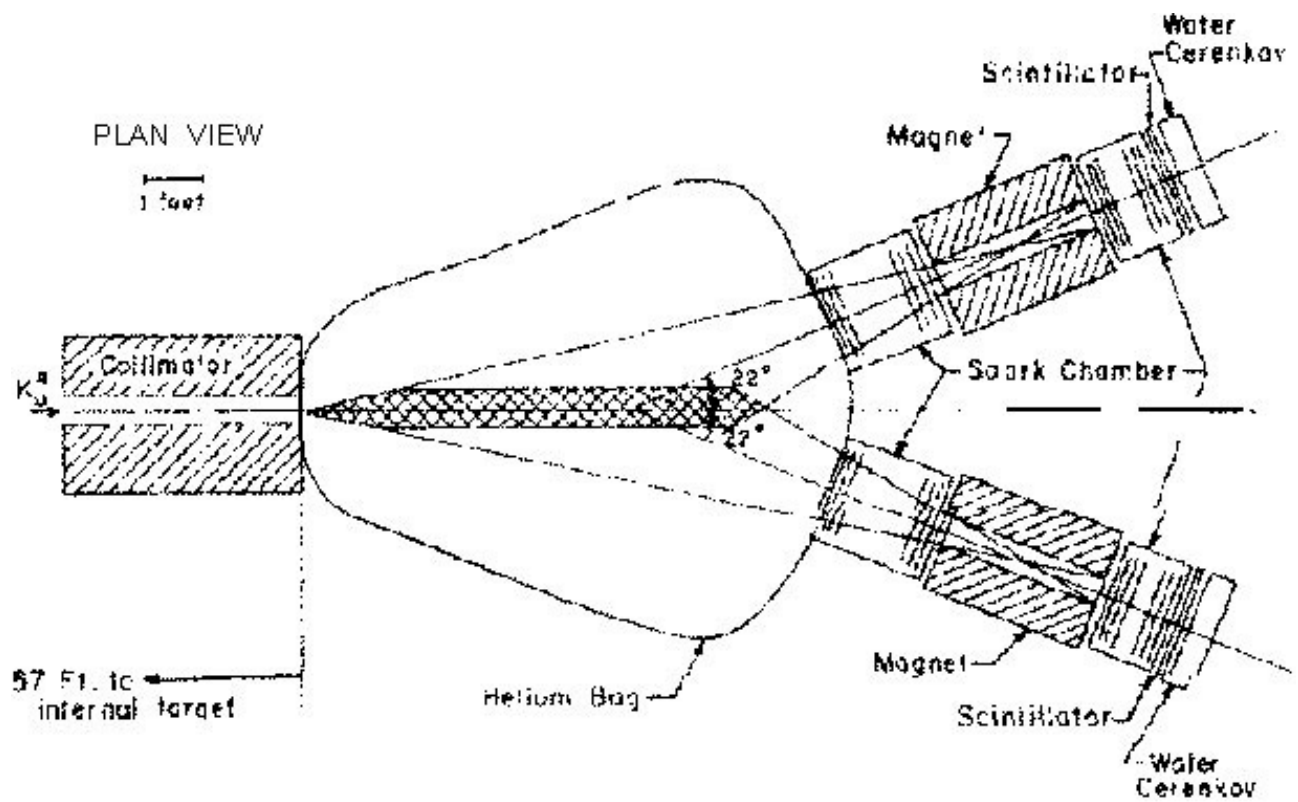


Fig. 1. Plan view of the apparatus as located at the A. G. S.

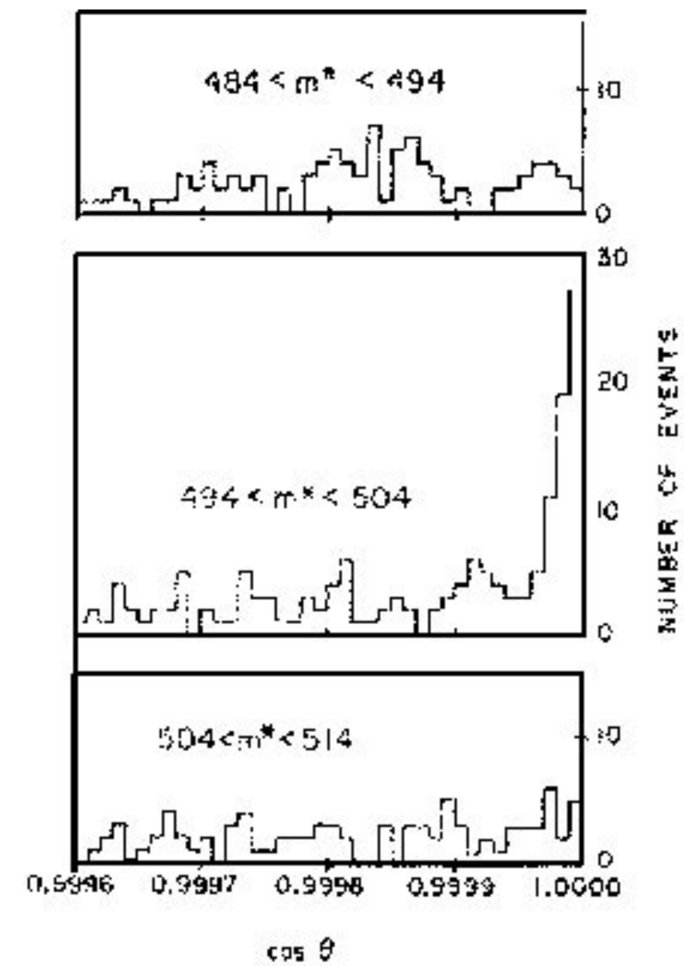
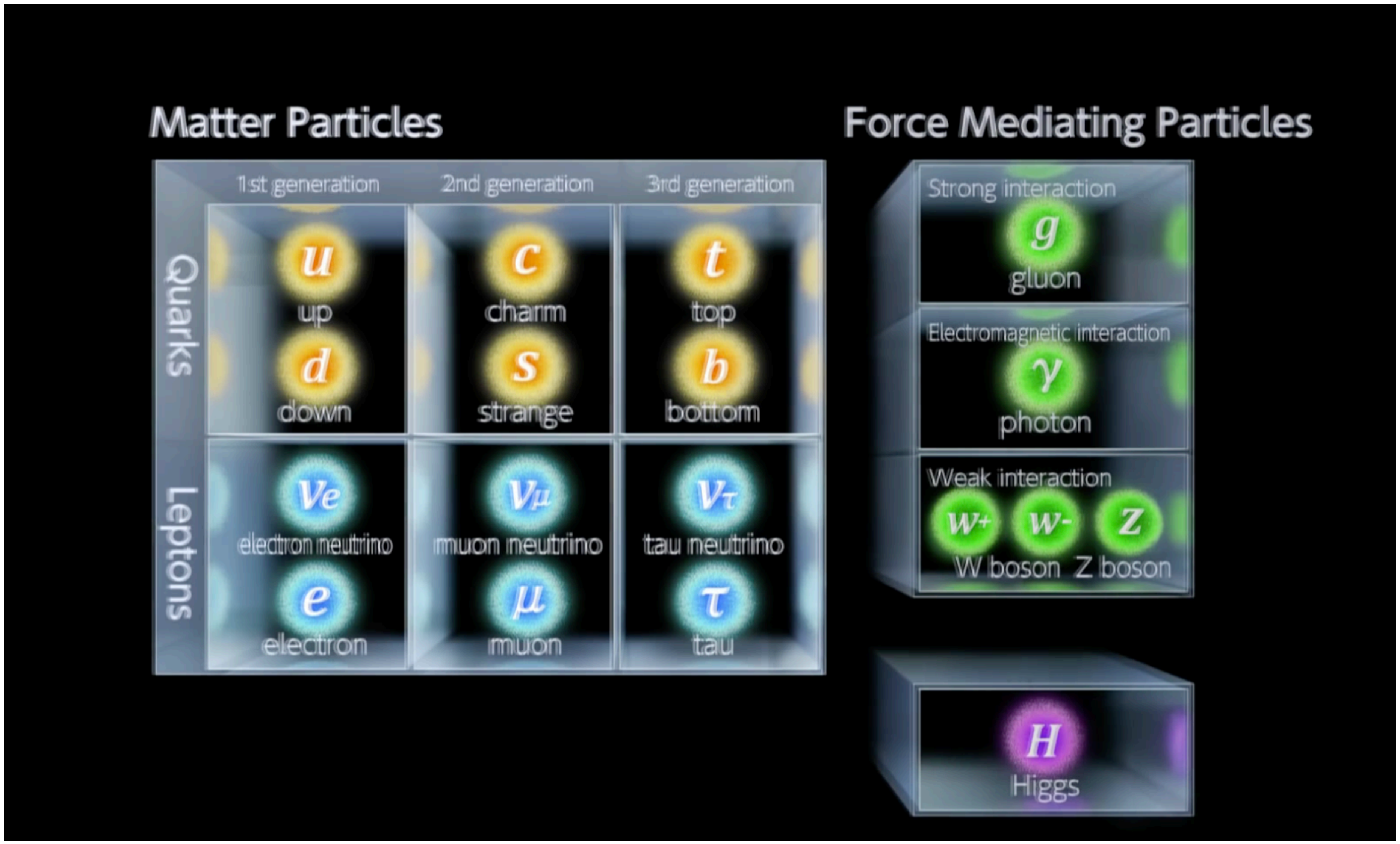


Fig. 3. Angular distribution of the events after measurement by a precise machine in three relevant mass regions.

$\Gamma(K_L \rightarrow \pi^+\pi^-) / \Gamma(K_L \rightarrow \text{all charged})$
$= (2.0 \pm 0.4) \times 10^{-3}$

$$|K_S\rangle = (1+|\varepsilon|^2)^{1/2}\left[|K_1\rangle + \varepsilon|K_2\rangle\right]$$
$$|K_L\rangle = (1+|\varepsilon|^2)^{1/2}\left[\varepsilon|K_1\rangle + |K_2\rangle\right]$$

The Standard Model of Particle Physics



Elementary particles make up the Universe

Matter particles (quarks and leptons)

Force mediating particles (bosons)

and Higgs !

2008 Nobel Prize in Physics

Photo: University of Chicago

Yoichiro Nambu

Prize share: 1/2

© The Nobel Foundation Photo: U. Montan

Makoto Kobayashi

Prize share: 1/4

© The Nobel Foundation Photo: U. Montan

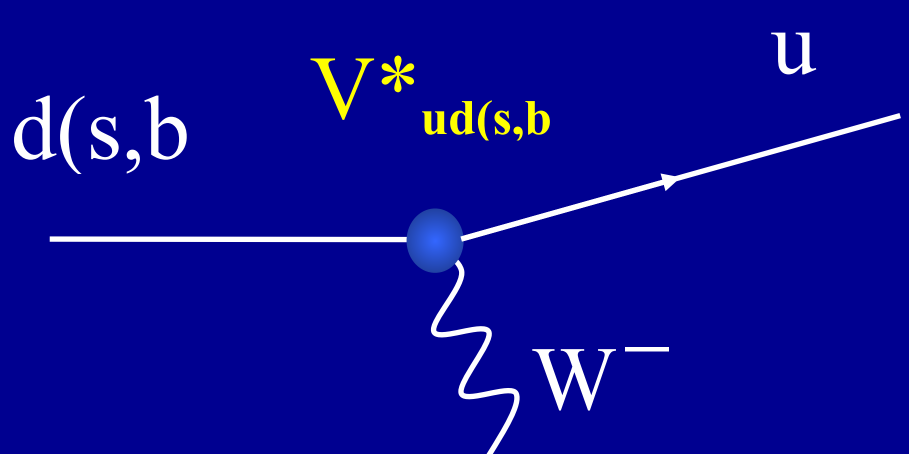
Toshihide Maskawa

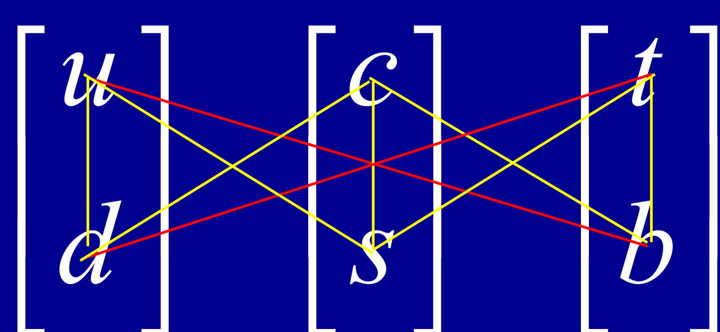
Prize share: 1/4

The Nobel Prize in Physics 2008 was divided, one half awarded to Yoichiro Nambu "for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics", the other half jointly to Makoto Kobayashi and Toshihide Maskawa "for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature."

Kobayashi-Maskawa Theory

- A quark change its flavor by emitting virtual W.
- 3X3 unitarity triangle has 3 rotational angles and one complex phase. → CP Violation





$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Flavor eigenstate | **CKM** | Mass eigenstate

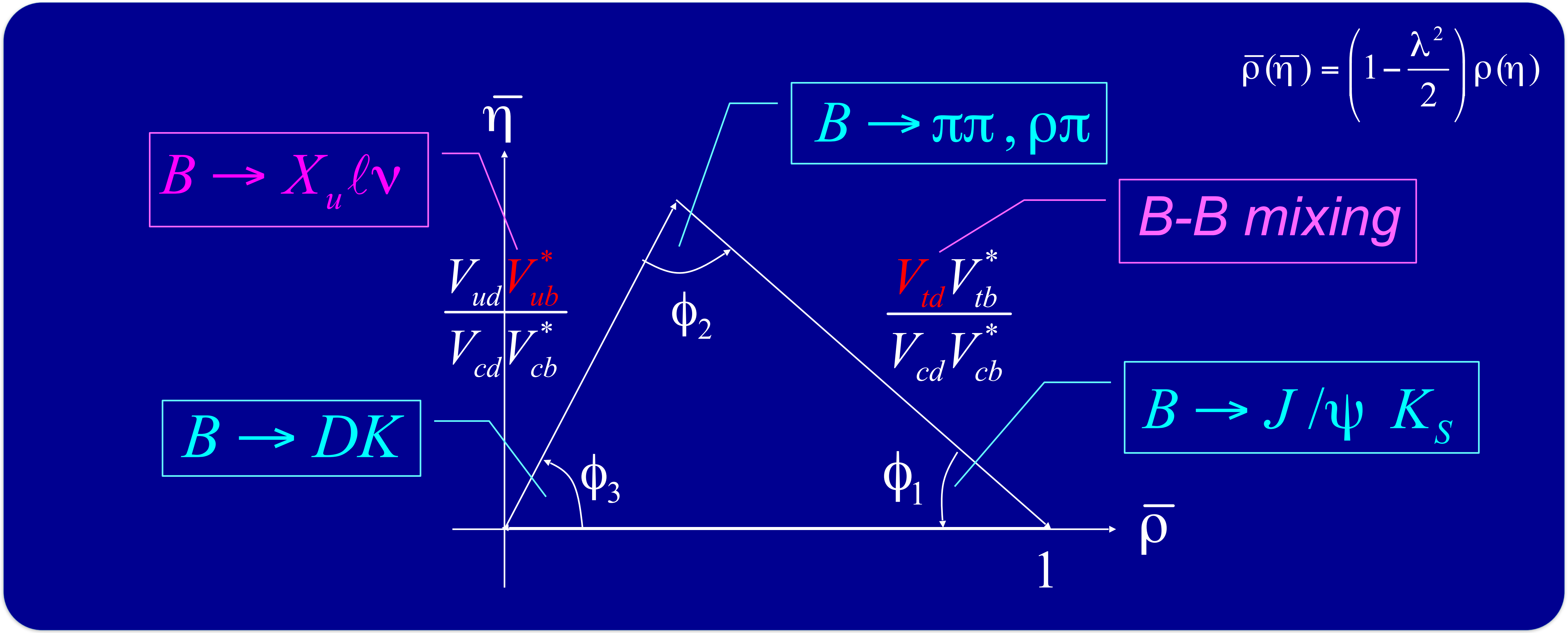
Unitarity Triangle

unitarity condition

$$V_{ud}V_{us}^* + V_{cd}V_{cs}^* + V_{td}V_{ts}^* = 0$$

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

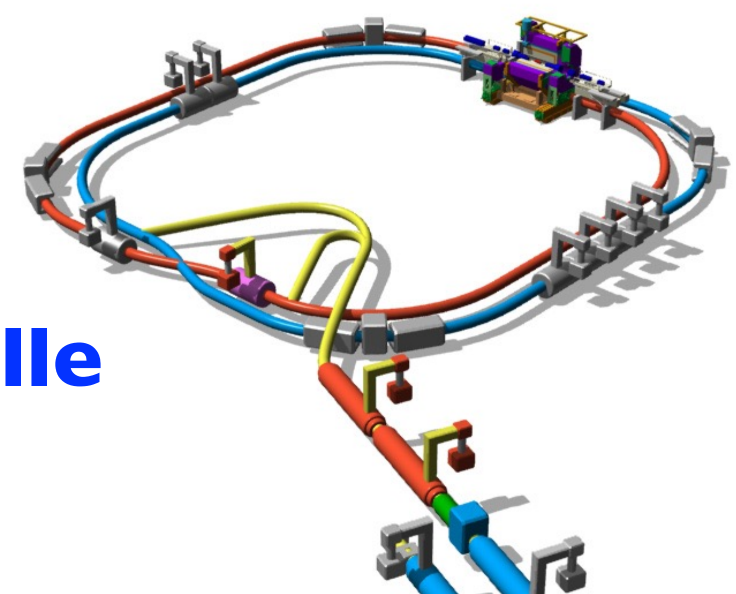
$$V_{us}V_{ub}^* + V_{cs}V_{cb}^* + V_{ts}V_{tb}^* = 0$$

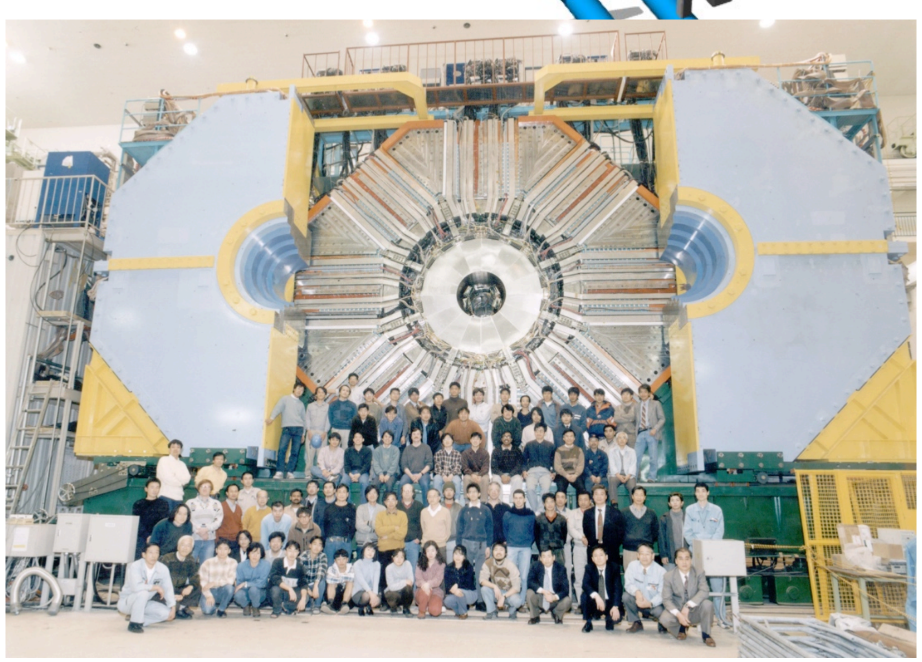


B-Factory Experiments

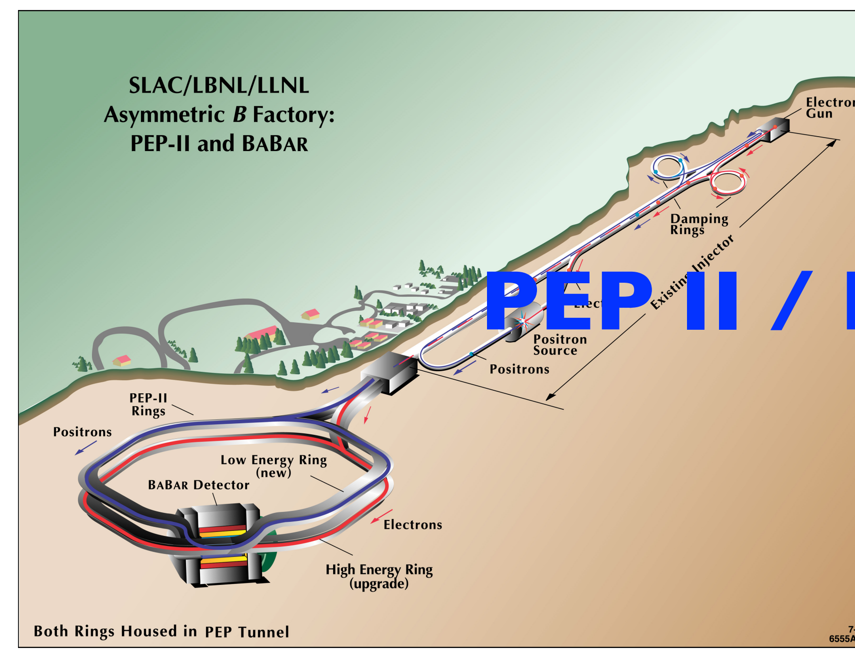
In 2001, the Belle experiment at KEK and the BaBar experiment at SLAC successfully measured CP violation in B meson decays as predicted by the Kobayashi-Maskawa theory.

KEKB / Belle

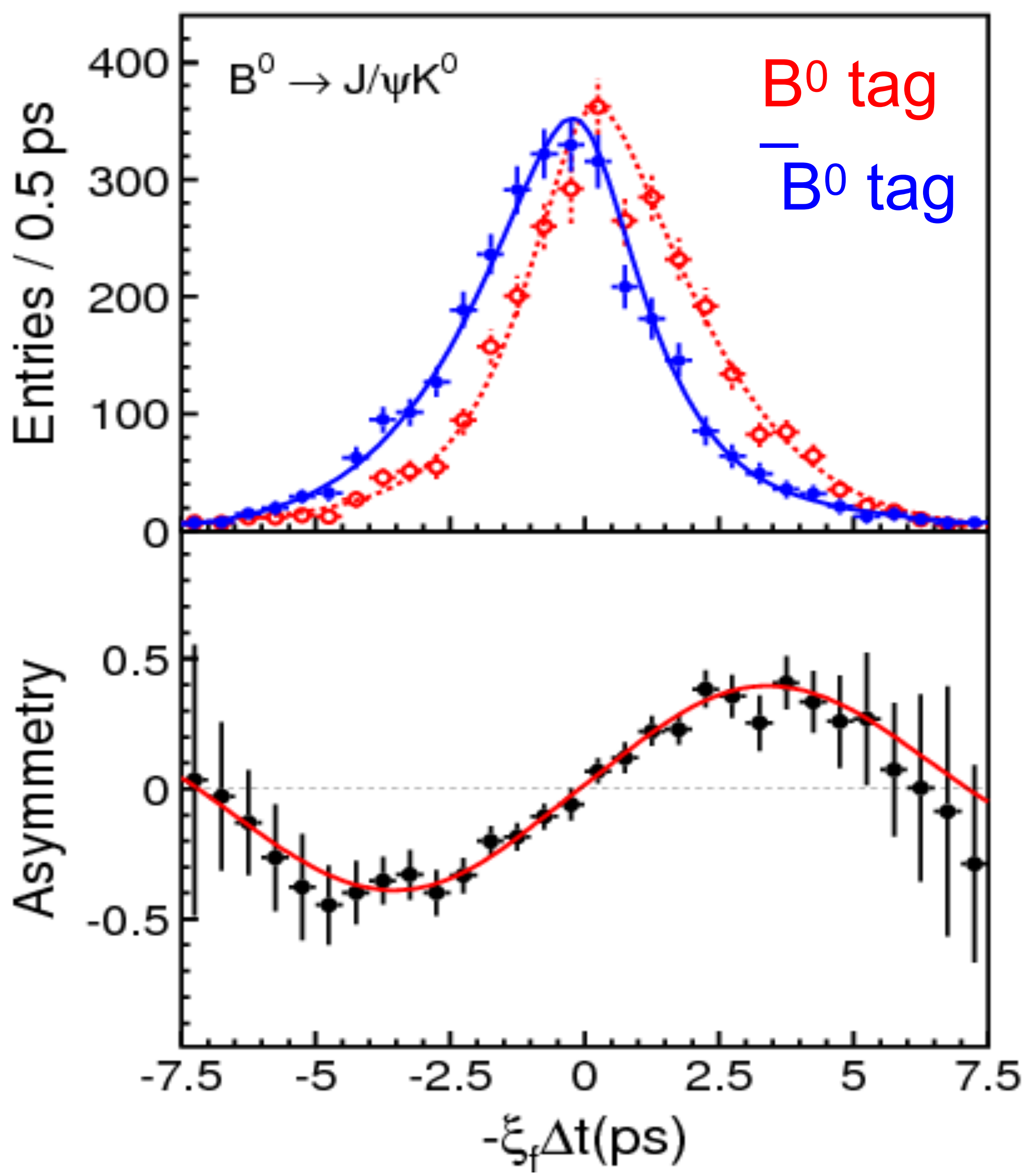


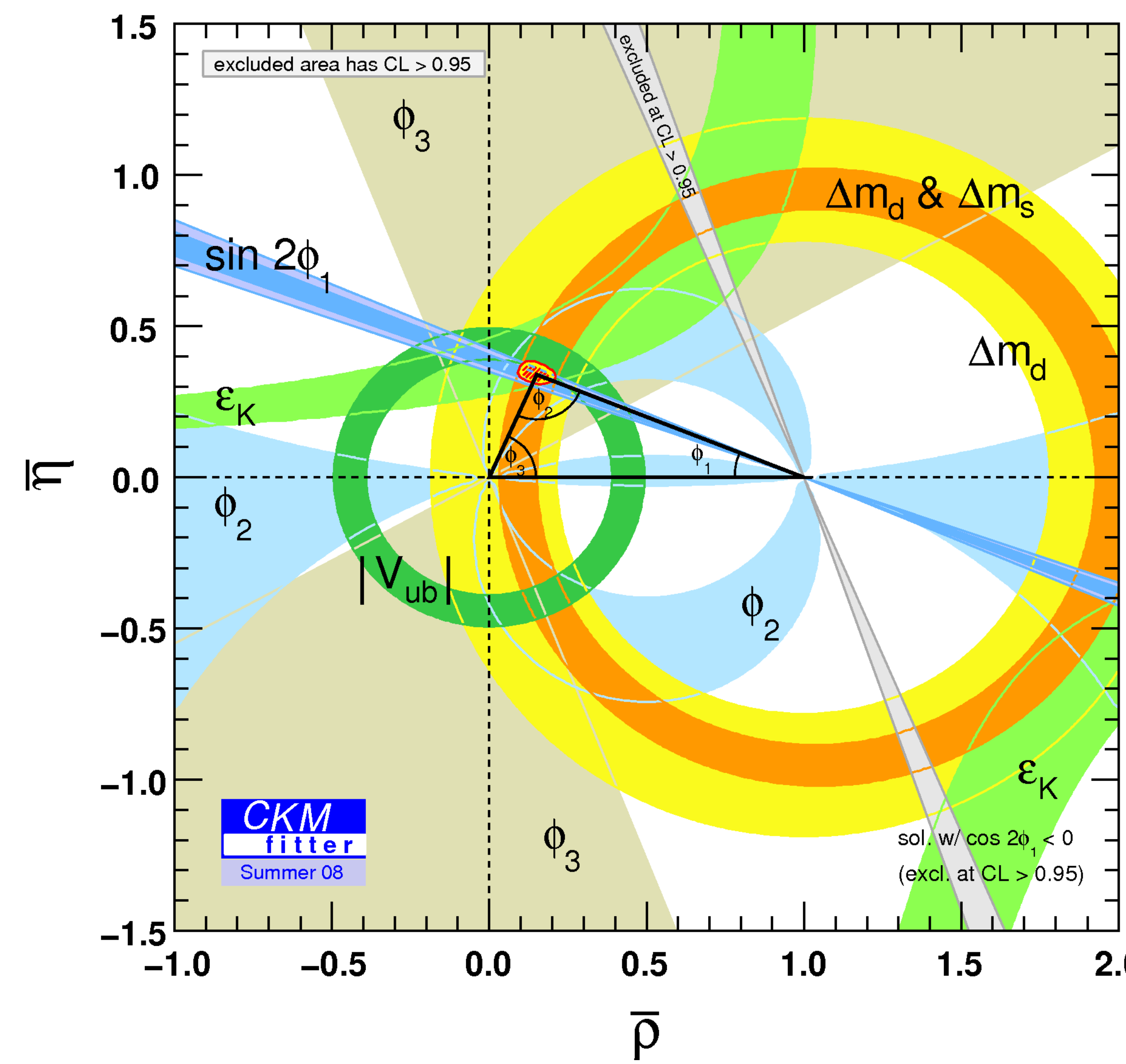


PEP II / BaBar



Confirmation of Kobayashi-Maskawa





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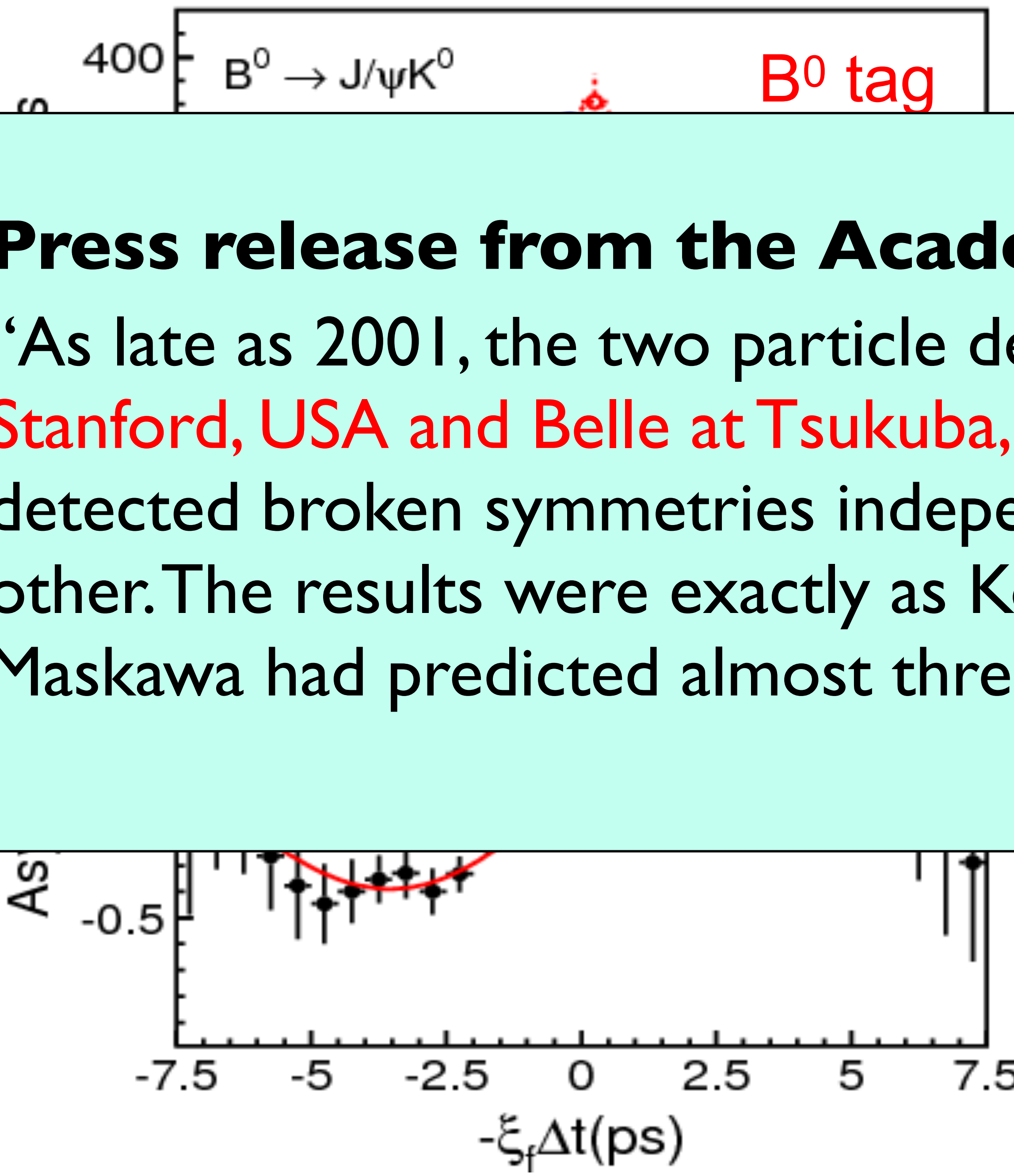
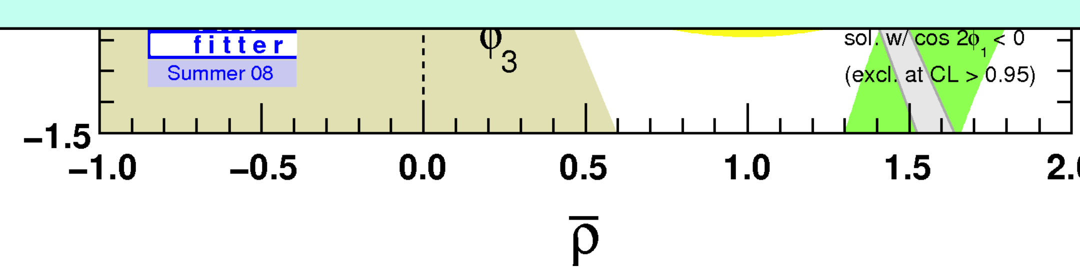
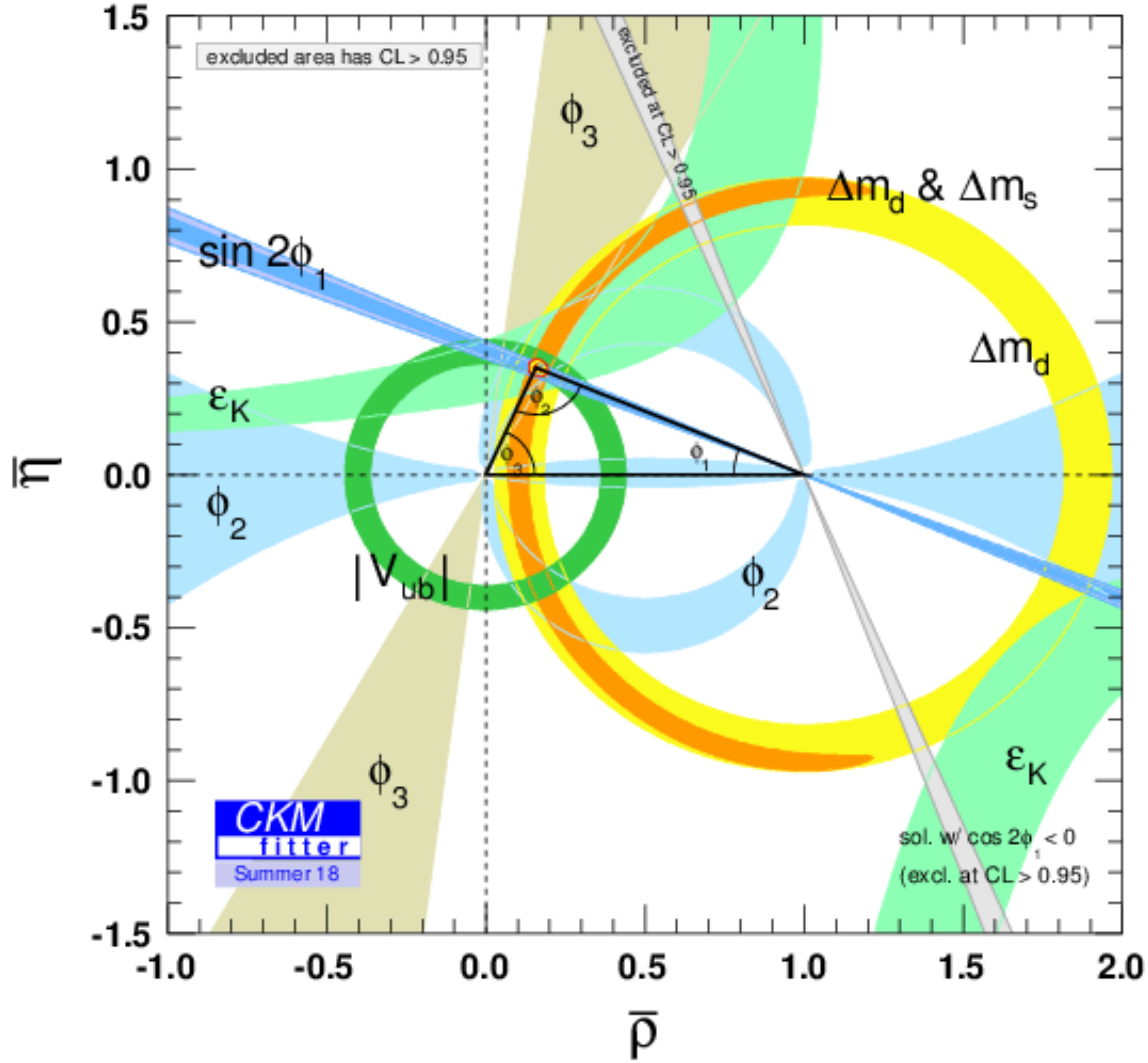


Press release from the Academy

"As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier."



Latest Results (Summer 2018)




Large Hadron Collider
周長27 Km
フランス
ジュネーブ空港
スイス
7TeVの陽子と7TeVの陽子を衝突
世界最高エネルギー14TeVの世界
14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Large Hadron Collider
周長27 Km
ヒッグス粒子発見!
フランス
ジュネーブ空港
スイス
ATLAS
Data 2011+2012
SM Higgs boson m_H=126.8 GeV (fit)
Bkg (4th order polynomial)
H→γγ
√s = 7 TeV ∫Ldt = 4.8 fb⁻¹
√s = 8 TeV ∫Ldt = 20.7 fb⁻¹
Events / 2 GeV
Events - Fitted bkg
m_γγ [GeV]
ATLAS, PLB726, 88 (2013)
7TeVの陽子と7TeVの陽子を衝突
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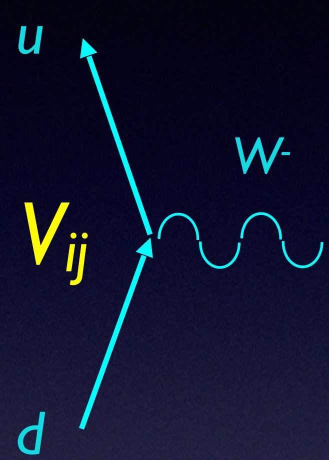
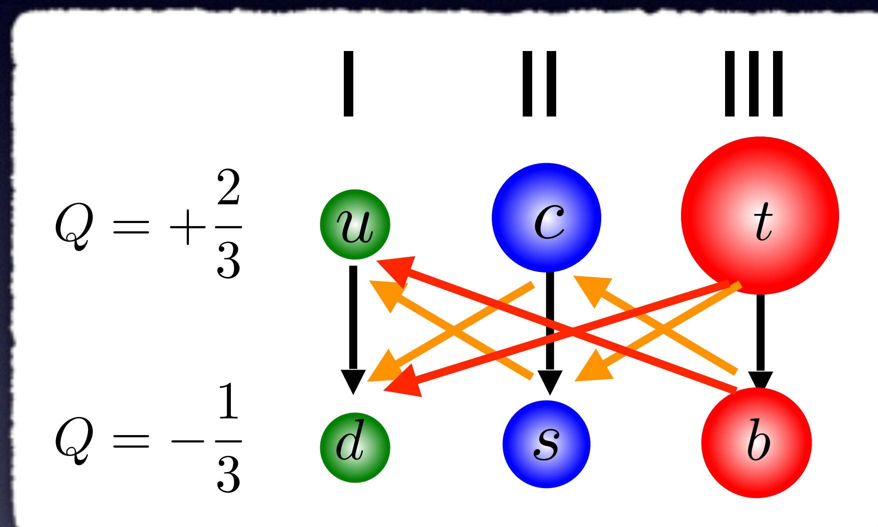
CP Violation and Mass

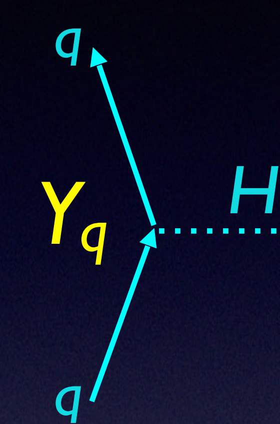
KM Matrix



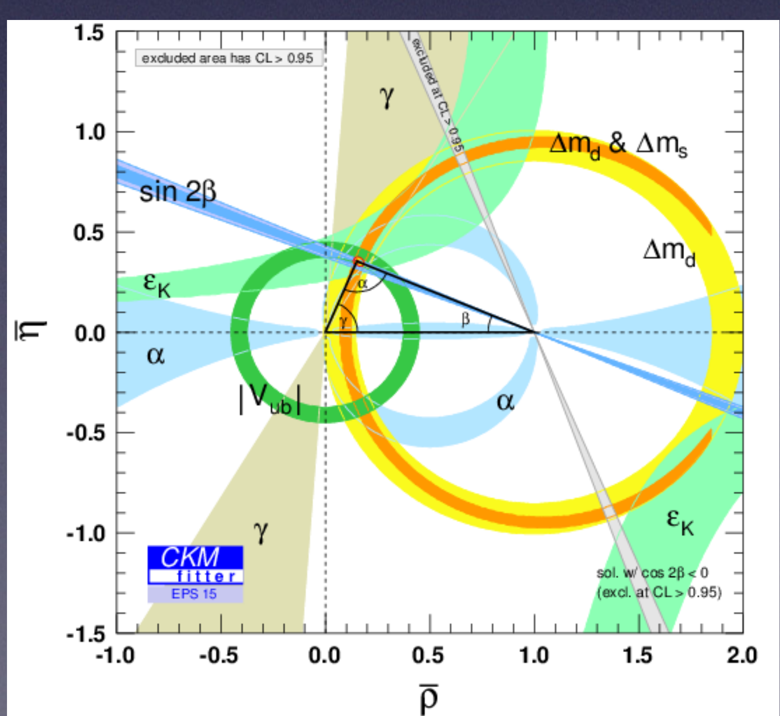
Test of CPV origin



Yukawa coupling



Test of mass origin



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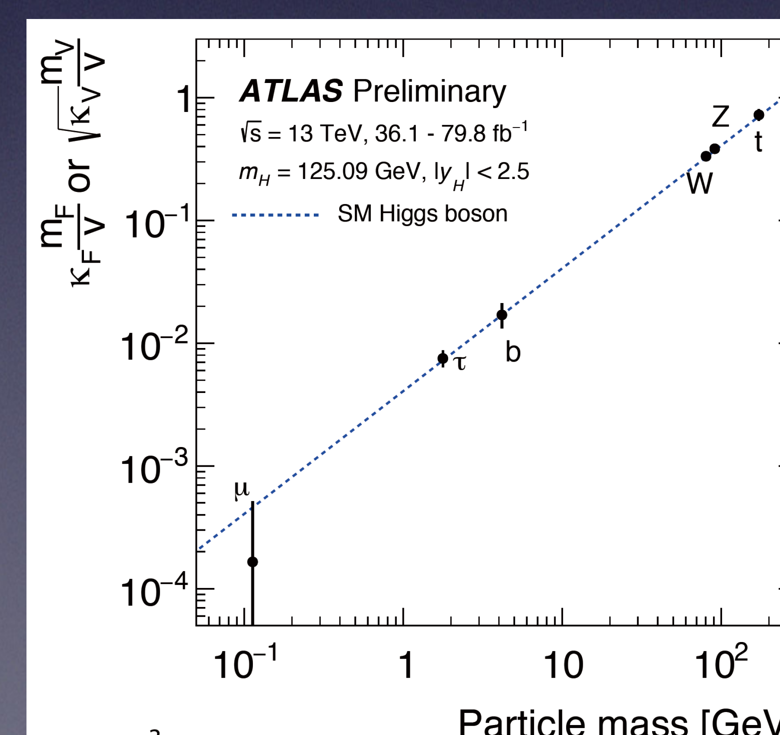
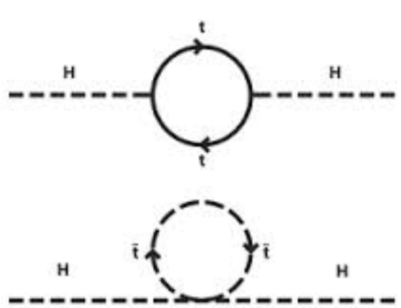
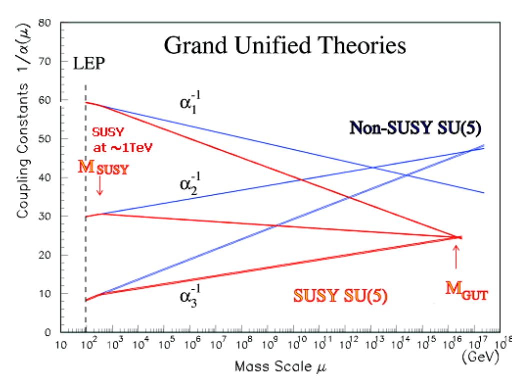


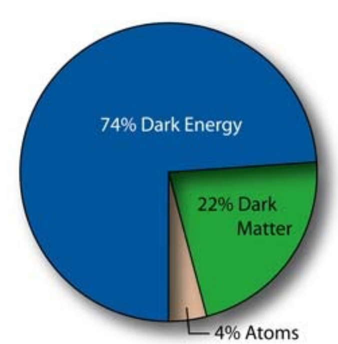
Why do we need go further ?

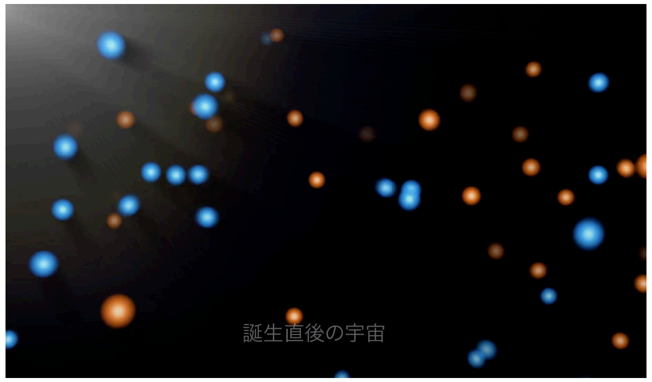
SM explains almost every phenomena so far, but cannot explain

- The Higgs mass (fine tuning problem)
- Grand unification
- Dark matter
- Baryon asymmetry in the Universe
- Origin of the 3 generations









New Physics ! @ O(1→ 10) TeV ?

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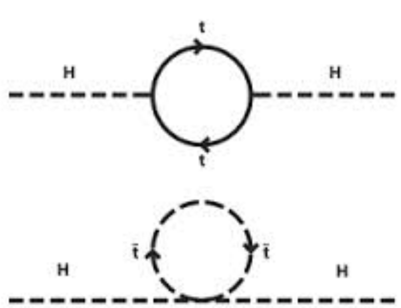
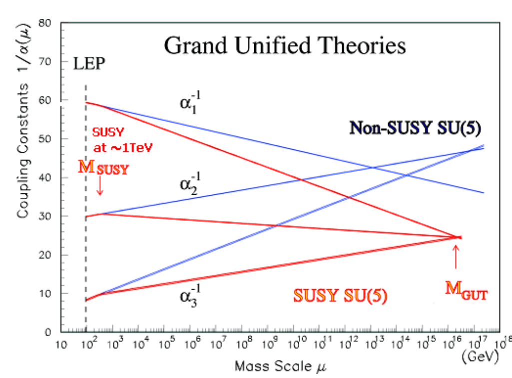
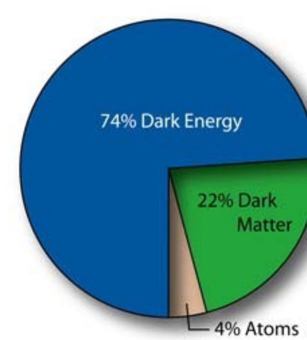
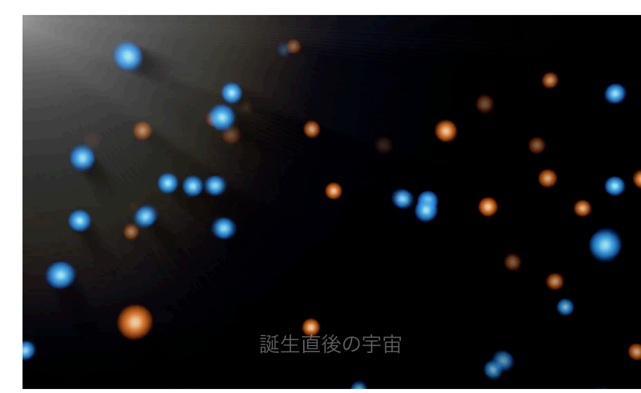




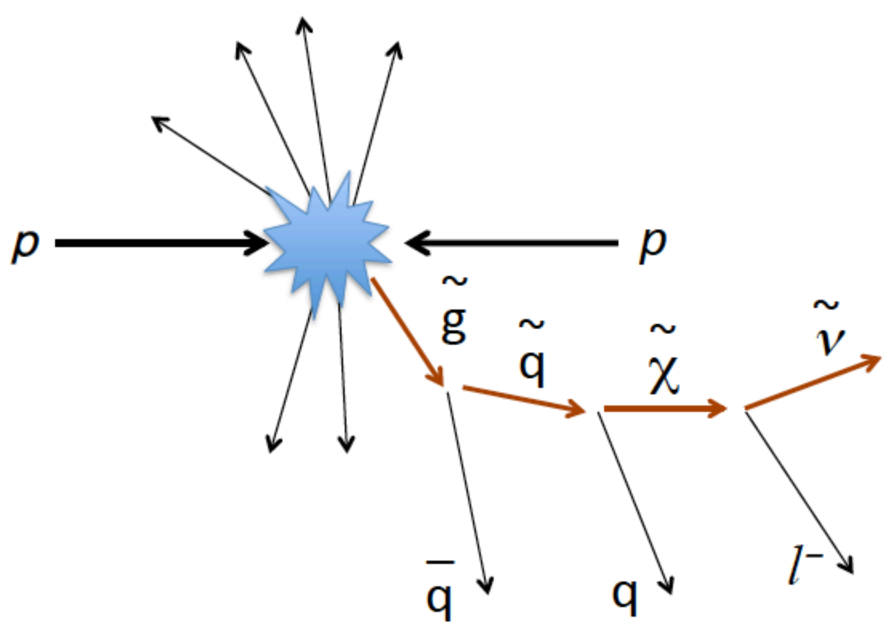


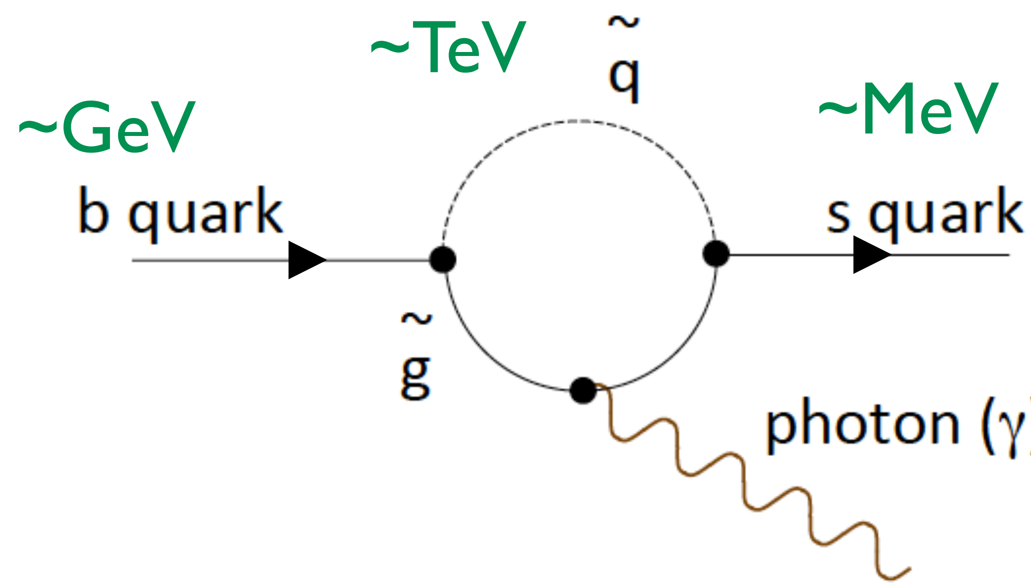


→ New Physics ! @ O(1→ 10) TeV ?

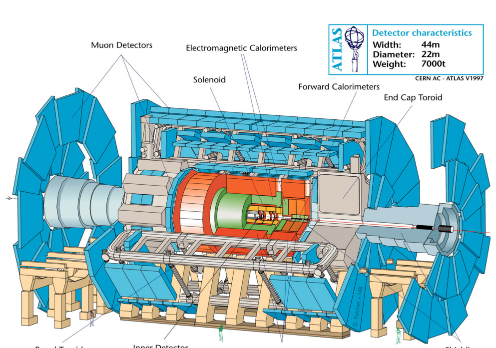
Two Ways to Find New Physics

- **Energy Frontier :** produces and detects a new particle directly in collisions of extremely high energy beams.
- **Luminosity Frontier :** measures reactions of known particles very precisely, and finds deviations from the Standard Model predictions.

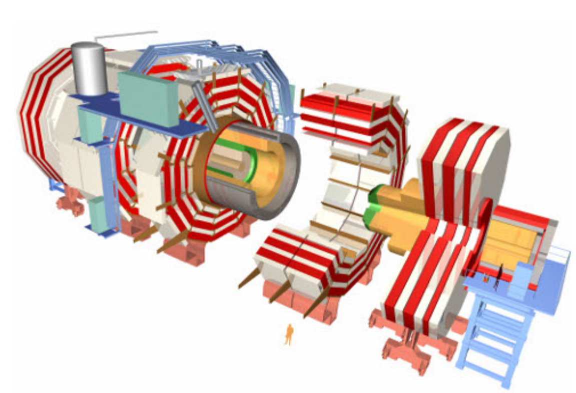




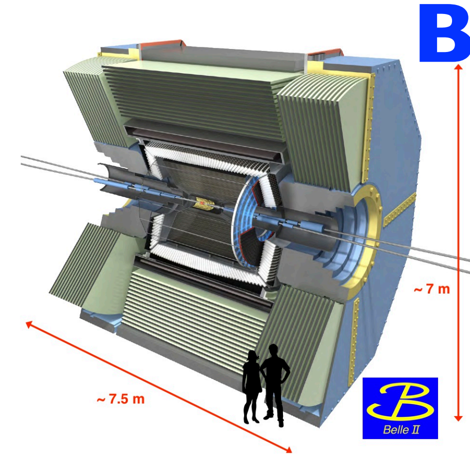
ATLAS



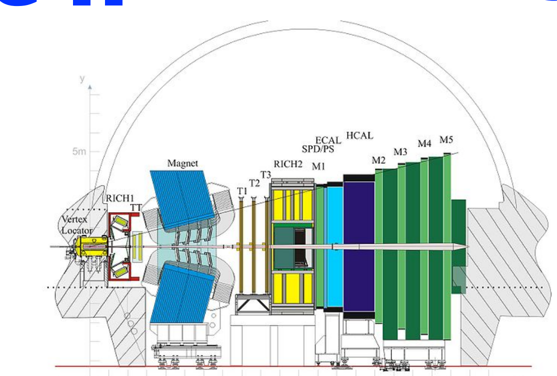
CMS



Belle II



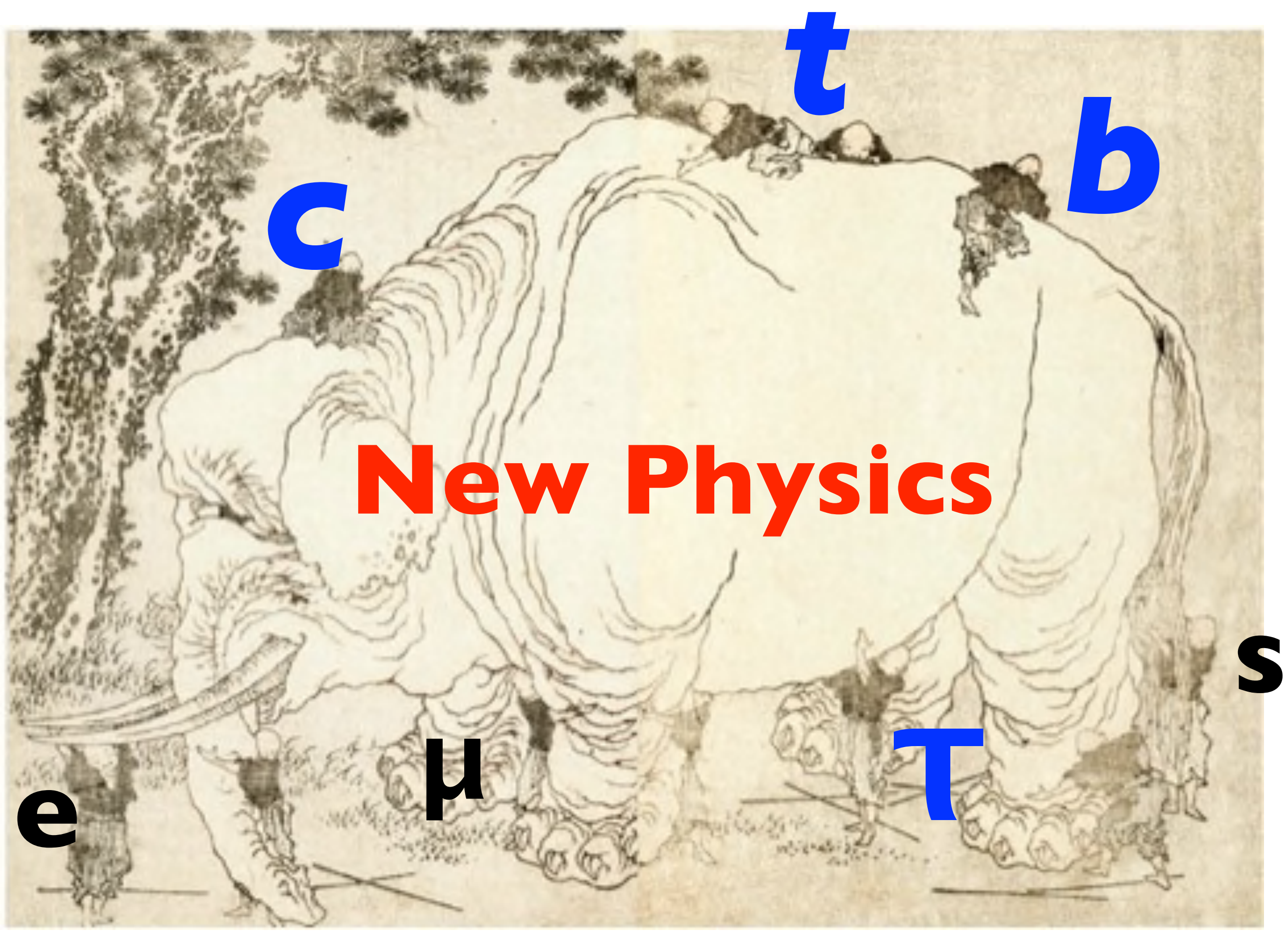
LHCb



Importance of Heavy Flavors

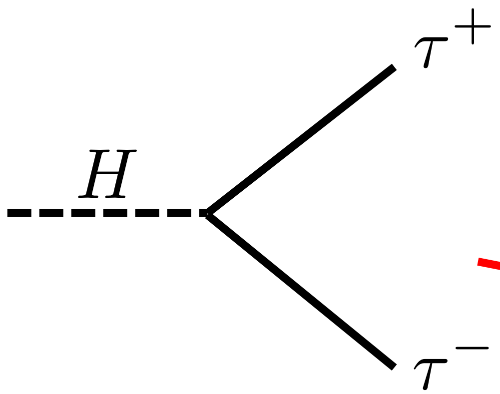
- New Physics is unknown.
- We need a variety of approaches to find and know it.
- Heavy flavor particles (*t*, *b*, *c*, τ) are good probes
  - Sensitive to New Physics

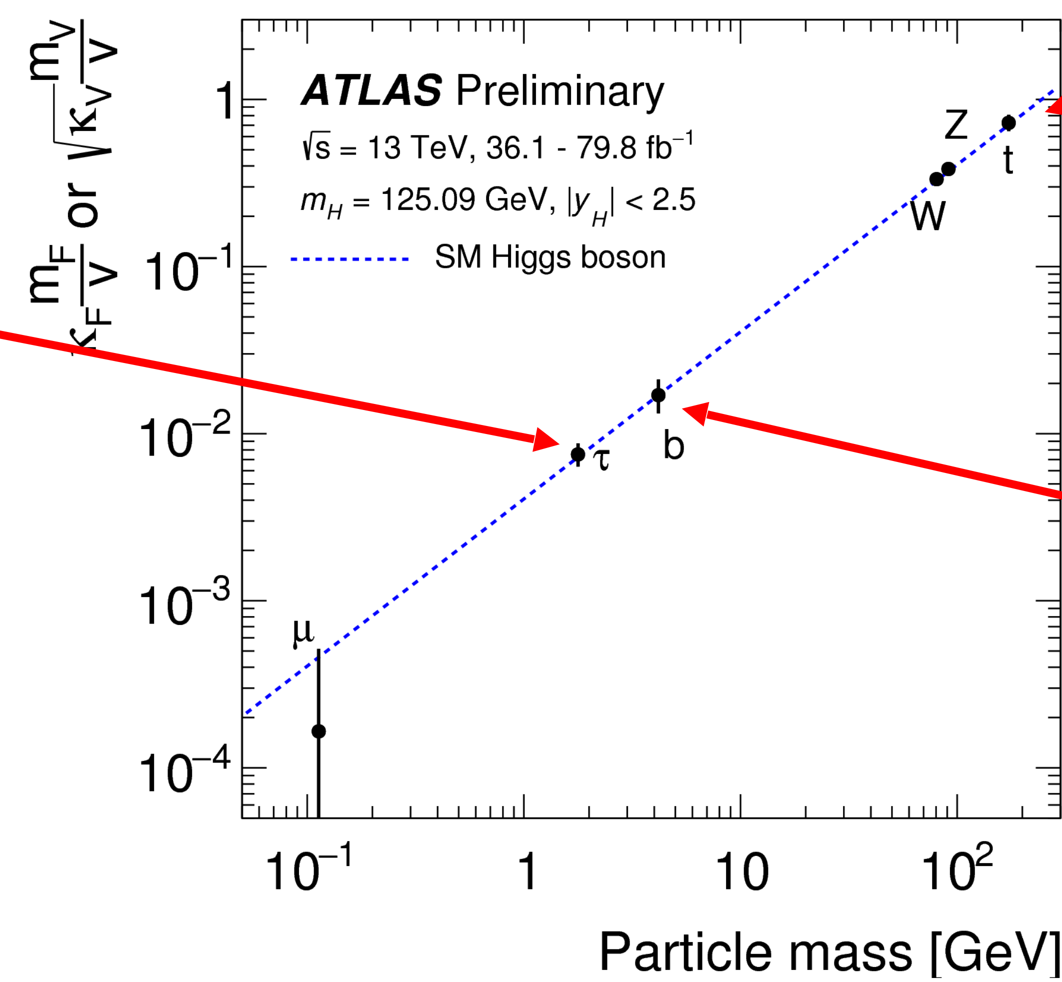
“群盲象を撫でる”

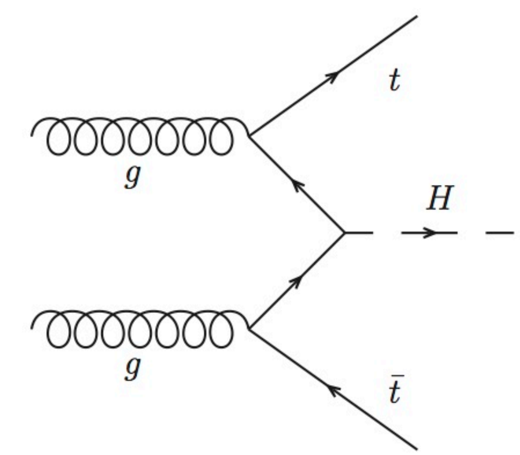


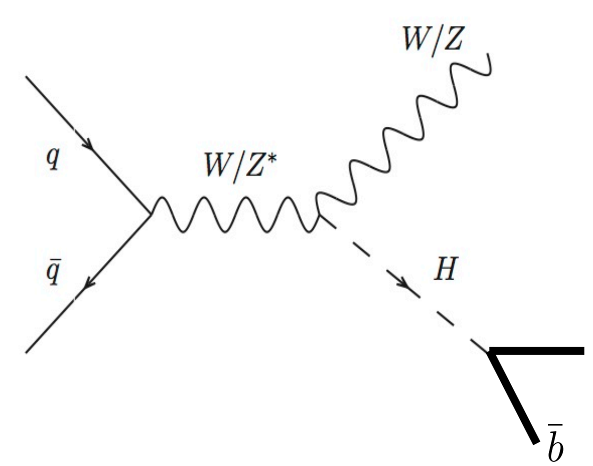
Yukawa couplings to *t*, *b*, τ

- Higgs has been discovered, and its couplings to fermions are being measured.
- Couplings to t, b, τ are just on the stage, and we need more precise measurements to test the SM and also to find NP.









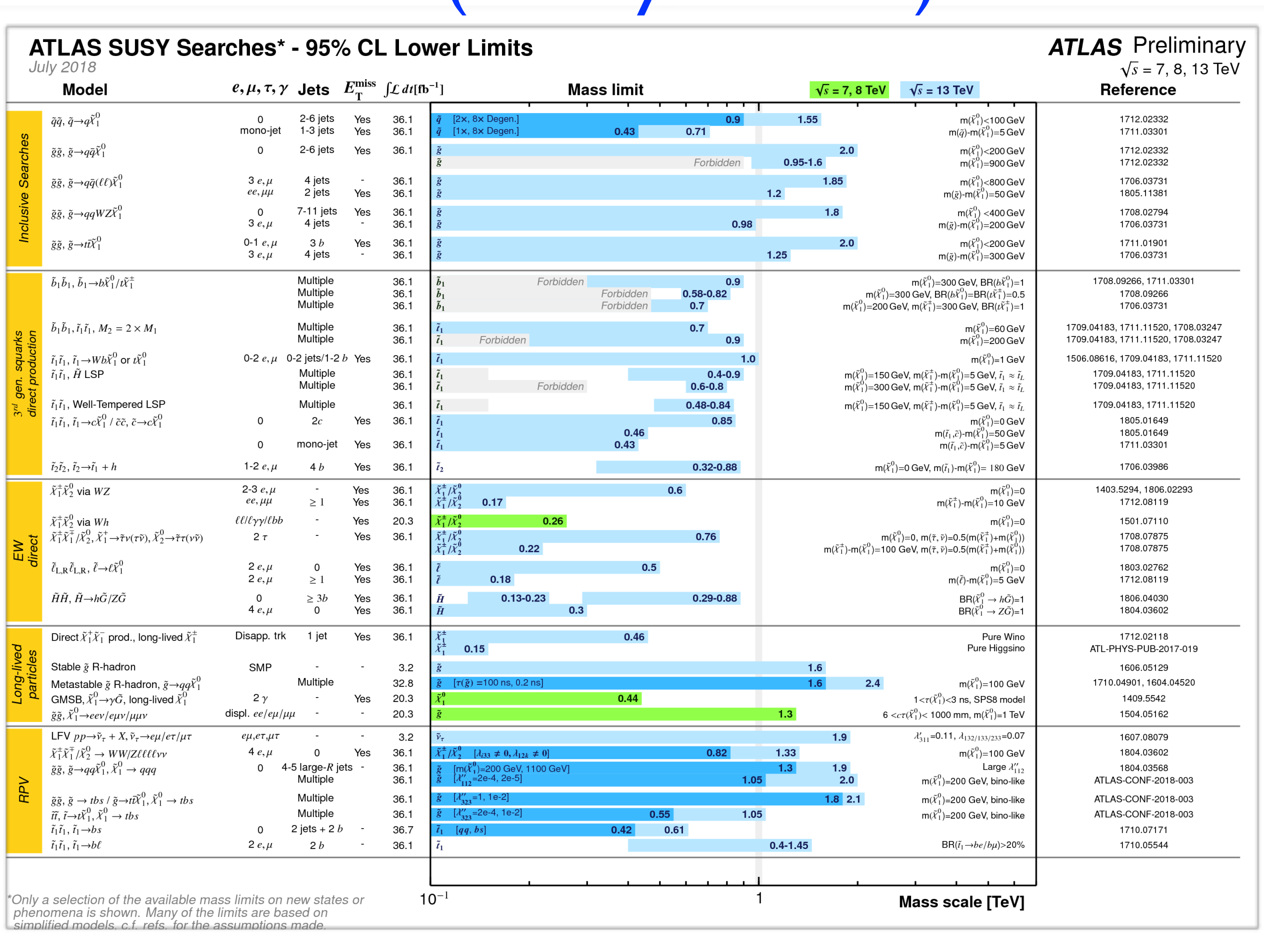
See talk by
Y. Nakahama

Direct NP Searches

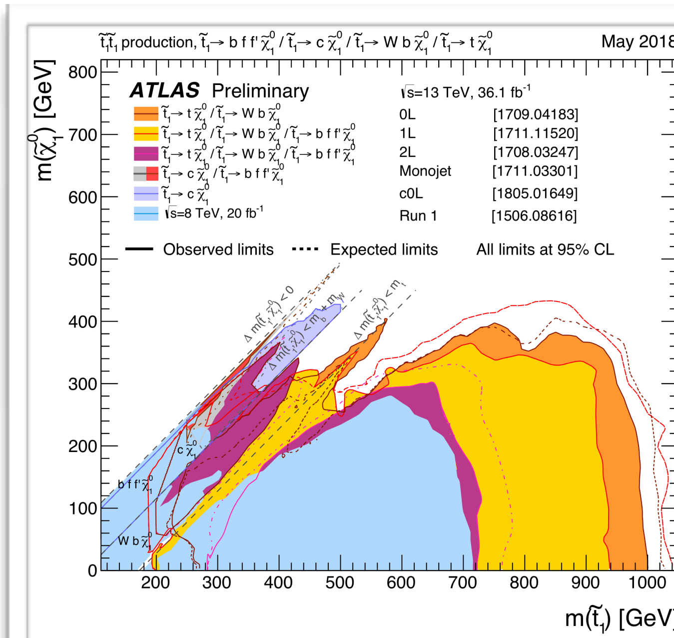
- LHC Run2 (6.5TeV+6.5TeV) completed.
- No NP so far from partial data analyses.
- Extensive analyses for accumulated data (~150fb^{-1}) are underway.

See talk by Y. Nakahama

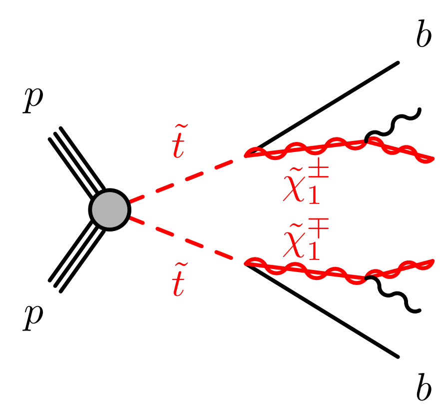
Summer 2018 (mostly 36.1fb^{-1})

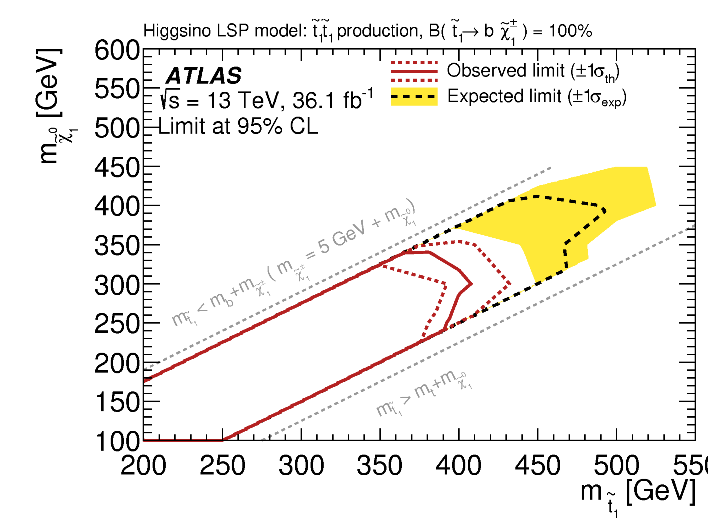


Top quark final states are important part of the LHC NP search program.



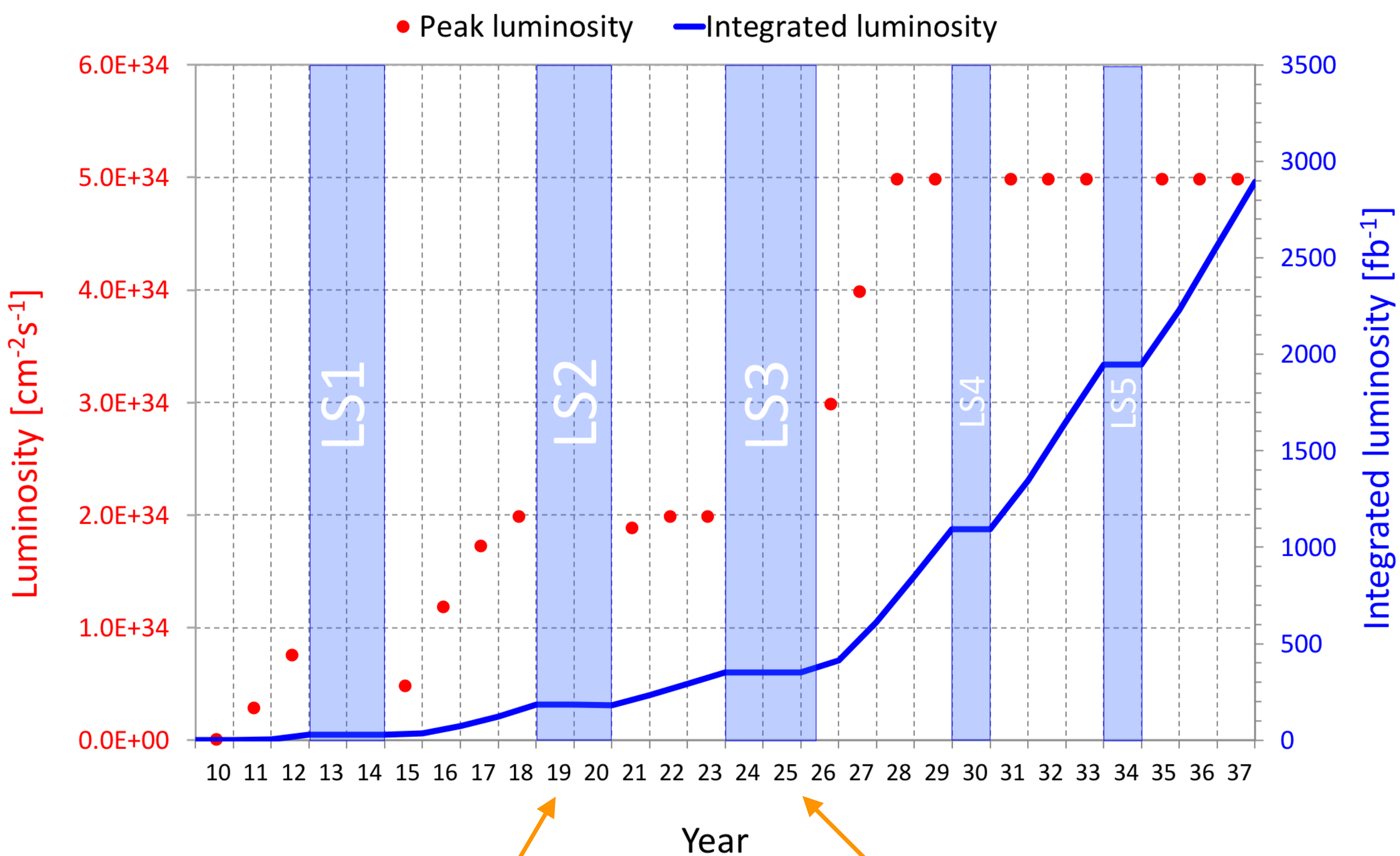
Search for the stop quark of compressed SUSY scenarios in 1-lepton, jets, and missing energy final state





LHC Long-term Plan

Run1	Run2	Run3	HL-LHC
7→8 TeV	13 TeV	14 TeV	14 TeV
$30 fb^{-1}$	$150 fb^{-1}$	$300 fb^{-1}$	$\rightarrow 3000 fb^{-1}$



ATLAS upgrade Phase 1

ATLAS upgrade Phase 2

See talk by Y. Okumura

SuperKEKB/Belle II

See talk by K. Trabelsi

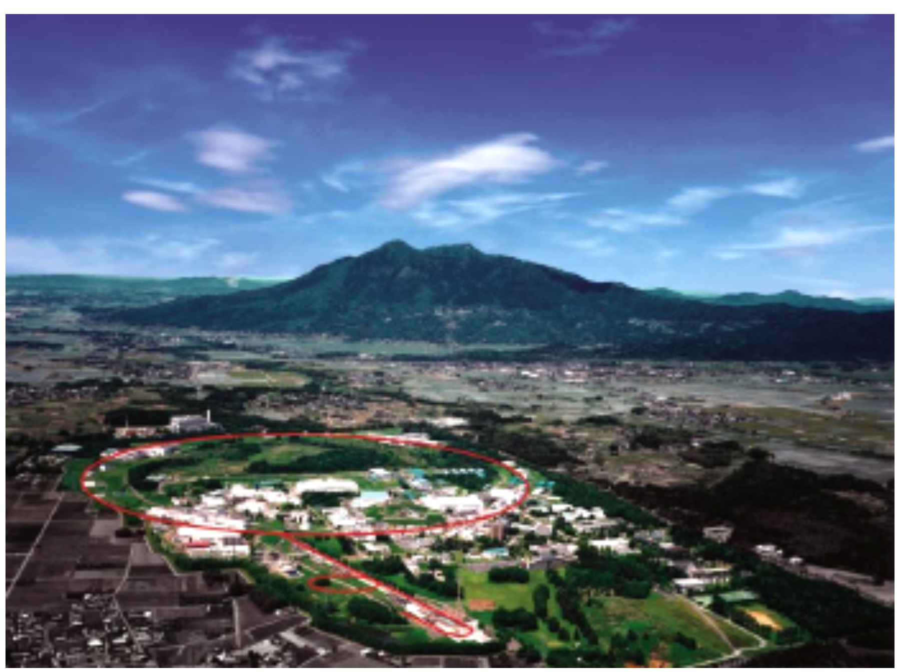
New intensity frontier facility at KEK

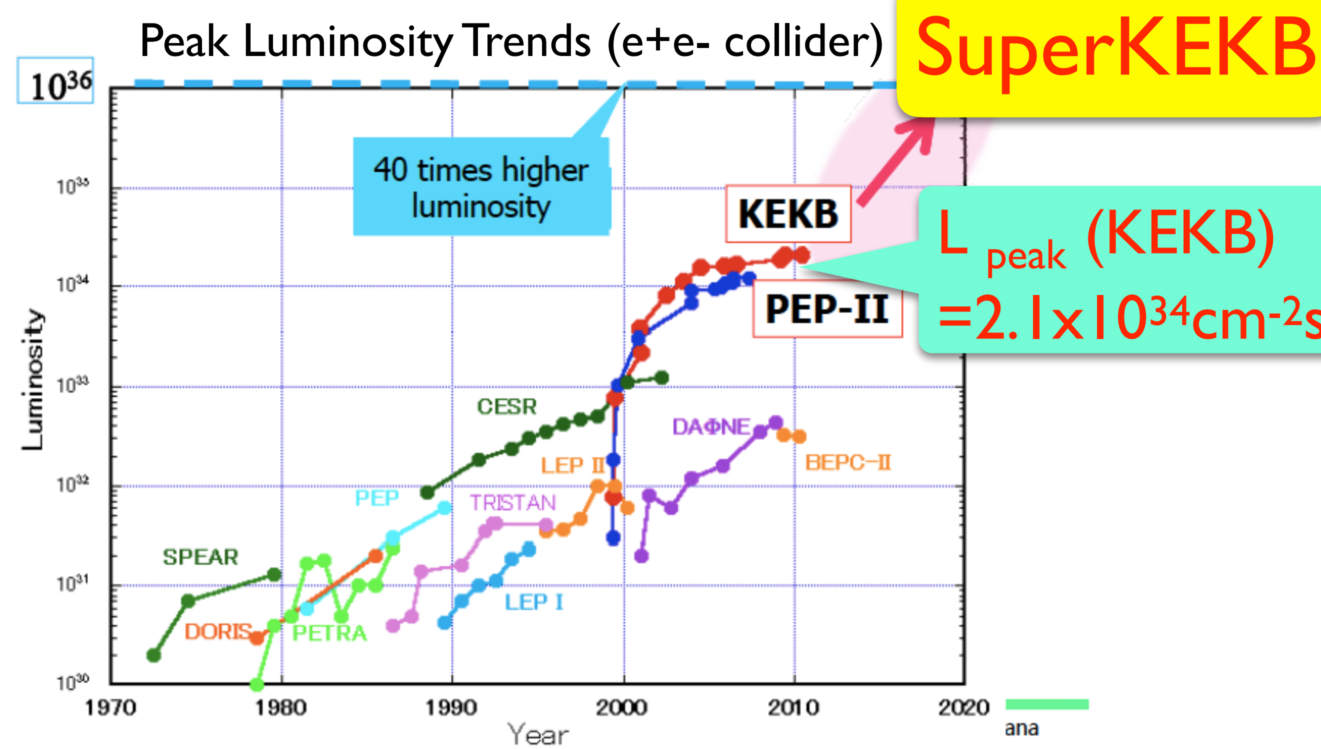
- Target luminosity ; $L_{peak} = 8 \times 10^{35} cm^{-2}s^{-1}$

  $\Rightarrow \sim 10^{10}\ B\bar{B}$, $\tau^+\tau^-$ and charms per year !

  $L_{int} > 50\ ab^{-1}$

- Rich physics program
  - Search for New Physics through processes sensitive to virtual heavy particles.
  - New QCD phenomena (XYZ, new states including heavy flavors) + more





The first particle collider after the LHC !

10 years later from KM's Nobel Prize,
we are starting a new experiment
SuperKEKB/Belle II
to search for new phenomena beyond KM.

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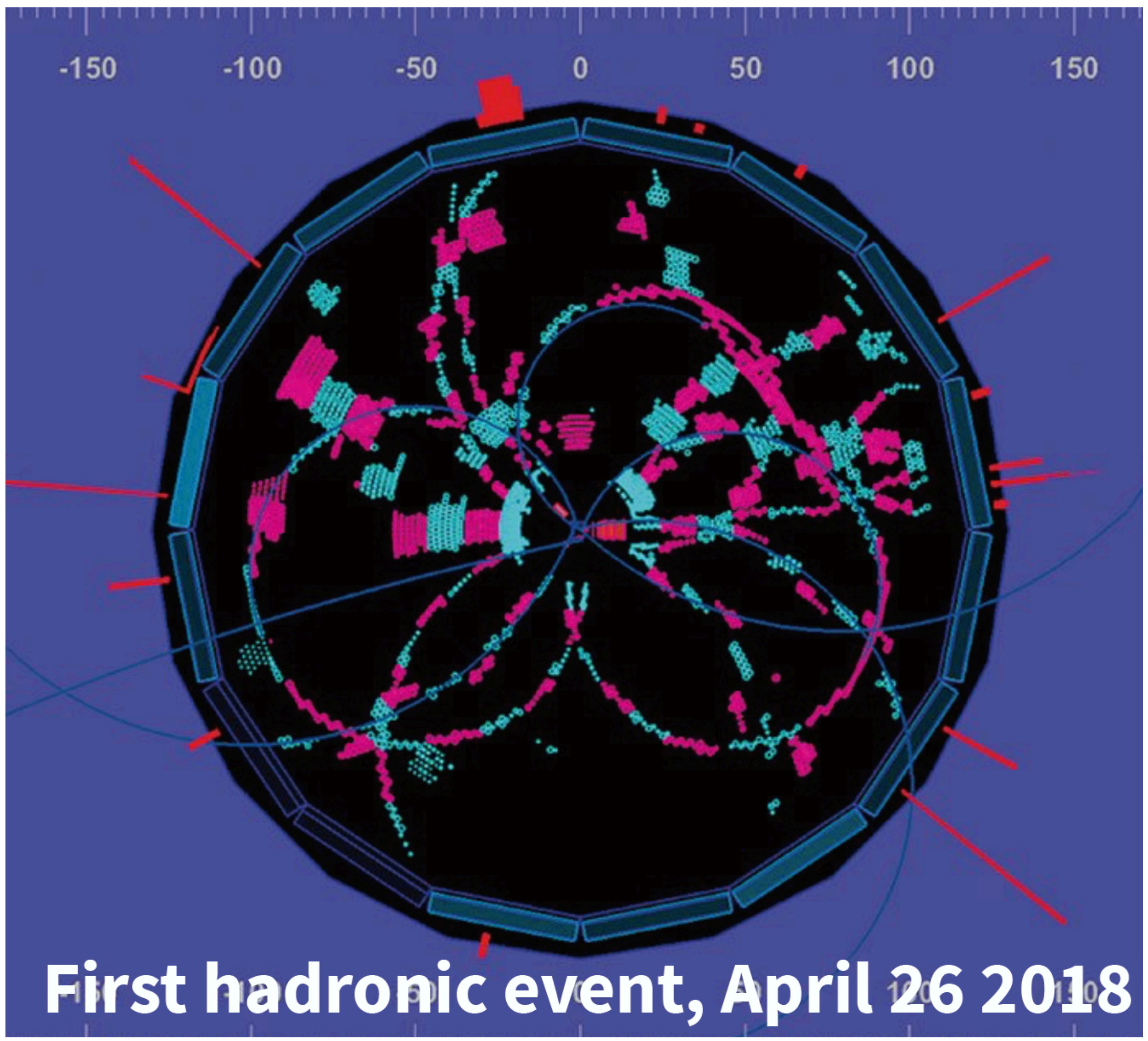
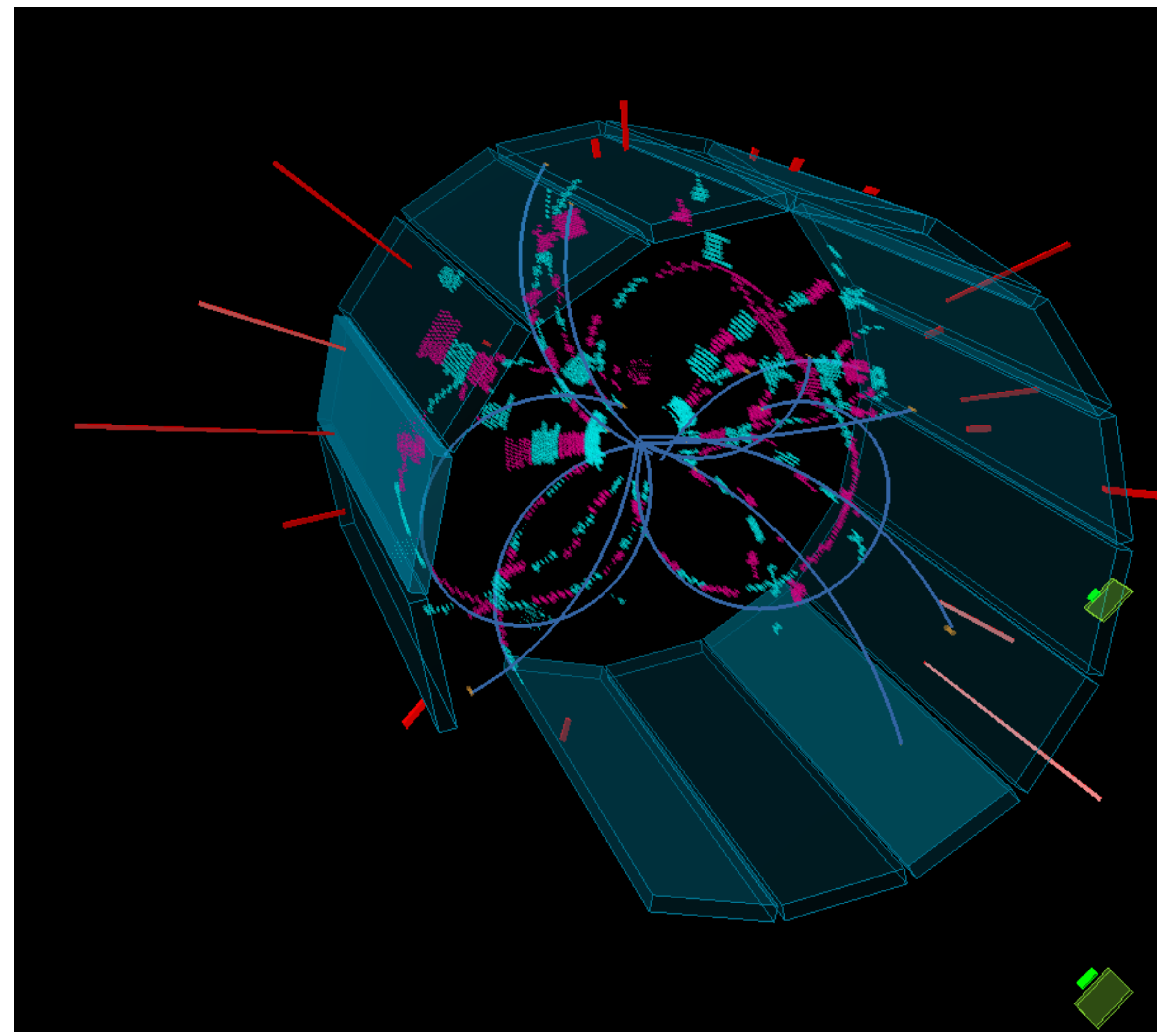
First Collision !

0:38, April 26, 2018





First Collision !

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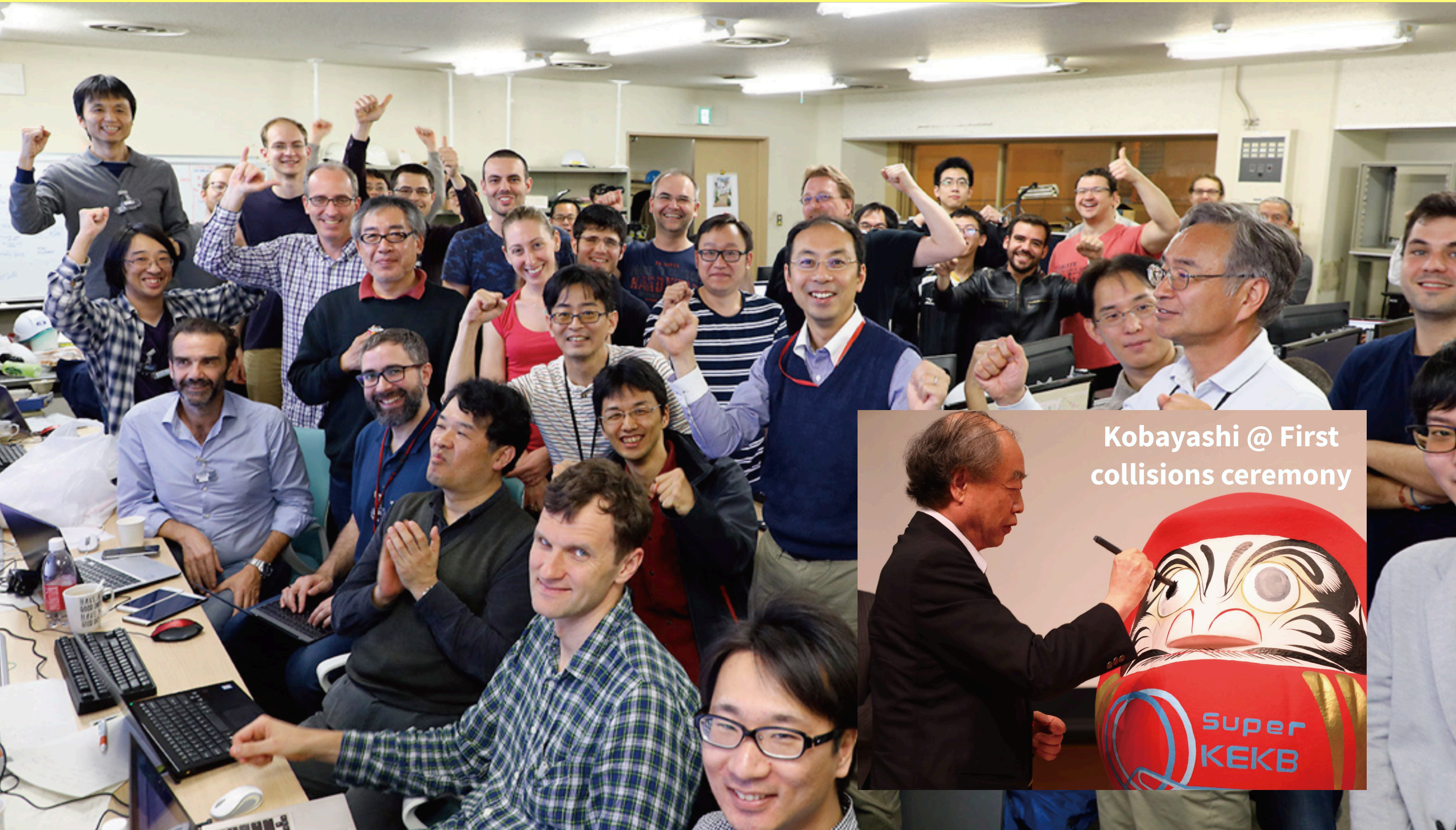
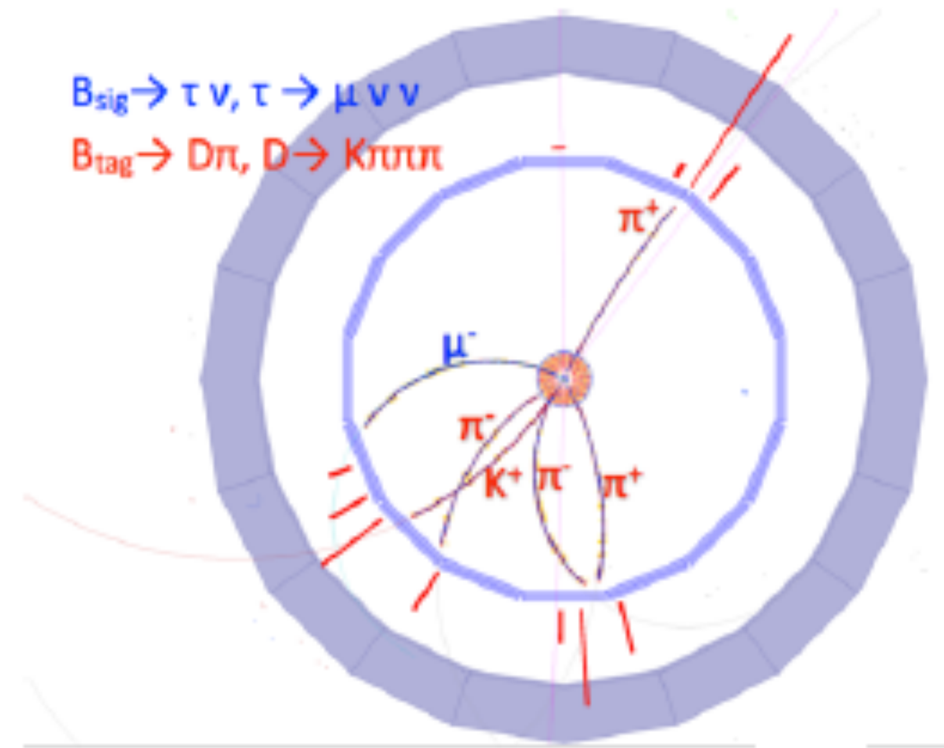
First Collision !

0:38, April 26, 2018

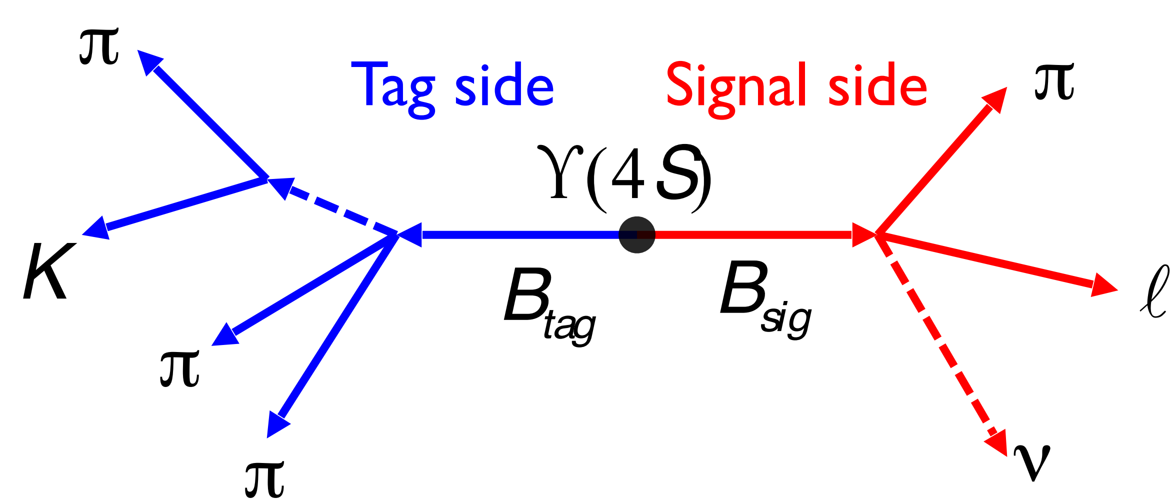


Advantage of e^+e^- Flavor Factory

- Clean environment
  - Efficient detection of neutrals (γ, π^0, η, …)
- Quantum correlated $B^0\overline{B}^0$ pairs
  - High effective flavor tagging efficiency :
  ~34%(Belle II) ⟷ ~3% (LHCb)
- Large sample of τ leptons
  - Search for LFV τ decays at $O(10^{-9})$



- Full reconstruction tagging possible
  - A powerful tool to measure;
    - b→u semileptonic decays (CKM)
    - decays with large missing energy



- Systematics different from LHCb
  - Two experiments are required to establish NP

$B \to \pi l \nu$

$B \to \tau \nu$, $D \tau \nu$

$B \to K \nu \nu$

Advantage of e^+e^- Flavor Factory

LHCb

Belle II

pp collision
large production rate

e^+e^- collision
low background

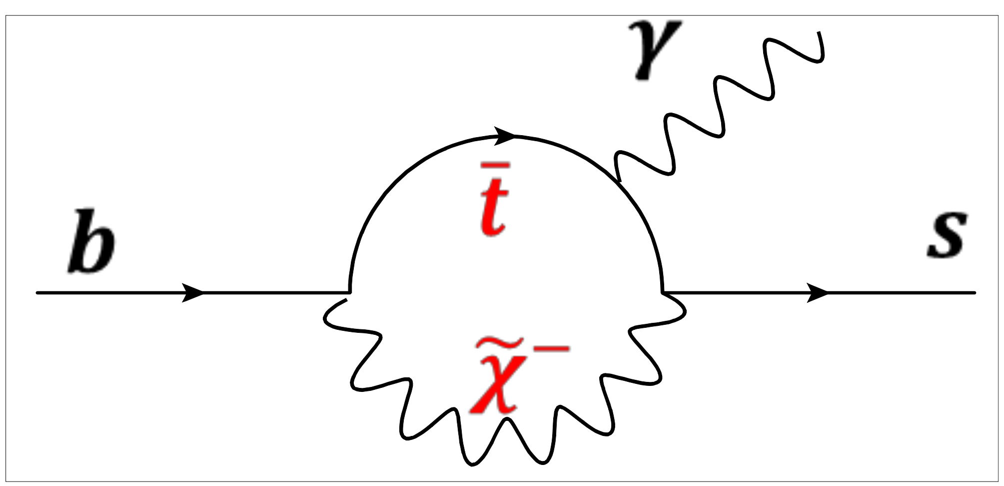
Powerful !

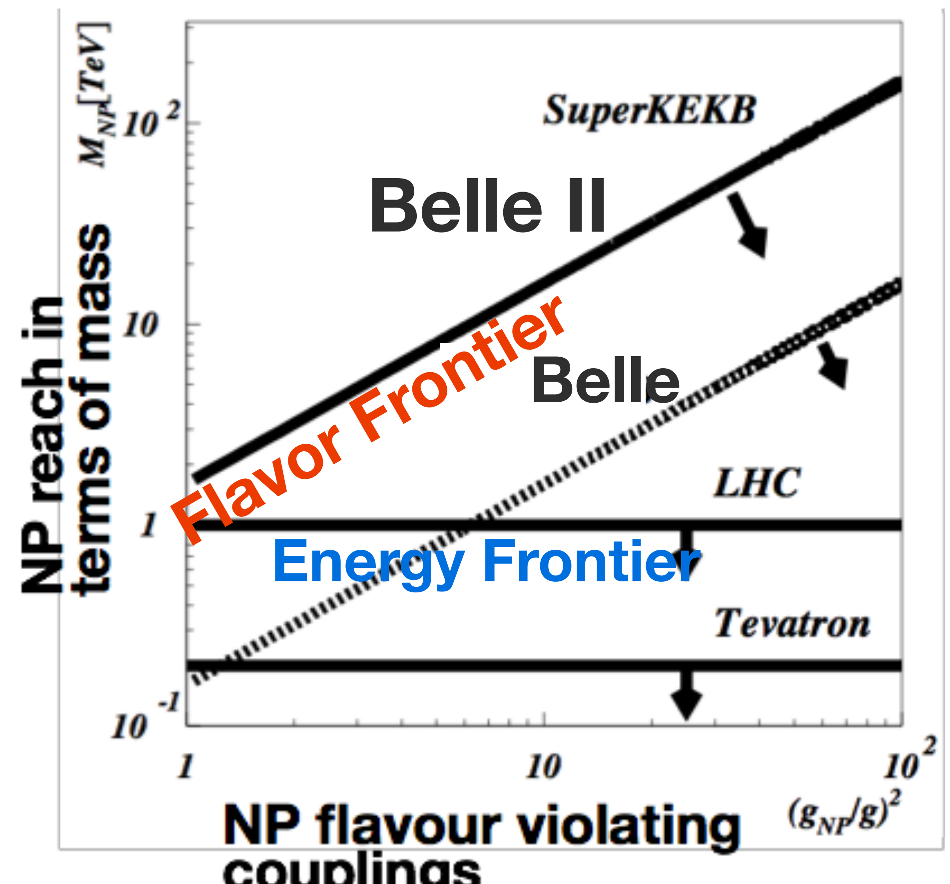
Clean !

TOYOTA FCV
NOW ON MARKET !

Role of the Belle II Experiment

- Complementary to direct search in LHC high P_T programs.
- Reach in mass scale is not limited by the collision energy.
  - Depend on NP flavor violating couplings.





Key Measurements at Belle II

arXiv:1002.5012

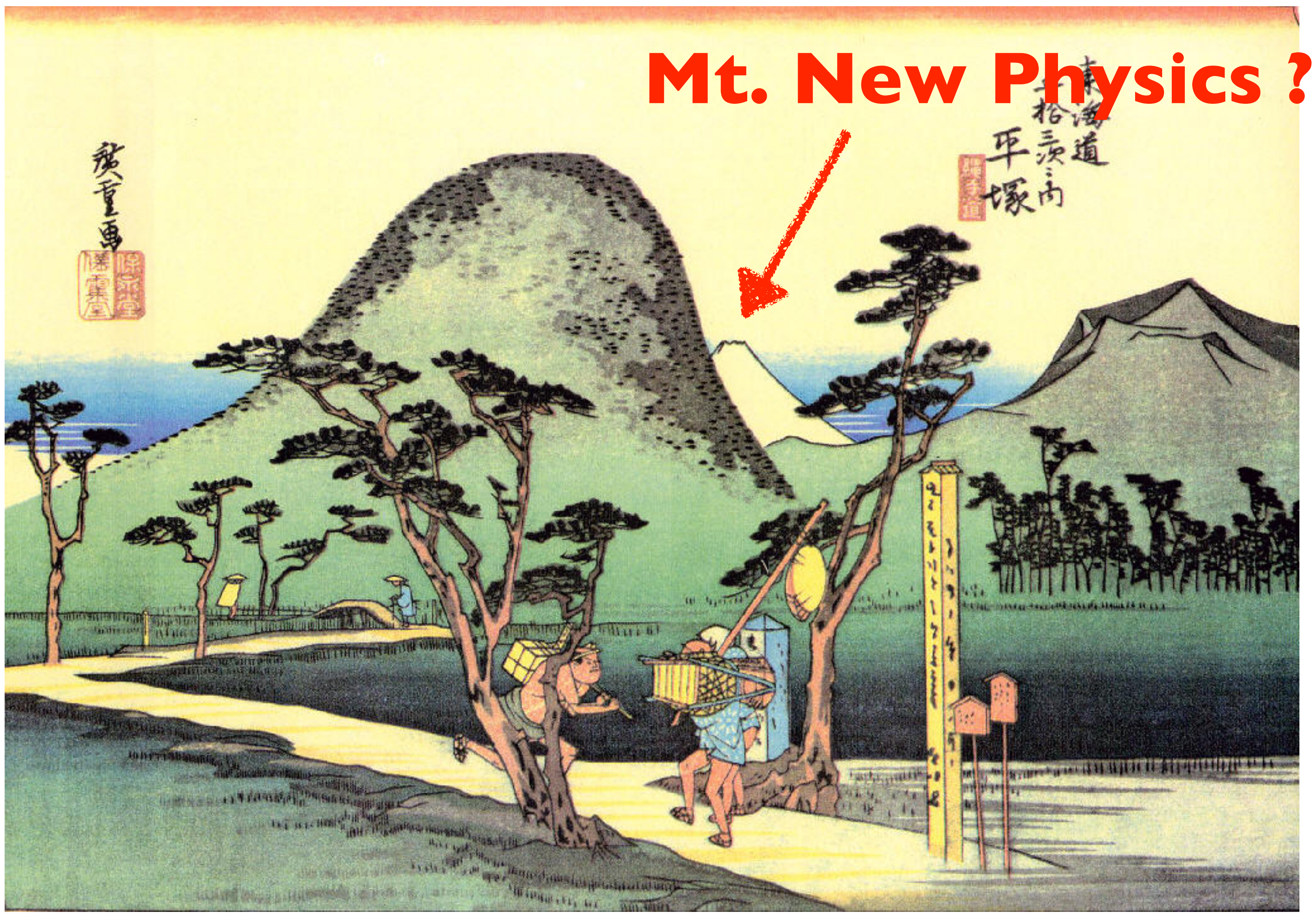
- CPV in b→s penguin decays
- FCNC
- Tauonic decays
- LFV τ decays

Observable	Belle 2006 ($\sim$0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})
Hadronic $b \to s$ transitions			
$\Delta\mathcal{S}_{\phi K^0}$	0.22	0.073	0.029
$\Delta\mathcal{S}_{\eta' K^0}$	0.11	0.038	0.020
$\Delta\mathcal{S}_{K^0_S K^0_S K^0_S}$	0.33	0.105	0.037
$\Delta\mathcal{A}_{\pi^0 K^0_S}$	0.15	0.072	0.042
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°
Radiative/electroweak $b \to s$ transitions			
$\mathcal{S}_{K^0_S \pi^0 \gamma}$	0.32	0.10	0.03
$\mathcal{B}(B \to X_s\gamma)$	13%	7%	6%
$A_{CP}(B \to X_s\gamma)$	0.058	0.01	0.005
C_9 from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-	11%	4%
C_{10} from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-	13%	4%
C_7/C_9 from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-		5%
R_K		0.07	0.02
$\mathcal{B}(B^+ \to K^+\nu\nu)$	$^{\dagger\dagger} < 3\ \mathcal{B}_{\rm SM}$		30%
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	$^{\dagger\dagger} < 40\ \mathcal{B}_{\rm SM}$		35%
Radiative/electroweak $b \to d$ transitions			
$\mathcal{S}_{\rho\gamma}$	-	0.3	0.15
$\mathcal{B}(B \to X_d\gamma)$	-	24% (syst.)	
Leptonic/semileptonic B decays			
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%
$\mathcal{B}(B^+ \to \mu^+\nu)$	$^{\dagger\dagger} < 2.4\mathcal{B}_{\rm SM}$	4.3 ab^{-1} for 5σ discovery	
$\mathcal{B}(B^+ \to D\tau\nu)$	-	8%	3%
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%
LFV in τ decays (U.L. at 90% C.L.)			
$\mathcal{B}(\tau \to \mu\gamma)$ [10^{-9}]	45	10	5
$\mathcal{B}(\tau \to \mu\eta)$ [10^{-9}]	65	5	2
$\mathcal{B}(\tau \to \mu\mu\mu)$ [10^{-9}]	21	3	1

Ultimate measurements down to theory error !

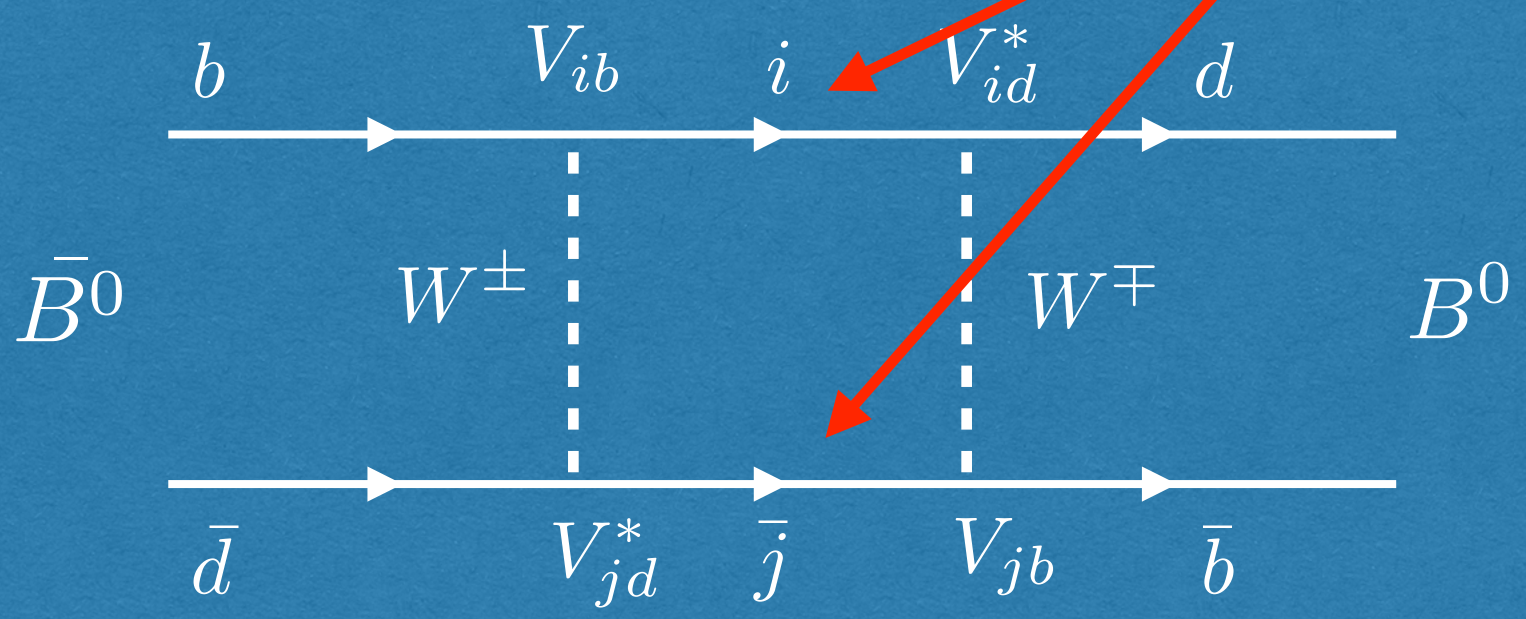
Physics w/ b-quark

We know this old road…



by Hiroshige Utagawa (1797-1858)

B-$\bar{\text{B}}$ Mixing and Top Quark



$$A(\bar{B}^0 \to B^0) = |A| \times e^{-\alpha_B}$$

$$\alpha \sim 2\arg(V_{td}V_{tb}^*)$$

OBSERVATION OF B^0–$\bar{B}^0$ MIXING

ARGUS Collaboration

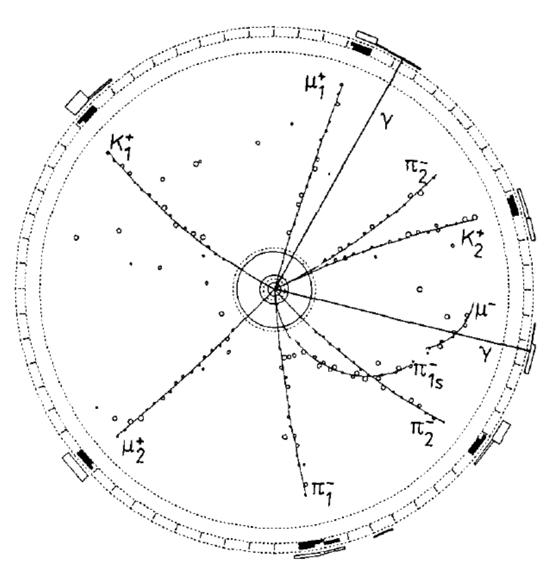


Fig. 2. Completely reconstructed event consisting of the decay $\Upsilon(4S) \to B^0B^0$.

$$B_1^0 \to D_1^{*-}\mu_1^+\nu_1$$
$$\downarrow$$
$$D_1^{*-} \to \pi_1^- \bar{D}^0$$
$$\downarrow$$
$$\bar{D}^0 \to K_1^+\pi_1^- ,$$

and

$$B_2^0 \to D_2^{*-}\mu_2^+\nu_2$$
$$\downarrow$$
$$D_2^{*-} \to \pi^0 D^-$$
$$\downarrow$$
$$D^- \to K_2^+\pi_2^-\pi_2^- .$$

e 3

ts on parameters consistent with the observed mixing rate.

Parameters	Comments
$r > 0.09$ (90%CL)	this experiment
$x > 0.44$	this experiment
$B^{1/2}f_B \approx f_\pi < 160$ MeV	B meson ($\approx$ pion) decay constant
$m_b < 5$ GeV/c^2	b-quark mass
$\tau < 1.4 \times 10^{-12}$s	B meson lifetime
$\|V_{td}\| < 0.018$	Kobayashi–Maskawa matrix element
$\eta_{QCD} < 0.86$	QCD correction factor [a]
$m_t > 50$ GeV/c^2	t quark mass

f. [18].

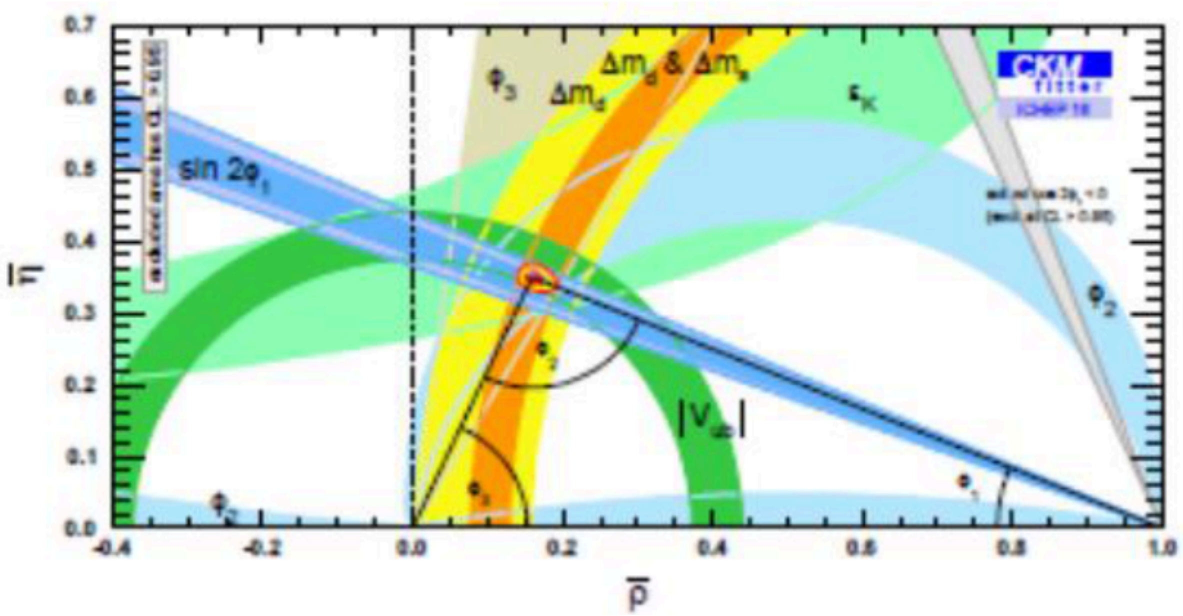
Mt > 50 GeV/c²

CKM fit w/ Belle II + LHCb

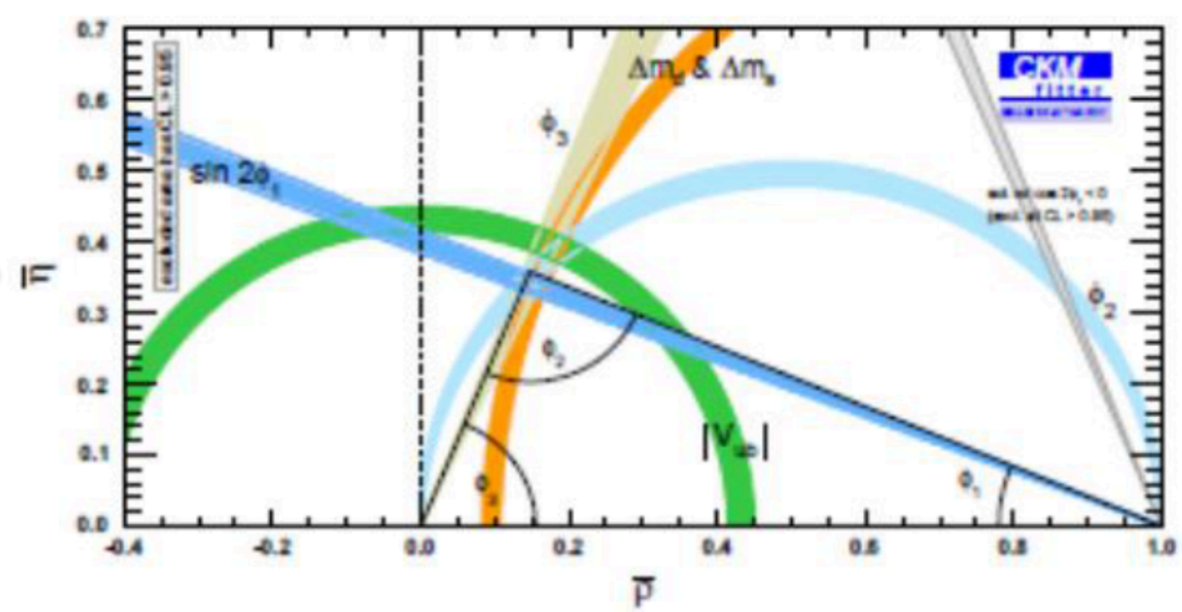
Input	Current WA	SM value Belle II	SM value Belle II+LHCb
A	$0.8227^{+0.0066}_{-0.0136}$	$^{+0.0025}_{-0.0027}$	$^{+0.0024}_{-0.0028}$
λ	$0.22543^{+0.00042}_{-0.00031}$	0.00036 -0.00030	0.00035 -0.00030
$\bar{\rho}$	$0.1504^{+0.0121}_{-0.0062}$	$^{+0.0054}_{-0.0044}$	$^{+0.0042}_{-0.0040}$
$\bar{\eta}$	$0.3540^{+0.00069}_{-0.0076}$	$^{+0.0037}_{-0.00040}$	$^{+0.0036}_{-0.00037}$

1808.10567

Current world average



Belle II projection @ $50ab^{-1}$



CKM fit w/ Belle II + LHCb

Input	Current WA	SM value Belle II	SM value Belle II+LHCb
A	$0.8227^{+0.0066}_{-0.0136}$	$^{+0.0025}_{-0.0027}$	$^{+0.0024}_{-0.0028}$
λ	$0.22543^{+0.00042}_{-0.00031}$	$^{0.00036}_{-0.00030}$	$^{0.00035}_{-0.00030}$
$\bar{\rho}$	$0.1504^{+0.0121}_{-0.0062}$	$^{+0.0054}_{-0.0044}$	$^{+0.0042}_{-0.0040}$
$\bar{\eta}$	$0.3540^{+0.00069}_{-0.0076}$	$^{+0.0037}_{-0.00040}$	$^{+0.0036}_{-0.00037}$

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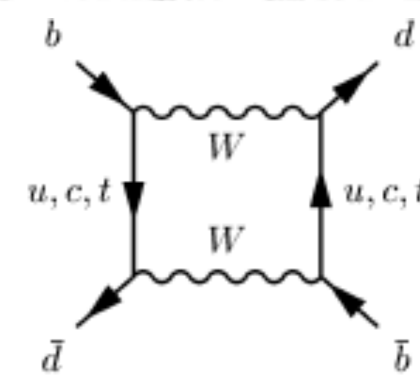
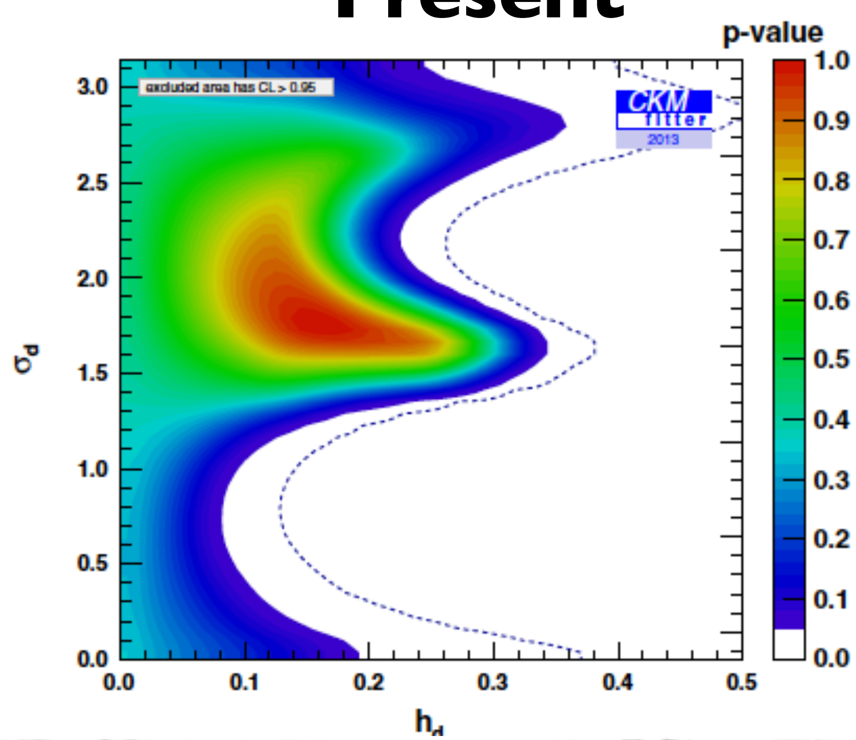
$$M_{12}^{d,s} = (M_{12}^{d,s})_{\rm SM} \times (1 + h_{d,s} e^{2i\sigma_{d,s}})$$

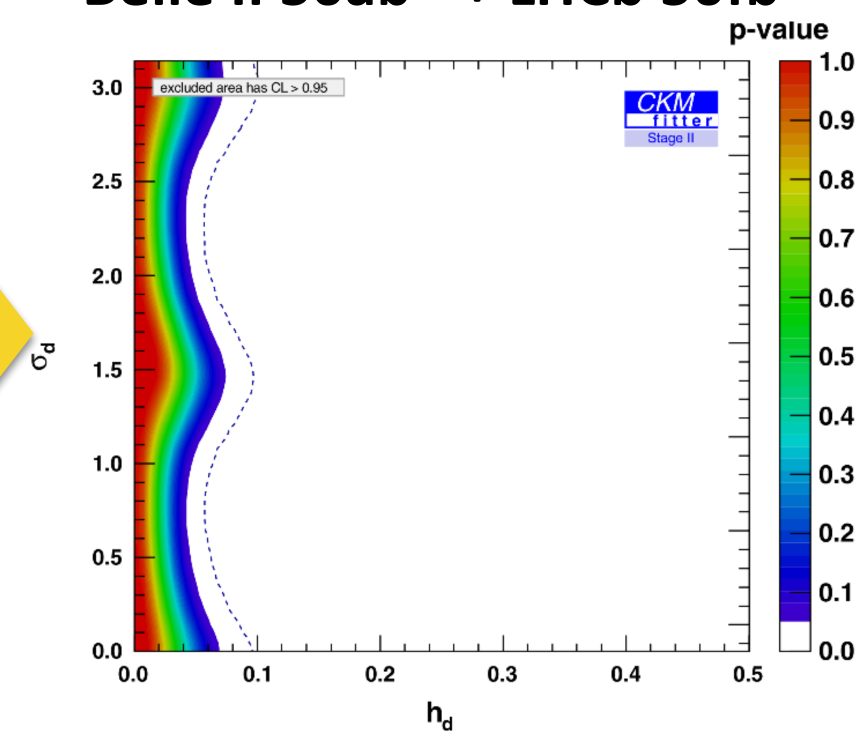


Relative amplitude (h) phase (σ)

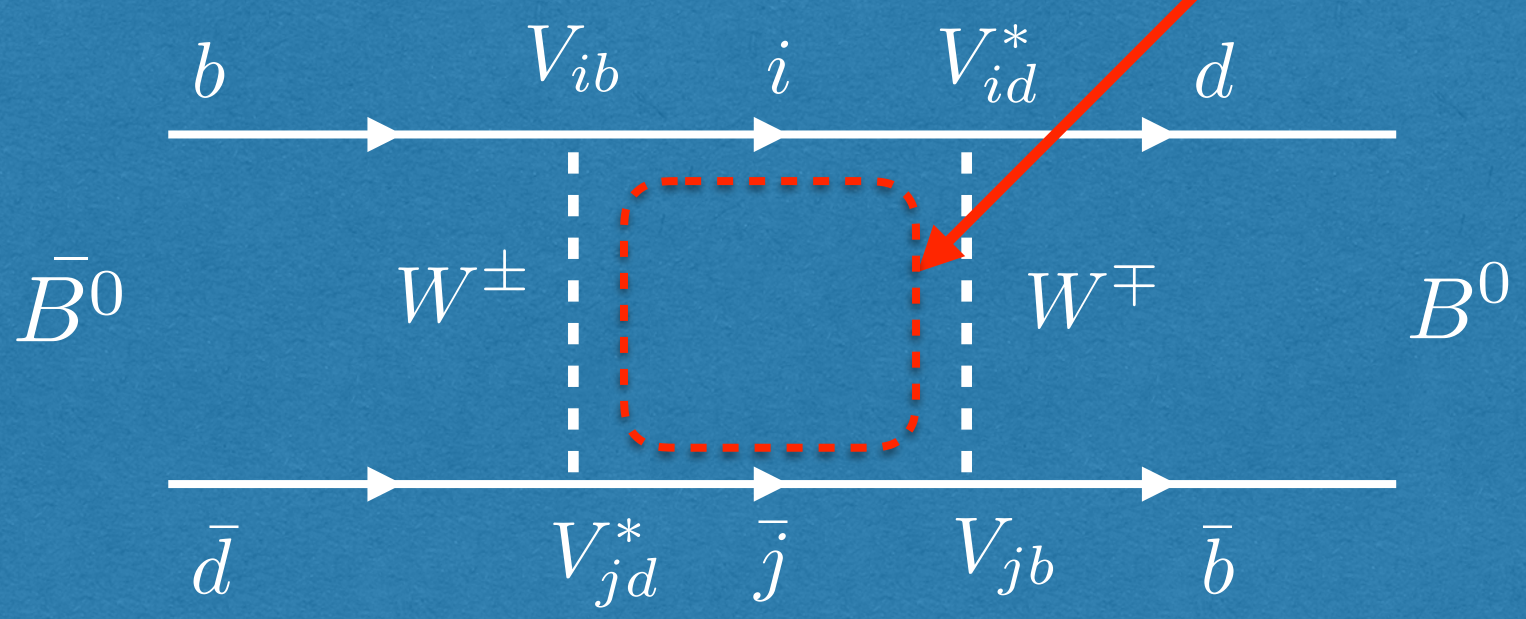
Present



Belle II 50ab^{-1} + LHCb 50fb^{-1}



B-$\bar{B}$ Mixing and New Physics



$$\frac{C_{ij}^2}{\Lambda^2}(\bar{q}_{i,L}\gamma^\mu q_{j,L})^2,$$

J. Charles et al., PRD89,033016(2014)

$$h \simeq 1.5 \frac{|C_{ij}|^2}{|\lambda_{ij}^t|^2} \frac{(4\pi)^2}{G_F \Lambda^2} \simeq \frac{|C_{ij}|^2}{|\lambda_{ij}^t|^2} \left(\frac{4.5\ \mathrm{TeV}}{\Lambda}\right)^2,$$

$$\sigma = \arg(C_{ij}\lambda_{ij}^{t*}),$$

$$\lambda_{ij}^t = V_{ti}^* V_{tj}$$

Couplings	NP loop order	Scales (in TeV) probed by B_d mixing	Scales (in TeV) probed by B_s mixing
$\lvert C_{ij}\rvert = \lvert V_{ti}V_{tj}^*\rvert$ (CKM-like)	tree level	17	19
	one loop	1.4	1.5
$\lvert C_{ij}\rvert = 1$ (no hierarchy)	tree level	2×10^3	5×10^2
	one loop	2×10^2	40

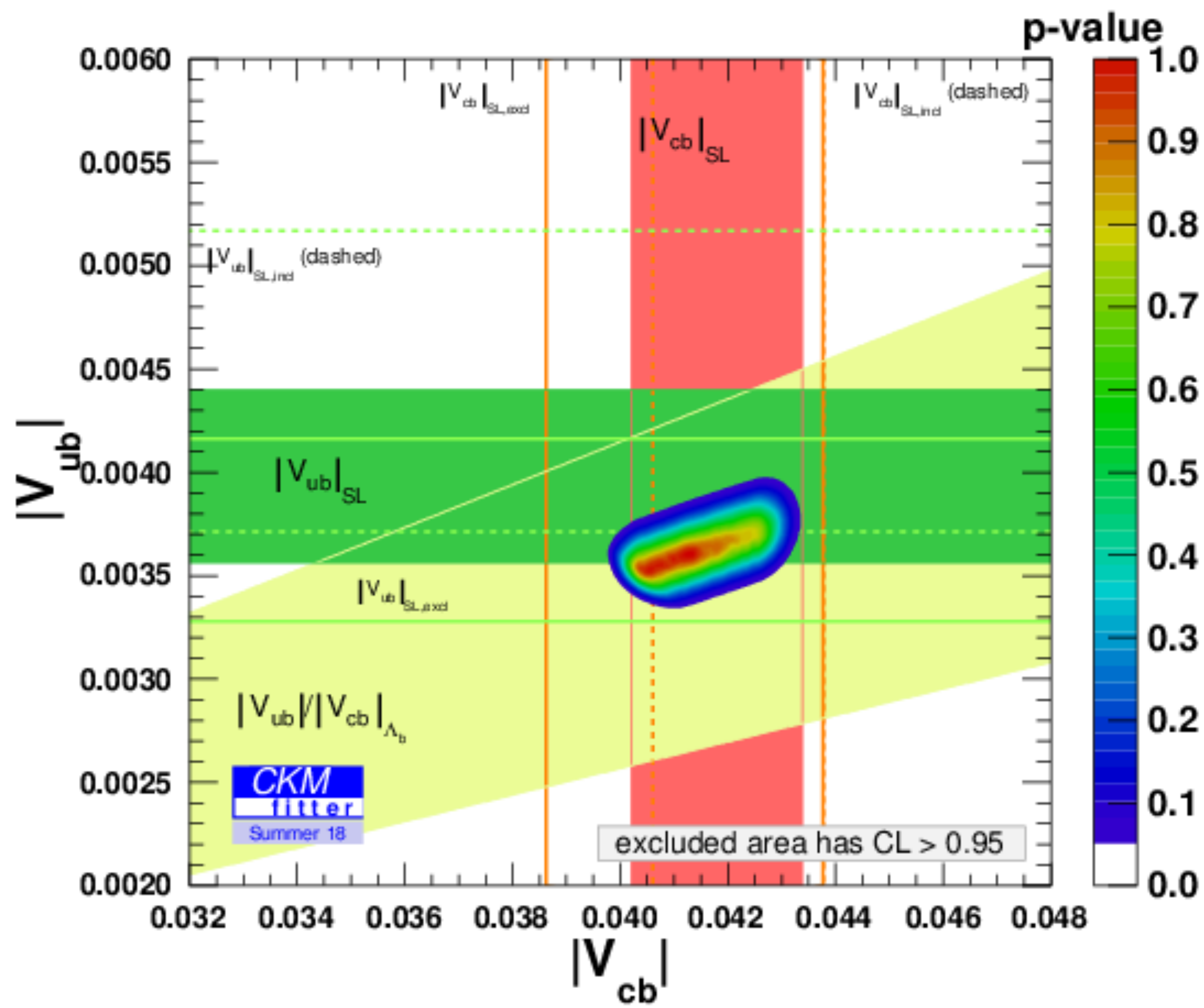
Mass reach (CKM-like): O(1)TeV → O(10) TeV !

Some theoretical issues

- Hadronic uncertainties to extract fundamental quantities from experimentally measured rates.

- ex. $|V_{c(u)b}|$ from $\Gamma(B \to X_{c(u)}\, l\, \nu)$.
  - Form factors $f(B \to D)$, $f(B \to \pi)$
  - Inclusive vs Exclusive

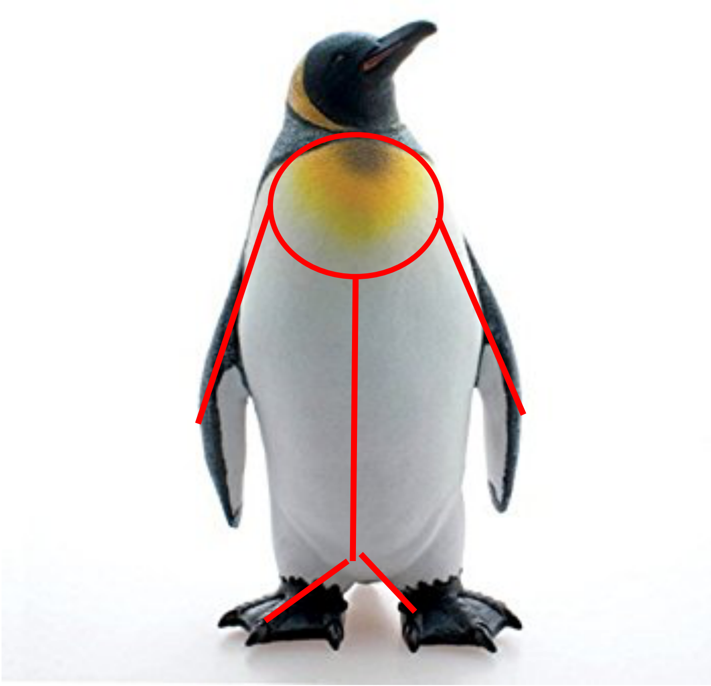
- Need more theoretical investigations.

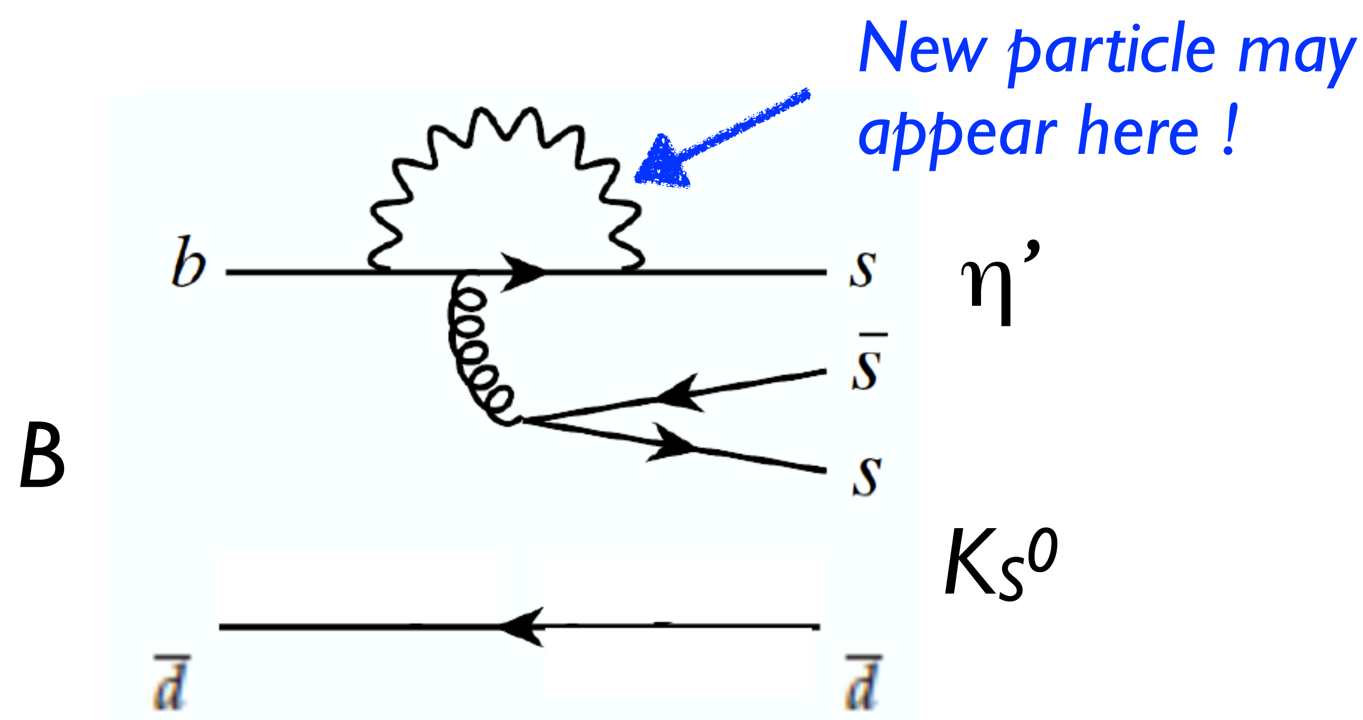


CP Violation by New Physics

Belle II can measure types of B meson decays which rarely happen (~ one per million B decays), known as "Penguin" decays.

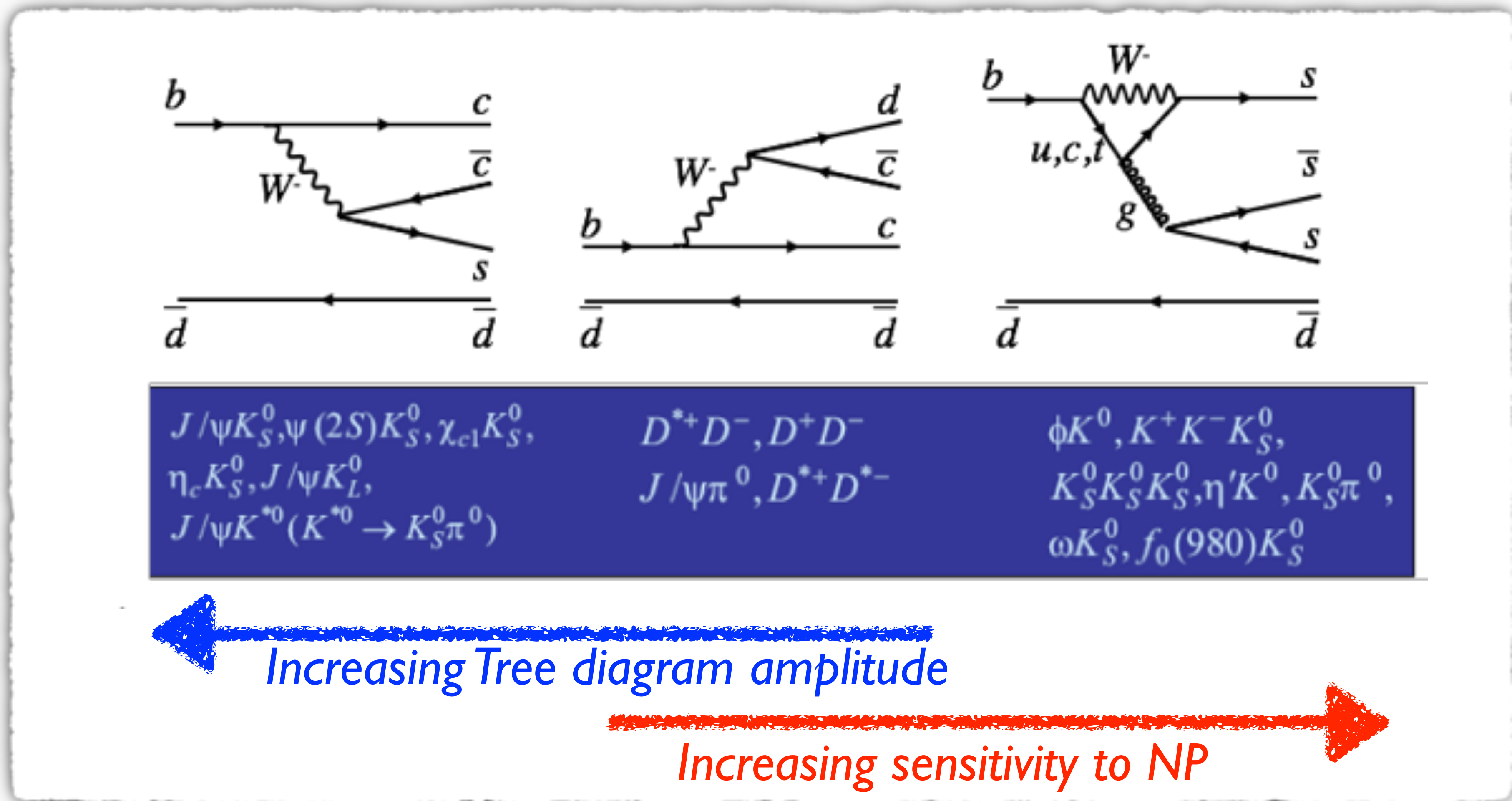
Q: Does CP violation in "Penguin" decays deviates from the SM ?





A. Gaz is leading the physics analysis in Belle II

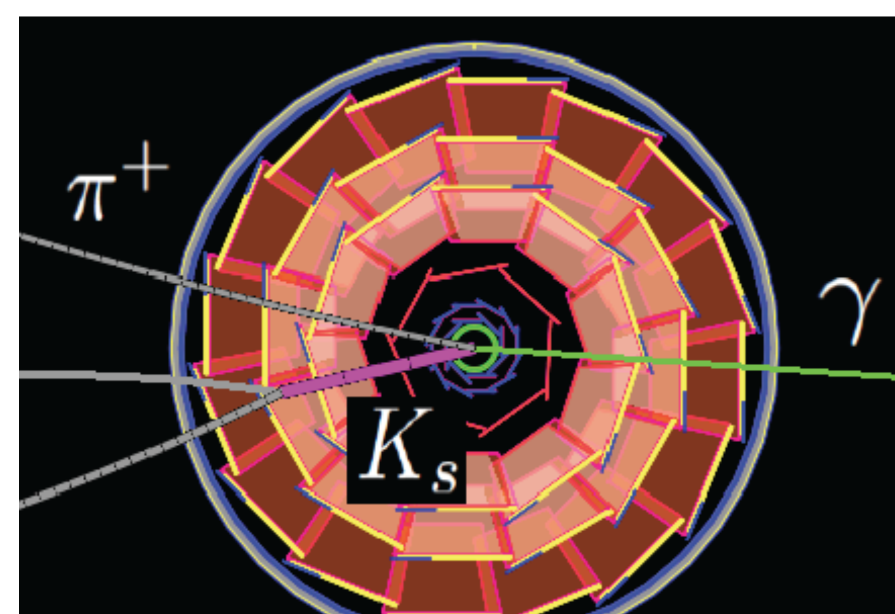
Time-dependent CPV



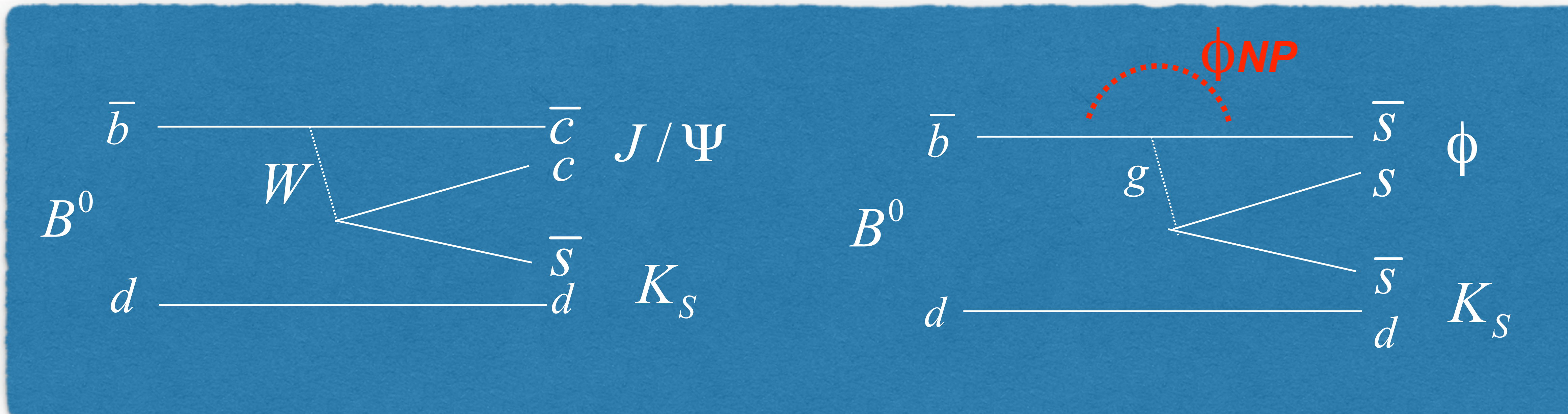
- Larger acceptance for Ks decay vertex +30%
- Improved vertex resolution

  σ(Z)~18μm @ Belle II ↔ ~61μm @ Belle

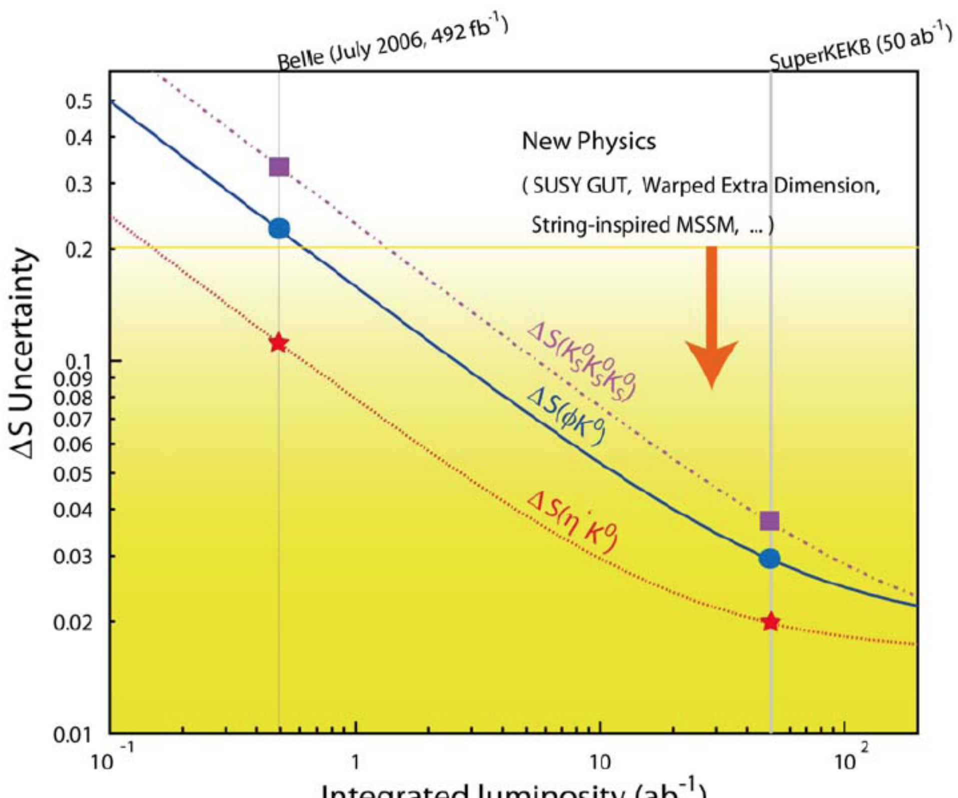
  → less systematic error

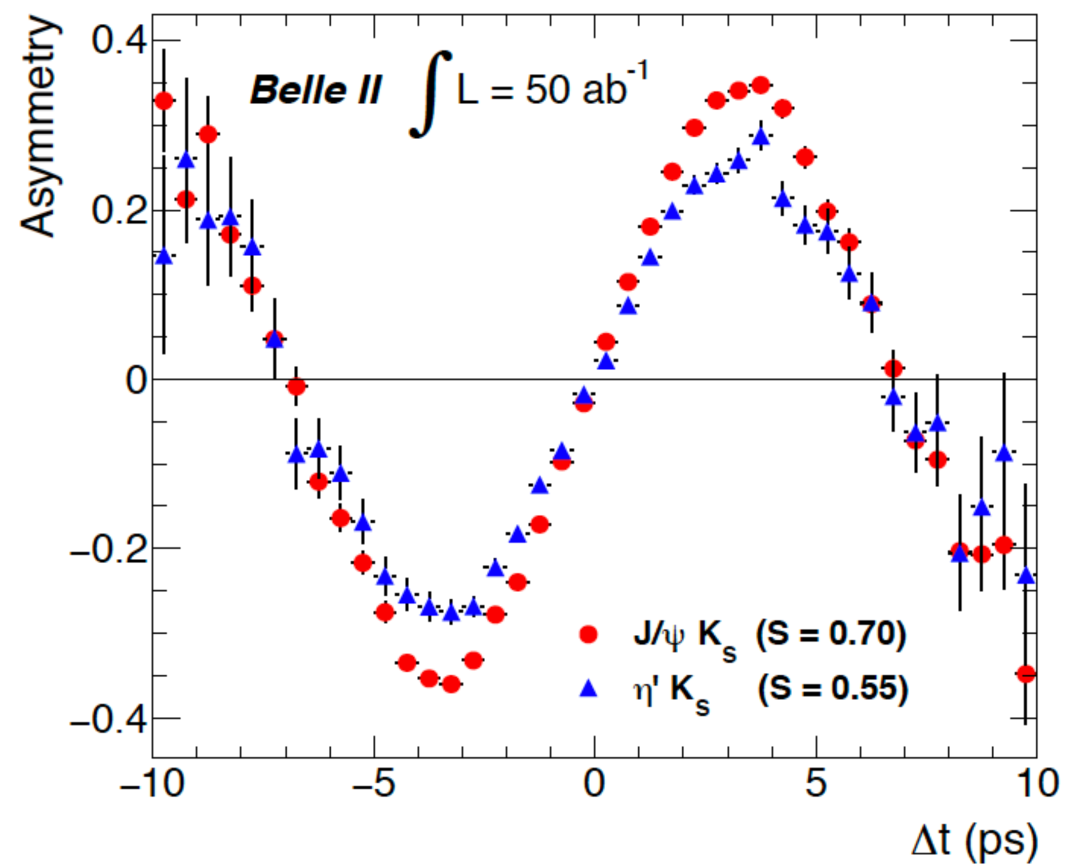


ϕ_1 ($\equiv\beta$) Projection



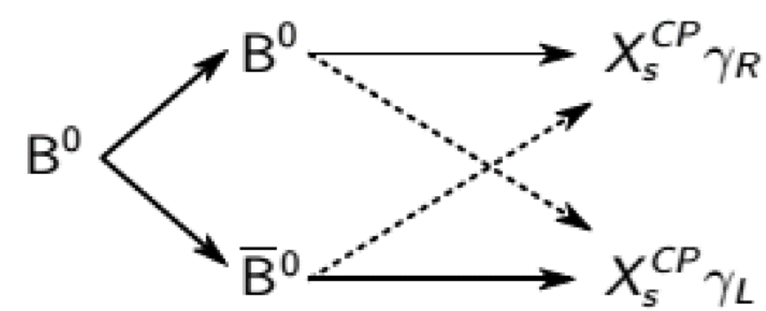
Belle II projection for $\sin 2\varphi_1^{eff}$ from $b \to s\,\bar{s}\,s$ *processes*





Time-dep. CPV in $b \to s,d + \gamma$

- In SM, photon from $b \to s,d + \gamma$ is almost left-handed.
- Right-handed photon causes interference, and large CPV.



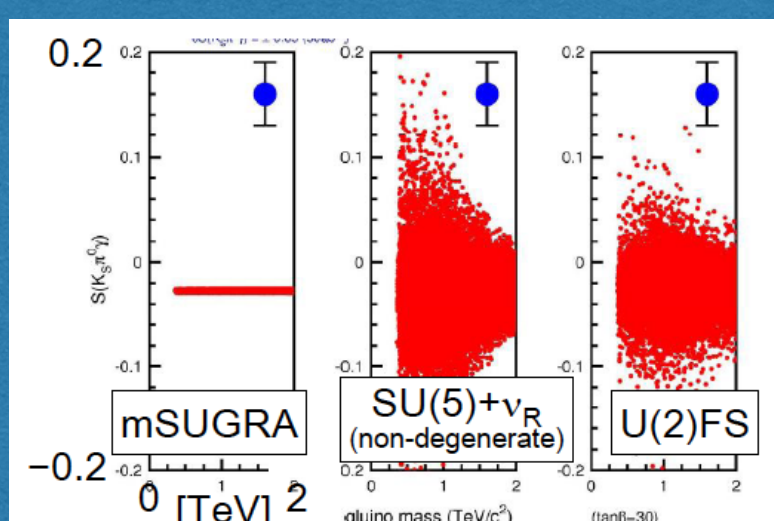
SM prediction

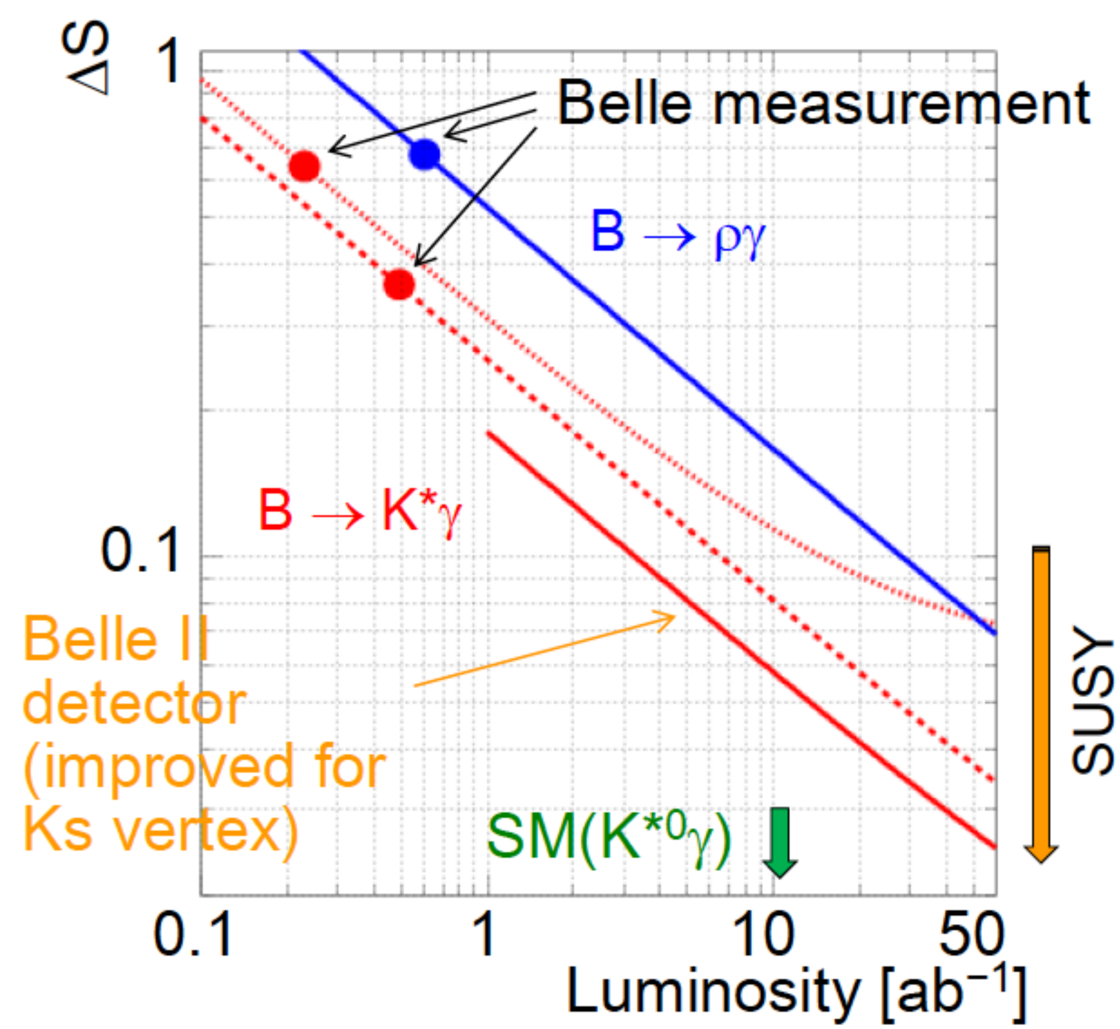
$$S(B \to V\gamma) \simeq -\frac{2m_s}{m_b}\sin 2\phi_1$$

$$|S(B \to K^*\gamma)| \lesssim 0.02$$

$$|S(B \to \rho\gamma)| \sim 0$$

SUSY models

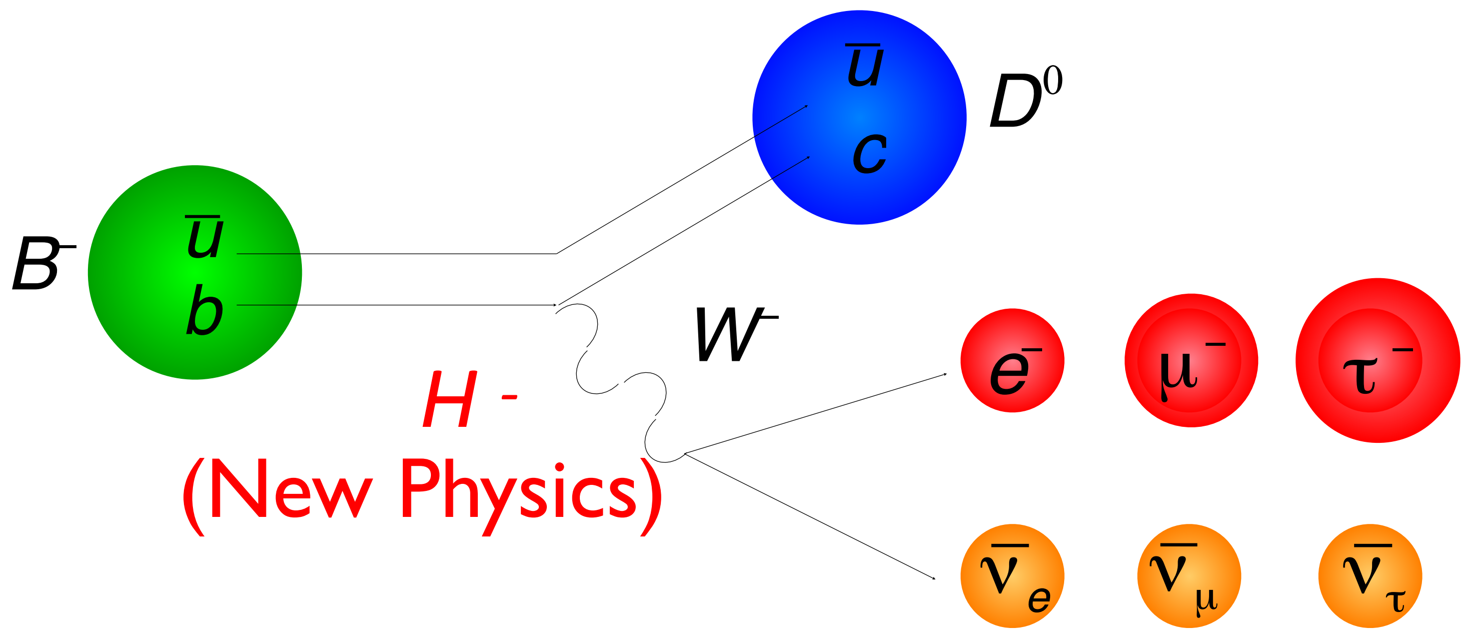




Lepton non-Universality (tree)

There are 3 modes in the B meson weak decay into the lepton final states; B→D e ν, D μ ν, D τ ν.

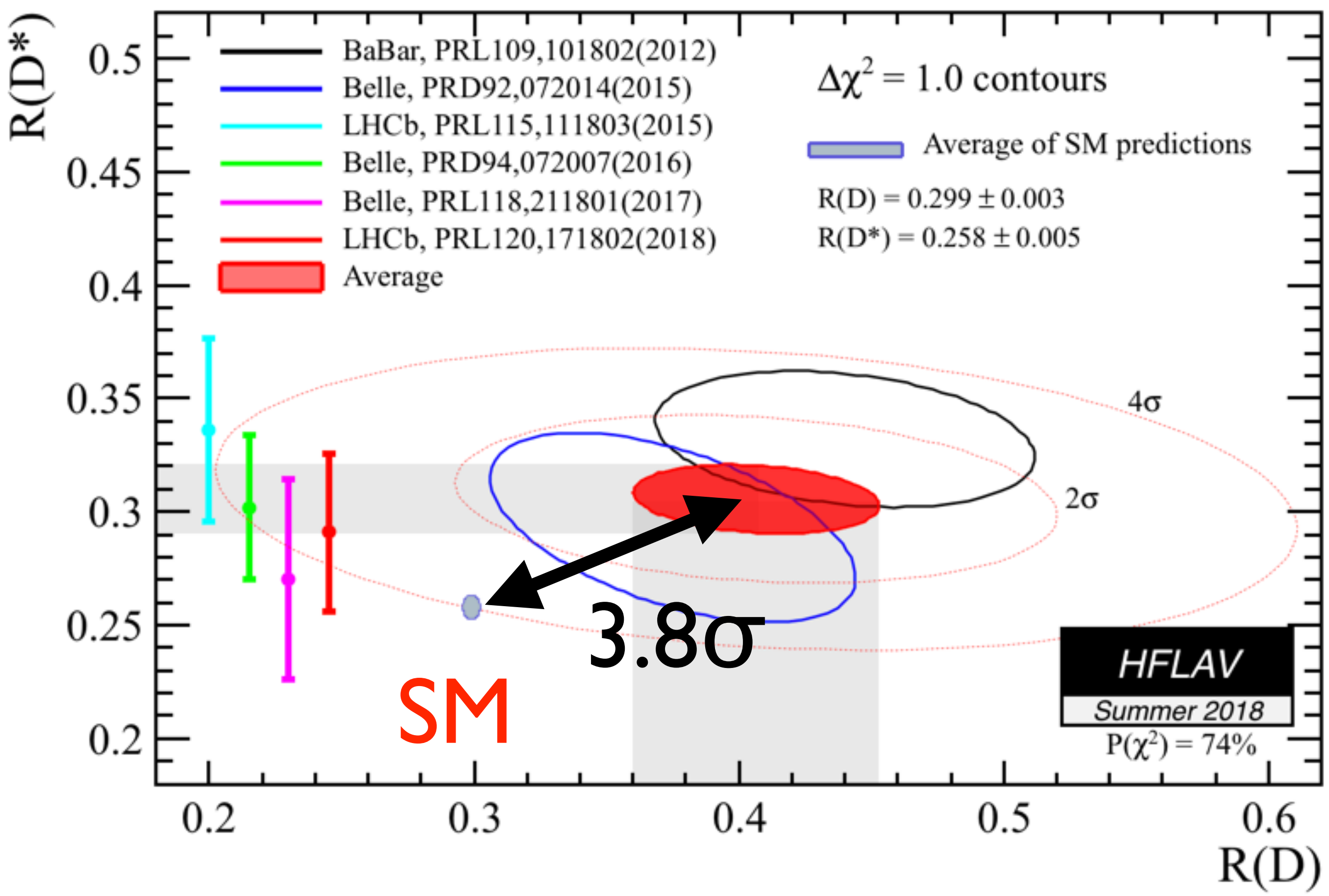
Q: Are they just the same (as in the SM) ?



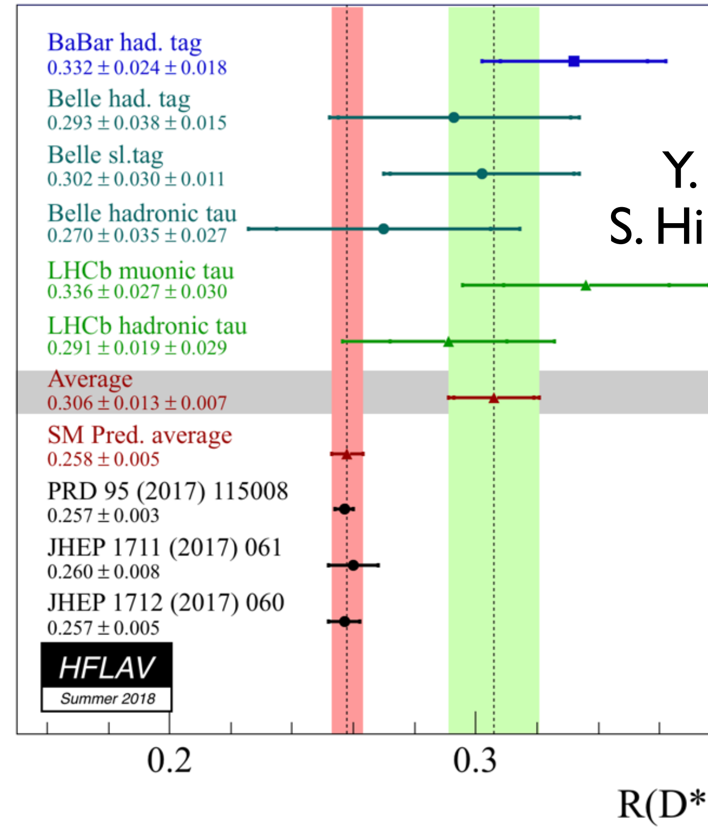
Hints of deviations in recent BaBar, Belle, LHCb data …

R(D), R(D*)

Summer 2018 update

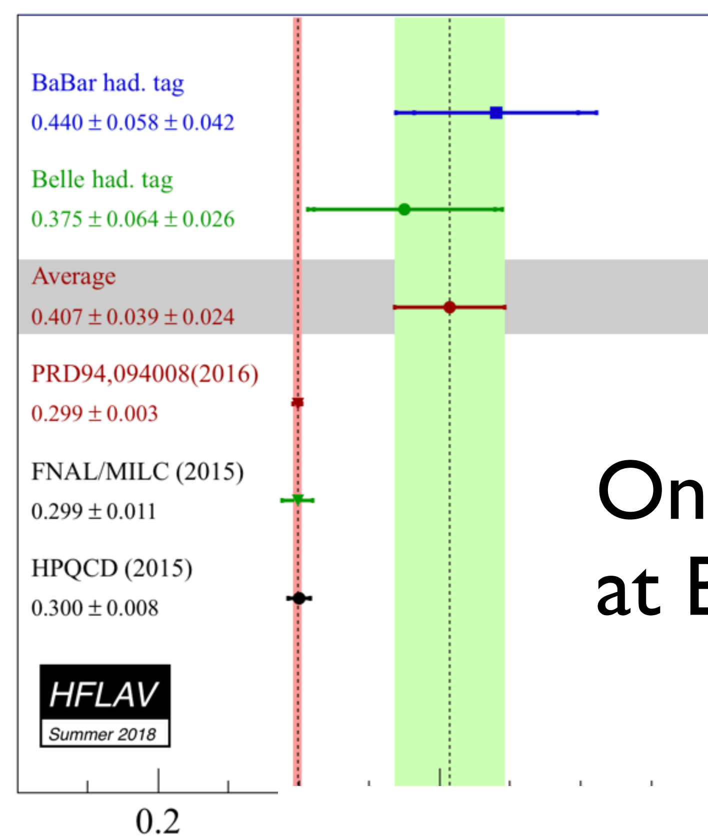


R(D*)



Y. Sato, T. Iijima et al.
S. Hirose, T. Iijima et al.

R(D)

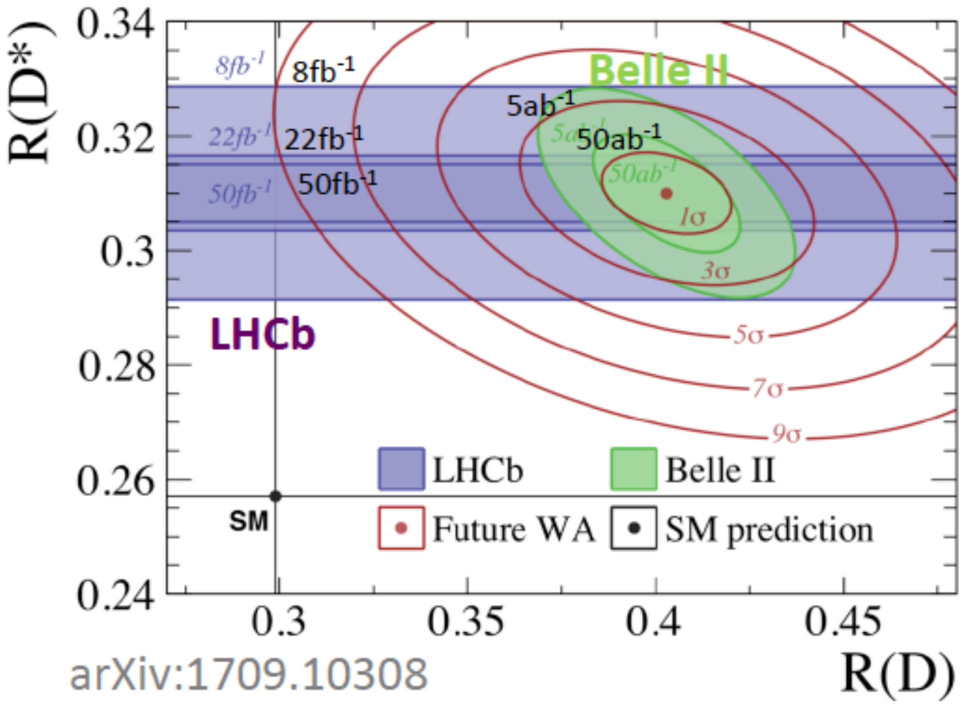


Only had. tag. at B-factories

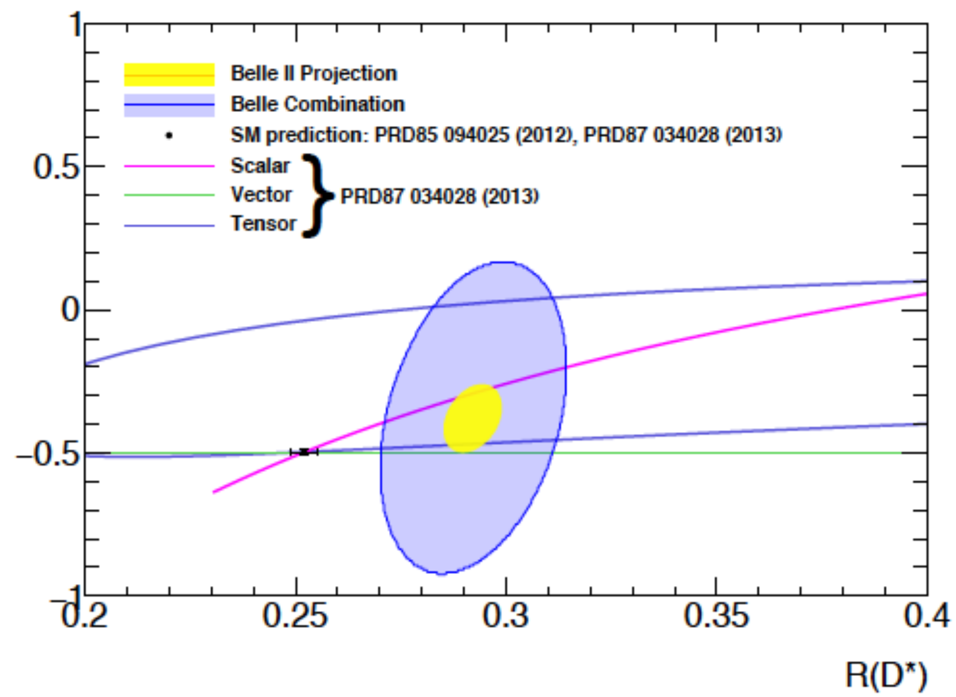
Deviation from SM slightly decreased from 4.1 → 3.8σ, mainly due to change in theoretical SM prediction.

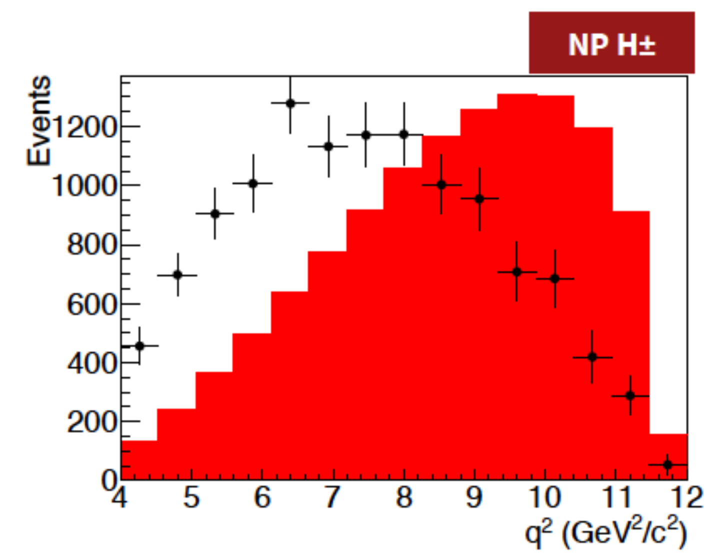
Belle II Projections

- Lepton universality violation may be established even with 5ab^{-1} (2020).
- High statistics data will provide more detailed information, such as τ polarization, q^2 distribution, to discriminate type of NP.



arXiv:1709.10308





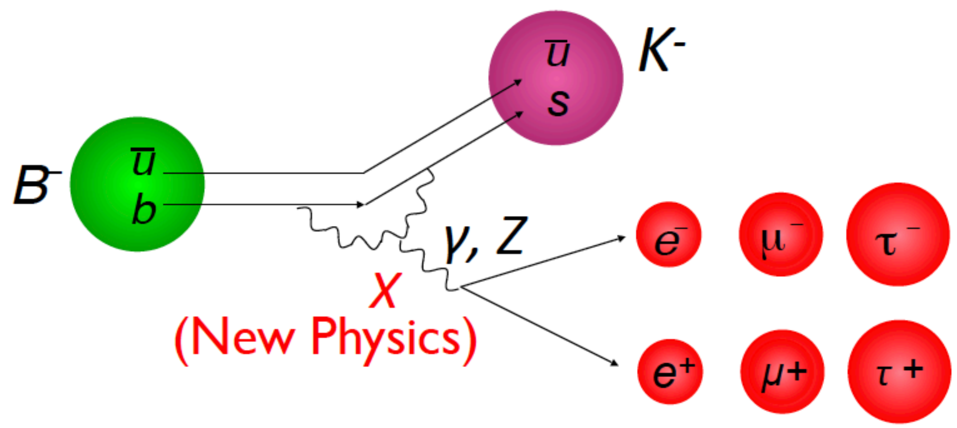
50 ab-1 projection of the subtracted q^2 spectrum in $B \to D^* \tau \nu$ (HT)

	ΔR(D) [%]			ΔR(D*) [%]		
	Stat	Sys	Total	Stat	Sys	Total
Belle 0.7 ab^{-1}	14	6	16	6	3	7
Belle II 5 ab^{-1}	5	3	6	2	2	3
Belle II 50 ab^{-1}	2	3	3	1	2	2

Will soon hit the systematic limit !

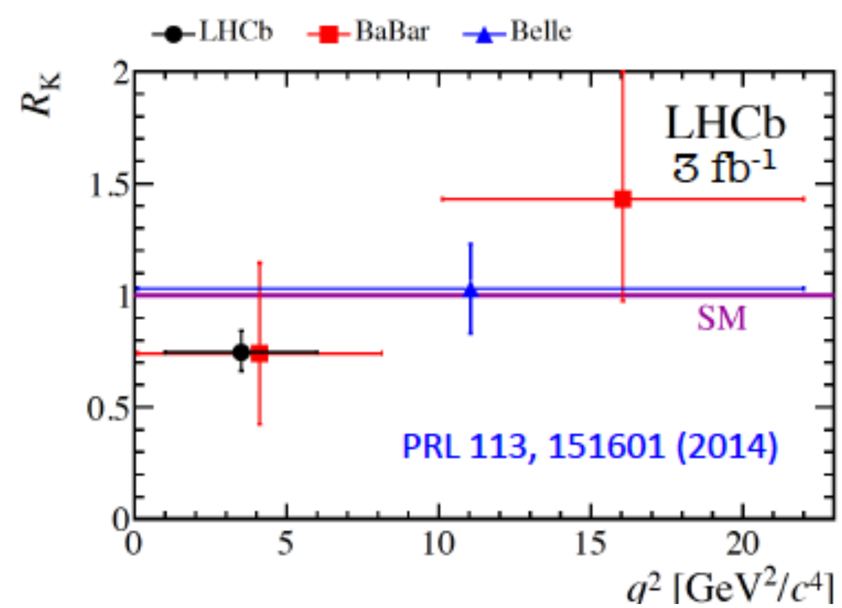
- More observables (distributions) !
  - P(τ), P(D*)
  - $d\Gamma/dq^2$, $d\Gamma/dp_{D(*)}$, $d\Gamma/dp_e$, …
- More modes !
  - $B \to \pi \tau \nu$,
  - $B_s \to D_s \tau \nu$ (at 5S runs) , …

Lepton non-Universality (loop)



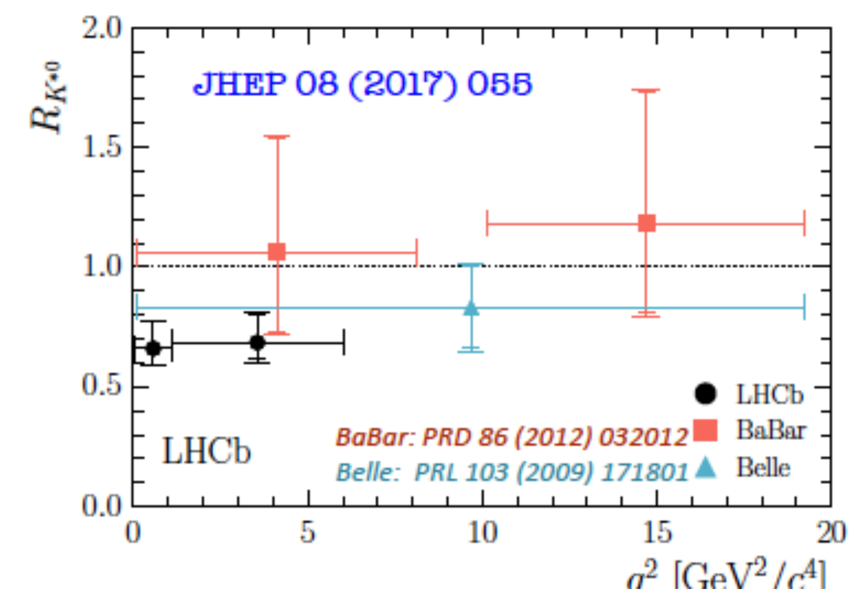
Hints of deviations in recent LHCb data …

$$R(K) = \frac{Br(B \to K\mu\mu)}{Br(B \to Kee)}$$
$$= 0.745^{+0.09}_{-0.07} \pm 0.036 (1 < q^2 < 6 \mathrm{GeV}^2)$$



R_K

$$R(K^*) = \frac{Br(B \to K^*\mu\mu)}{Br(B \to K^*ee)}$$
$$= 0.66^{+0.11}_{-0.07} \pm 0.03 (0.045 < q^2 < 1.1 \mathrm{GeV}^2)$$
$$= 0.69^{+0.11}_{-0.07} \pm 0.05 (1.1 < q^2 < 6 \mathrm{GeV}^2)$$



$R_{K^{*0}}$

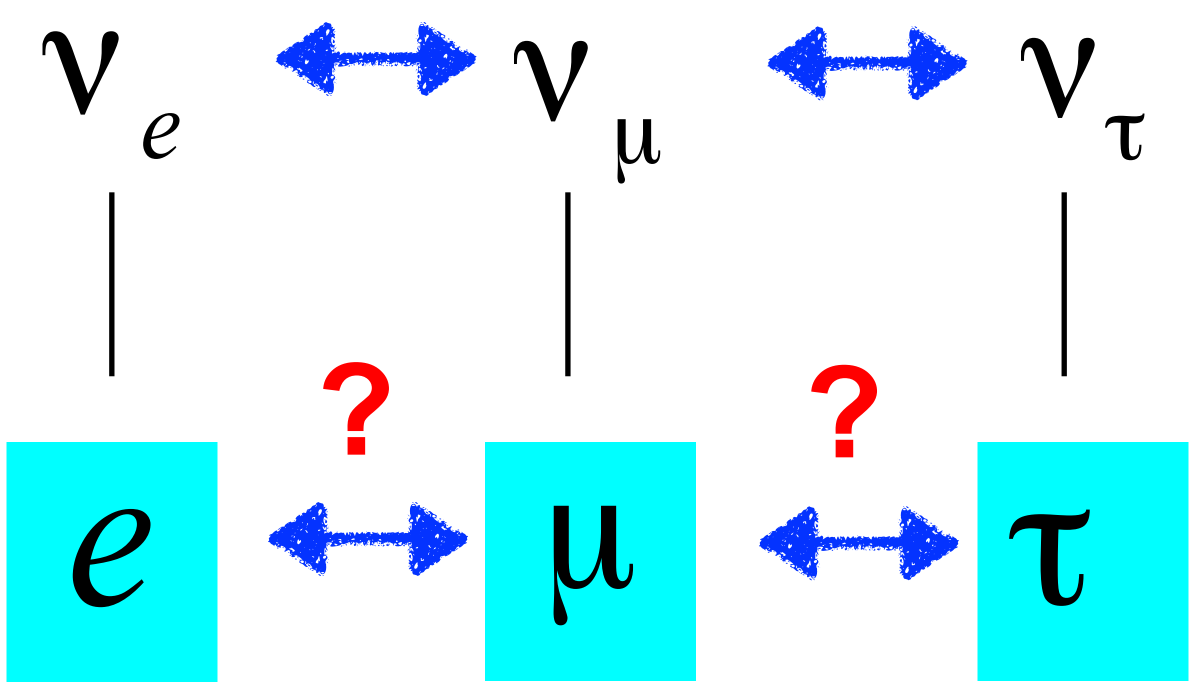
Precision at Belle II : ~3% at 50ab^{-1} and also inclusive measurement (less theory ambiguity) possible.

Lepton Flavor Violation

See talk by K. Hayasaka

SuperKEKB produces also a lot of tau-leptons, which can be studies in detail by Belle II.

Q: Does the tau-lepton changes to the muon or electron, similarly to the case of the neutrino (neutrino oscillation).



neutrino oscillation

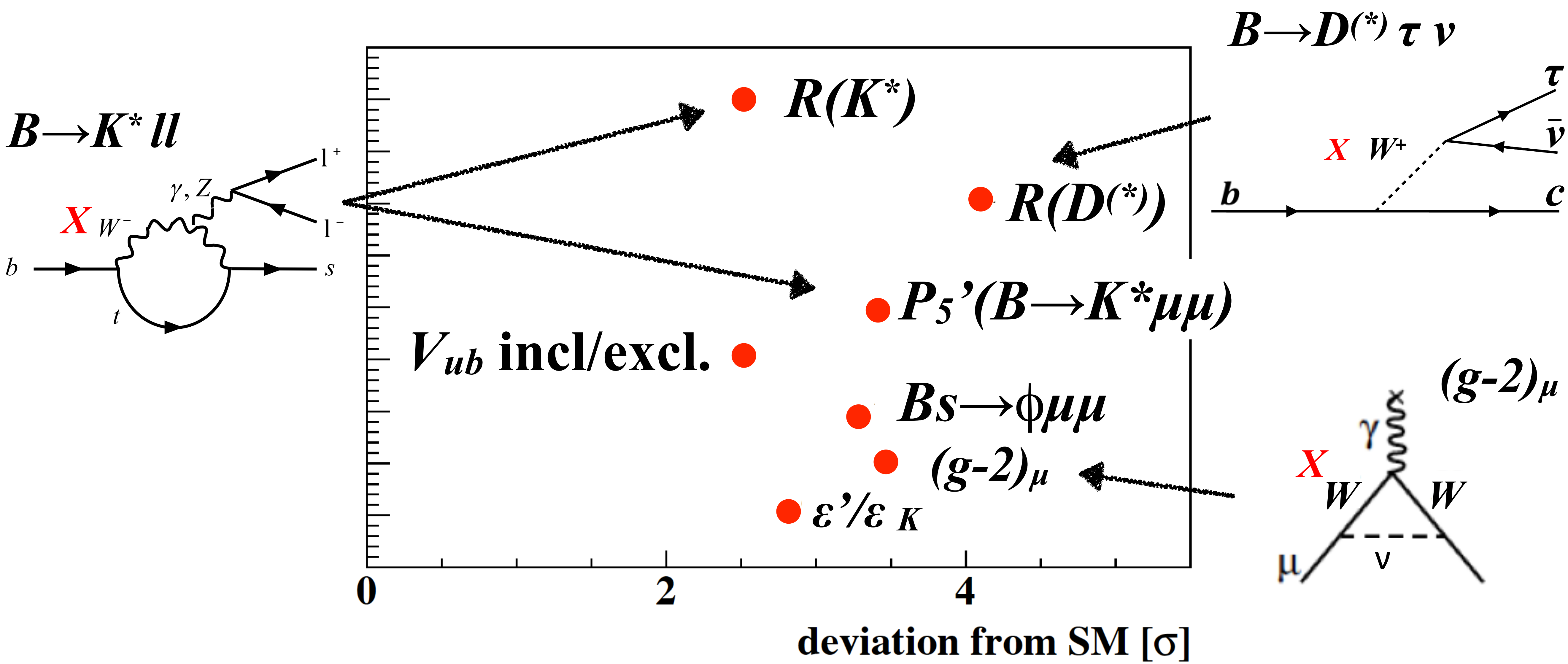
are there decays like

$\tau \rightarrow \mu\gamma$?

$\tau \rightarrow e\gamma$?

Lepton Non Universality

Observed deviation from SM



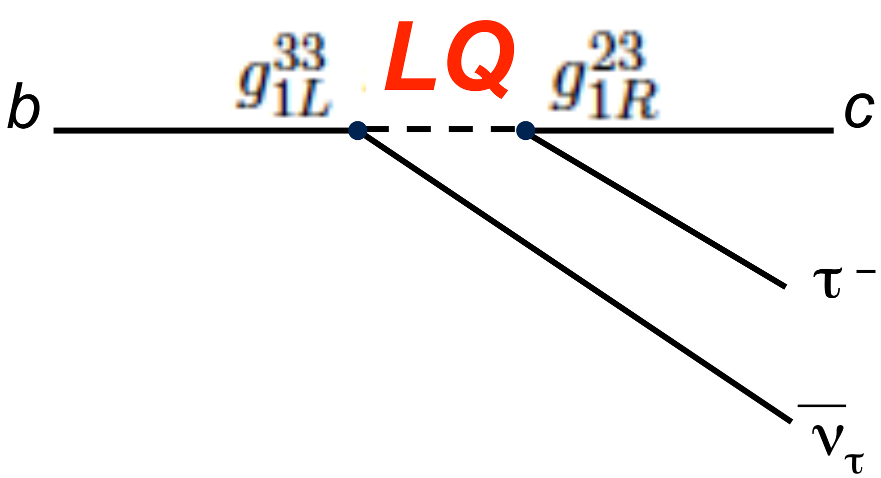
Is Lepton Non-universality the clue to NP ?

Testing B anomalies at ATLAS/ CMS (e.g. LQ model)

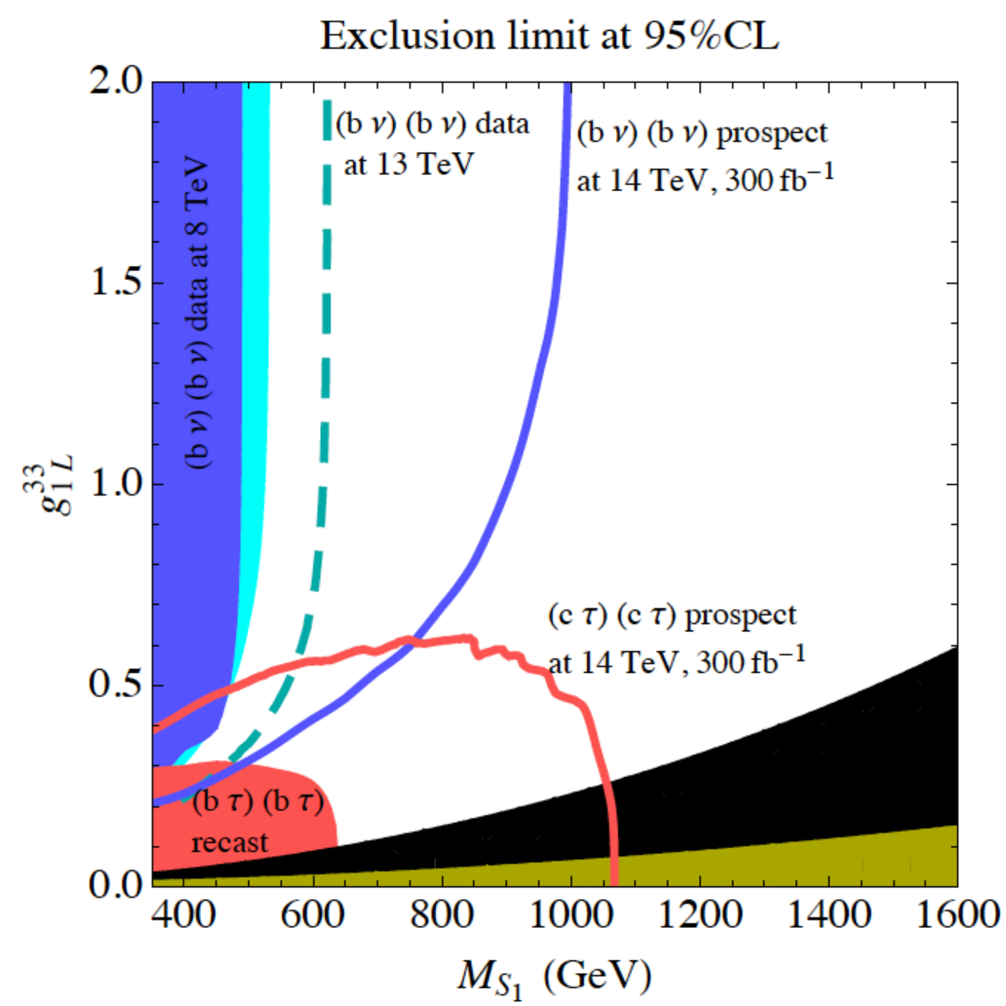
1808.10567

- The Leptoquark (LQ) model is a favored model, which can explain observed anomalies consistently: P5', R_K(*), R(D(*))
  - Coupling to 3rd gen. > to 2nd gen. >> to 1st gen.

e.g. : scalar leptoquark



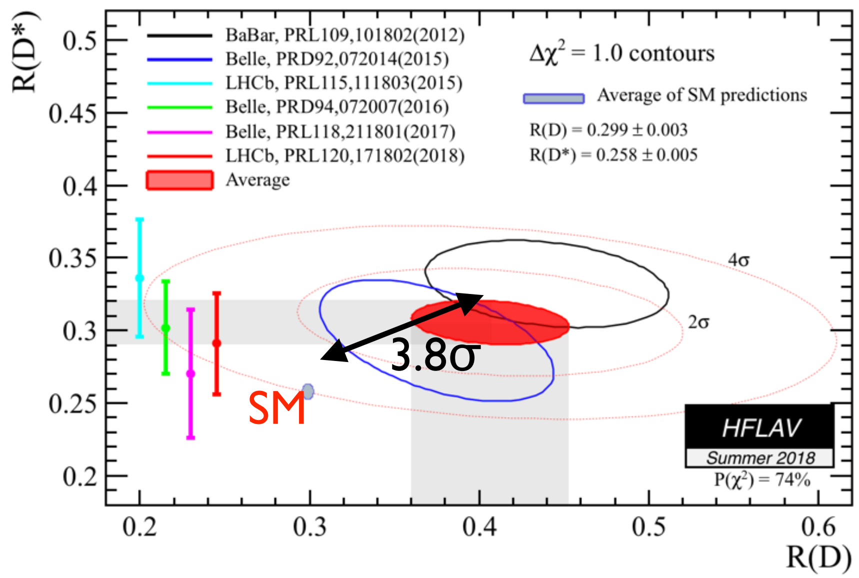
$$2\sqrt{2}G_F V_{cb} C_{LQ_2} = -\frac{g_{1L}^{33}\, g_{1R}^{23*}}{M_{S_1}^2}$$

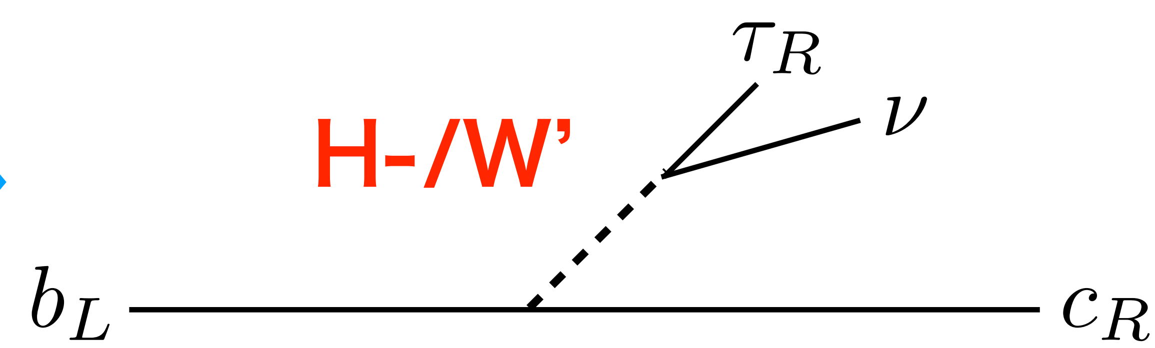


Once B anomalies are confirmed, it would be interesting to see results of ATLAS/CMS w/ 300fb^{-1}

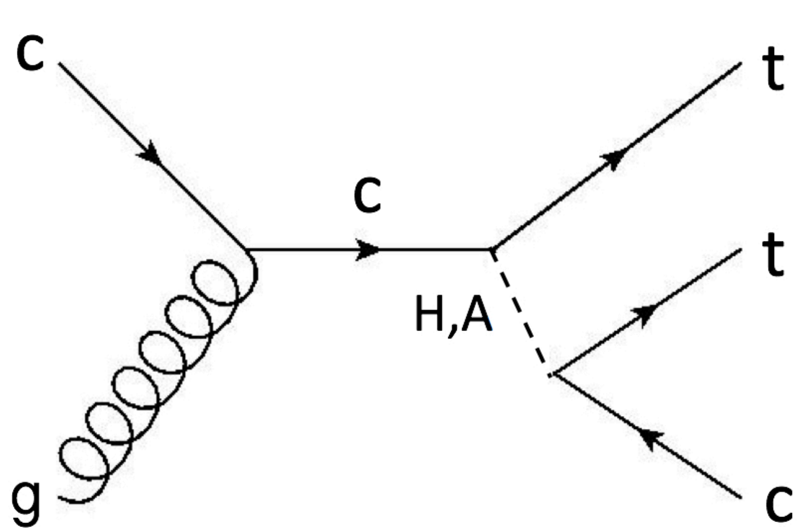
Work by Nagoya Theory Group

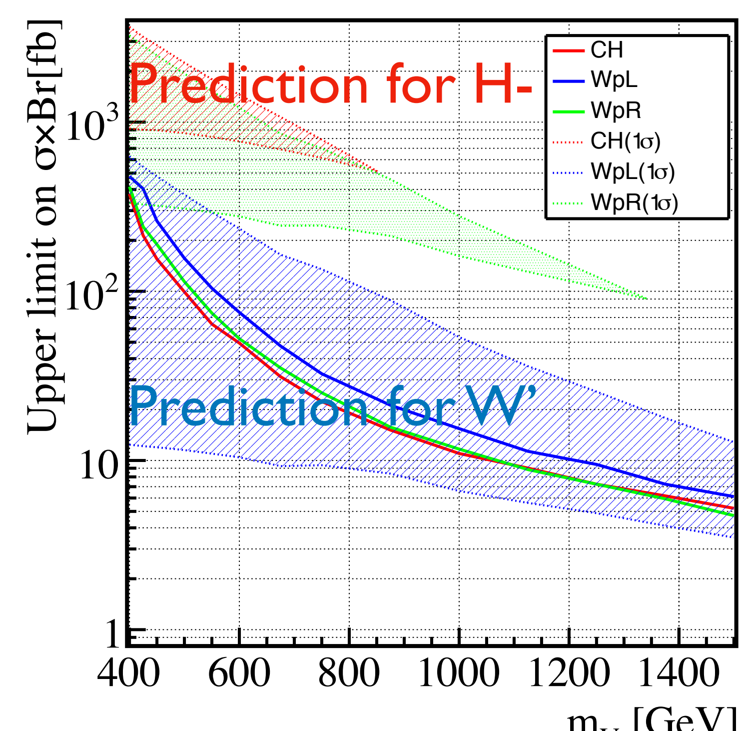
- Building a model, which can explain the "B anomalies", and predict and suggest tests at LHC.





Reaction testable at LHC





H- in this model excluded.

W' can be tested with more data.

World Research Unit for Heavy Flavor Particle Physics (“WPI-next”)

SuperKEKB/Belle II

Toru Iijima
- B, Tau Physics
- Exotic hadrons

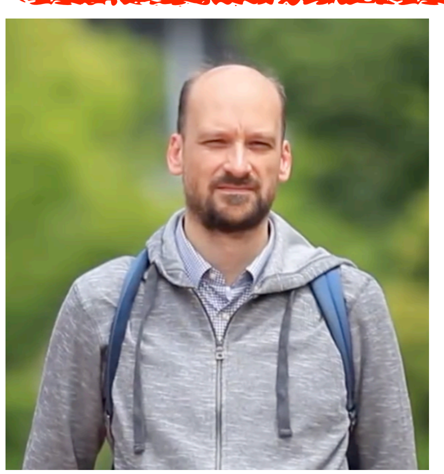
LHC-ATLAS

Makoto Tomoto
- Top physics
- Higgs

Peter Krizan
(Ljubljana)

Theory

Junji Hisano
Flavor Physics
Dark Matter



Alessandro Gaz

Kodai Matsuoka

Yuji Omura

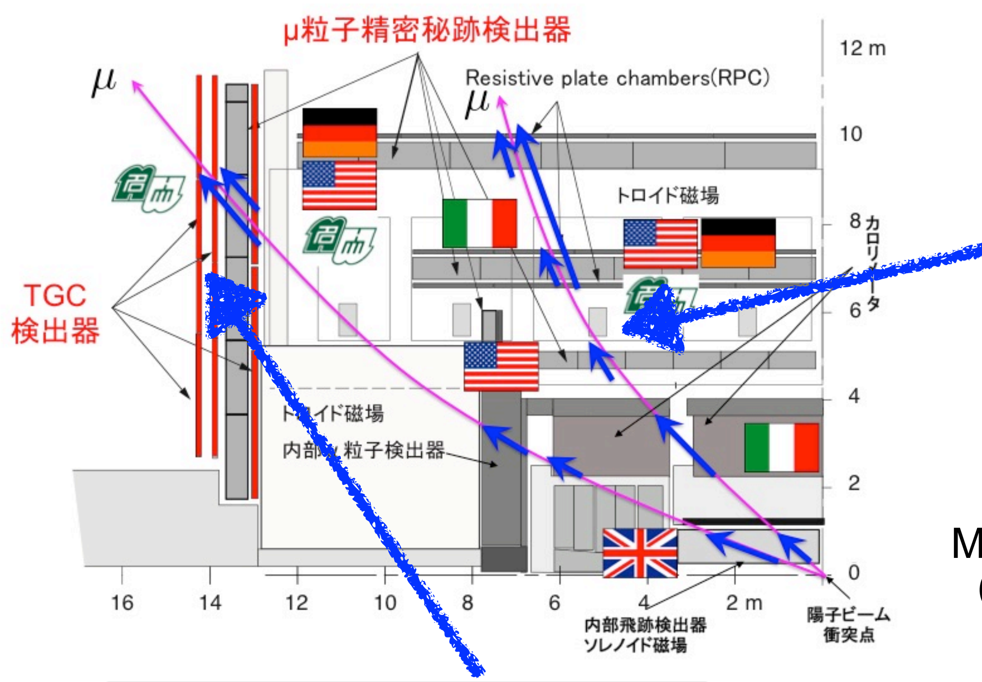
Gino Isidori
(Zurich)

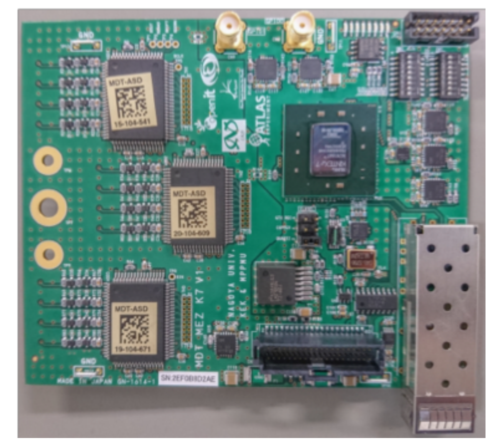
Yu Nakahama

Tim Gershon
(Warwick)

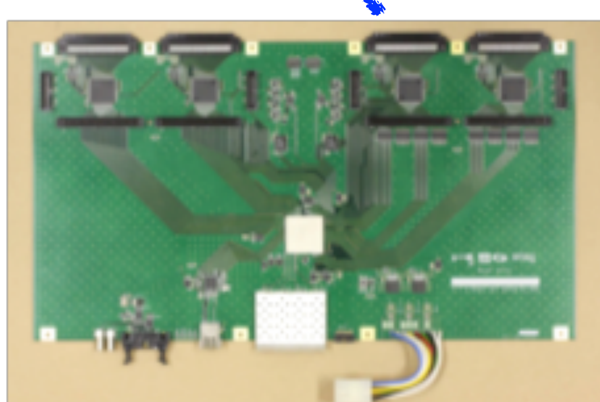
R&D for ATLAS Muon Trigger

HL-LHC advanced muon trigger
Realized high speed muon track trigger by processing 1M channel signals with large-scale FPGA.

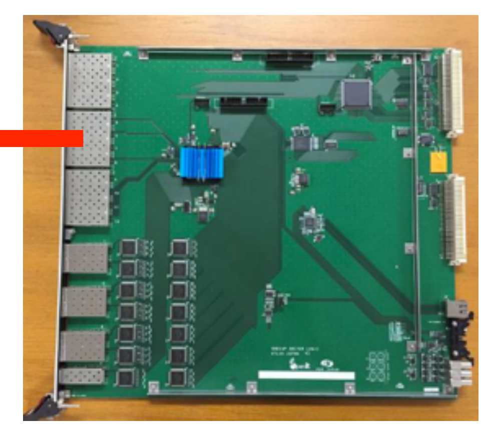




MDTトリガーの前段回路　試作機
（TDC 分解能：100 ps）



光ファイバ3000本
計24Tb/秒

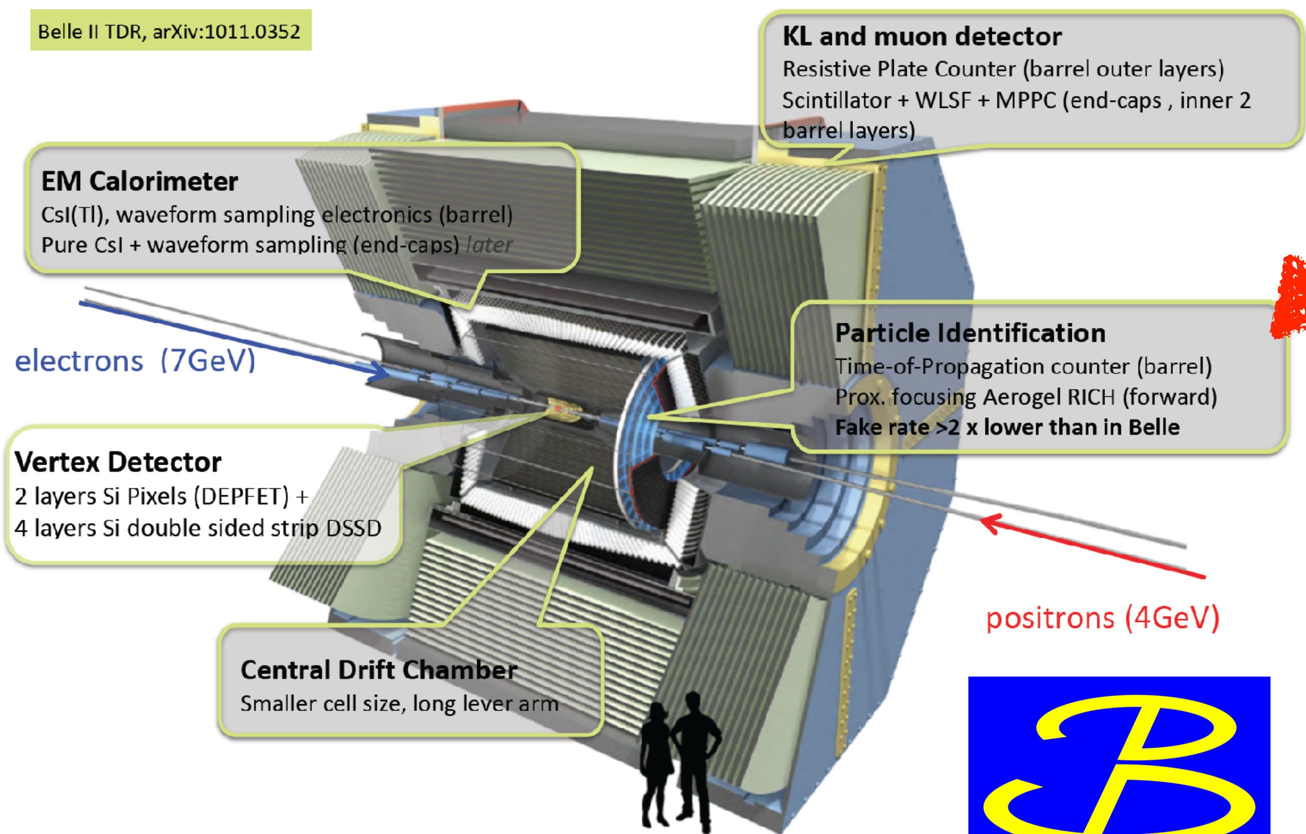


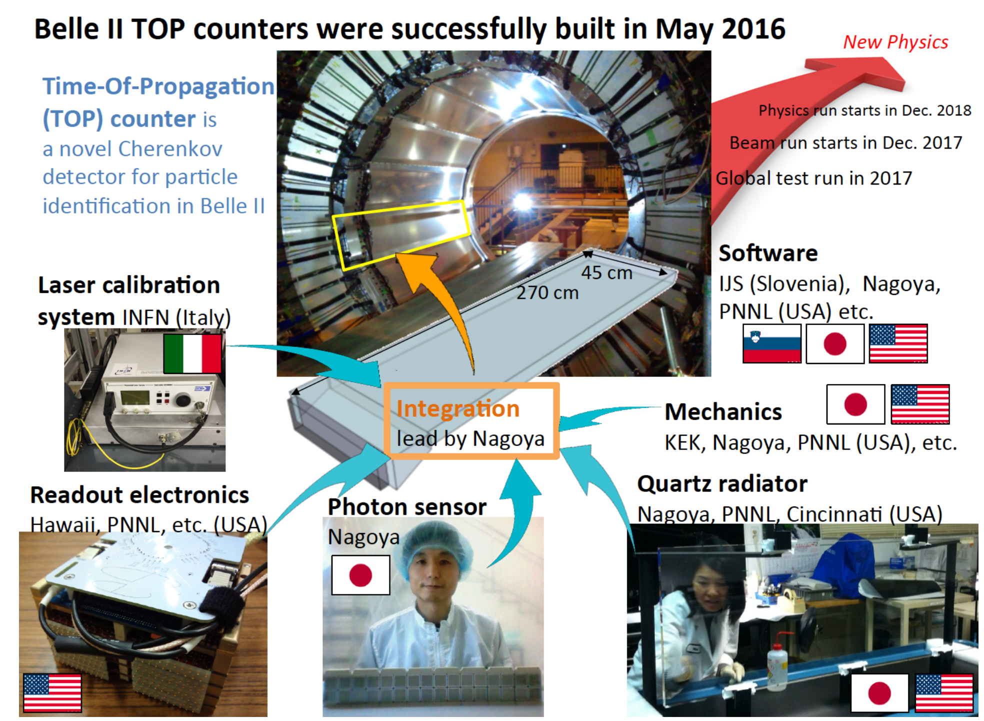
MDTトリガーの前段回路　試作機
（TDC 分解能：100 ps）

TGCトリガープロセッサー回路試作機
高速飛跡再構成を実現

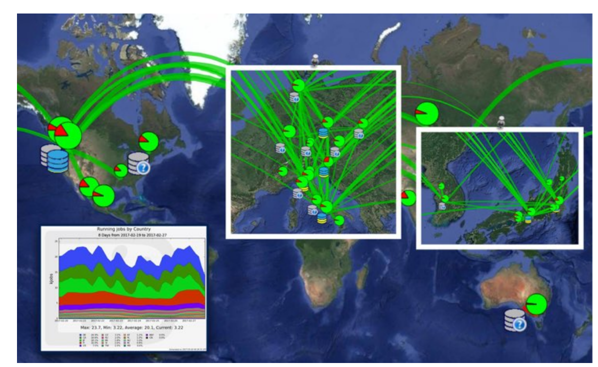
Belle II Experiment

- Deal with higher background (10-20×), radiation damage, higher occupancy, higher event rates (L1 trigg. 0.5→30 kHz)
- Improved performance and hermeticity





Belle II

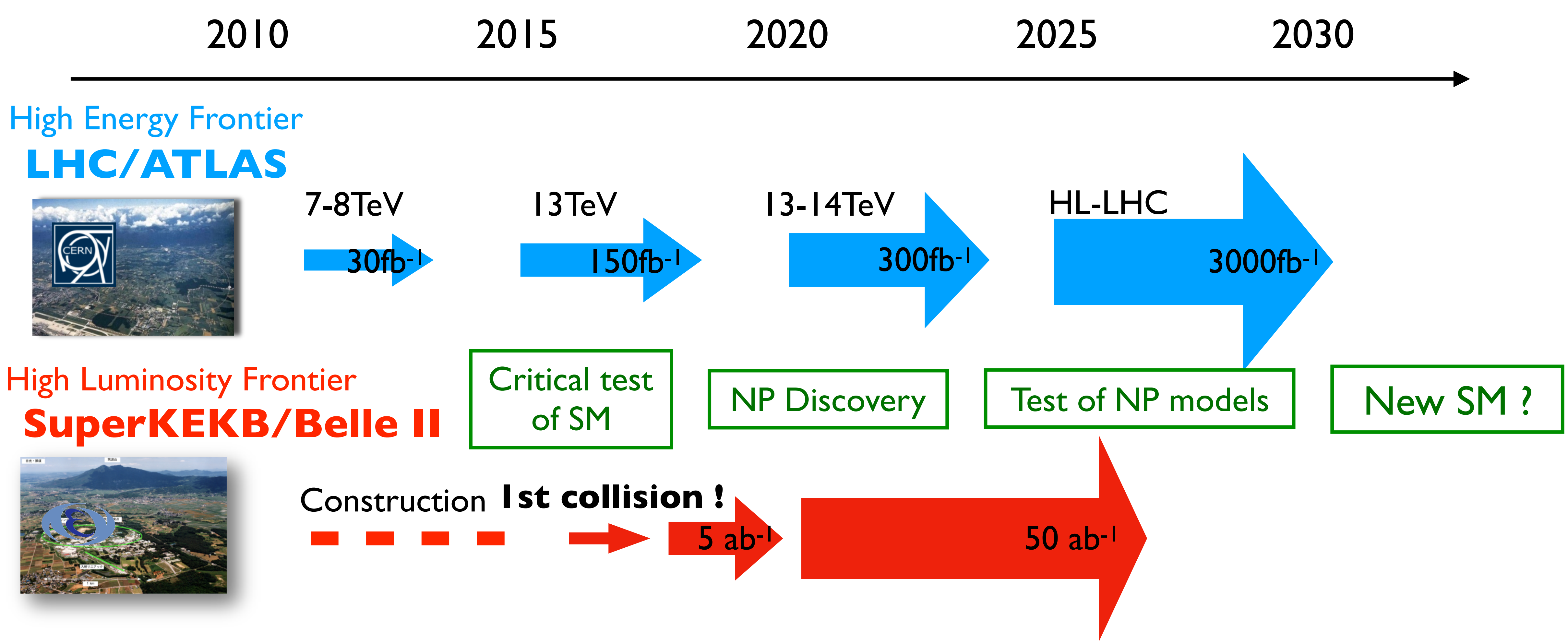


Nagoya group takes leading roles: Particle ID, Computing, Physics analyses

T.I will be the spokesperson from June, 2019.

Summary

- The CPV phenomena observed in flavor changing quark interactions (in *K*, *B* decays so far) can be explained by the Kobayashi-Maskawa.
- But, we are still far from explaining the Matter-Antimatter asymmetry in the Universe.
- Search for New Physics is the clue to investigate more the issue.
- Researches on heavy flavors are important in coming years.



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