

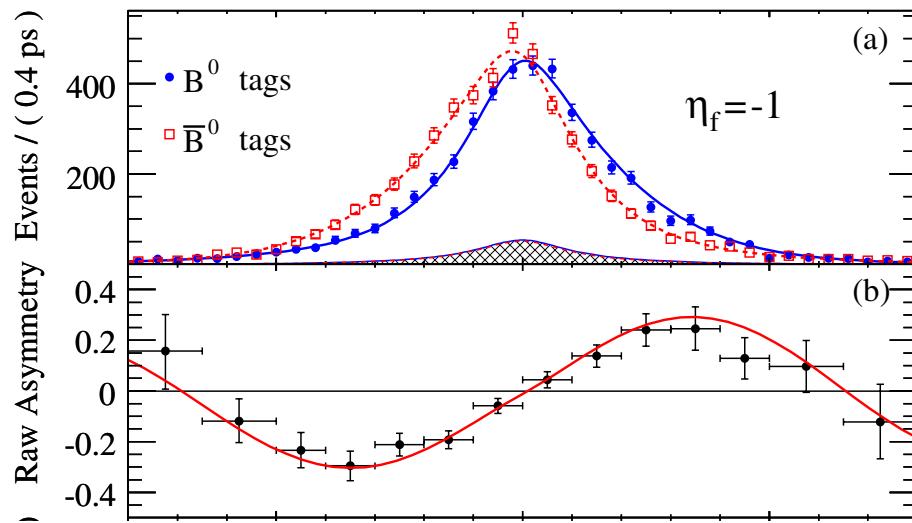
Stato e prospettive dell'esperimento Belle II

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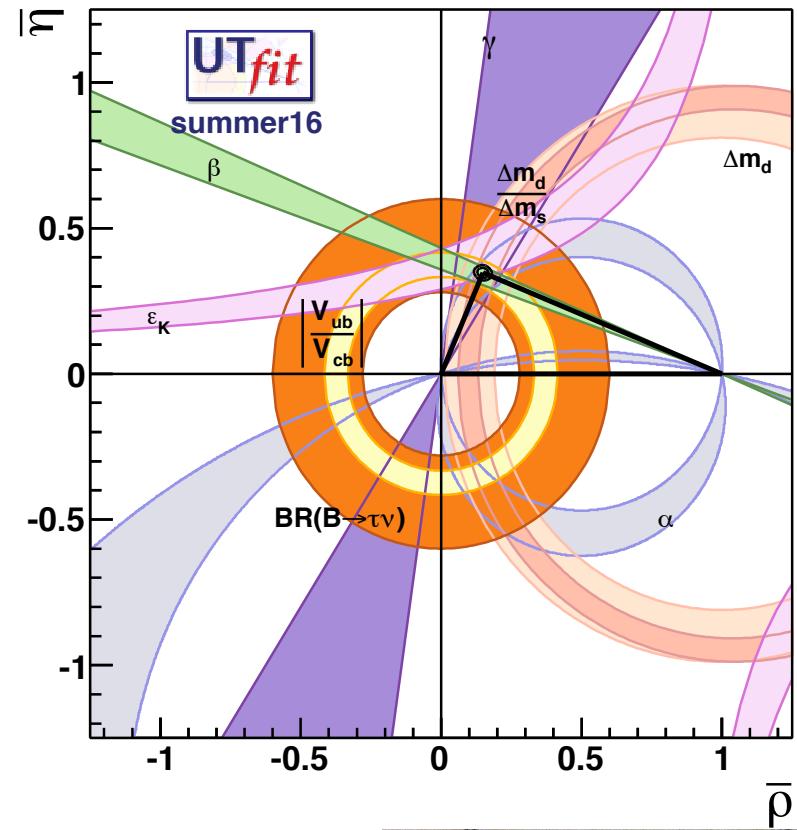
Incontri di Fisica delle Alte Energie
19-21 Aprile 2017



BaBar and Belle B-factories



Successful experimental program
Established CP violation in B system and
remarkable consistency of the CKM
mechanism of the SM



Nobel Prize in Physics
In 2008 awarded to
Kobayashi and
Maskawa



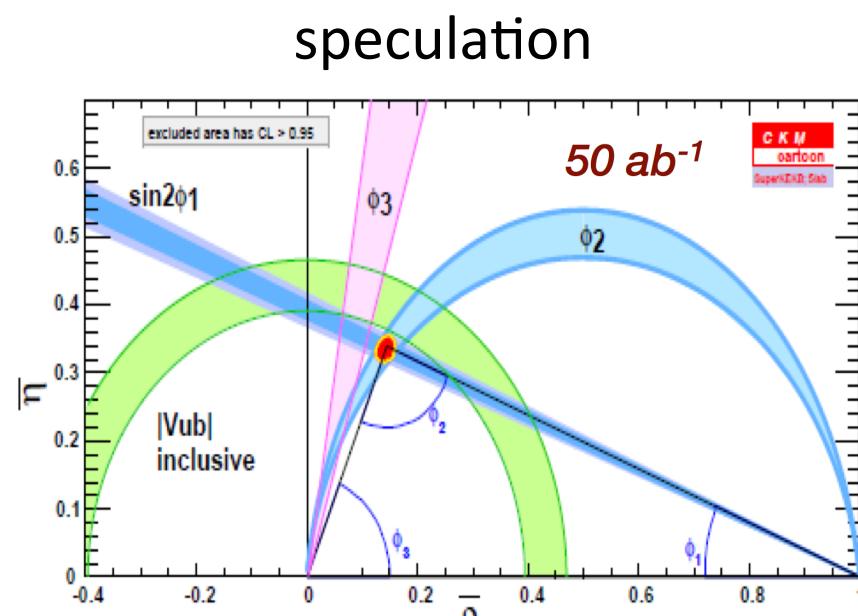
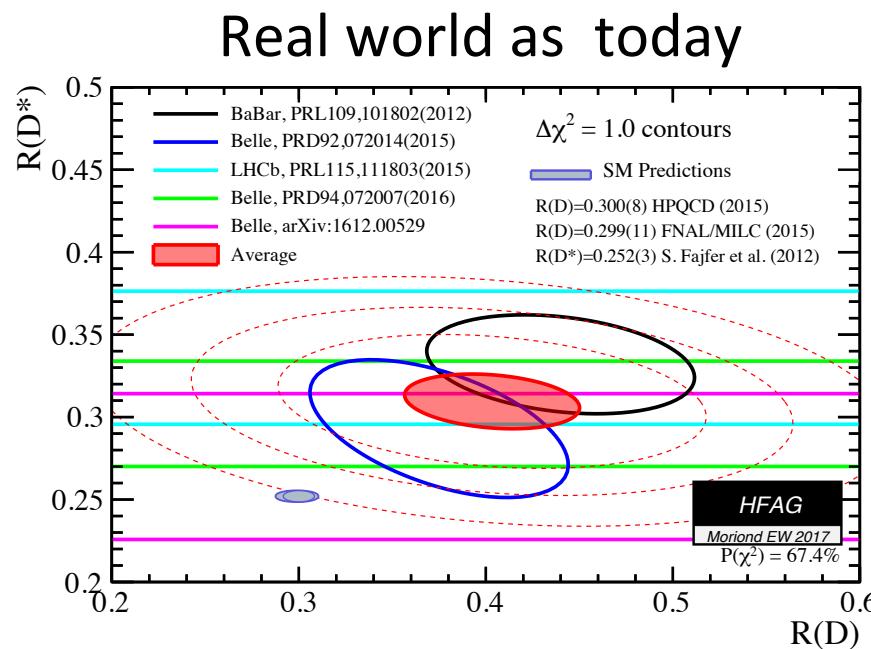
2008



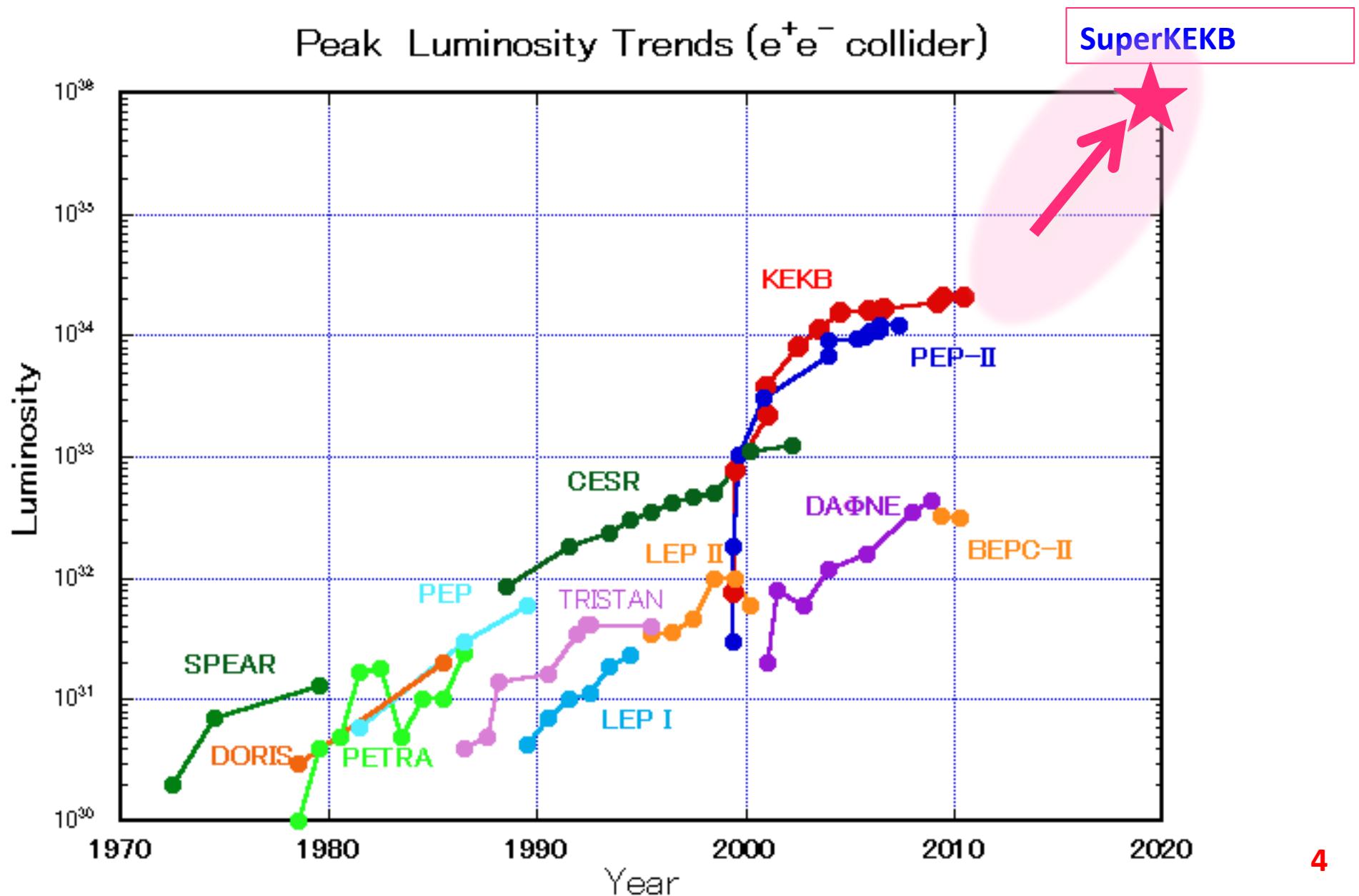
Motivazioni per il flavour a più alta luminosità

Misure di precisione in processi proibiti, soppressi o predetti con precisione nel Modello Standard sono sensibili agli effetti di una fisica oltre il modello standard

Esempio reale: ci sono misure che oggi mostrano un eccesso a 4σ rispetto a quanto atteso dal MS come $R(D^*)$. Anche altre tensioni...

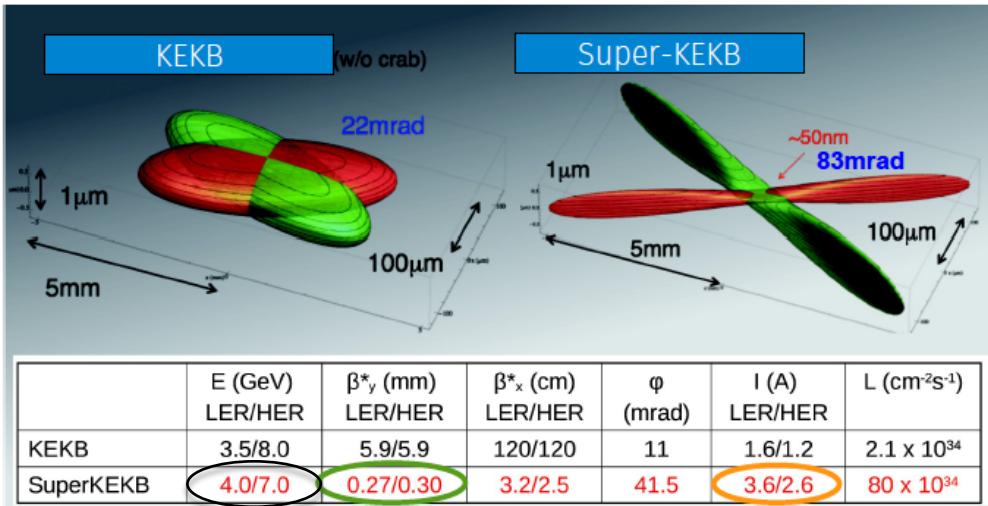


Acceleratore SuperKEKB



Acceleratore: da KEKB a SuperKEKB

Nano-beam scheme firstly proposed by P. Raimondi for SuperB



factor 20
boost ridotto
fattore $\sim 40\text{-}50$ in luminosità

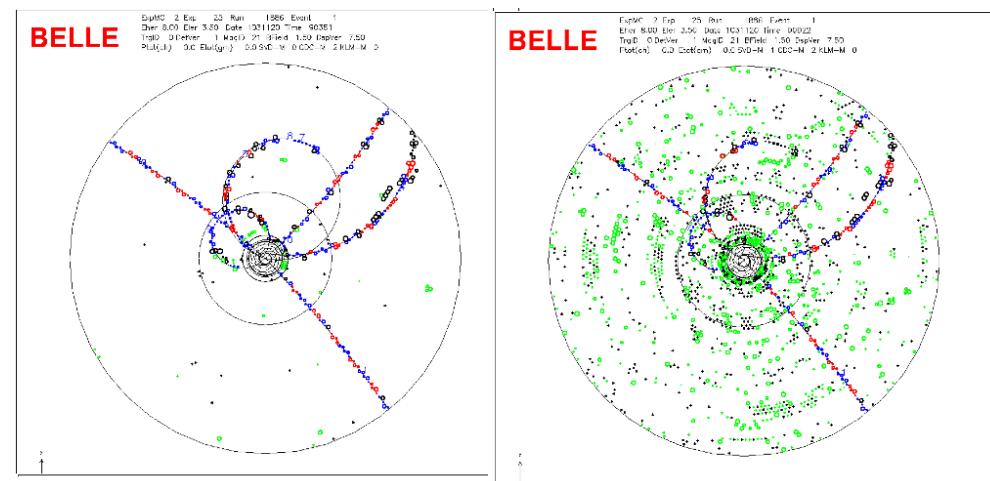
$$\text{Luminosità } L = \frac{\gamma_{\pm}}{2e r_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*}\right) I_{\pm} \xi_{y\pm} \frac{R_L}{R_{\xi_y}}$$

beam current
vertical beta function at IP

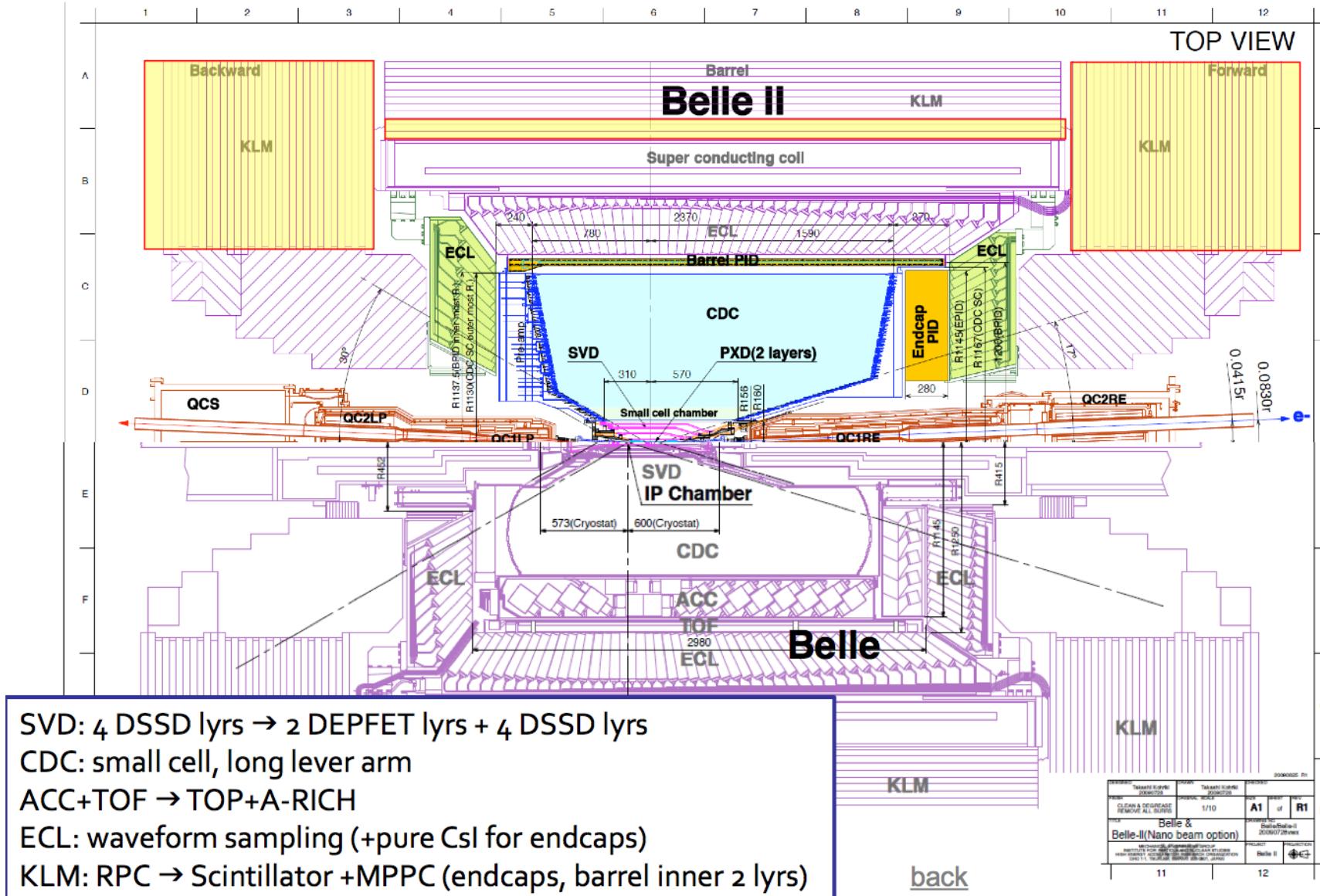
Critical issues at $L = 8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$

Higher event rate (x40)
trigger rate, DAQ, computing

Higher machine backgrounds
radiation damage
occupancy
fake hits and pile-up in the calorimeter



Detector: da Belle a Belle II



Caratteristiche uniche di Belle II

Exactly 2 quantum correlated B mesons at Y(4S)

No trigger bias – almost 100% for B pairs

Excellent efficiency and resolution in tracking
as well as in detecting photons, K_L , π^0
→ reconstruction of intermediate resonances
→ Dalitz plot studies

Clean environment (w.r.t. to hadron machines)
allows “full interpretation” of the event
→ powerful tool for physics with missing
energy (many neutrinos) or fully inclusive
analyses

Large sample of B, D, and τ with low
background

Physics deliverables

Improved precision on CKM elements and
UT angles

Measurement for CP violation phases:

Inclusive measurements $b \rightarrow s/d \gamma$ $b \rightarrow s l l$

Missing energy modes

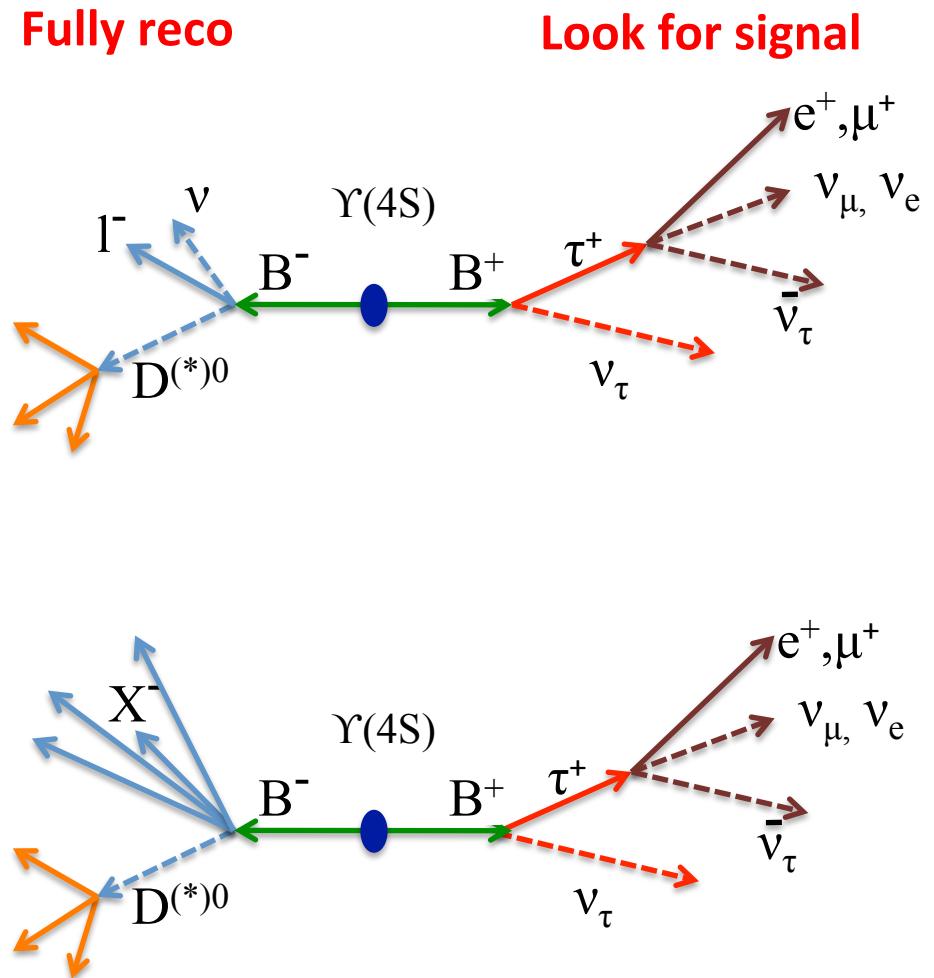
$B \rightarrow l \nu$ $B \rightarrow K \nu \nu$, $B \rightarrow X_{u,c} l \nu$

LFV in $\tau \rightarrow l \gamma$, $3l$

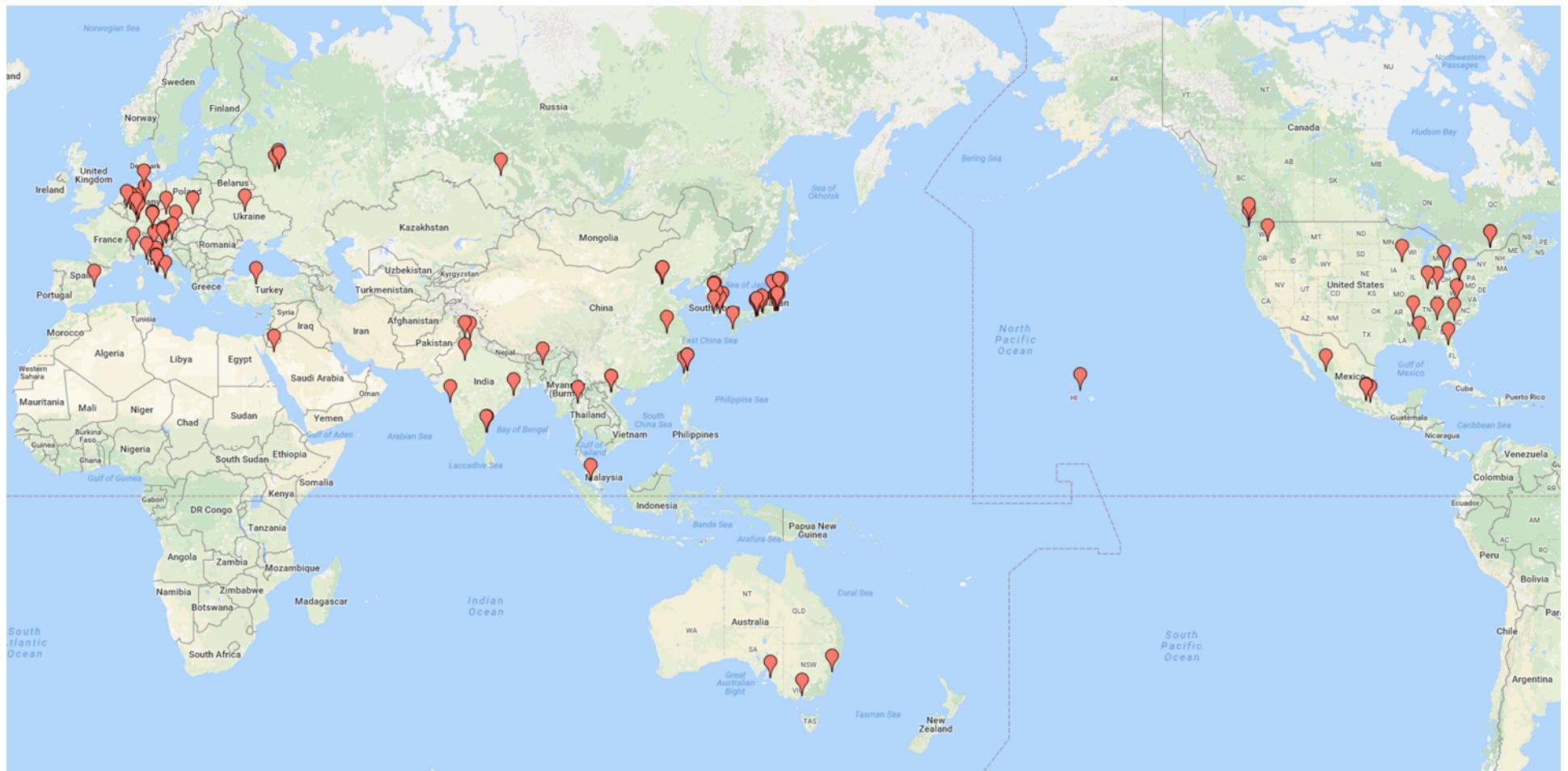
Dark matter, spectroscopy, Hidden sector

Solo a Belle II: Full Event Interpretation

- For signal with weak exp. signature
 - Decay with missing momentum (many neutrinos in the final state)
 - Inclusive analyses
- background rejection improved fully reconstructing the companion B (tag)
- Tag with semileptonic decays
 - PRO: Higher efficiency $\epsilon_{\text{tag}} \sim 1.5\%$
CON: more backgrounds,
B momentum unmeasured
- Tag with hadronic decays
 - PRO: much cleaner events,
B momentum reconstructed
CON: smaller efficiency $\epsilon_{\text{tag}} \sim 0.3\%$



Collaborazione al 2017



750 persone – 101 Istituzioni – 23 Paesi

Roll in del rivelatore: 11 Aprile 2017

GIAPPONE, BELLE II È IN POSIZIONE: SI AVVICINA L'AVVIO DELL'ACCELERATORE DI PIÙ ALTA INTENSITÀ AL MONDO CHE ESPLORERÀ L'IGNOTO

 Pubblicato: 12 Aprile 2017



Il rivelatore Belle II è ora in posizione nel punto di collisione dell'acceleratore SuperKEKB, al laboratorio KEK, in Giappone. È stato così portato a termine un nuovo fondamentale passo verso l'inizio dell'attività scientifica di quello che sarà l'acceleratore di più alta intensità al mondo. Nel pomeriggio dell'11 aprile, è stato, infatti, completato con successo il "roll-in", cioè il posizionamento dell'intero sistema del rivelatore Belle II sulla linea di fascio delle particelle, operazione che segue il completamento nell'area di assemblaggio del montaggio e dell'integrazione dei vari componenti del rivelatore. Belle II, alto 8 metri, costituito da sette sotto-rivelatori, con un peso totale di circa 1400 tonnellate, è stato spostato lentamente e con estrema cautela di circa 13 metri, dal punto di assemblaggio al punto di collisione del fascio, appunto. Ed è ora pronto a raccogliere i dati delle future collisioni prodotte dall'acceleratore, previste per l'inizio del prossimo anno.

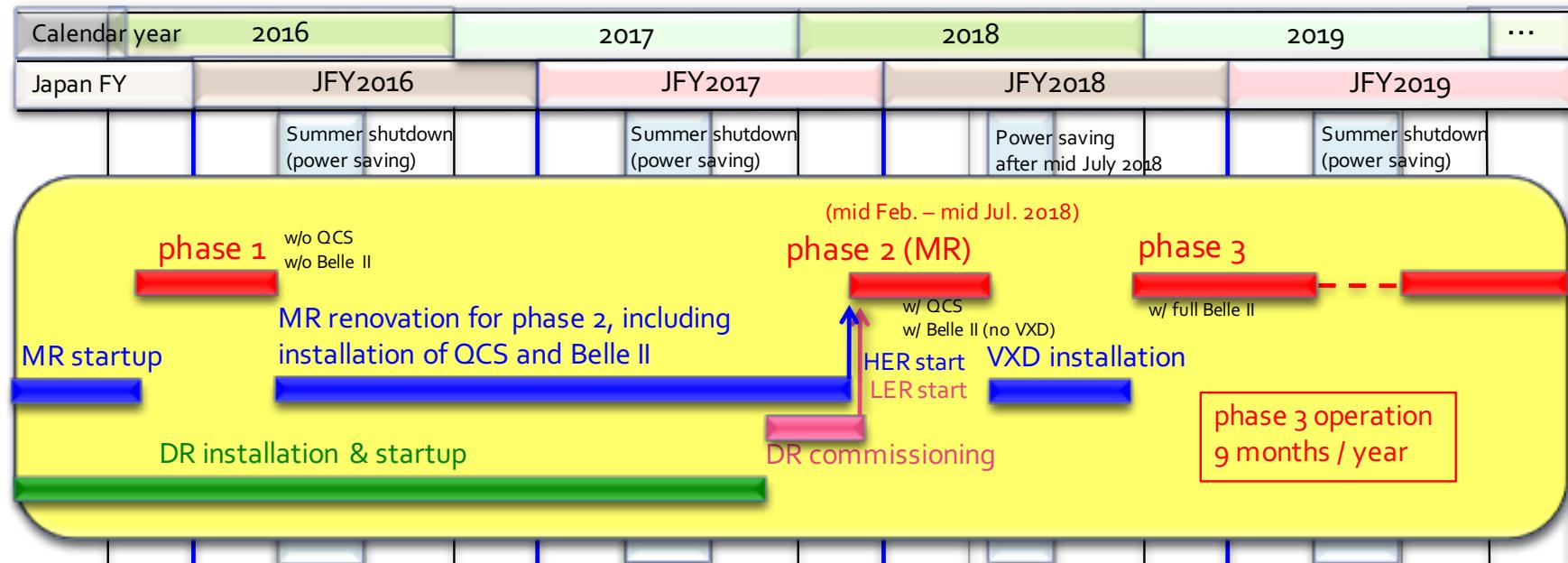
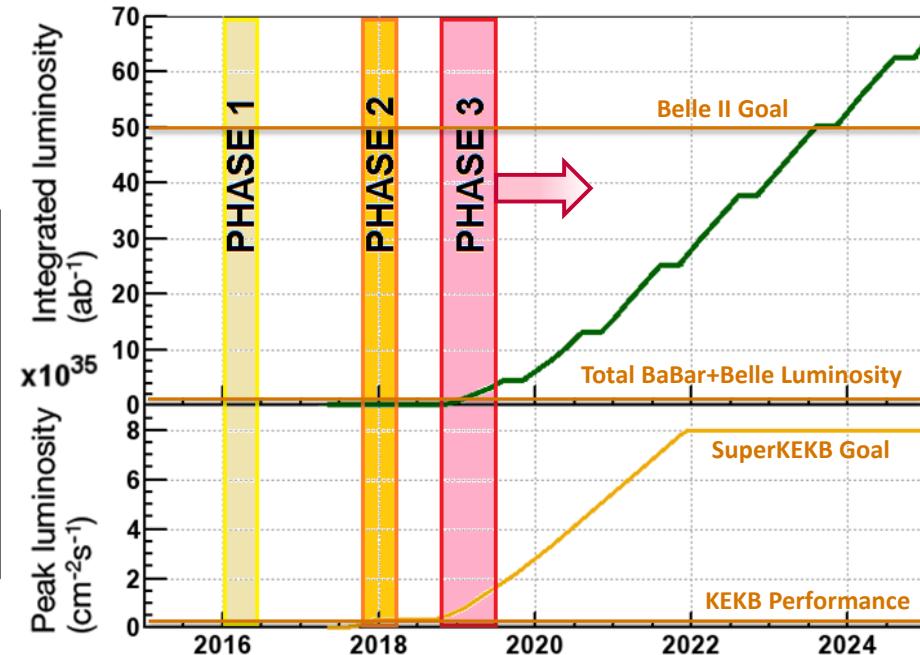
"L'obiettivo scientifico dell'esperimento è l'esplorazione della fisica oltre il modello standard", spiega Francesco Forti, dell'Università ed INFN di Pisa, presidente del comitato esecutivo dell'esperimento, "una fisica ad oggi ignota, e che speriamo possa essere chiarita attraverso le misure di altissima precisione che Belle II potrà effettuare."

Stato e schedule

Phase 1 Accelerator commissioning
BEAST misure del background macchina

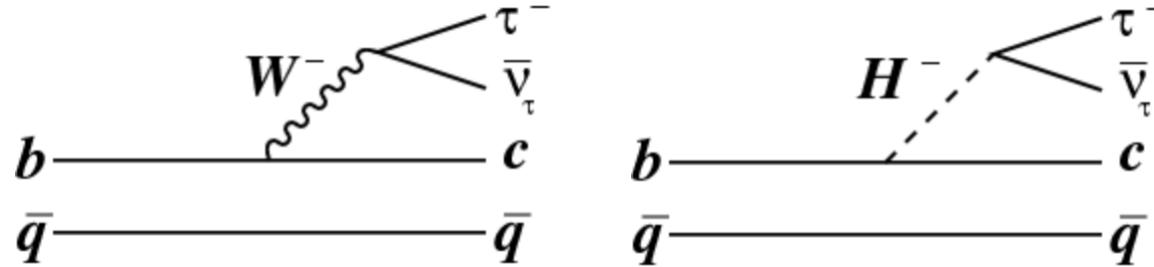
Phase 2 $e^+ e^-$ collisions w/o vertex detector

Phase 3 Data taking with the Full detector



PROSPETTIVE DI FISICA (HIGHLIGHTS)

$B \rightarrow D^{(*)} \tau \nu$



Standard Model prediction theoretically clean
Yield and q^2 distribution from a form factor
Nothing special w.r.t. $B \rightarrow D^{(*)} \mu/e \nu$

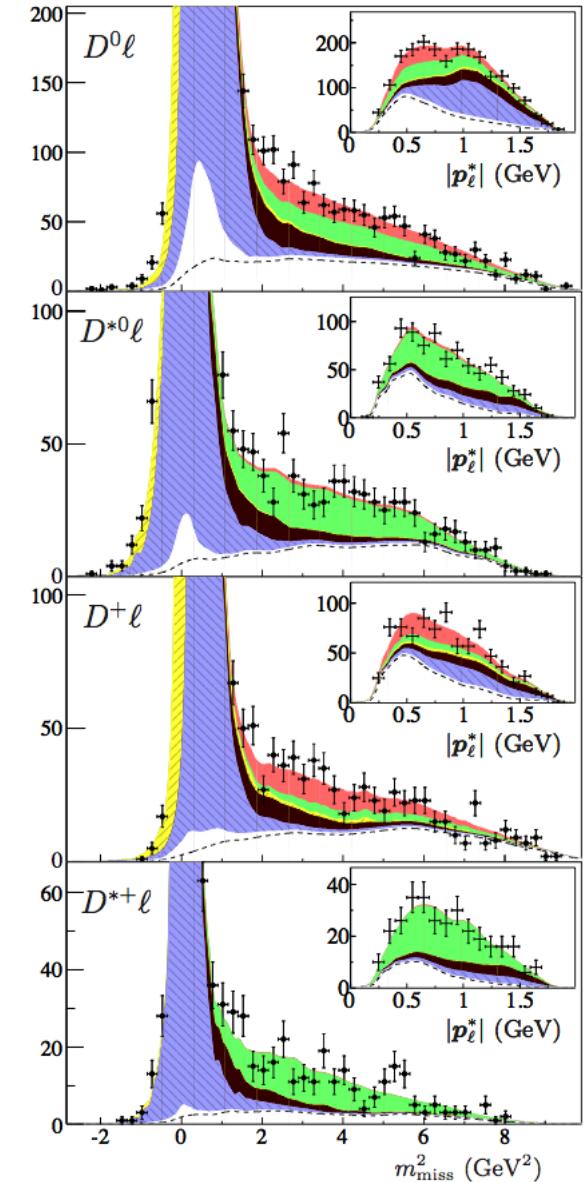
Simplest case of new Physics: from Charged Higgs

Measure a ratio $R = B(B \rightarrow D^{(*)} \tau \nu) / B(B \rightarrow D^{(*)} l \nu)$

Experimentally hard: signature is not a peak on a smooth background!

Data driven methods to control the backgrounds
(combinatorial and D^{**} backgrounds)

$\textcolor{red}{\square} \overline{B} \rightarrow D \tau^- \bar{\nu}_\tau$	$\textcolor{yellow}{\square} \overline{B} \rightarrow D \ell^- \bar{\nu}_\ell$	$\textcolor{black}{\blacksquare} \overline{B} \rightarrow D^{**}(\ell^-/\tau^-)\bar{\nu}$
$\textcolor{green}{\square} \overline{B} \rightarrow D^* \tau^- \bar{\nu}_\tau$	$\textcolor{blue}{\square} \overline{B} \rightarrow D^* \ell^- \bar{\nu}_\ell$	\square Background



Belle II projections

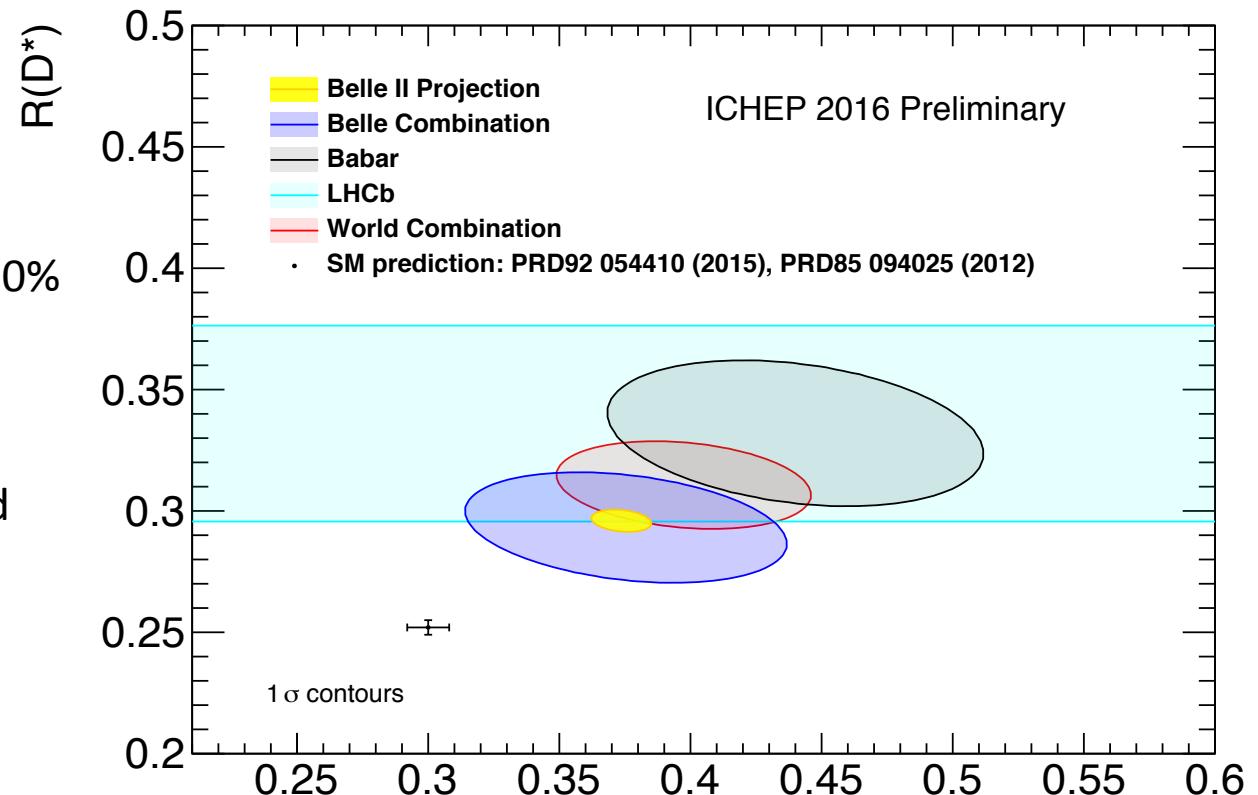
Will confirm the excess early

3% (6%) uncertainty in R after 10% of data taking.

Then systematically limited.

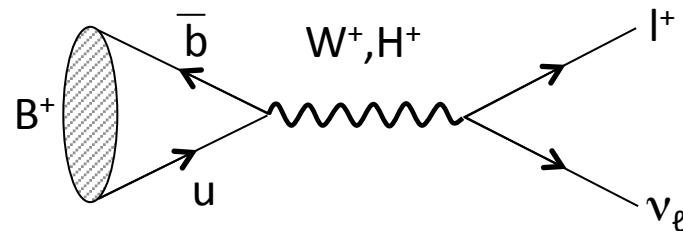
Detailed measurement of q^2 and other kinematical distribution.

Polarization of the τ



	$\Delta R(D) [\%]$			$\Delta R(D^*) [\%]$			$R(D)$
	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	

Decadimenti Leptonici



Very clean theoretically, hard experimentally
SM is helicity suppressed
Sensitive to NP contribution (charged Higgs)

$$\mathcal{B}(B \rightarrow l\nu) = \frac{G_F^2 m_B}{8\pi} m_l^2 \left(1 - \frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

$$\mathcal{B}(B \rightarrow l\nu) = \mathcal{B}(B \rightarrow l\nu)_{SM} \times r_H$$

$$r_H = \left(1 - \tan^2 \beta \frac{m_B^2}{m_H^2}\right)^2 \quad \text{in 2HDM type II}$$

Belle II can also test lepton flavour universality

$$R^{\tau e} = \frac{\Gamma(B \rightarrow e\nu)}{\Gamma(B \rightarrow \tau\nu)}$$

$$R^{\tau\mu} = \frac{\Gamma(B \rightarrow \mu\nu)}{\Gamma(B \rightarrow \tau\nu)}$$

Mode	SM BR	Current meas.	Belle II 5 ab-1	Belle II 50 ab-1
$\tau\nu$	10^{-4}	20% uncertainty	15%	6%
$\mu\nu$	10^{-6}	Need Belle II	20%	7%
$e\nu$	10^{-11}	Beyond reach	-	-

Belle II Full simulation with expected background conditions with hadronic tags only

Extrapolation of untagged Belle analysis

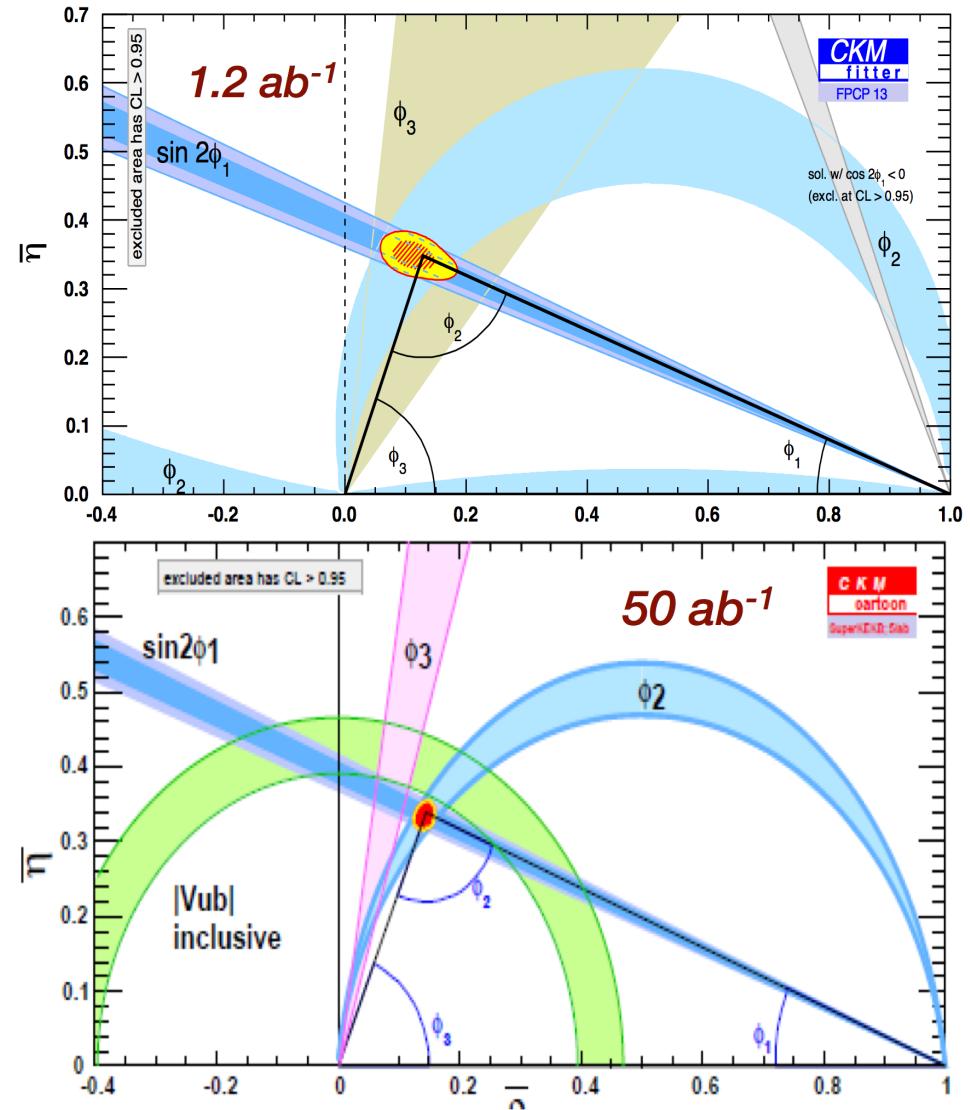
CKM UT angles

Uncertainties on UT angles will be substantially reduced

Competitive with LHC-b
In addition accurate measurements on many final states (with neutrals):
ex: $B \rightarrow \pi\pi, \rho\pi, \rho\rho$ etc...

Angle	WA 2016	Belle II
α	5°	1°
β	0.7°	0.3°
γ	7°	1.5°

Measurement of γ and $|V_{ub}|$ can have the role of setting the SM baseline for interpreting deviations as NP signals



FCNC $b \rightarrow s$

$B \rightarrow K^* \mu \mu$ decays tension with SM expectation in the q^2 distribution

LHC-b observes 3σ disagreement with SM expectation and will dominate measurements in this channel

LHC-b observes a 2.5σ deviation from SM

in $R_{K^*} = \text{BR}(B \rightarrow K^* e e) / \text{BR}(B \rightarrow K^* \mu \mu)$

Belle II: smaller statistics but adds

- Clean electron mode $B \rightarrow K^{(*)} e^+ e^-$ competitive with LHC-b
- Inclusive analysis of $B \rightarrow X_s l^+ l^-$ only at Belle II
- Third generation $B \rightarrow K \tau \tau$ only at Belle II

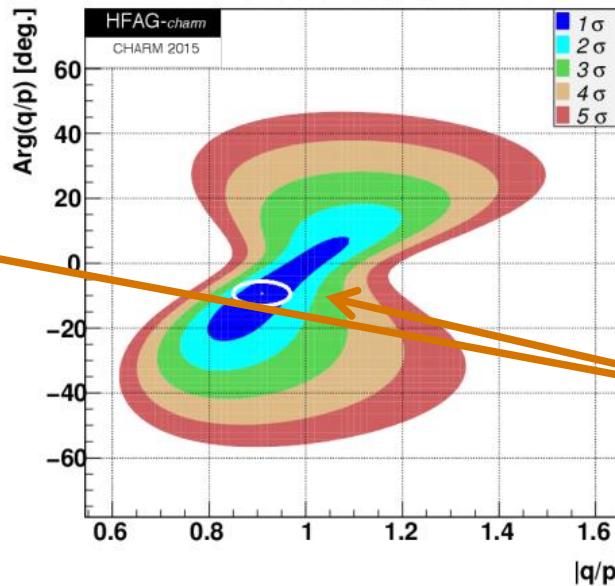
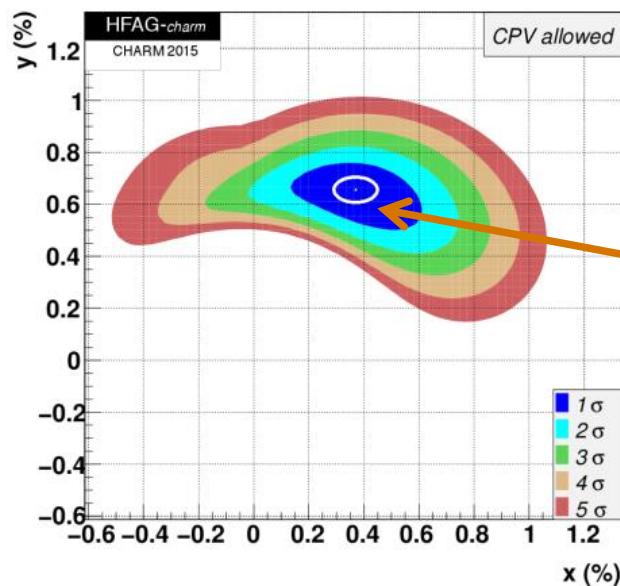
$B \rightarrow K^{(*)} \nu \nu$ rare and out of reach of past B-factories and LHC-b

- SM expectation BR at 10^{-6}
- Belle II expected uncertainty with full dataset 20%

Charm

Belle II is also a super charm factory.

Expected 10x improvements w.r.t. to Belle results on CP violation measurements



δx	0.15%
δy	0.10%
$\delta q/p $	0.05%
$\delta \text{arg } q/p $	5°

Belle II projection

Much more details on Giacomo De Pietro's poster!

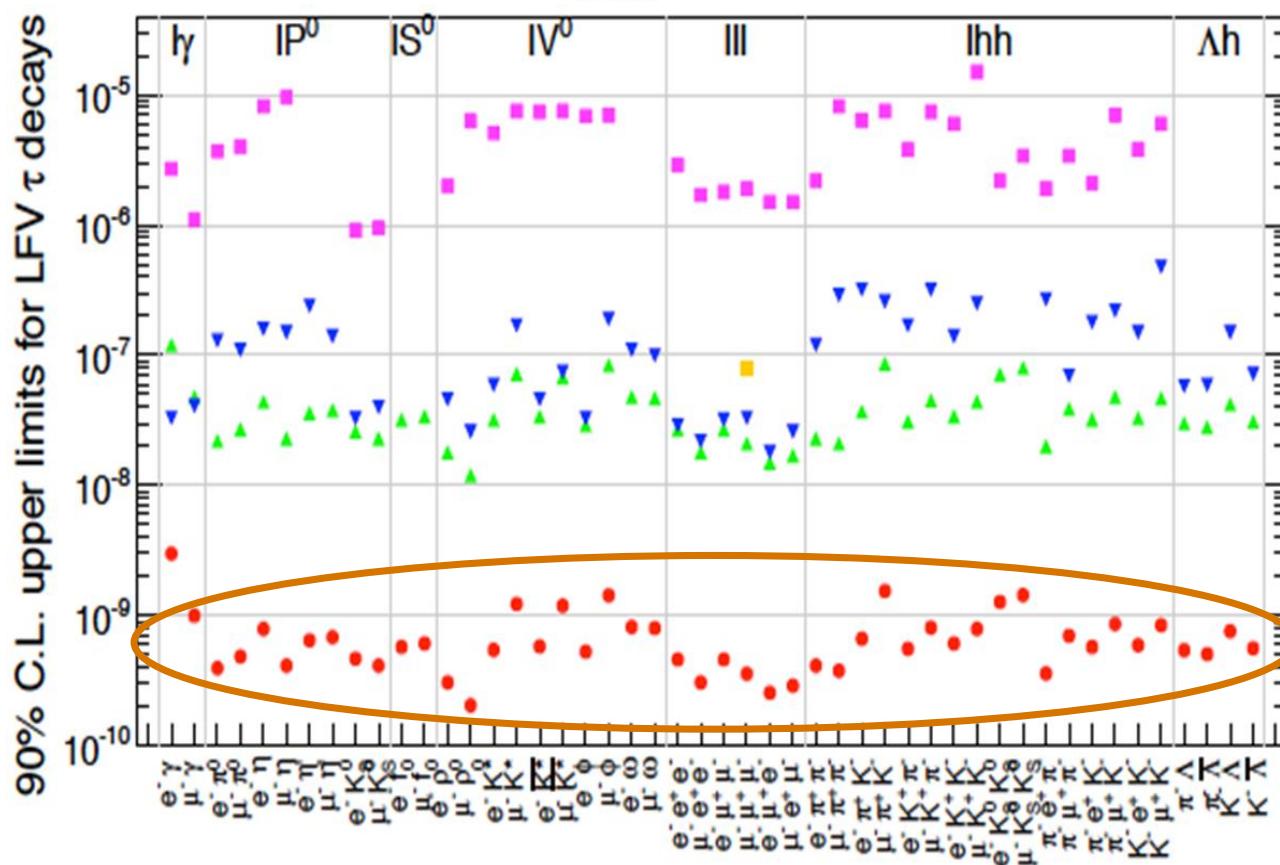
Lepton flavour violation in τ decays

LFV in τ decays clean null test of SM

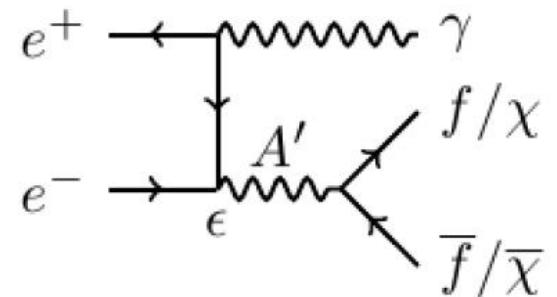
$\tau \rightarrow \mu\mu\mu$ and eee background free searches

LHCb not competitive (?)

	reference	$\tau \rightarrow \mu\gamma$	$\tau \rightarrow \mu\mu\mu$
SM + heavy Maj ν_R	PRD 66(2002)034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547(2002)252	10^{-9}	10^{-8}
SUSY SO(10)	PRD 68(2003)033012	10^{-8}	10^{-10}
mSUGRA+seesaw	PRD 66(2002)115013	10^{-7}	10^{-9}
SUSY Higgs	PLB 566(2003)217	10^{-10}	10^{-7}



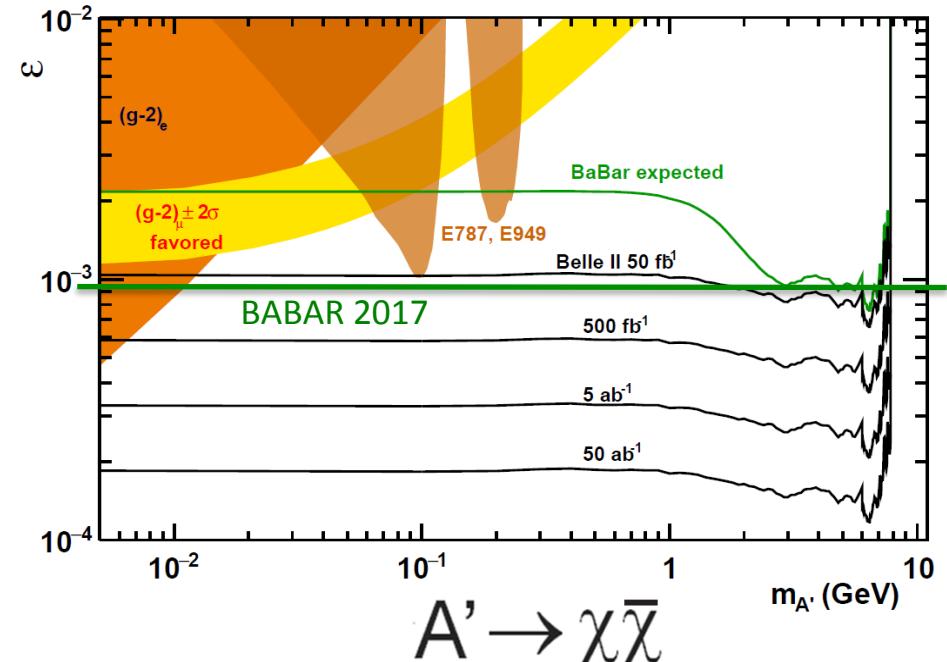
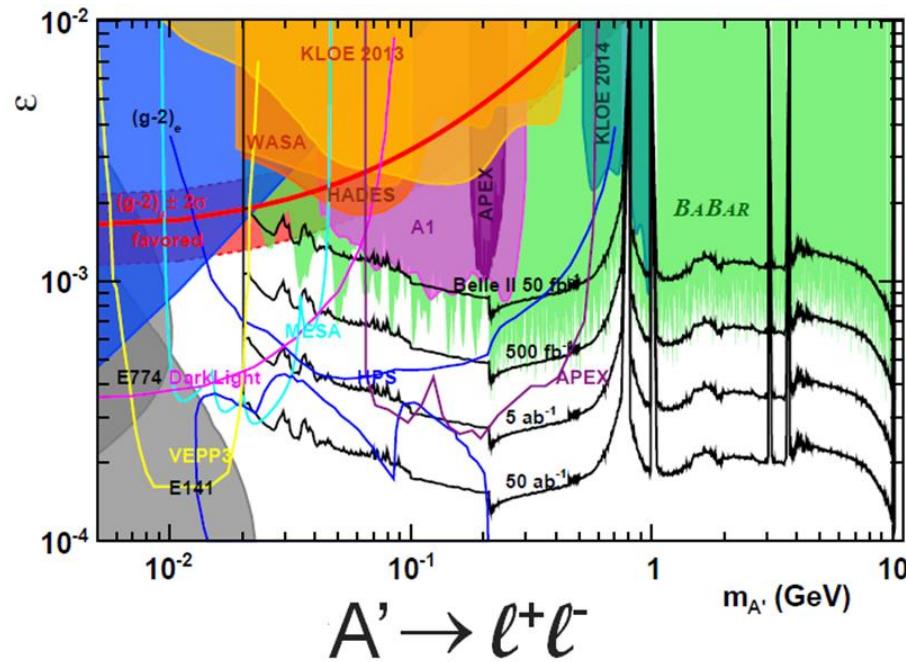
Dark sector



Dark photon A' mixing with SM.

For $A' \rightarrow \chi\bar{\chi}$ decays a custom single photon trigger is being developed

Can extend reach in parameter space search done by BaBar \rightarrow Fabio Anulli's talk



Conclusioni

Le caratteristiche uniche delle collisioni $e^+ e^-$ a SuperKEKB e del detector Belle II forniscono un grande potenziale di scoperta.

Il programma di Fisica è competitivo e in grande parte complementare con quello di LHC-b

Commissioning acceleratore e circolazione di singoli fasci. Misure dei background e validazione simulazioni (Fase I). Completato nel 2016.

Posizionamento del rivelatore (roll in) avvenuto l'11 Aprile 2017.

Fase II: collisioni $e^+ e^-$ senza vertice attese a Febbraio 2018. Data taking fino all'estate.

Fase III: Data taking (in condizioni sicure per il vertice) atteso tra Novembre 2018 e Gennaio 2019