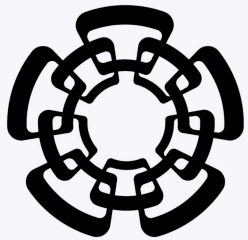
Prospects for the Mexican Collaboration at Belle II

J. Martínez-Ortega



Physics Department, Cinvestav, México

Reunión Red FAE
Pachuca, Hidalgo, November 10, 2016

Overview

Introduction

The Belle II Experiment

Physics at Belle II

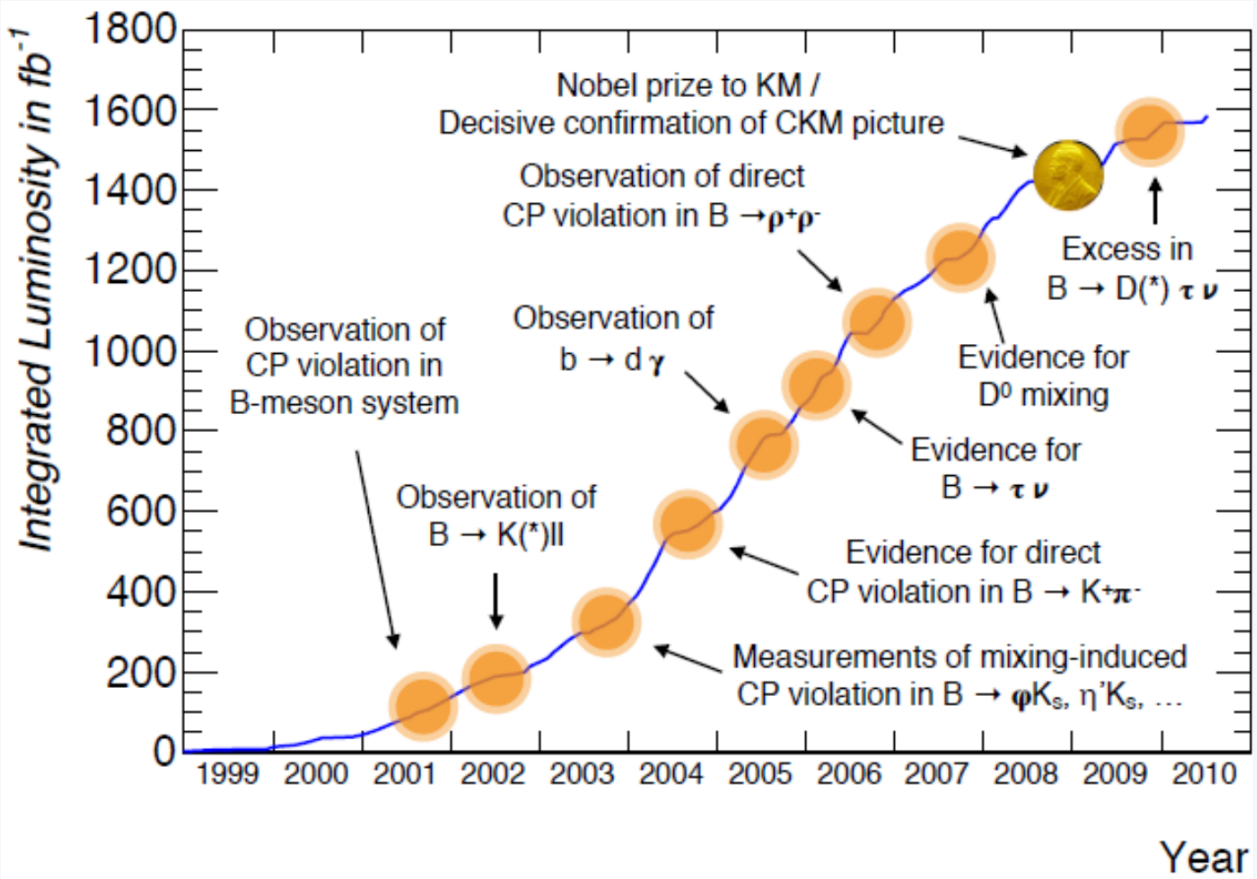
Mexican Collaboration at Belle II

Conlusions

Introduction

B factories

- The B factories ran from 1999 to 2010.
- They recorded over 1.5ab^{-1} of data $(1.25 \times 10^9 \bar{B}B)$.
- Provided the experimental evidence that led to the 2008 Nobel prize "for the discovery of the origin of broken symetry which predicts the existance of at least three families of quarks in nature".



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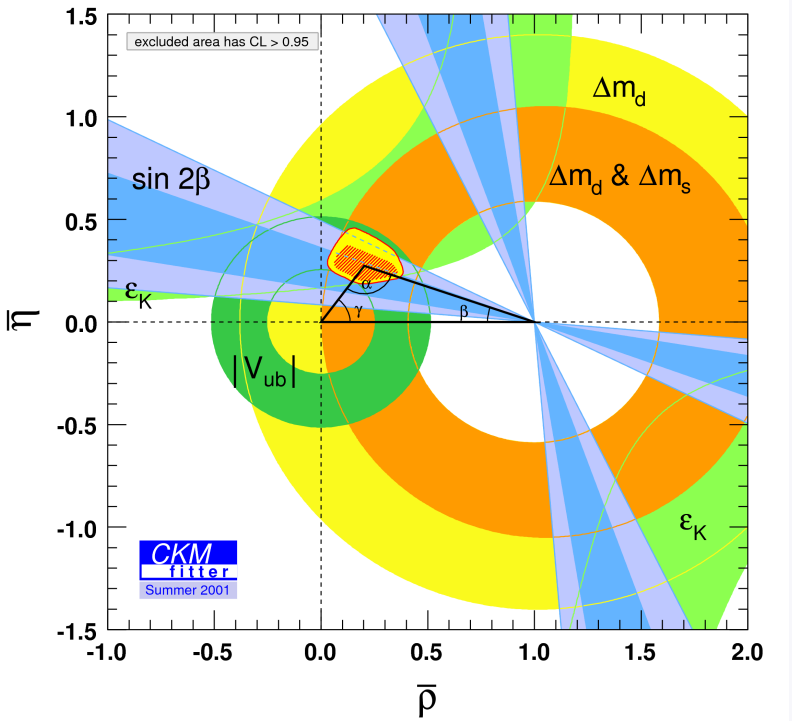
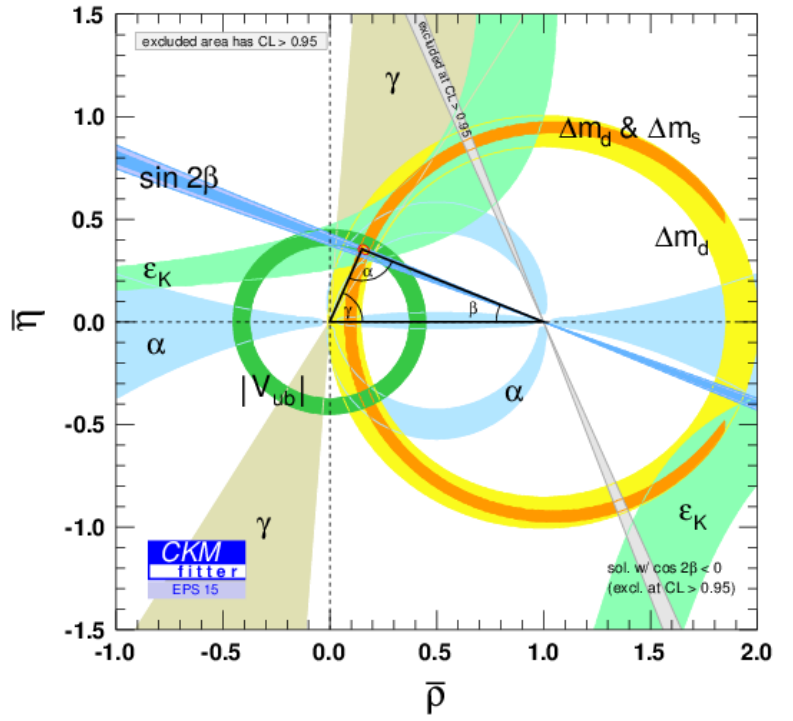




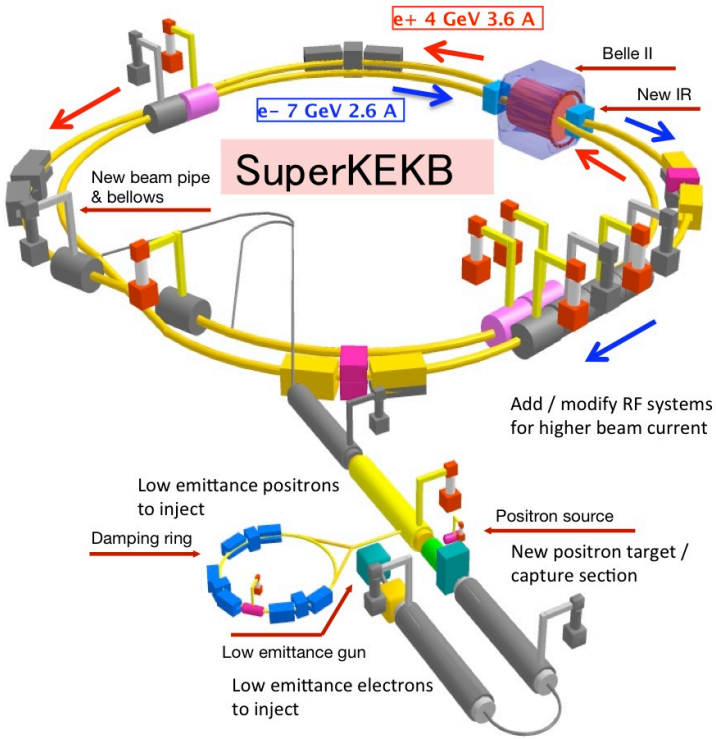
Is B physics done?

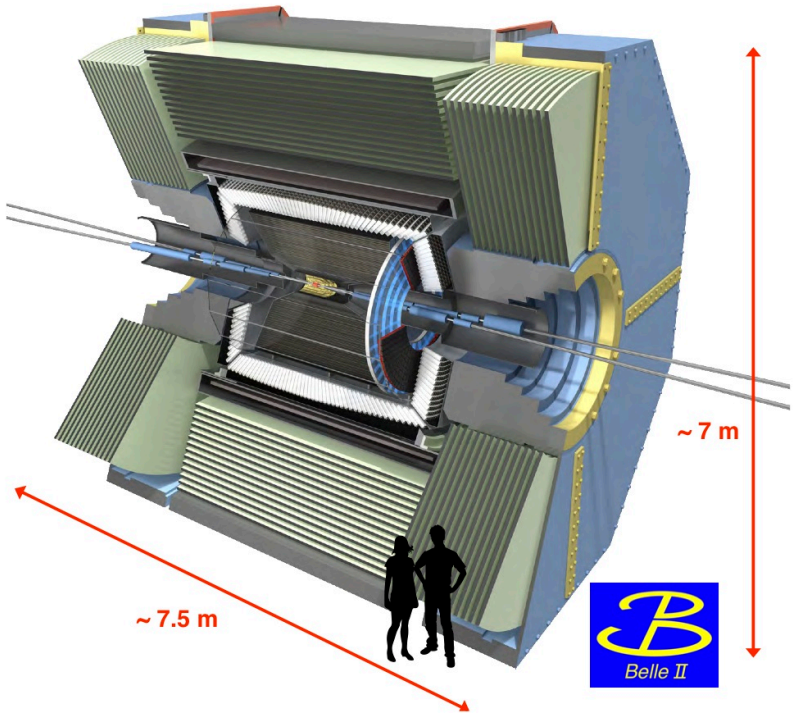
Prospects for New Physics at Belle II

- There is still room for new physics contributions (FCNC,LFV,$B \to \tau$ tree level NP, new sources of CPV)
- Search for NP in the flavor sector at the intensity frontier, provides a probe for beyond the TeV scale.
- Signatures of new particles or psocesses observed through meaurements of suppresses flavor physics reactions or from deviatons from the SM predictions.
- Belle II physics program is much more than just CKM:
  - Lepton Flavor/Number Violation (LFV)/(LNV)
  - Dark sector searches
  - QCD exotics
  - etc.

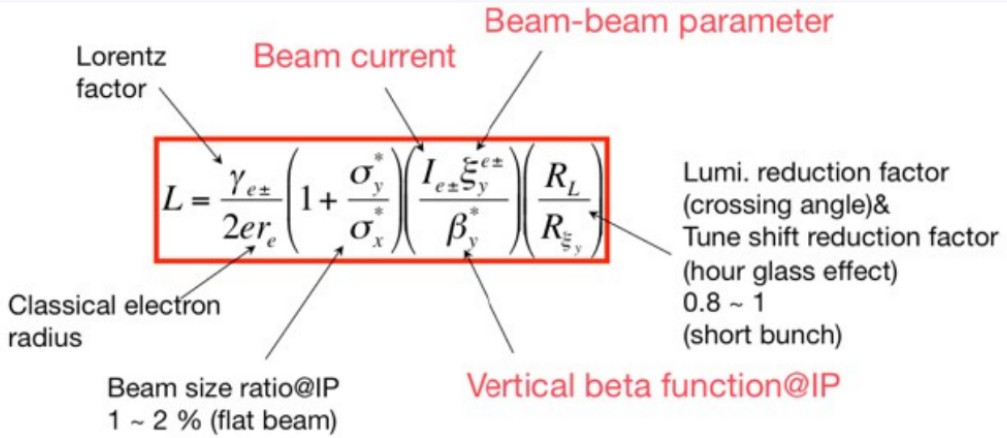
The Belle II Experiment

SuperKEKB

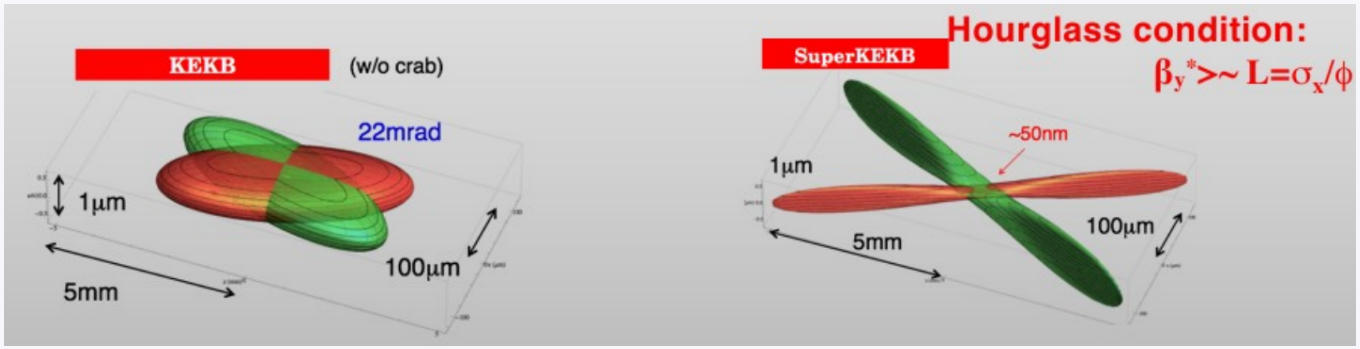

e+ 4 GeV 3.6 A
Belle II
New IR
e- 7 GeV 2.6 A
SuperKEKB
New beam pipe
& bellows
Add / modify RF systems
for higher beam current
Low emittance positrons
to inject
Positron source
Damping ring
New positron target /
capture section
Low emittance gun
Low emittance electrons
to inject


~ 7 m
~ 7.5 m
Belle II

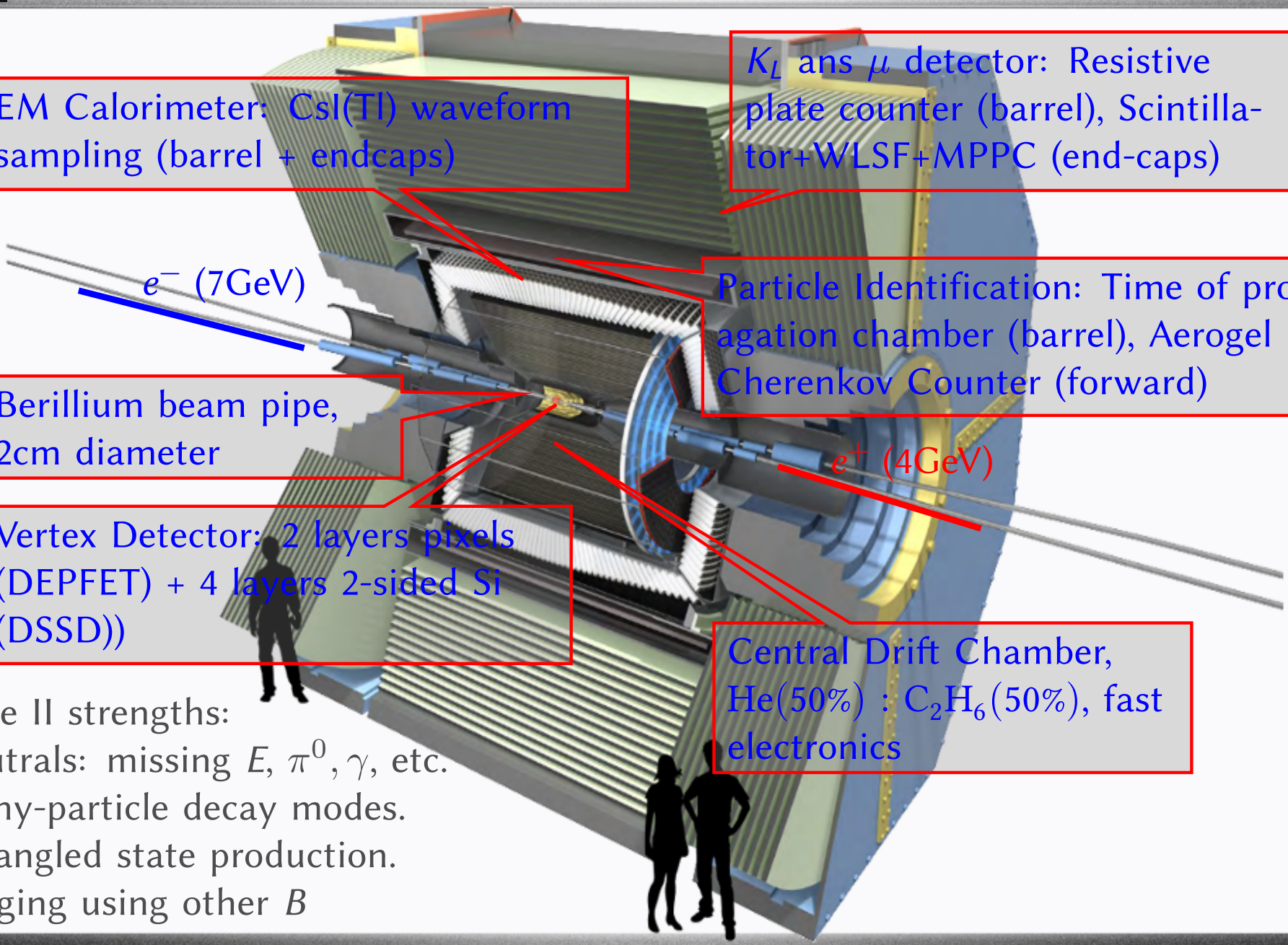
SuperKEKB



	E (GeV) LER/HER	β^*_y (mm) LER/HER	β^*_x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1×10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80×10^{34}



The Belle II Detector



Belle II strengths:
Neutrals: missing E, π^0, γ, etc.
Many-particle decay modes.
Entangled state production.
Tagging using other B

Physics at Belle II

Physics Goals of Belle II

- *CPV* in B decays,
- B/Bottomonium spectroscopy,
- CPV in charmed mesons,
- QCD,
- Semileptonic decays,
- Charm/Charmonium spectroscopy,
- $BF(B^+ \to \tau^+ \nu_\tau)$. Extra Higgs?
- Confirm or resolve $R(D^*) : R(D)$ excess in $R(D^{(*)}) = BF(B^+ \to D^{(*)} \tau^+ \nu_\tau)/BF(B^+ \to D^{(*)} \ell^+ \nu_\ell)$.
- Evidence for Lepton Flavor Violation,
- Heavy Majorana neutrino through $\Delta L = 2$
- FCNC in new decays?
- Dark photons, or other light dark matter?
- Many more.

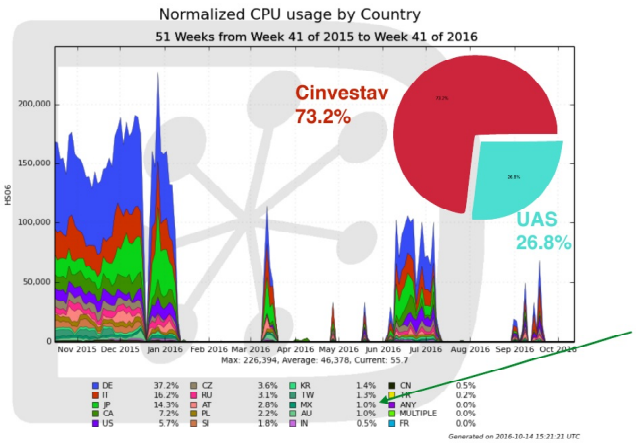
Observables

	Observables	Belle (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
UT angles	$\sin 2\beta$	$0.667 \pm 0.023 \pm 0.012$ [56]	0.012	0.008
	α [°]	85 ± 4 (Belle+BaBar) [24]	2	1
	γ [°]	68 ± 14 [13]	6	1.5
Gluonic penguins	$S(B \to \phi K^0)$	$0.90^{+0.09}_{-0.19}$ [19]	0.053	0.018
	$S(B \to \eta' K^0)$	$0.68 \pm 0.07 \pm 0.03$ [57]	0.028	0.011
	$S(B \to K^0_S K^0_S K^0_S)$	$0.30 \pm 0.32 \pm 0.08$ [17]	0.100	0.033
	$\mathcal{A}(B \to K^0\pi^0)$	$-0.05 \pm 0.14 \pm 0.05$ [58]	0.07	0.04
UT sides	$\lvert V_{cb}\rvert$ incl.	$41.6 \cdot 10^{-3}(1 \pm 1.8\%)$ [8]	1.2%	
	$\lvert V_{cb}\rvert$ excl.	$37.5 \cdot 10^{-3}(1 \pm 3.0\%_{\text{ex.}} \pm 2.7\%_{\text{th.}})$ [10]	1.8%	1.4%
	$\lvert V_{ub}\rvert$ incl.	$4.47 \cdot 10^{-3}(1 \pm 6.0\%_{\text{ex.}} \pm 2.5\%_{\text{th.}})$ [5]	3.4%	3.0%
	$\lvert V_{ub}\rvert$ excl. (had. tag.)	$3.52 \cdot 10^{-3}(1 \pm 9.5\%)$ [7]	4.4%	2.3%
Missing E decays	$\mathcal{B}(B \to \tau\nu)$ [10^{-6}]	$96(1 \pm 27\%)$ [26]	10%	5%
	$\mathcal{B}(B \to \mu\nu)$ [10^{-6}]	< 1.7 [59]	20%	7%
	$R(B \to D\tau\nu)$	$0.440(1 \pm 16.5\%)$ [29]†	5.2%	3.4%
	$R(B \to D^*\tau\nu)^\dagger$	$0.332(1 \pm 9.0\%)$ [29]†	2.9%	2.1%
	$\mathcal{B}(B \to K^{*+}\nu\bar{\nu})$ [10^{-6}]	< 40 [31]	< 15	20%
	$\mathcal{B}(B \to K^+\nu\bar{\nu})$ [10^{-6}]	< 55 [31]	< 21	30%
Rad. & EW penguins	$\mathcal{B}(B \to X_s\gamma)$	$3.45 \cdot 10^{-4}(1 \pm 4.3\% \pm 11.6\%)$	7%	6%
	$A_{CP}(B \to X_{s,d}\gamma)$ [10^{-2}]	$2.2 \pm 4.0 \pm 0.8$ [60]	1	0.5
	$S(B \to K^0_S\pi^0\gamma)$	$-0.10 \pm 0.31 \pm 0.07$[20]	0.11	0.035
	$S(B \to \rho\gamma)$	$-0.83 \pm 0.65 \pm 0.18$ [21]	0.23	0.07
	C_7/C_9 $(B \to X_s\ell\ell)$	~20% [37]	10%	5%
	$\mathcal{B}(B_s \to \gamma\gamma)$ [10^{-6}]	< 8.7 [40]	0.3	–
	$\mathcal{B}(B_s \to \tau\tau)$ [10^{-3}]	–	< 2 [42]‡	–
Charm Rare	$\mathcal{B}(D_s \to \mu\nu)$	$5.31 \cdot 10^{-3}(1 \pm 5.3\% \pm 3.8\%)$ [44]	2.9%	0.9%
	$\mathcal{B}(D_s \to \tau\nu)$	$5.70 \cdot 10^{-3}(1 \pm 3.7\% \pm 5.4\%)$ [44]	3.5%	3.6%
	$\mathcal{B}(D^0 \to \gamma\gamma)$ [10^{-6}]	< 1.5 [47]	30%	25%
Charm CP	$A_{CP}(D^0 \to K^+K^-)$ [10^{-2}]	$-0.32 \pm 0.21 \pm 0.09$ [61]	0.11	0.06
	$A_{CP}(D^0 \to \pi^0\pi^0)$ [10^{-2}]	$-0.03 \pm 0.64 \pm 0.10$ [62]	0.29	0.09
	$A_{CP}(D^0 \to K^0_S\pi^0)$ [10^{-2}]	$-0.21 \pm 0.16 \pm 0.09$ [62]	0.08	0.03
Charm Mixing	$x(D^0 \to K^0_S\pi^+\pi^-)$ [10^{-2}]	$0.56 \pm 0.19 \pm {}^{0.07}_{0.13}$ [50]	0.14	0.11
	$y(D^0 \to K^0_S\pi^+\pi^-)$ [10^{-2}]	$0.30 \pm 0.15 \pm {}^{0.05}_{0.08}$ [50]	0.08	0.05
	$\lvert q/p\rvert(D^0 \to K^0_S\pi^+\pi^-)$	$0.90 \pm {}^{0.16}_{0.15} \pm {}^{0.08}_{0.06}$ [50]	0.10	0.07
	$\phi(D^0 \to K^0_S\pi^+\pi^-)$ [°]	$-6 \pm 11 \pm {}^{4}_{5}$ [50]	6	4
Tau	$\tau \to \mu\gamma$ [10^{-9}]	< 45 [63]	< 14.7	< 4.7
	$\tau \to e\gamma$ [10^{-9}]	< 120 [63]	< 39	< 12
	$\tau \to \mu\mu\mu$ [10^{-9}]	< 21.0 [64]	< 3.0	< 0.3

Urquijo, Phillip, Physics prospects at the Belle II experiment, Nucl. Part. Phys. Proc. 263-264 (2015), pp 15-23, 10.1016j.nuclphysbps.2015.04.004

Mexican Collaboration at Belle II

Country Contribution



CPU:
1.9 kHS06
(1.56 in 2015)

Cores:
156
(120 in 2015)

MX: 1.0%

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Upgrade respect to 2015

- From 4 to **5 modules**
  3 PowerEdge R730
  1 PowerEdge R630
  1 PowerEdge T630

- From 96 to **108 physical cores.**
  Intel(R) Xeon(R) CPU E5-2670 v3 @ 2.30GHz
- From 254 to **282 GB of RAM**
- SL CERN 6.6 and **SL 6.7**

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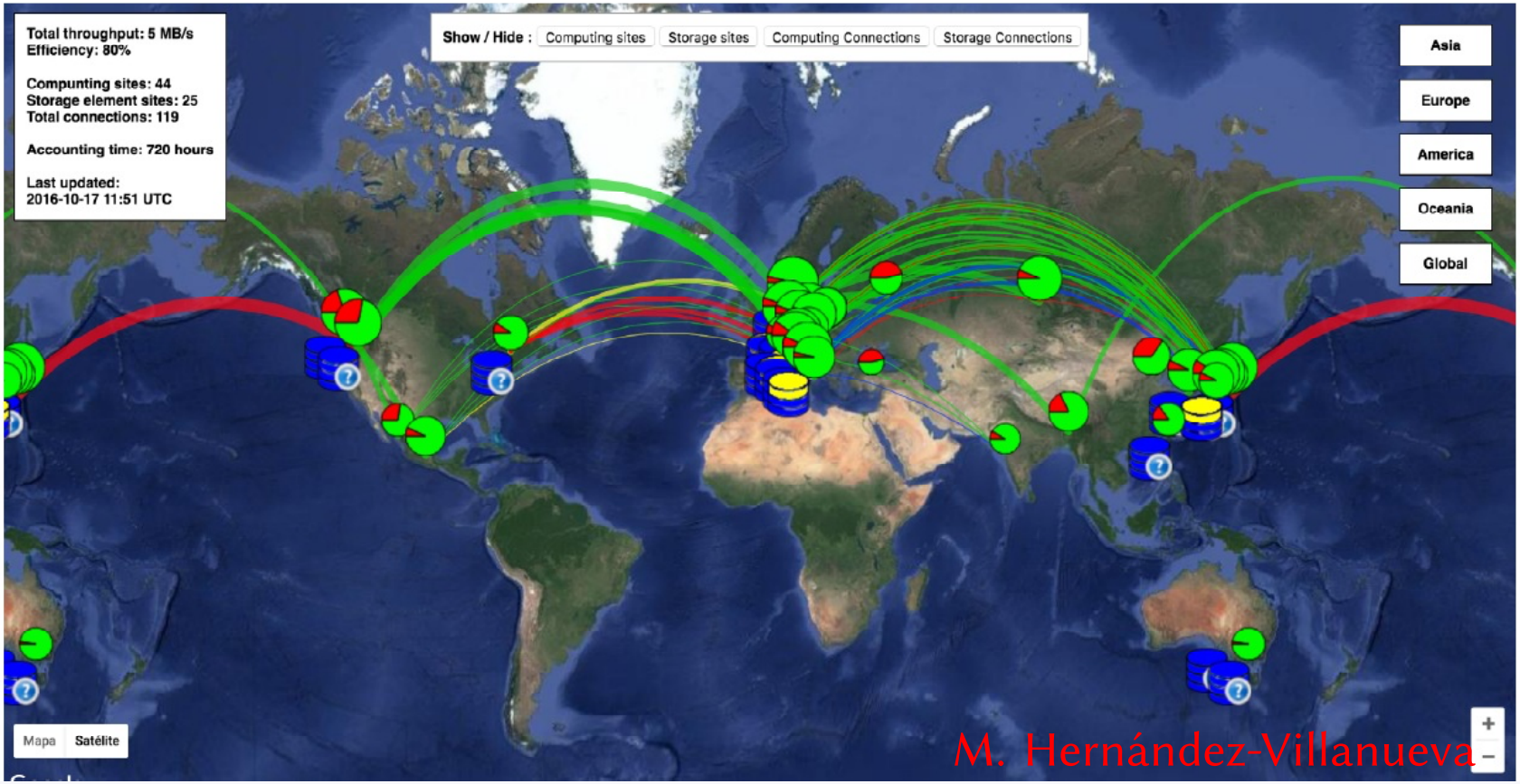
Upgrade respect to 2015

- From 1 to **2 modules**
  2 PowerEdge R730
- From 24 to **48 physical cores**
  Intel(R) Xeon(R) CPU E5-2670 v3 @ 2.30GHz
- From 64 to **416 GB of RAM**
- From Scientific Linux CERN 6.6 to **Scientific Linux CERN 6.8**.

Belle II Computing Map



TAUOLA

- MC simulator for τ decays,
- Belle II Analysis Software Framework, `basf2`, includes an old version, not allowing to include new models,
- The latest version of TAUOLA performs a fit on experimental data, having less systematic uncertainties than theoretical predictions.
- The goal is to be able to include new models without modifying the code, using the lates version,
- We are working to update the TAUOLA version used in KKMC included in `basf2`,

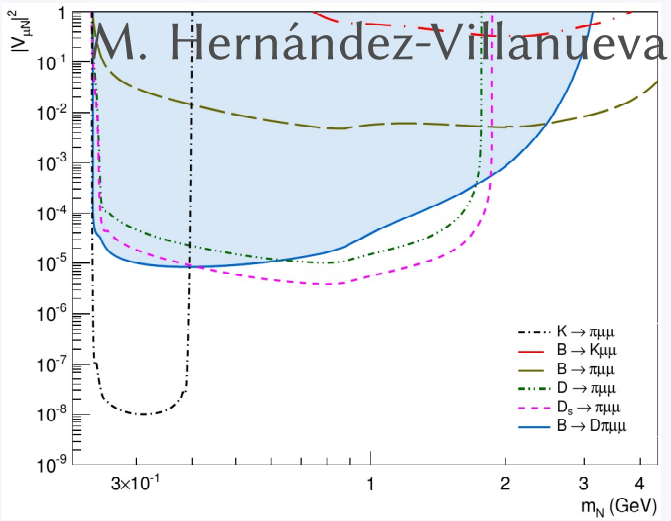
Lepton Number Violation, $B^0 \to D^- \pi^- \ell^+ \ell^+$

- $\Delta L = 2$ decays, signal of Majorana neutrinos.
- Assuming lepton universality, it is possible to write BR as:

$$BR(B^0 \to D^- \pi^- \ell^+ \ell^+) = \frac{1}{(\Gamma_N/|V_{\ell N}|^2)} |V_{\ell N}|^2 f(m_N), \qquad (1)$$

where $(\Gamma_N/|V_{\ell N}|^2)$ it is been estimated, and $f(m_N)$ only contains measured parametes, except for m_N.

- Sensitivity study in $BR(B^0 \to D^- \pi^- \ell^+ \ell^+)$ probably will be published in **Belle II Physics Book**.
- UAS group is working on $BR(\tau^- \to \pi^+ \ell^- \ell^- \nu_\tau)$.



[1] N. Quintero, G. Lopez Castro, and D. Delepine. "Lepton number violation in top quark and neutral B meson decays". In: *Phys. Rev.* D84 (2011). [Erratum: Phys. Rev.D86,079905(2012)], p. 096011. DOI: 10.1103/PhysRevD.86.079905,10.1103/PhysRevD.84.096011. arXiv: 1108.6009 [hep-ph].

$\tau \to \eta^{(\prime)}\pi\nu_\tau$, Second Class Current

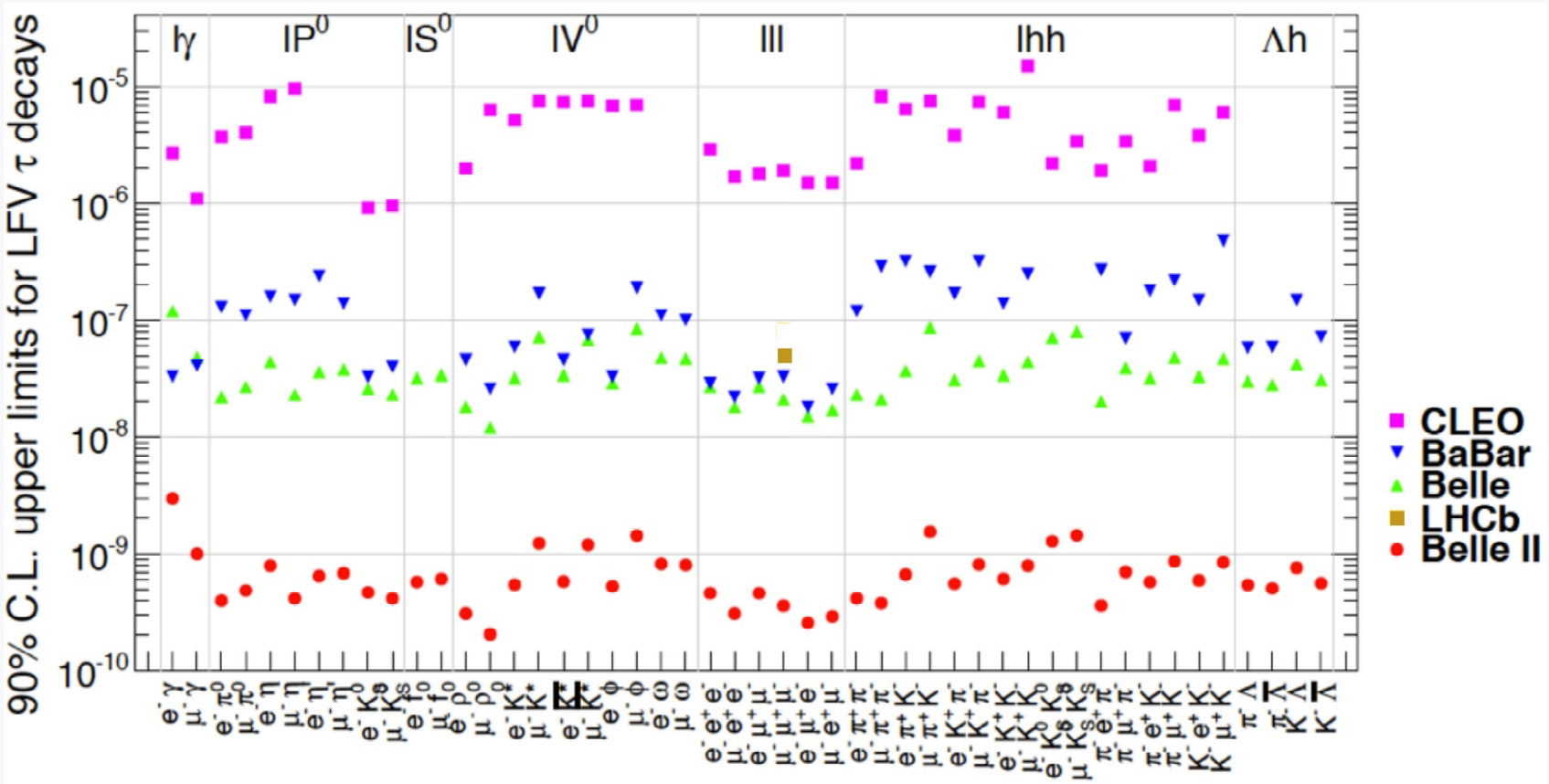
- This process is suppresed in SM,
- However they can also proceed from a charged Higgs Mechanism.
- M. Hernández-Villanueva is creating the analysis tools to measure it in Belle II detectos.

BR_V	BR_S	BR	Reference
$< 10^{-7}$	$[0.2, 1.3] \cdot 10^{-6}$	$[0.2, 1.4] \cdot 10^{-6}$	Nussinov, Soffer [38]
$[0.14, 3.4] \cdot 10^{-8}$	$[0.6, 1.8] \cdot 10^{-7}$	$[0.61, 2.1] \cdot 10^{-7}$	Paver, Riazuddin [39]
$1.11 \cdot 10^{-8}$	$2.63 \cdot 10^{-8}$	$3.74 \cdot 10^{-8}$	Volkov, Kostunin [34]
$[0.3, 5.7] \cdot 10^{-10}$	$[1 \cdot 10^{-7}, 1 \cdot 10^{-6}]$	$[1 \cdot 10^{-7}, 1 \cdot 10^{-6}]$	**P. Roig**
		BR	Experimental collaboration
		$< 4 \cdot 10^{-6}$ (90% CL)	BaBar [13]
		$< 7.2 \cdot 10^{-6}$ (90% CL)	BaBar [40]

[2] Pablo Roig. "Towards the (Mexican) discovery of second class currents at Belle-II". . In: *J. Phys. Conf. Ser.* 761.1 (2016), p. 012067. DOI: 10.1088/1742-6596/761/1/012067. arXiv: 1608.02538 [hep-ph].

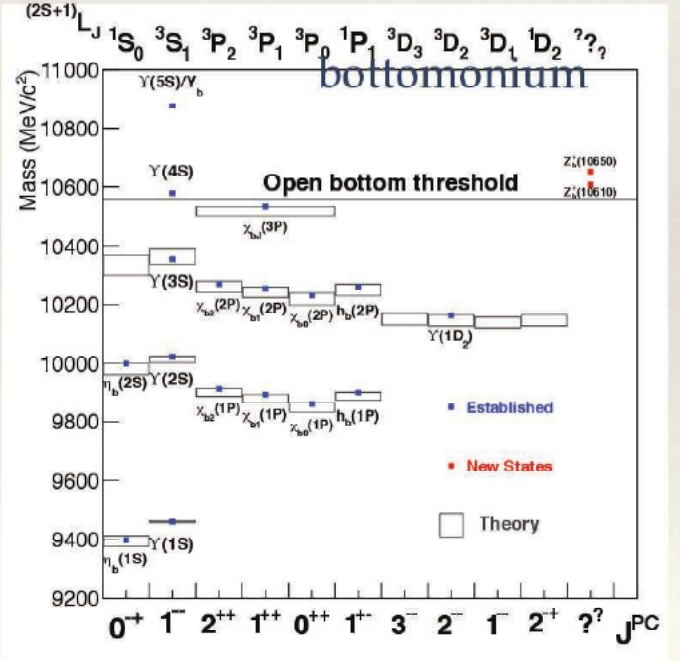
τ decays

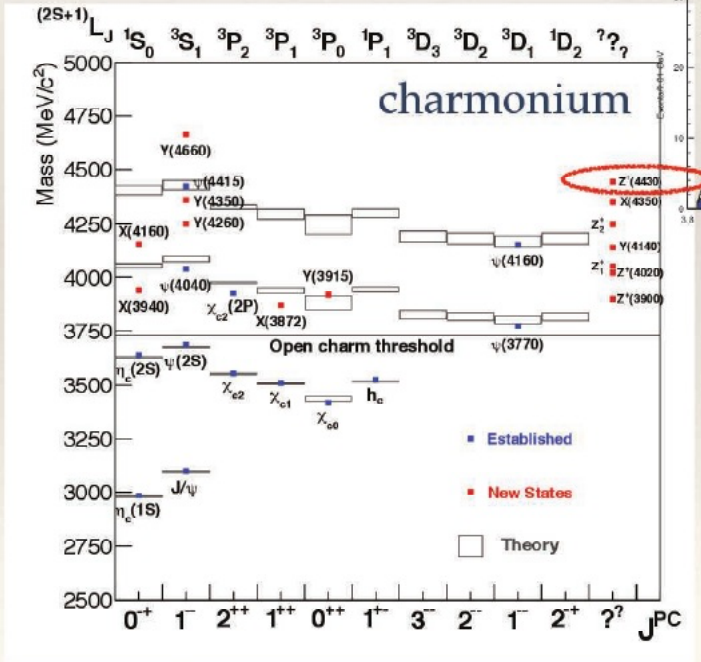
Also plan contribute in LFV in τ decays.

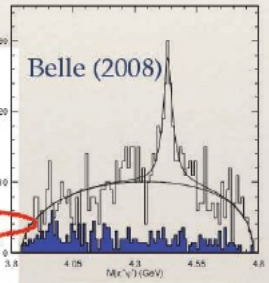


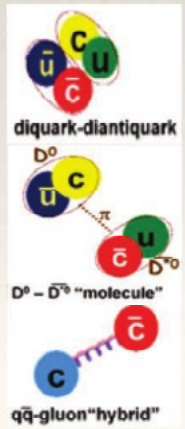
Quarkonium

- Observe and characterize (m, J, P, Br(X→f), etc.) $c\bar{c}$ and $b\bar{b}$ hadrons.
- Belle/BaBar (/BESIII/LHCb/…) found many states that do not fit the mass spectra predicted by the standard quark model: tetraquarks, molecules, hybrids, glueballs, … ?









Conlusions

Conclusions

- Mexican Collaboration in Belle II is having a significant contribution,
- Contributions in Computing, Hardware, Software and Analysis,
- We have a strong theoretical group propossing interesting ananlysis,
-