Status of Belle II and Physics Prospects

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Capri2016, June 13, 2016

Overview

1. Introduction

2. Status of SuperKEKB and Belle II

3. Prospects for Physics at Belle II
   – based on the discussion in B2TIP

4. Summary

1. Introduction

- Up to now, there is no symptom of New Physics(NP) observed in ATLAS/CMS experiments. There is a possibility that the scale of NP is even more than 10 TeV, which is out of reach by them.

- The indirect search for NP at ***Belle II***, a new generation B-factory where the search region can be extended to more than O(10TeV), will be more important.

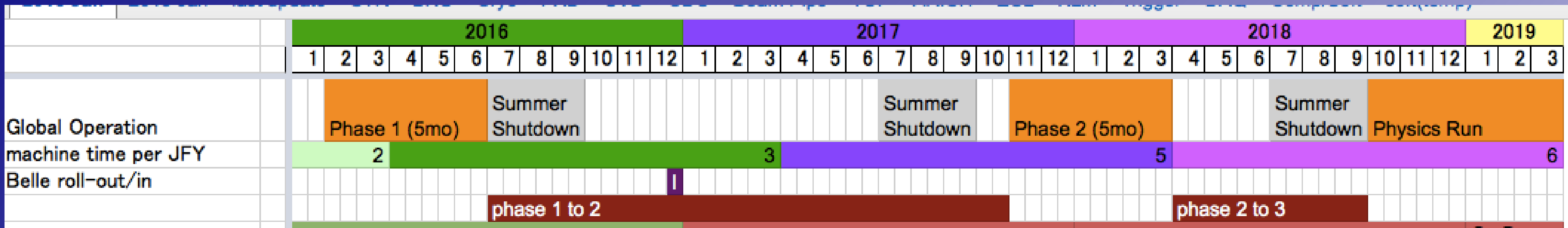
- However, the effect of NP in the indirect processes is expected to be tiny, and a clear signature has not yet been observed by Belle/BaBar/LHCb so far.

- To go beyond, more precise measurements in much higher statistics of events in a clean environment is required.

KEKB/Belle upgrade to achieve > x40 higher luminosity. = SuperKEKB/Belle II

2. Status of SuperKEKB and Belle II

Belle II Schedule



- The operation of SuperKEKB accelerator has been started from the beginning of this year although the beams are not yet collided.

- "BEAST" detector is now implemented in the IP to monitor the background level

June 7, 2016 (LER beam current at 845 mA, HER at 780 mA)

Beam-beam parameter

Lorentz factor

Beam current

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

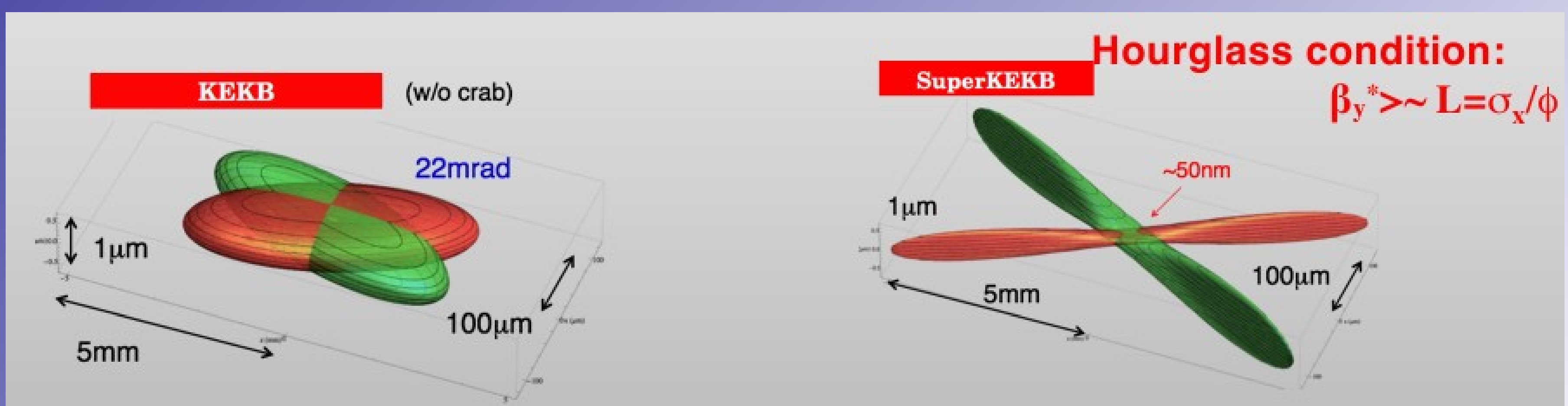
Lumi. reduction factor (crossing angle)&
Tune shift reduction factor (hour glass effect)
0.8 ~ 1
(short bunch)

Classical electron radius

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

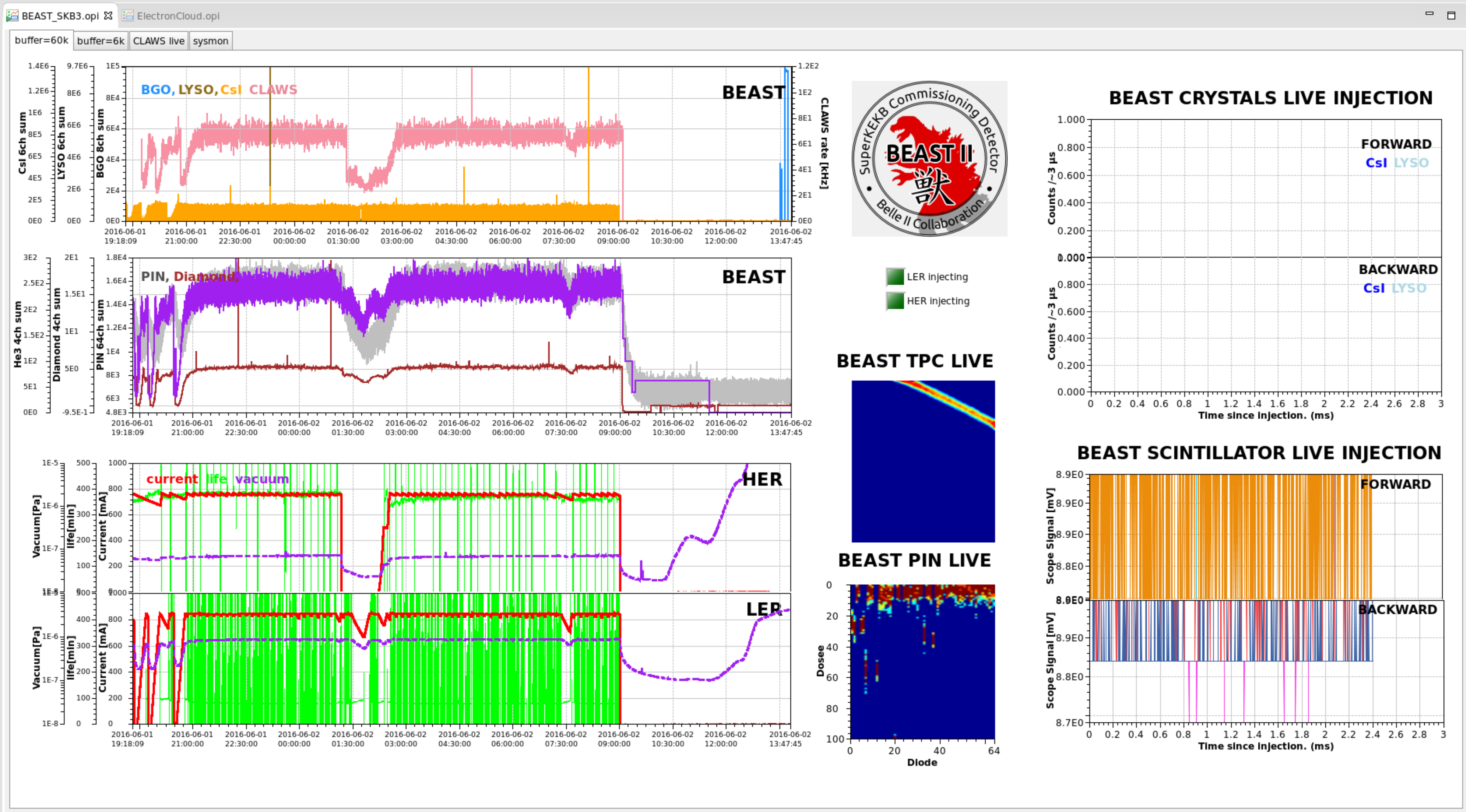
Vertical beta function@IP

	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}



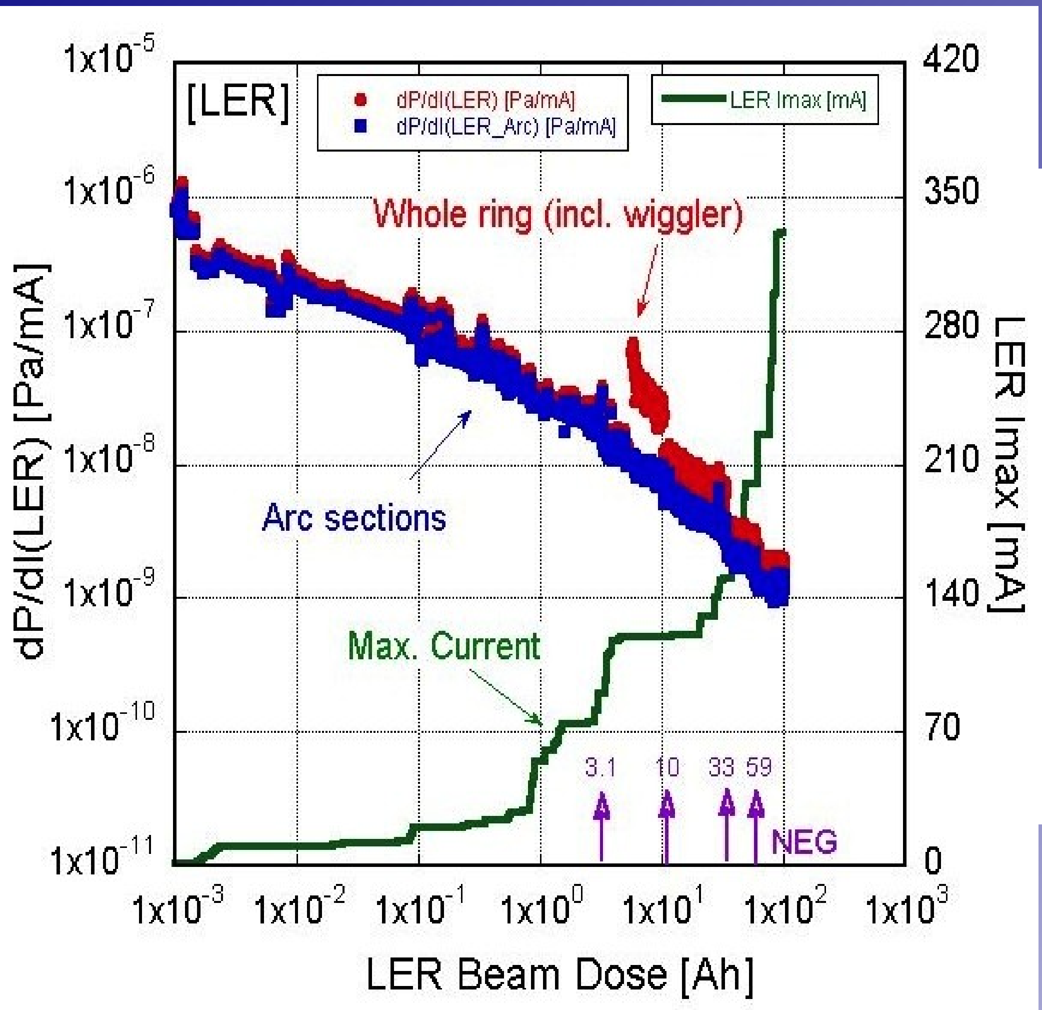
Collision commisioning is scheduled in “Phase II” run.

BEAST operation snapshot

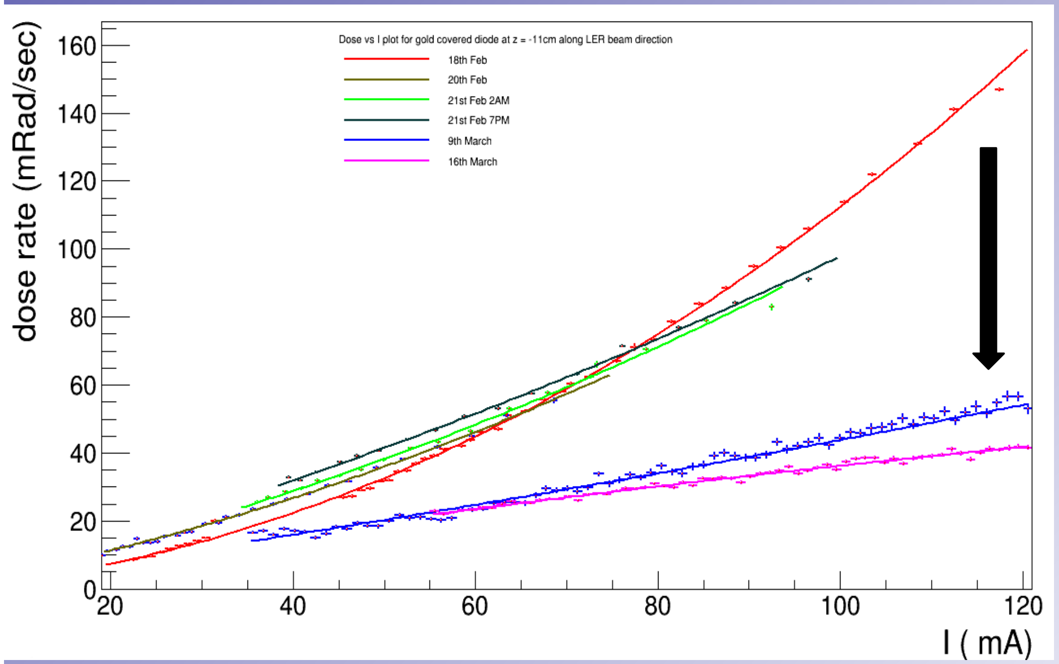


Vacuum scrubbing is going on to reduce the background caused by the beam gas.

LER integrated beam dose > 100 A-h



BEAST background in the LER vs time



BEAST data shows the LER backgrounds decreasing as vacuum scrubbing proceeds.

Belle II Collaboration

As of Feb. 2016

23countries/regions
98 institutions
~700 researchers

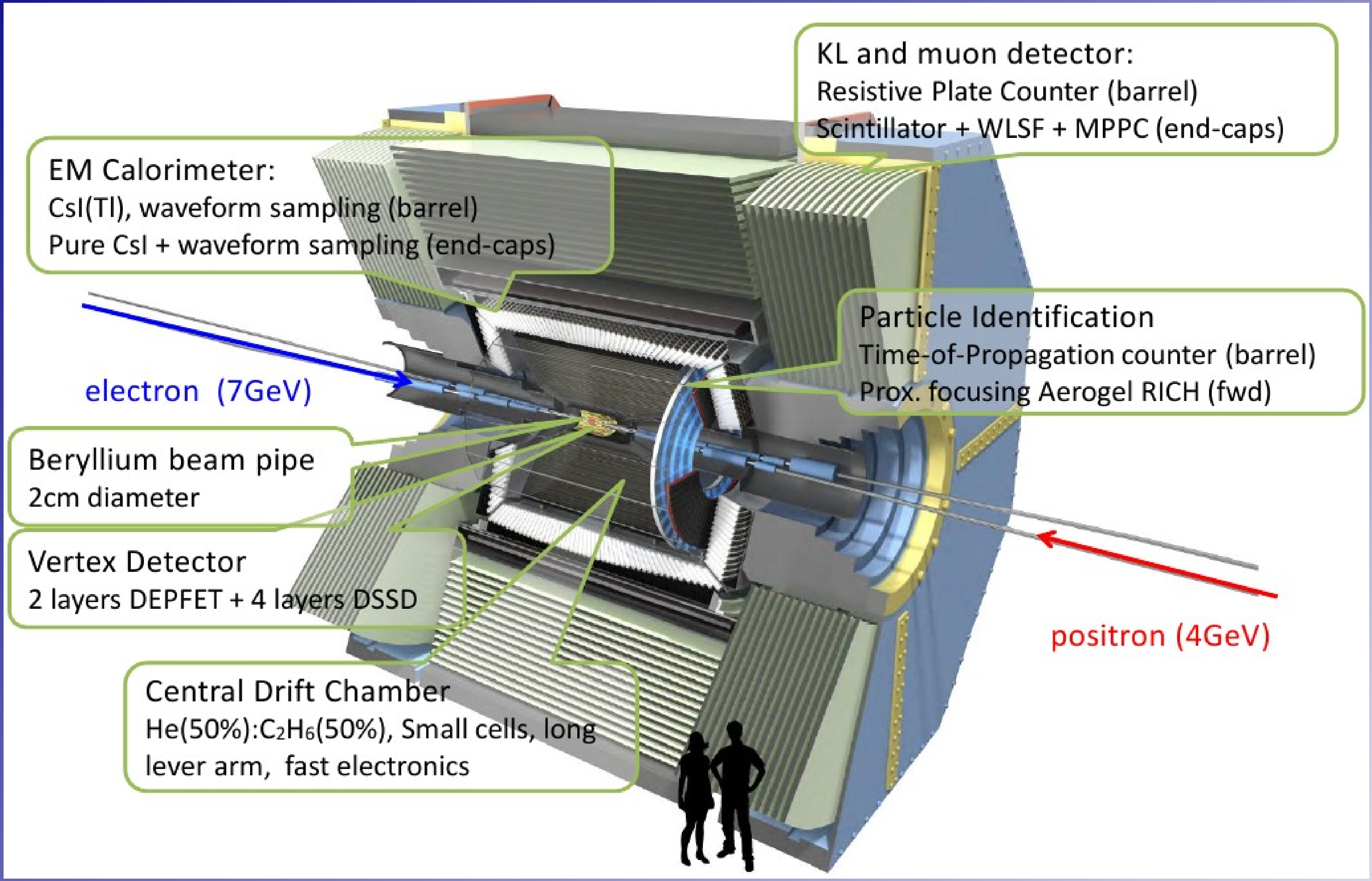
Europe	262
Austria	13
Czech	6
Germany	96
Italy	69
Poland	12
Russia	44
Slovenia	18
Spain	2
Ukraine	2

Asia	313
Saudi Arabia	5
Australia	26
China	22
India	33
Japan	156

Korea	37
Malaysia	7
Vietnam	4
Taiwan	20
Thailand	1
Turkey	2

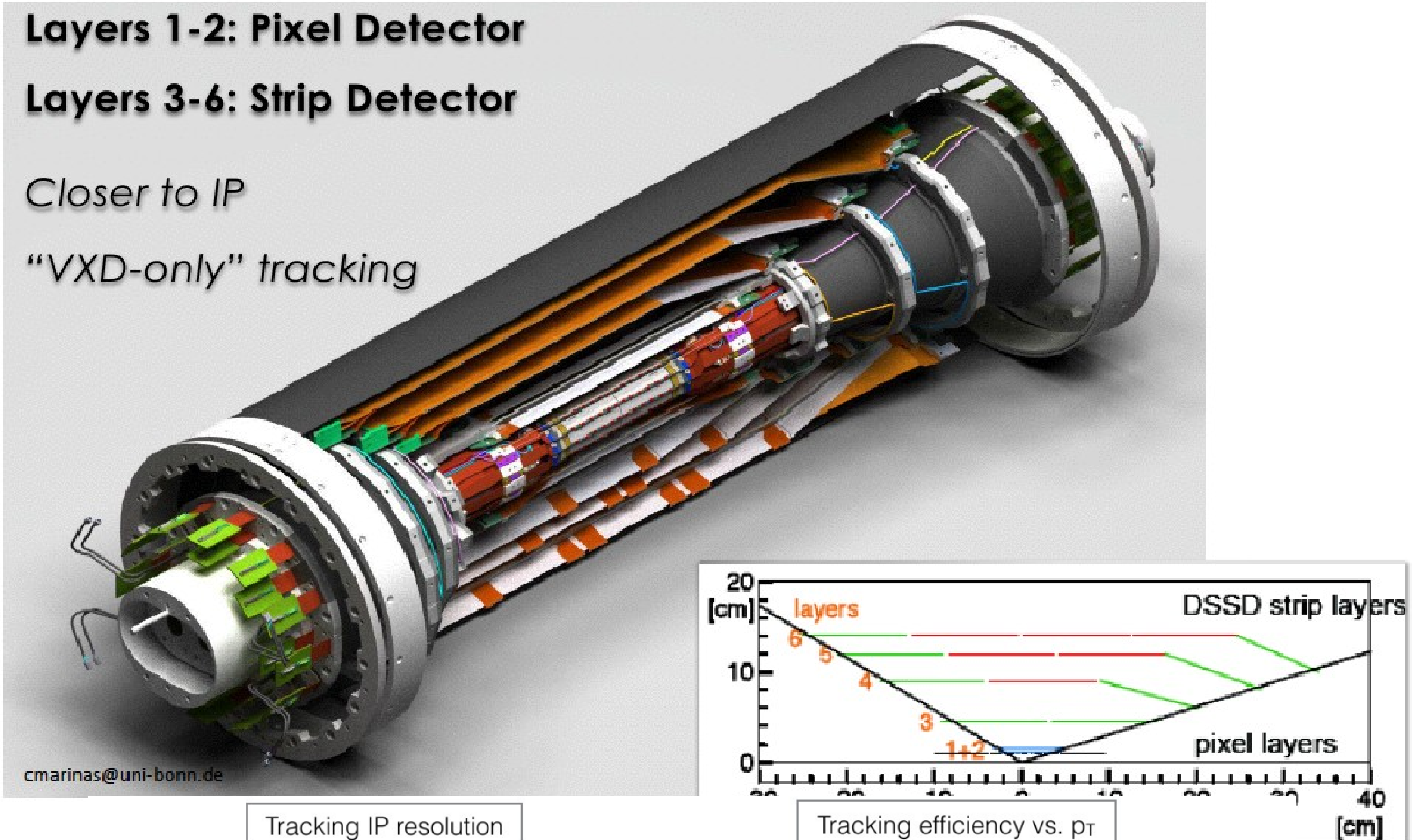
America	111
Canada	26
Mexico	10
USA	75

The Belle II detector

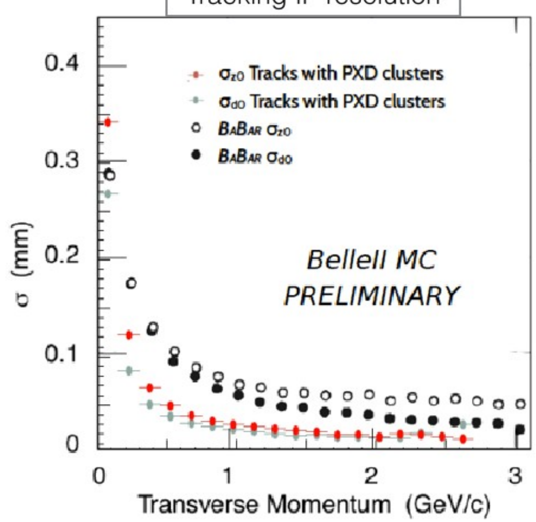


- High granularity "pixelized" sensors ← to be tolerable for high rate
  * Improved vertex detector with DEPFET Pixel sensors + DSSD
  * Improved particle ID devices (TOP, ARICH)
- High bandwidth DAQ (>30GB/sec data flow @30kHz, >1MB/event)

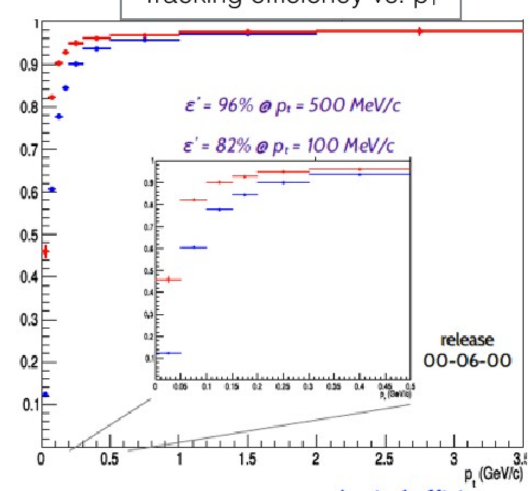
Vertex Detector : Pixel detector + Silicon strip detector



Tracking IP resolution

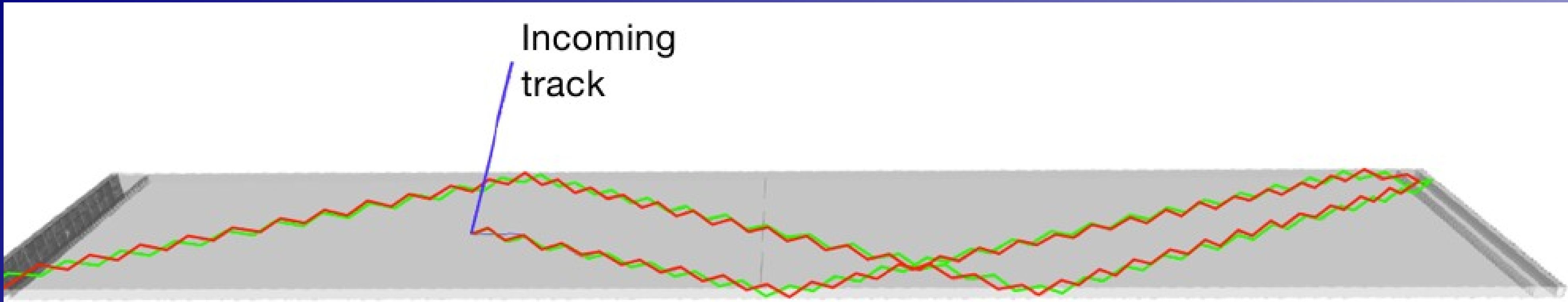


Tracking efficiency vs. p_T



• physical efficiency
• geometrical acceptance and

*release-6 (December 2015)



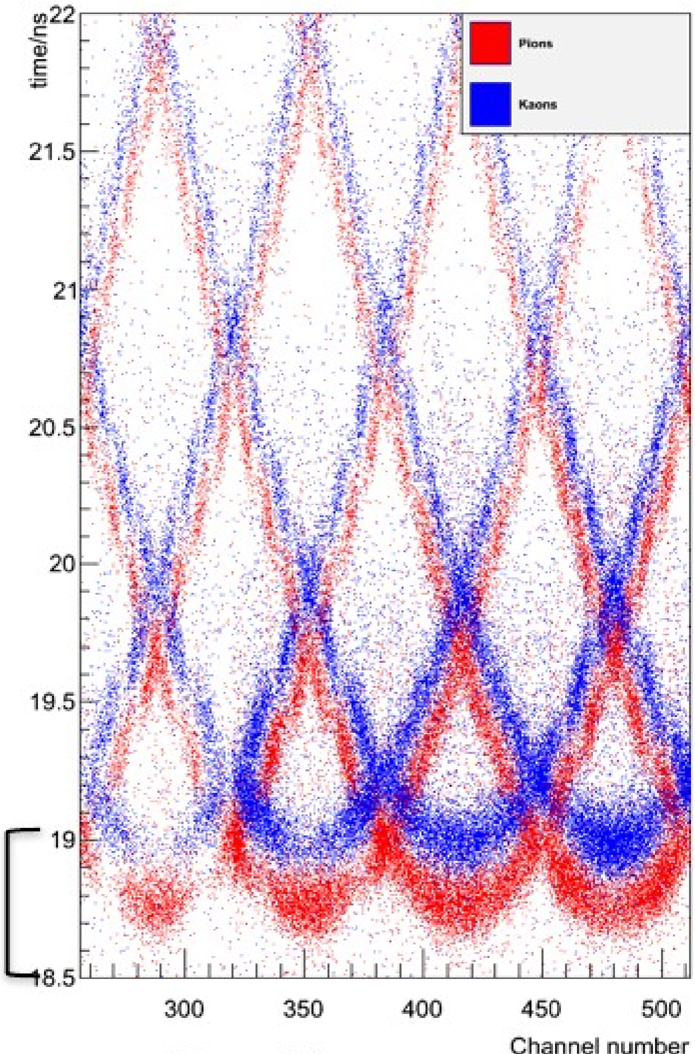
Channel Vs. time for 3GeV pions/kaons with beam test setup

At 3 GeV *Timing at the ~100 ps level is needed to separate pion and Kaon*

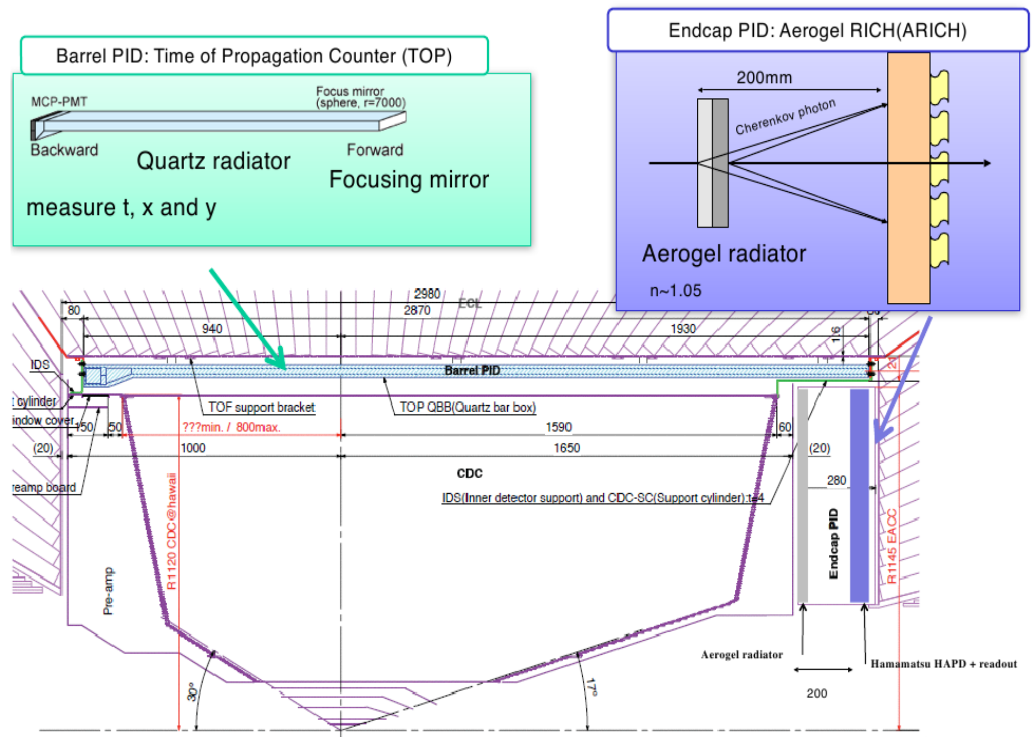
Particle ID : TOP + ARICH

Time in ns

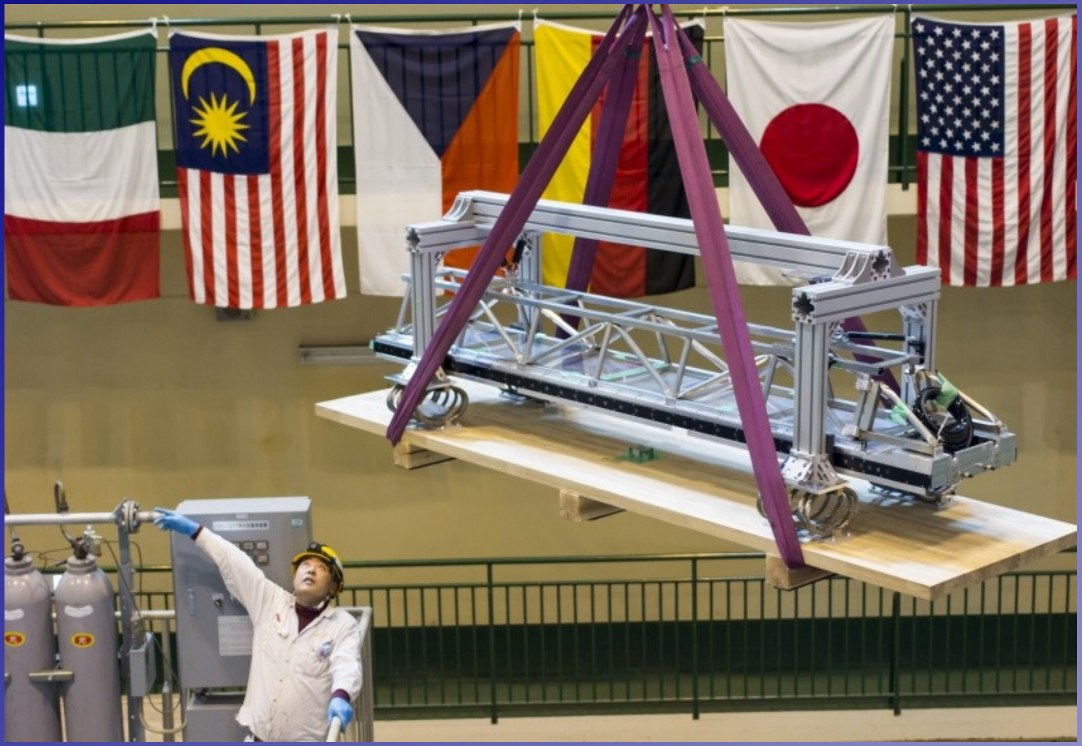
500ps



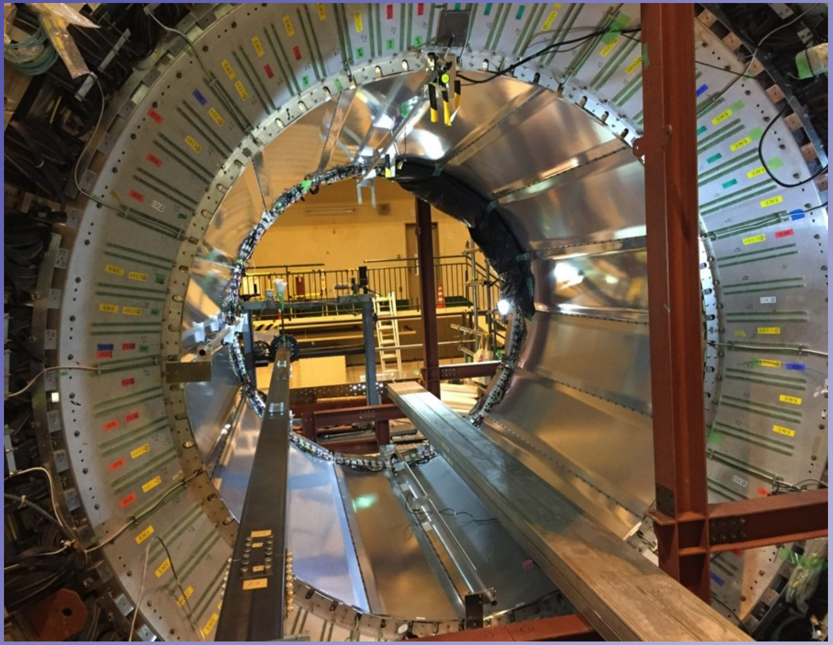
X position



TOP detector at Tsukuba Hall



First TOP module arriving at Tsukuba Hall



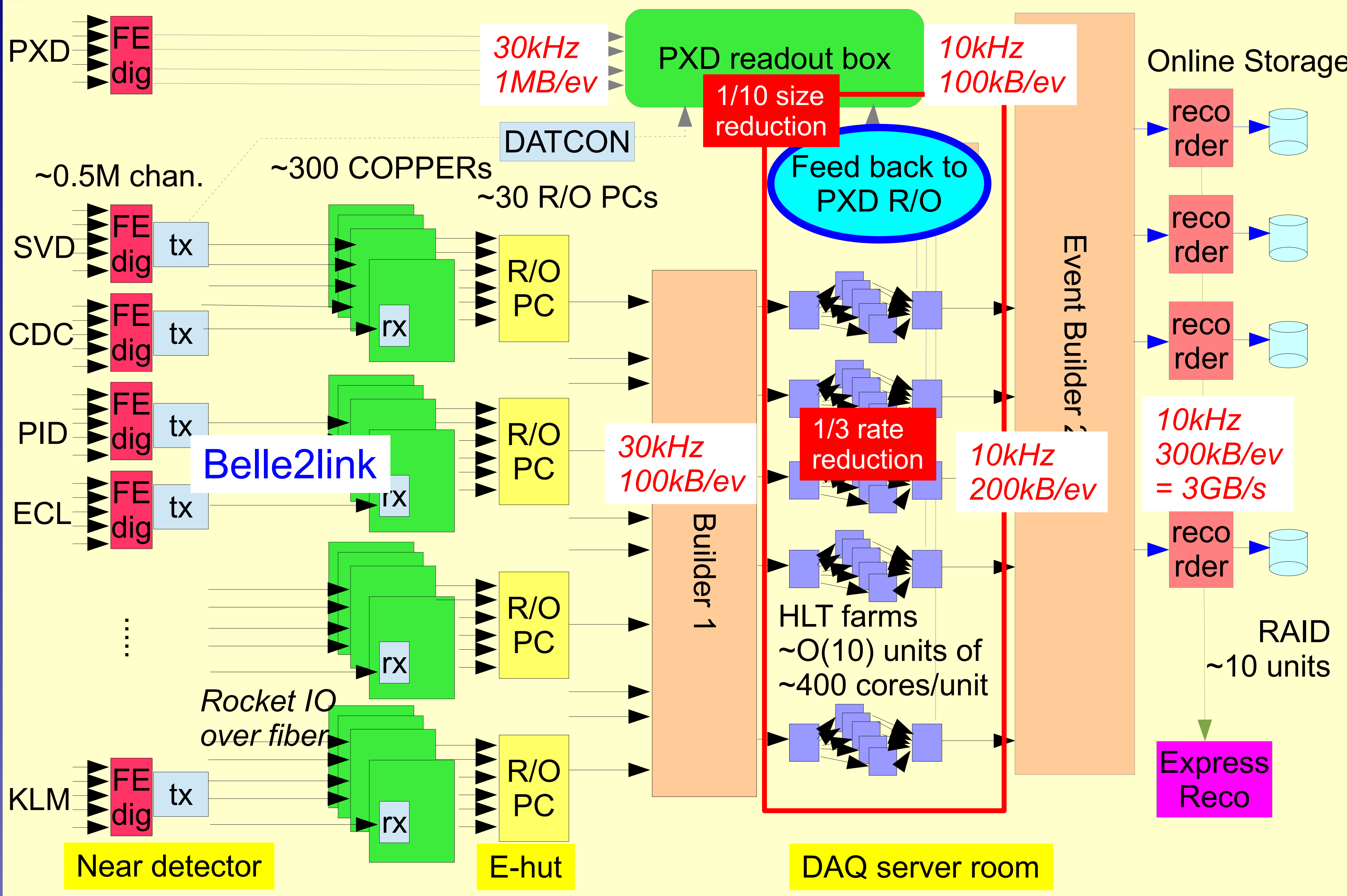
May 2016: Belle II structure

Update: May 20, 2016 all 16 TOP modules were installed into the Belle II structure. Magnetic field mapping then CDC installation in the summer.

CDC (Central Drift Chamber)

Outer detectors (ECL and KLM) were already installed.

Belle II DAQ

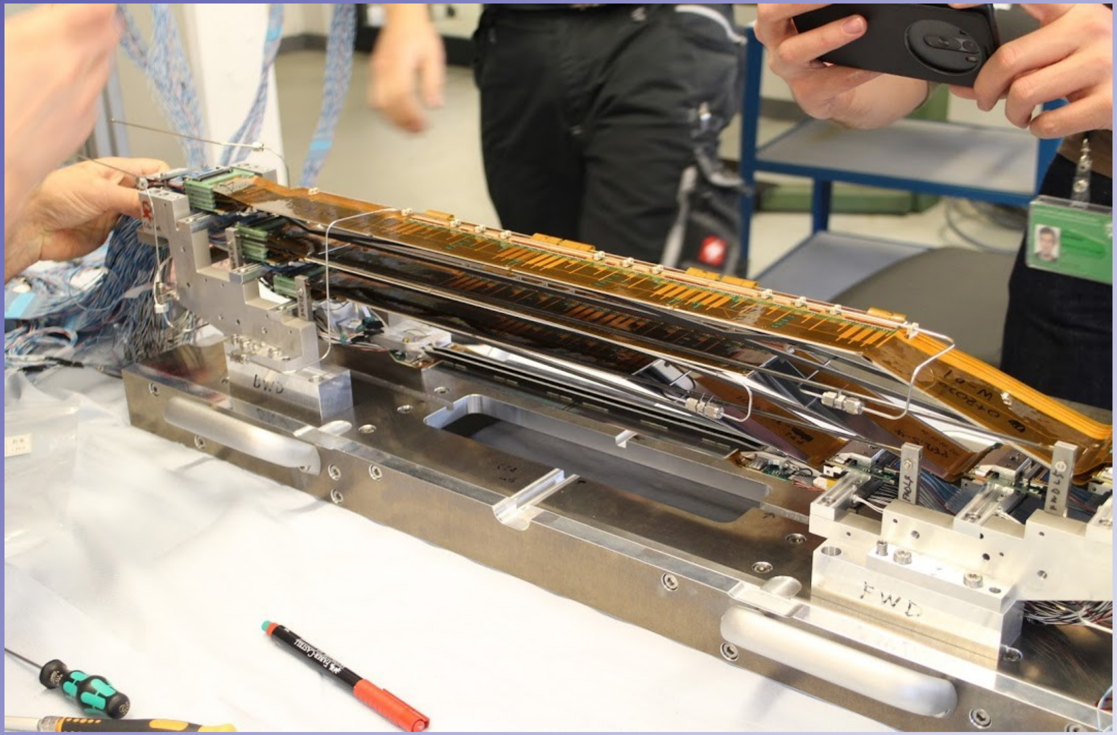

PXD
FE dig
30kHz
1MB/ev
PXD readout box
1/10 size reduction
10kHz
100kB/ev
Online Storage
DATCON
~0.5M chan.
~300 COPPERs
~30 R/O PCs
Feed back to PXD R/O
SVD
CDC
PID
ECL
KLM
tx
rx
R/O PC
Belle2link
30kHz
100kB/ev
Builder 1
1/3 rate reduction
10kHz
200kB/ev
Event Builder 2
reco rder
10kHz
300kB/ev
= 3GB/s
HLT farms
~O(10) units of
~400 cores/unit
RAID
~10 units
Rocket IO
over fiber
Express Reco
Near detector
E-hut
DAQ server room

Beam tests of PXD+SVD+DAQ at DESY (Jan 2014 and Apr 2016)

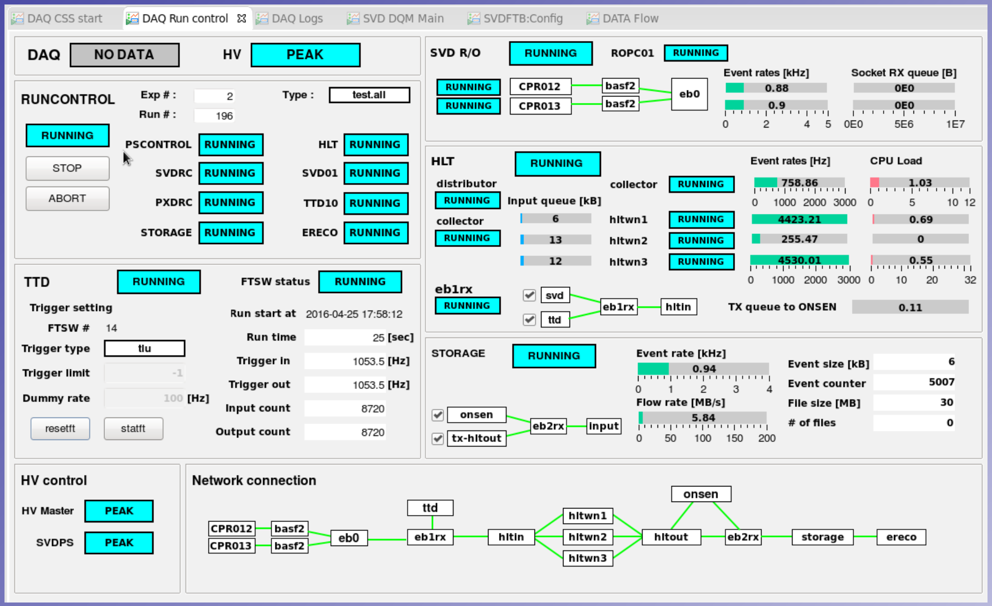
- Test of full tracking performance of SVD+PXD
- The PXD data reduction by RoI feedback using reconstructed tracks by SVD.

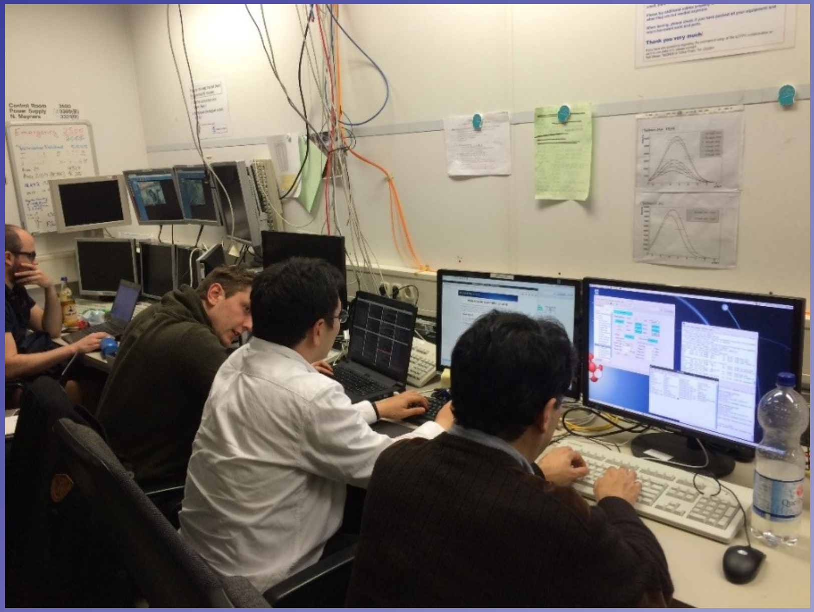
Test full-sized PXD modules in a beam. [Measure efficiency and S/N].

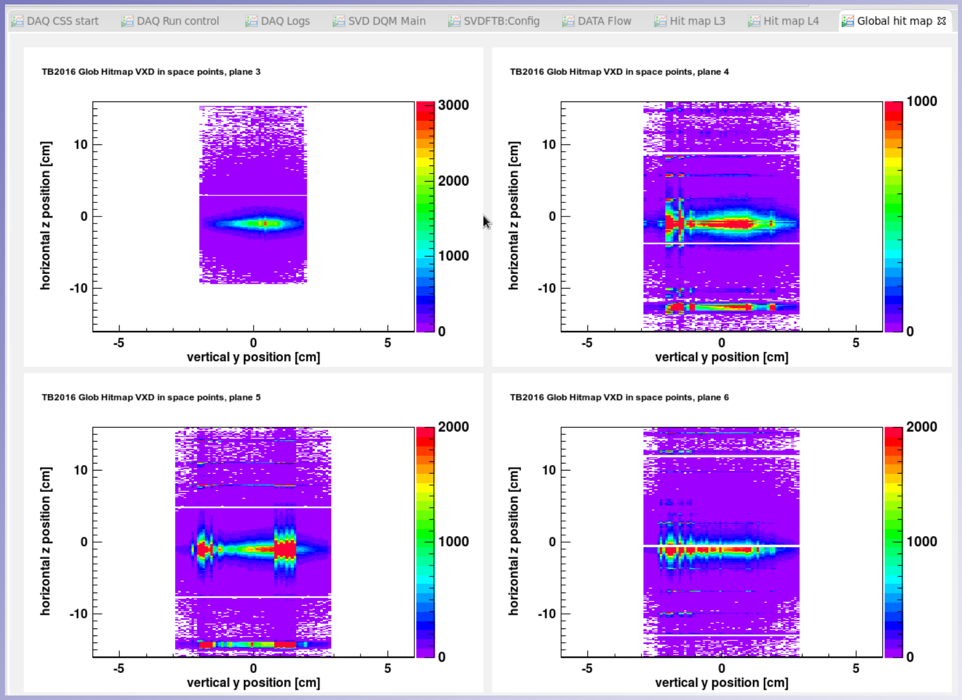
Working examples of L3, L4, L5, L6 SVD ladders

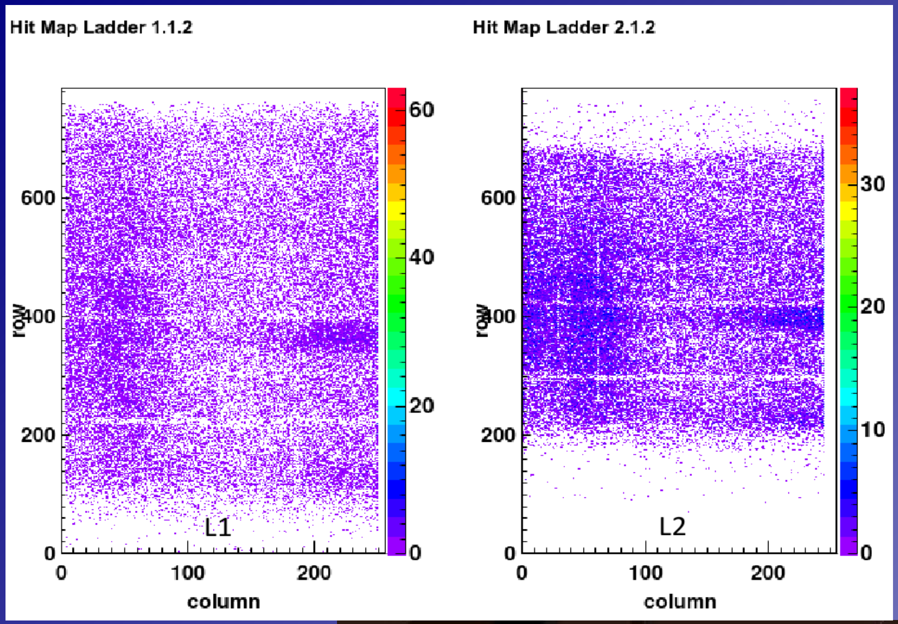


Test the integrated PXD-SVD system. This includes ROI (region of interest) extrapolation from the SVD tracker to the PXD, which is needed to reduce the *large data volume*.


DAQ CSS start
DAQ Run control
DAQ Logs
SVD DQM Main
SVDFTB:Config
DATA Flow
DAQ
NO DATA
HV
PEAK
RUNCONTROL
RUNNING
STOP
ABORT
TTD
HV control
Network connection
SVD R/O
HLT
STORAGE

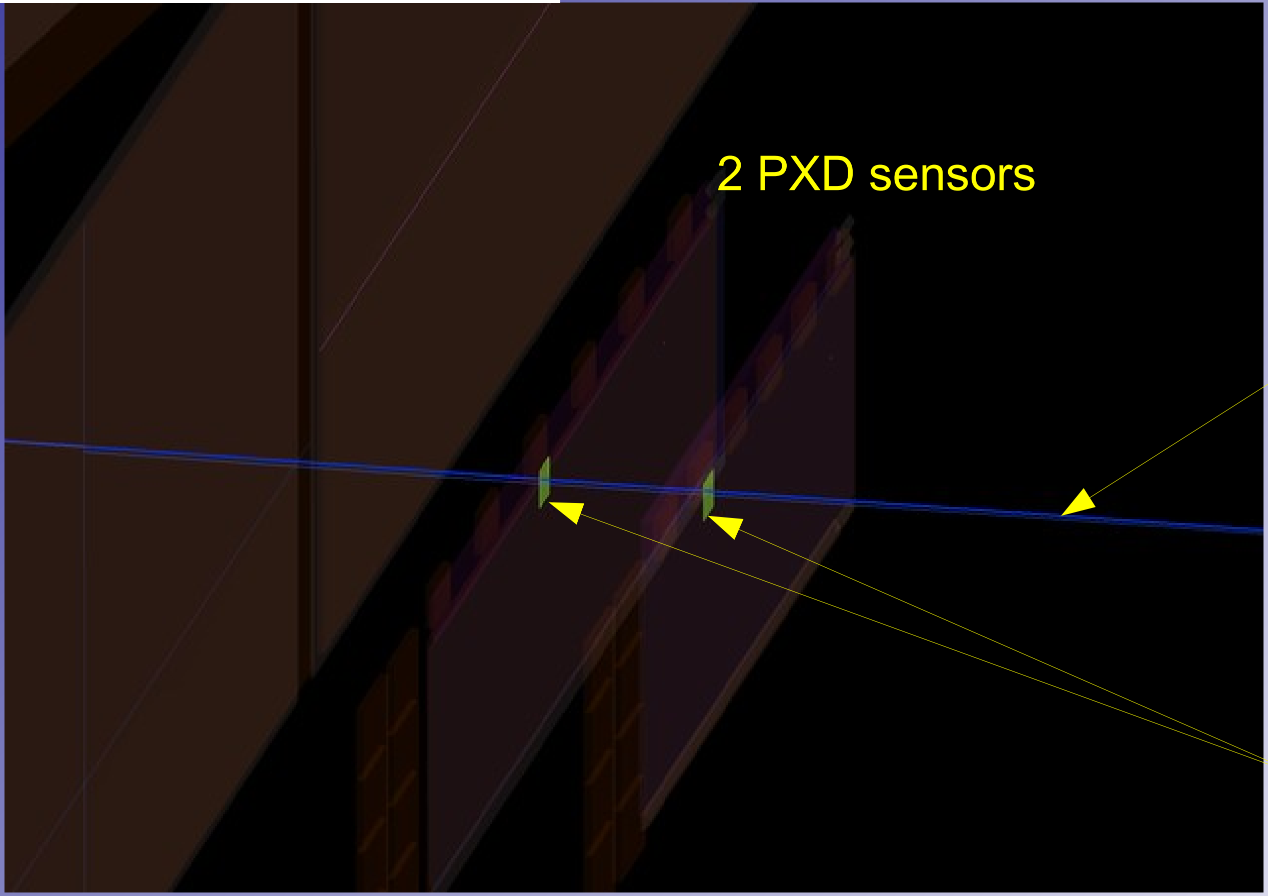



Global hit map
TB2016 Glob Hitmap VXD in space points, plane 3
TB2016 Glob Hitmap VXD in space points, plane 4
TB2016 Glob Hitmap VXD in space points, plane 5
TB2016 Glob Hitmap VXD in space points, plane 6
horizontal z position [cm]
vertical y position [cm]



Real time PXD hit map

Real time RoI selection



track reconstructed by HLT

RoIs obtained from tracks

3. Physics Prospects

- The physics strategy at Belle II is being discussed in B2TIP (Belle II Theory Interface Platform).

- It is a joint effort of both theorists and experimentalists to have a close communication.

- The activity was started in 2014 aiming at delivering a full report by early 2017.

- We had 4 dedicated + 3 satellite workshops until now.

- The last workshop was held in Pittsburgh in May 23-26.

- I will show some of the discussion summary as our prospects for Belle II physics.

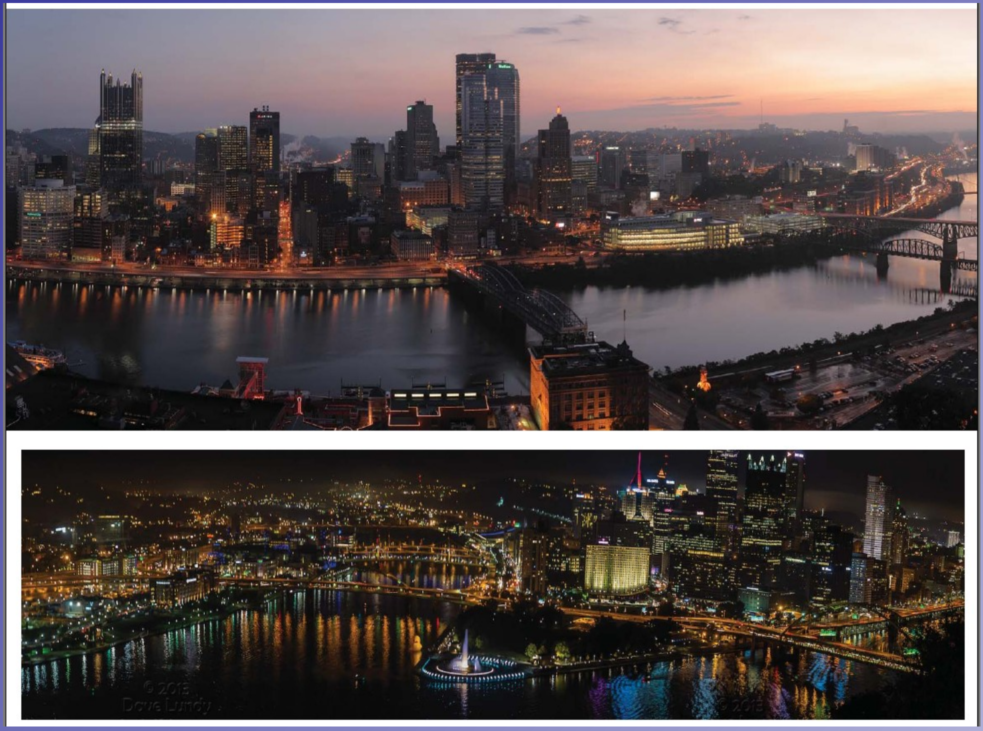
9 working groups

See details on the B2TiP website

https://belle2.cc.kek.jp/~twiki/bin/view/Public/B2TIP

WG1	G. De Nardo, A. Zupanic, M. Tanaka, F. Tackmann, A. Kronfeld
WG2	A. Ishikawa, J. Yamaoka, U. Haisch, T. Feldmann
WG3	T. Higuchi, L. Li Gioi, J. Zupan, S. Mishima
WG4	J. Libby, Y. Grossman, M. Blanke
WG5	P. Goldenzweig, M. Beneke, C.-W. Chiang, S. Sharpe
WG6	G. Casarosa, A. Schwartz, A. Kagan, A. Petrov
WG7	Ch.Hanhart, R.Mizuk, R.Mussa, C.Shen, Y.Kiyo, A.Polosa, S.Prelovsek
WG8	K. Hayasaka, T. Feber, E. Passemar, J. Hisano
WGNP	R.Itoh, F.Bernlochner, Y.Sato, U.Nierste, L.Silvestrini, J.Kamenik, V.Lubicz

I: Leptonic/Semi-leptonic II: Radiative/Electroweak III: phi1(beta)/phi2(alpha) IV: phi3 (gamma)
V: Charmless/hadronic B decays VI: Charm VII: Quarkonium(like) VIII: Tau & low multiplicity NP: New Physics

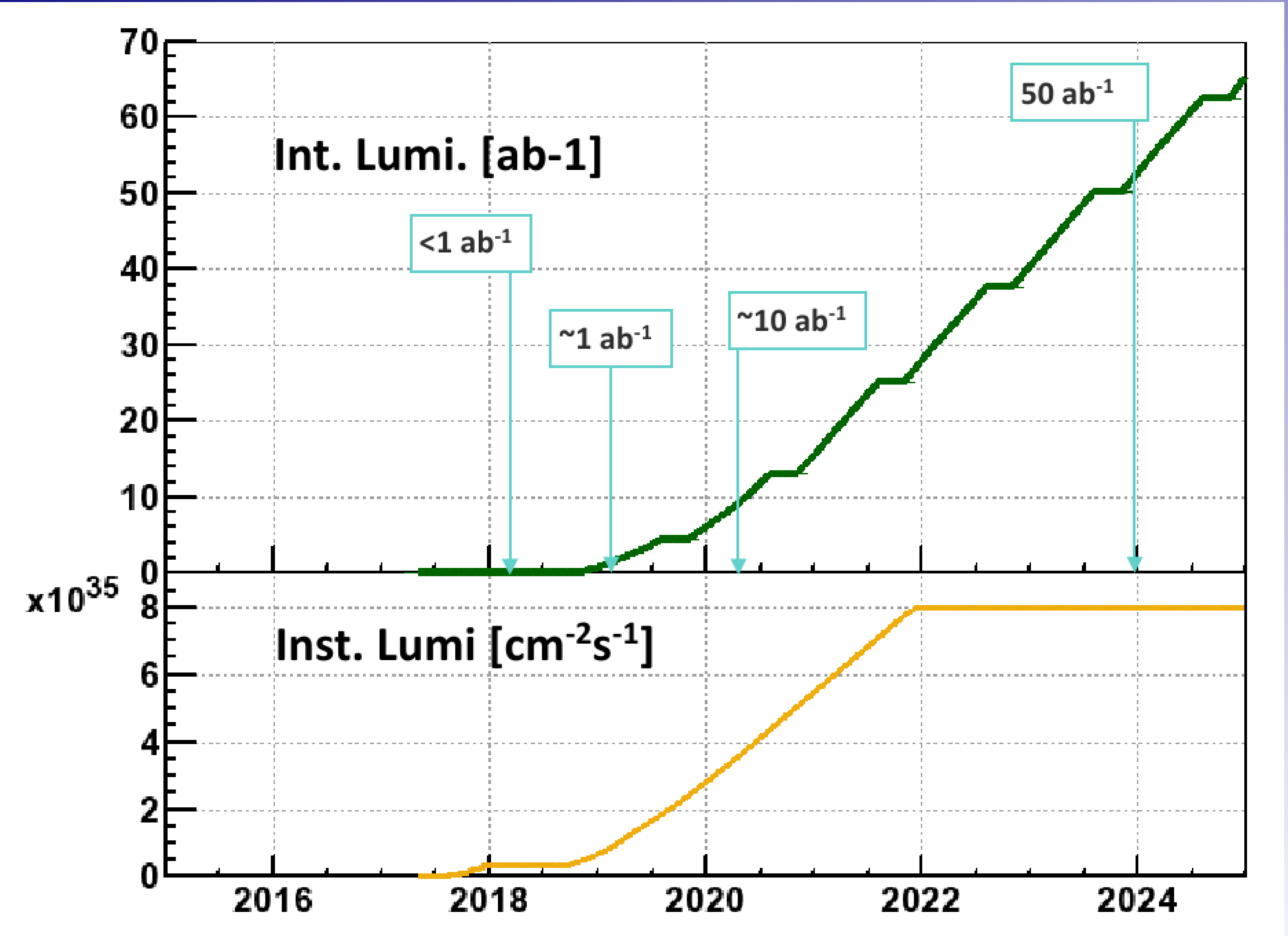


4th B2TIP Workshop in Pittsburgh

Univ. of Pittsburgh

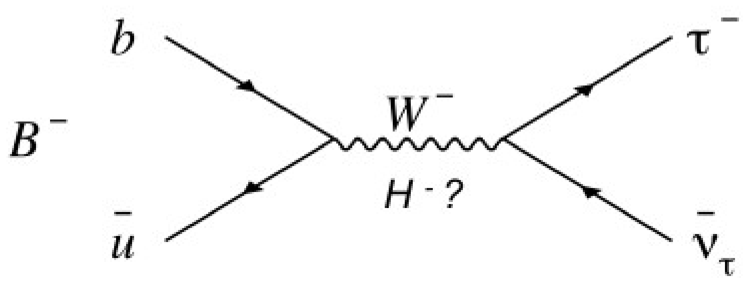
May 23-25, 2016

B2TIP goal : to clarify possible physics targets with a luminosity of 1, 10 and 50 ab^{-1}



WG1: Leptonic B decays

a) Pure leptonic decay of B meson



$$\mathcal{B}(B^+ \to \tau^+\nu) = \frac{G_F^2\, m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2\, |V_{ub}|^2\, \tau_B$$

$$\mathcal{B}(B^+ \to \tau^+\nu) = \mathcal{B}_{SM} \cdot \left(1 - m_B^2 \frac{\tan^2\beta}{m_H^2}\right) \quad \text{(2HDM)}$$

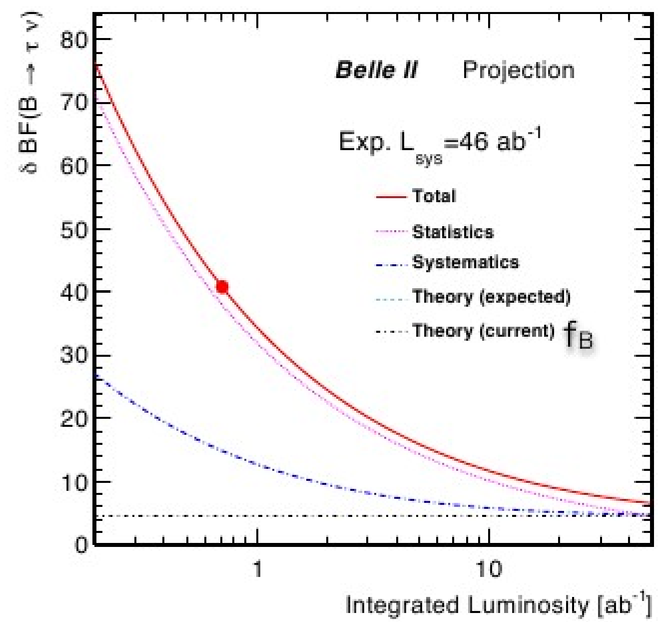
SM : $\mathrm{Br}(B\to\tau\nu)_{SM} = (1.11\pm0.28)\times10^{-4}$

- f_B = (191±9) MeV (HPQCD, PDG12)
- $|V_{ub}|$ = (4.15±0.49) 10^{-3} (PDG12)

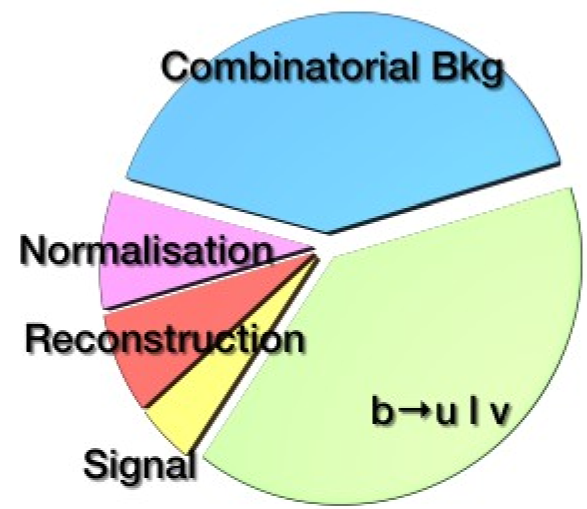
HFAG14 $\mathrm{Br}(B\to\tau\nu) = (1.14\pm0.22)\times10^{-4}$

Prospect in Belle II

δ(Br) ~ 5% @ 50ab^{-1}(Hadron Tag only)
~ 3% (with SL tag)



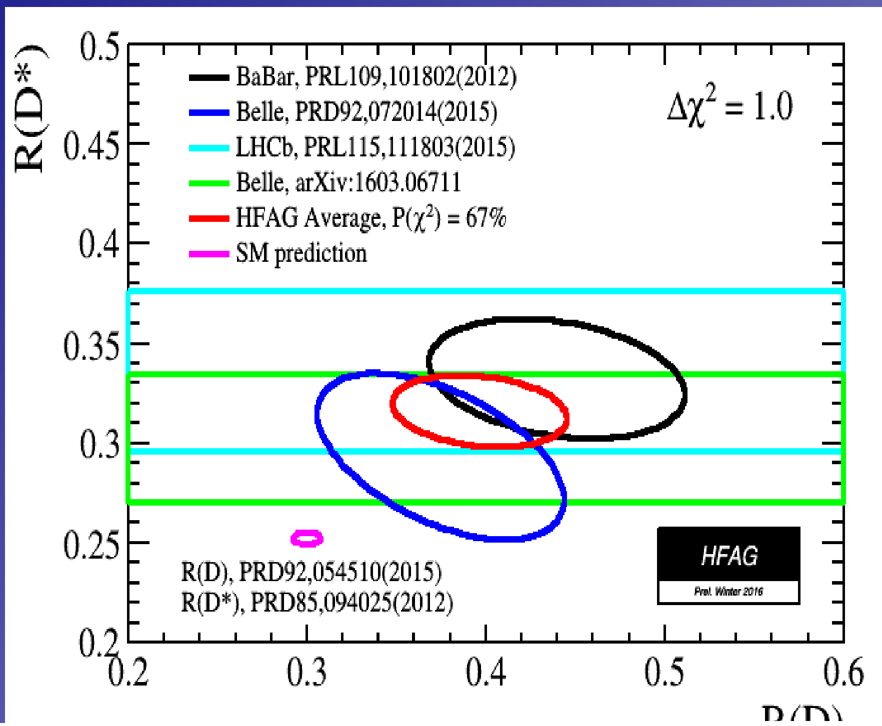
BF Systematics

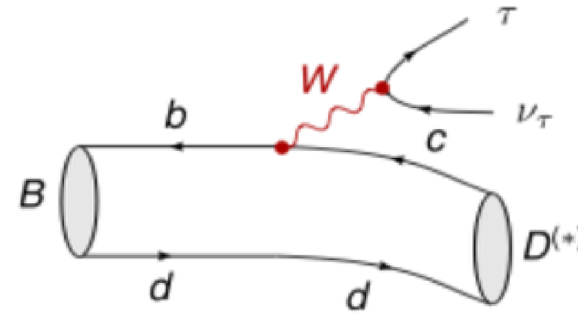


b) $B \to D^{(*)}\tau\nu$

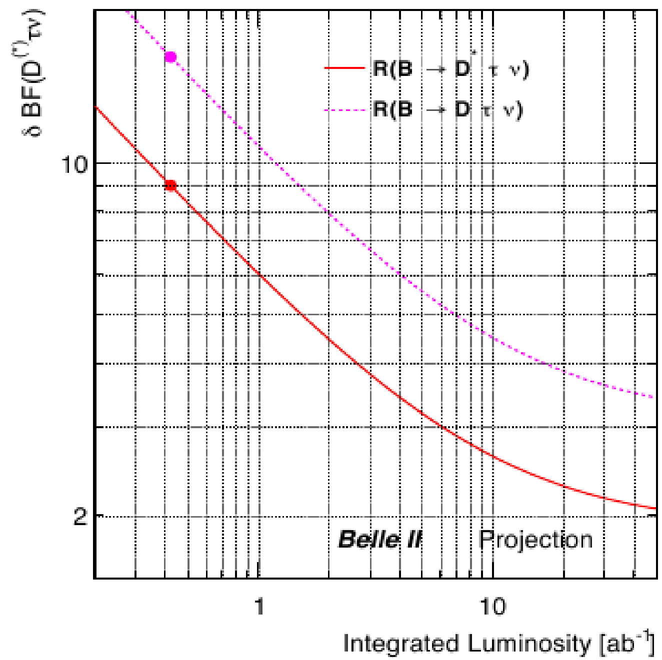
- World Average is shifted
  4.0σ from SM prediction!

with Belle: arXiv:1603.06711





➢Involves ≥ 2 ν (Missing E):



$R(D)$

Error	stat.	tot.
B-Factories	13%	16.2%
Belle II 5/ab	3.8%	5.6%
Belle II 50/ab	1.2%	**3.4%**

$R(D^*)$

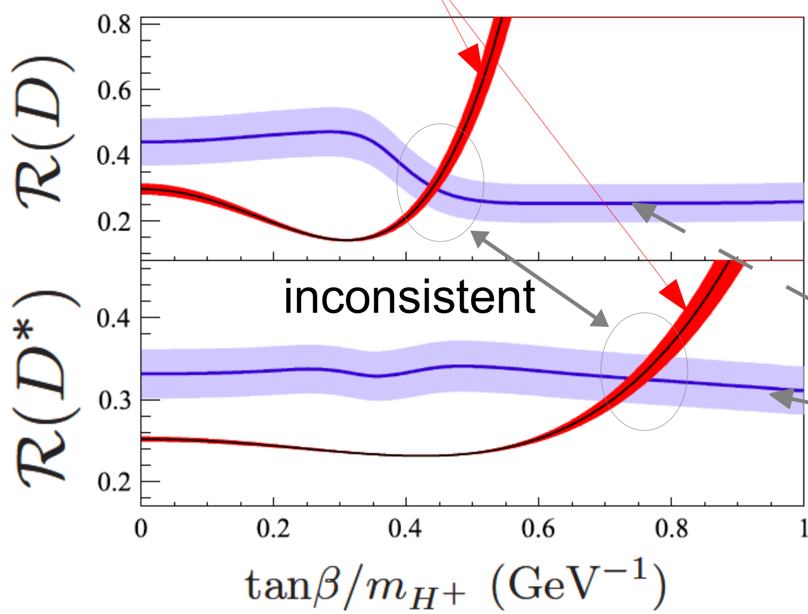
Error	stat.	tot.
B-Factories	7.1%	9.0%
Belle II 5/ab	2.1%	3.2%
Belle II 50/ab	0.7%	**2.1%**

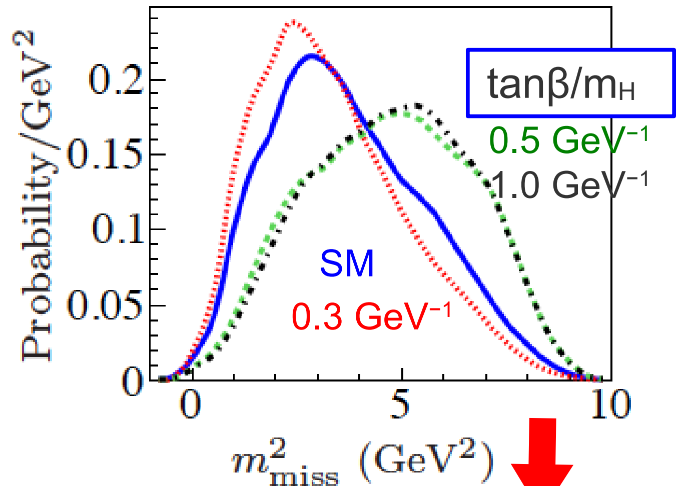
New approach to use $B \to \pi\tau\nu$ is under discussion

BaBar

PRL109, 101802; PRD 88, 072012

2HDM Type II predictions



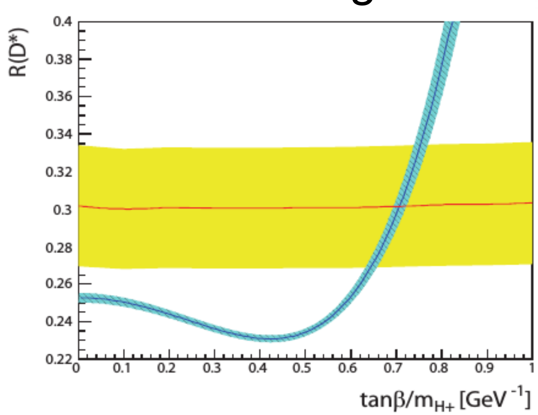


Measurements:
- Values change for different tanβ/m$_H$ due to different missing mass distr.

Belle

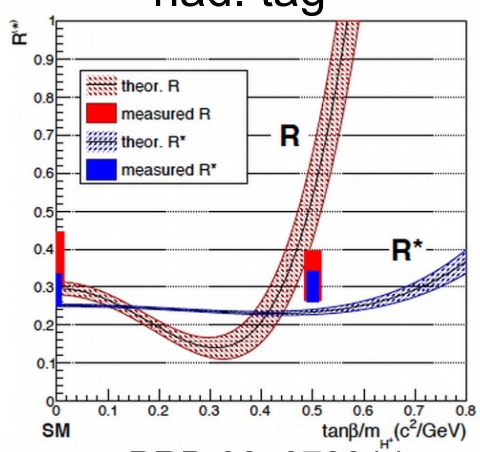
Latest analysis results

SL tag

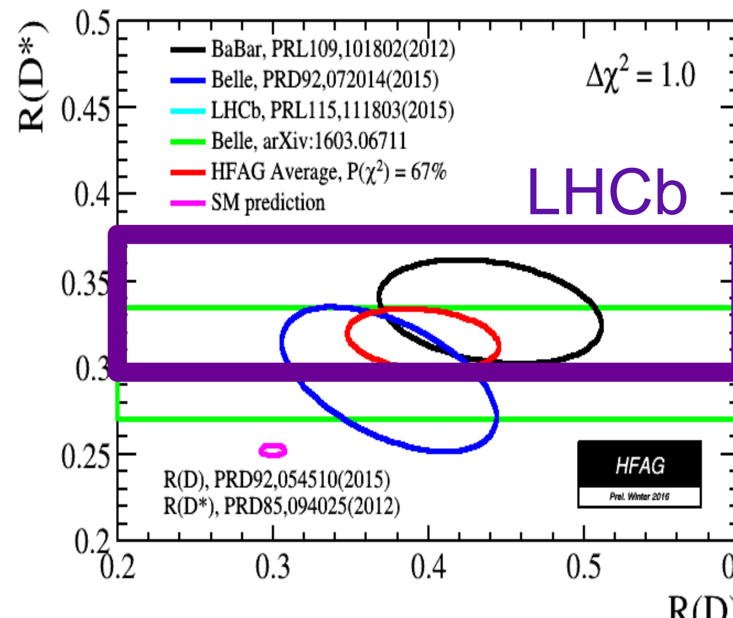


arXiv:1603.06711

had. tag

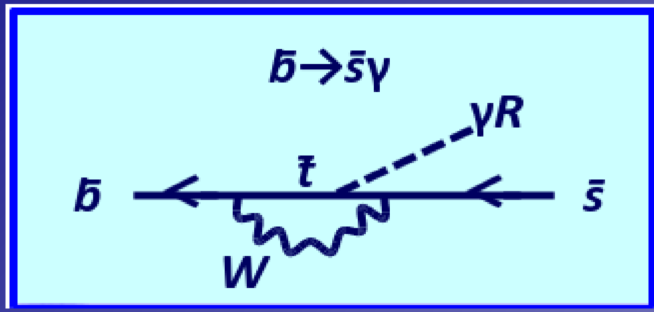


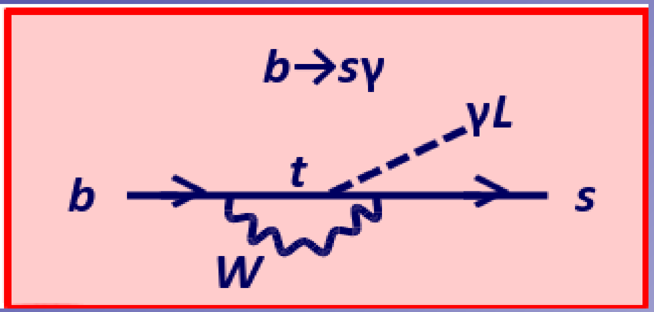
PRD 92, 072014



WG2: Radiative and Electroweak Penguins

a) CPV in $B^0 \to K^0_S \pi^0 \gamma$ ($b \to s\gamma$)





$\bar{b} \to \bar{s}\gamma_R$: right handed photon

$b \to s\gamma_L$: left handed photon

$$S^{SM} \cong (\sin 2\phi_1) \times \left(-\frac{2m_s}{m_b} \right)$$

$$S^{\text{average}} = -0.15 \pm 0.20$$

Average by Heavy Flavor Averaging Group (2009 winter).

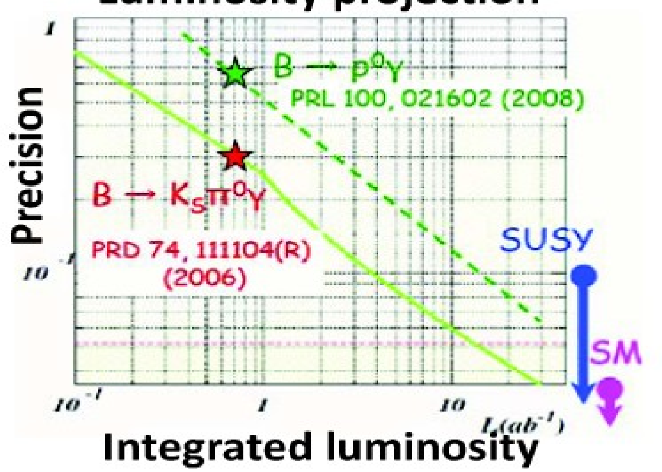
SM: **$S = -2(m_s/m_b)\sin(2\phi_1) \sim -0.03$**

$$S^{NP} \cong +0.67$$

A NP (left-right symmetric model) may enhance *CP* violation in this decay.

D. Atwood *et al.*, Phys. Rev. Lett. **79**, 185 (1997).

Luminosity projection



Prospect in Belle II

$\delta(S_{b\to s\gamma}) \sim 0.09$ @ $5ab^{-1}$
$\delta(S_{b\to s\gamma}) \sim 0.03$ @ $50ab^{-1}$

b) B→Xsll

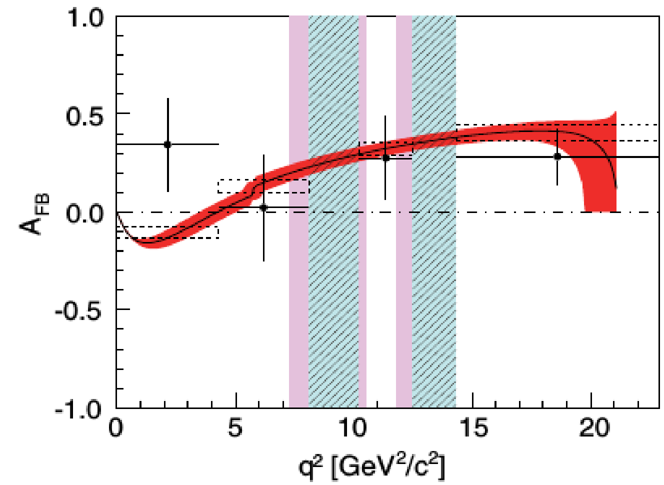
* Study of inclusive B→Xsll is one of the key measurements at Belle II to understand the LHCb “anomaly” in B→K*ll.
* The detailed angular analysis is supposed to be performed.
* “Pure inclusive” might be a bit difficult -> “semi-inclusive” like Belle.

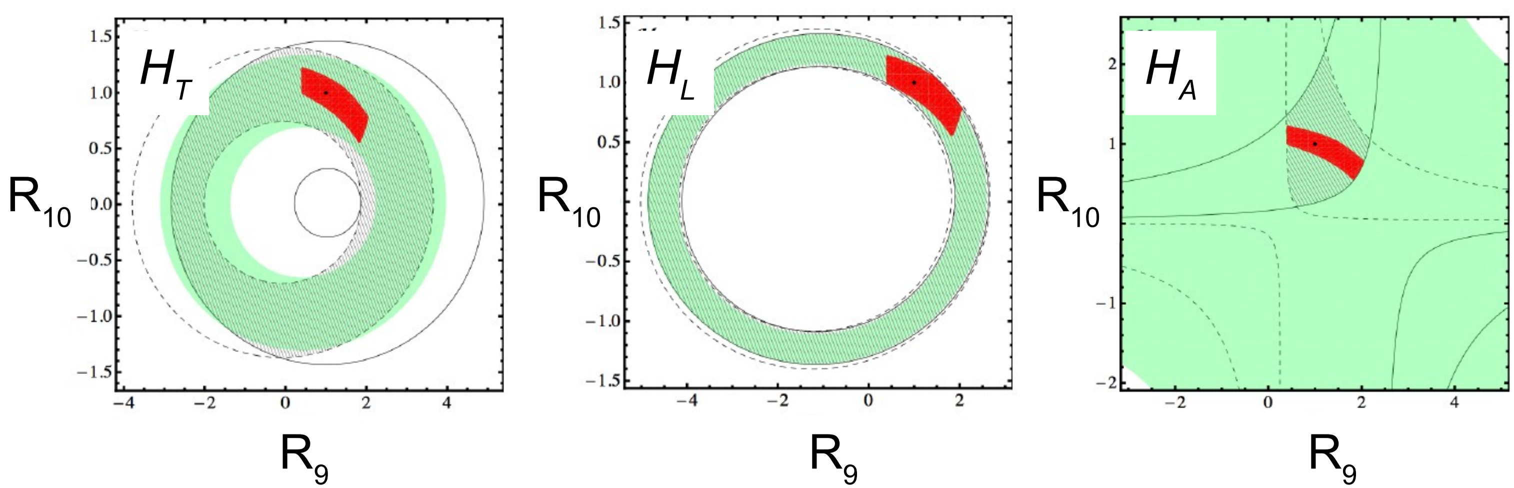
<- “Full-recon” tag could be used, but low statistics even with 50ab^{-1}

TABLE I. The 18 hadronic final states used to reconstruct X_s. The 8 final states enclosed in parentheses are not used for the measurement of $\mathcal{A}_{FB}$.

$\bar{B}^0$ decays		B^- decays	
	(K_S^0)	K^-	
$K^-\pi^+$	$(K_S^0\pi^0)$	$K^-\pi^0$	$K_S^0\pi^-$
$K^-\pi^+\pi^0$	$(K_S^0\pi^-\pi^+)$	$K^-\pi^+\pi^-$	$K_S^0\pi^-\pi^0$
$K^-\pi^+\pi^-\pi^+$	$(K_S^0\pi^-\pi^+\pi^0)$	$K^-\pi^+\pi^-\pi^0$	$K_S^0\pi^-\pi^+\pi^-$
$(K^-\pi^+\pi^-\pi^+\pi^0)$	$(K_S^0\pi^-\pi^+\pi^-\pi^+)$	$(K^-\pi^+\pi^-\pi^+\pi^-)$	$(K_S^0\pi^-\pi^+\pi^-\pi^0)$

Belle: PRD 93, 032008 (2016)

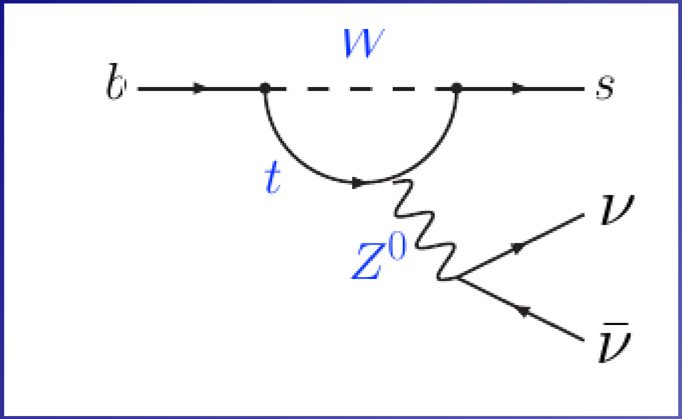




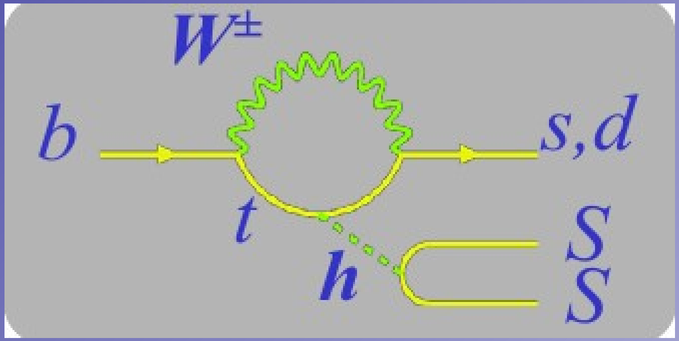
Sensitivity with 50/ab

T.Huber, T.Hurth, E.Lunghi, JHEP 1506, 176 (2015)

c) EW penguin with neutrinos



+ NP?



* Sensitive to NP and theoretically very clean
* Could be a hint to lepton universality breakdown? by the comparison with $K^{(*)}l^+l^-$

$B^0 \to K_S \nu\bar{\nu}$ SM ~ 2.2 x 10^{-6}

Error	stat.
B-Factories	590%
Belle II 5/ab	220%
Belle II 50/ab	**94%**

$B^0 \to K^{*0} \nu\bar{\nu}$ SM ~ 9.5 x 10^{-6}

Error	stat.
B-Factories	112%
Belle II 5/ab	42%
Belle II 50/ab	**22%**

$B^+ \to K^+ \nu\bar{\nu}$ SM ~ 4.7 x 10^{-6}

Error	stat.
B-Factories	130%
Belle II 5/ab	49%
Belle II 50/ab	**22%**

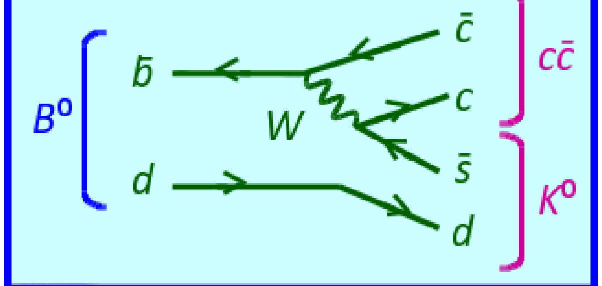
$B^+ \to K^{*+} \nu\bar{\nu}$ SM ~ 10.2 x 10^{-6}

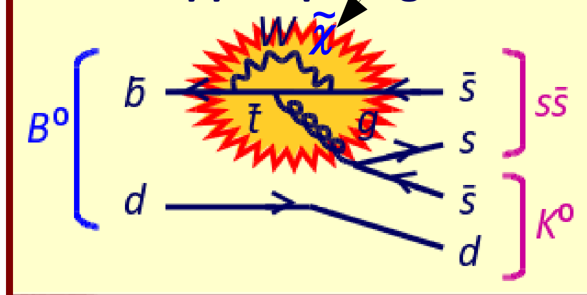
Error	stat.
B-Factories	120%
Belle II 5/ab	45%
Belle II 50/ab	**22%**

WG3: ϕ_1 and ϕ_2

CPV in $b \to s$ transition

possible contribution of new particle





Current measurement

$$\sin 2\phi_{1\ \mathrm{W.A}}^{sq\bar{q}} = +0.64 \pm 0.03$$

$$\sin 2\phi_{1\ \mathrm{W.A}}^{c\bar{c}s} = +0.682 \pm 0.019$$

* Deviation ~0.8σ

SM predicts the same value
at a precision of ~1%.

$B \to \eta' K^0$

Error on sin(2β)	tot.
B-Factories	9.4%
Belle II 5/ab	4.2%
Belle II 50/ab	**1.6%**

$B \to \phi K^0$

Error on sin(2β)	tot.
B-Factories	17.8%
Belle II 5/ab	7.9%
Belle II 50/ab	**2.7%**

$B \to K^0 K^0 K^0$

Error on sin(2β)	tot.
B-Factories	33.9%
Belle II 5/ab	15.1%
Belle II 50/ab	**4.9%**

Prospect in Belle II (combined)

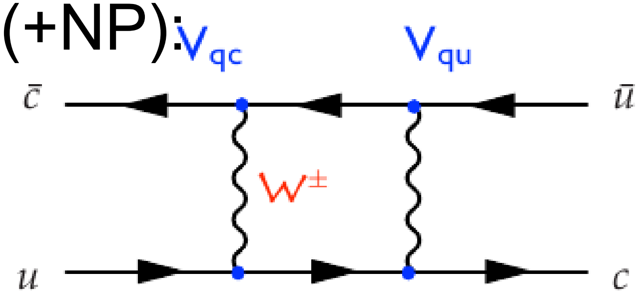
$\delta(\sin 2\phi_1 (s\bar{q}q))=$
~1.2%@50ab^{-1}

* Some of systematics are cancelled by taking the difference between measurements for $c\bar{c}s$ and $s\bar{q}q$.

WG6: Charm

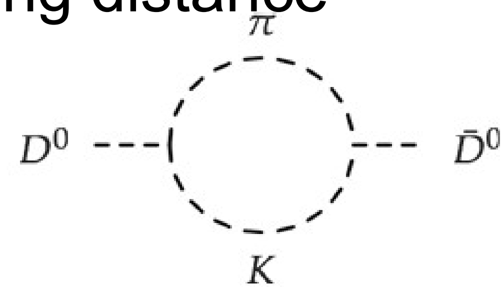
CP Violation in D^0-$\overline{D}^0$ mixing

SM (+NP):



+

Long distance

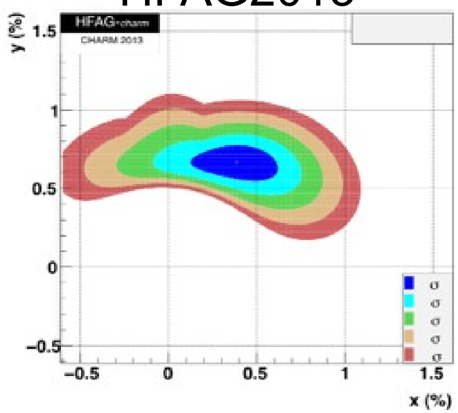


$$x = \frac{m_1 - m_2}{\Gamma}$$

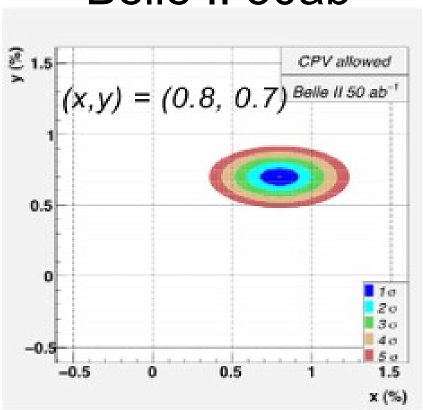
$$y = \frac{\Gamma_1 - \Gamma_2}{2\Gamma}$$

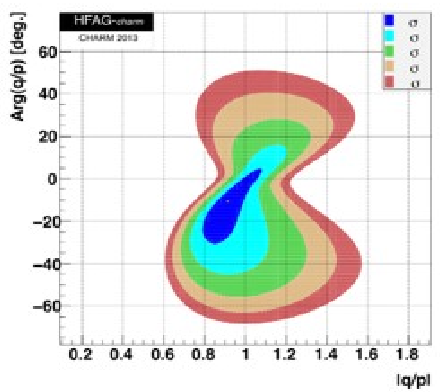
$$\phi = \arg\left(\frac{q}{p}\right)$$

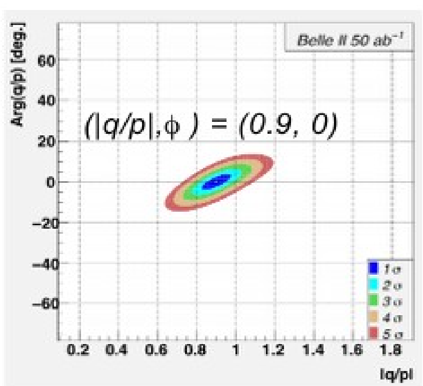
HFAG2013



Belle II 50ab^{-1}





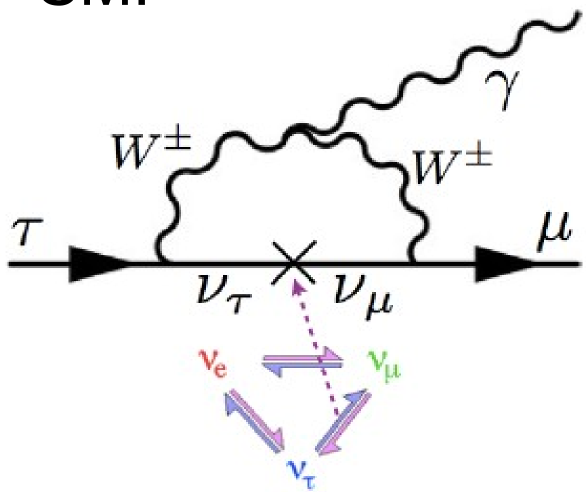


WG8 : Tau, low multiplicity and EW

Lepton Flavor Violation (LFV) : $\tau \to \mu\gamma$, $\tau \to \mu\mu\mu$

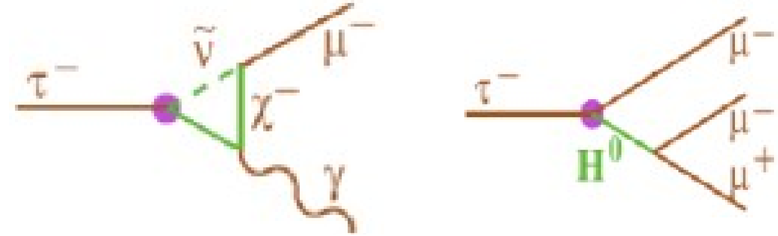
Theoretically very clean test of Standard Model

SM:

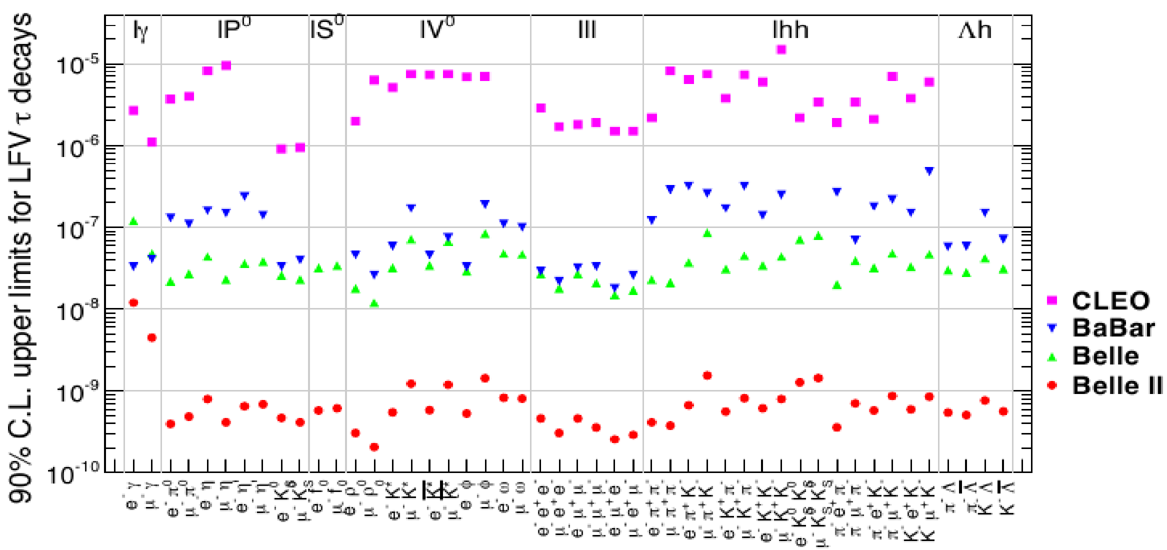


Br ~ 10^{-25}

NP:



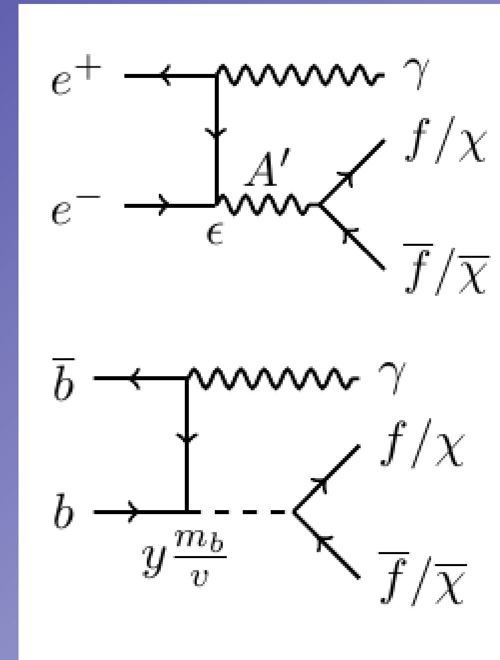
	reference	$\tau \to \mu\gamma$	$\tau \to \mu\mu\mu$
SM + heavy Maj ν_R	PRD 66(2002)034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547(2002)252	10^{-9}	10^{-8}
SUSY SO(10)	PRD 68(2003)033012	10^{-8}	10^{-10}
mSUGRA+seesaw	PRD 66(2002)115013	10^{-7}	10^{-9}
SUSY Higgs	PLB 566(2003)217	10^{-10}	10^{-7}

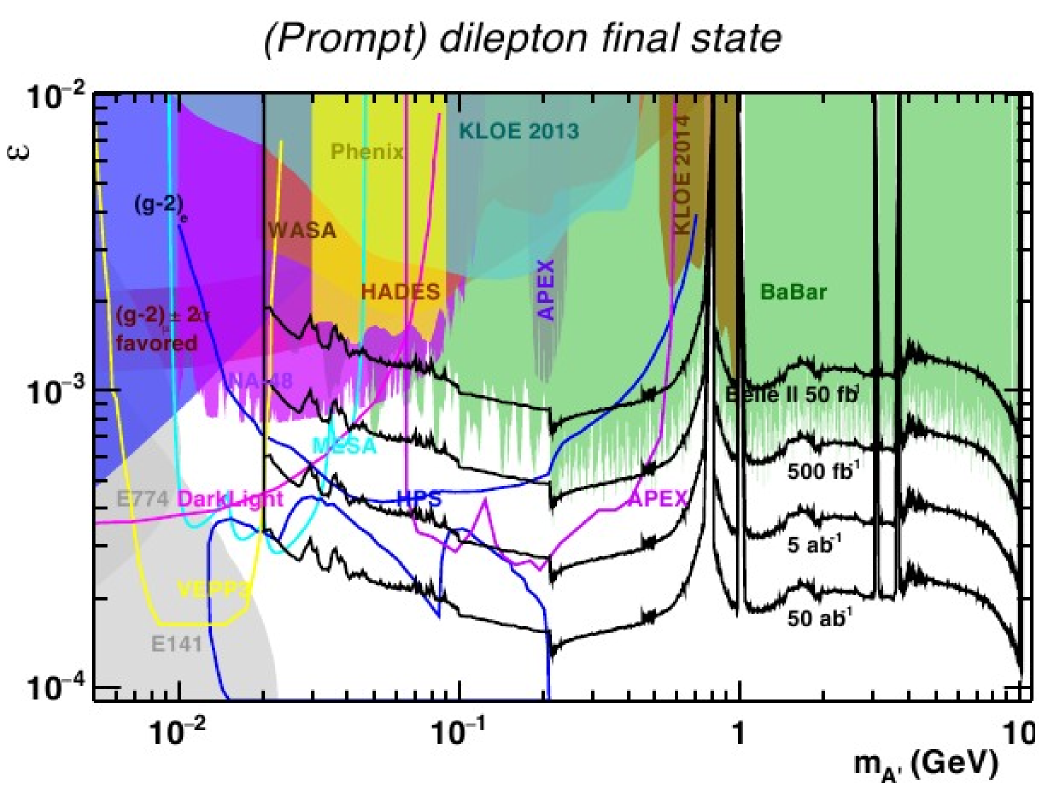


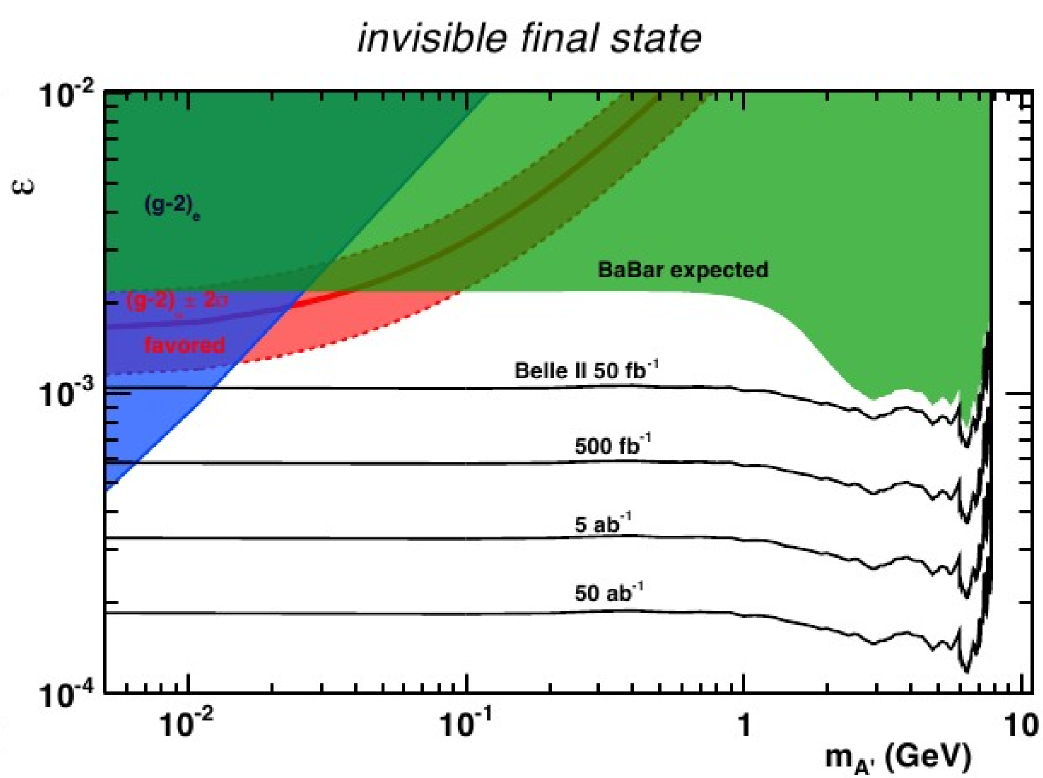
Prospect in Belle II
$< \sim 10^{-9}$ $(\tau \to \mu\gamma)$
$< \sim 10^{-10}$ $(\tau \to \mu\mu\mu)$

“Dark photon” search

Triggers		Some Ideas
Single Photon (γ)		• Cascade: different thresholds with separate pre-scale factors • Use different pre-scale factors for Barrel and Endcap
e^+e^-		• two Bhabha triggers, “accept” and “veto” • “accept” : flattening scheme • “veto”: 2D→3D ECL Bhabha is being investigated • salvage: retain a pre-scaled sample of physics triggers without veto
$\mu^+\mu^-$		• independent CDC and KLM triggers for luminosity systematics
$\gamma\gamma$		• reduce pre-scale to 10 instead of 100
γ+ 2 trks	γe^+e^- [hlt]	• dedicated triggers for calibration (CDC,ECL)
	$\gamma\mu^+\mu^-$	• dedicated triggers for detectors study (CDC, ECL, KLM)
	γh^+h^-	• high efficiency for all γ energies and h^+h^- invariant masses • one high energy cluster in ECL, one track in opposite hemisphere
Additional trigger information		• CDC-TOP-ECL-KLM Matching • More detectors information……



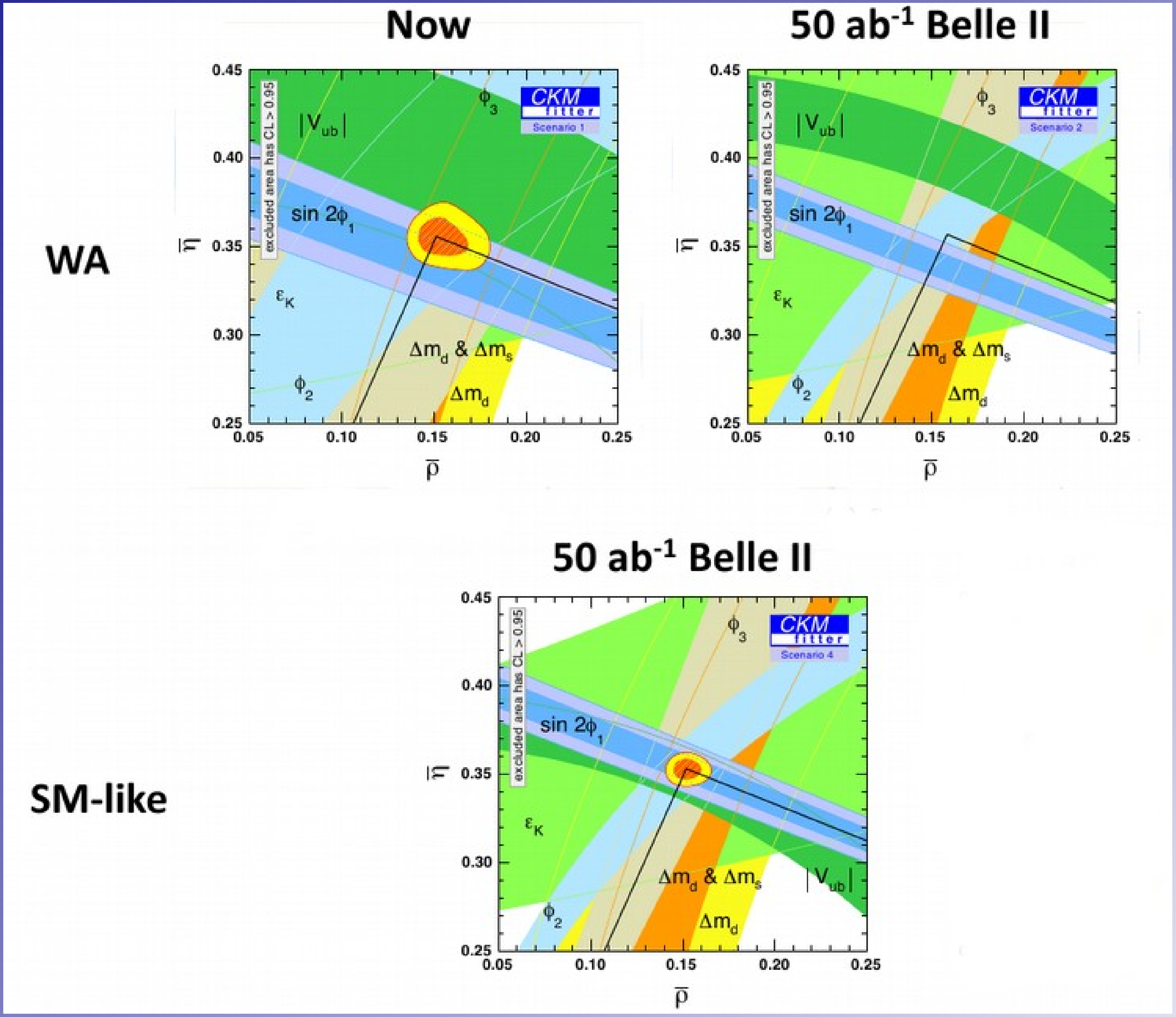




WGNP (WG9) : New Physics

- Study of sensitivity to NP by combining Belle II measurements

a) Precision constraint on CKM triangle

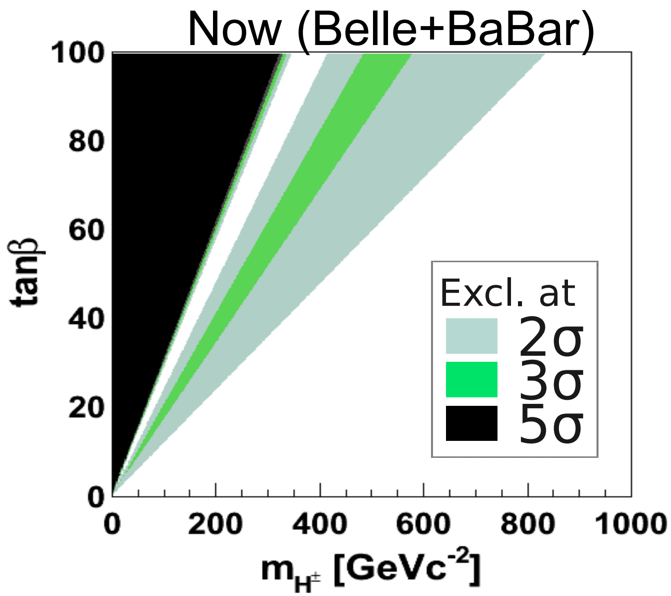


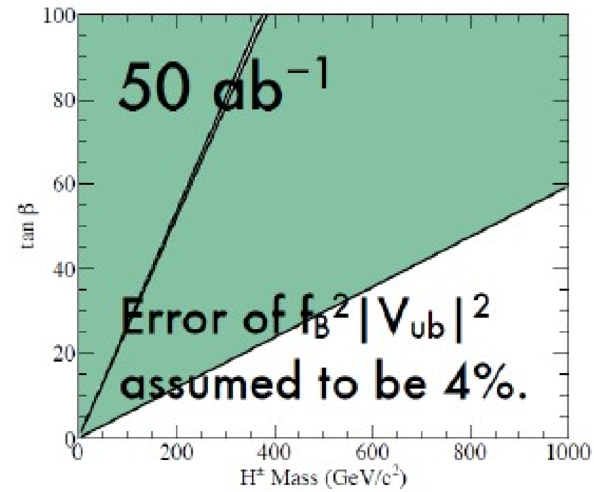
b) Constraint on Charged Higgs

NP-Japan

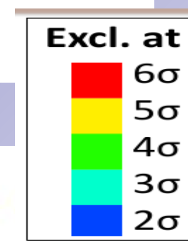
$B \to \tau\nu$

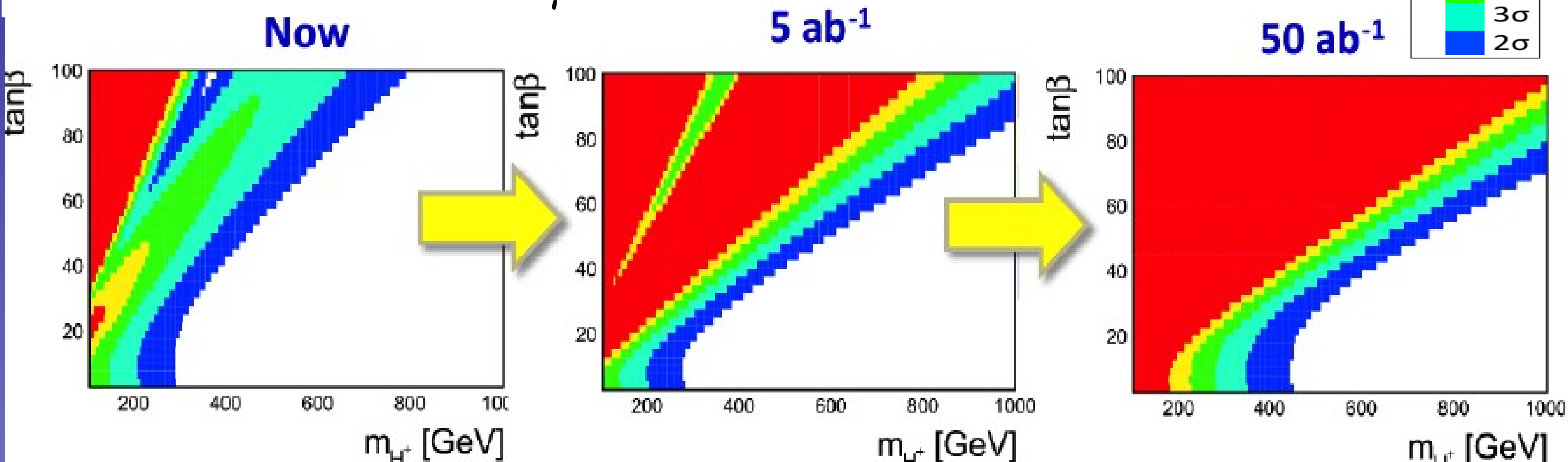
2HDM (Type II)





$B \to \tau\nu + B \to D^{(*)}\tau\nu + b \to s\gamma$ (Note: based on Belle only results)





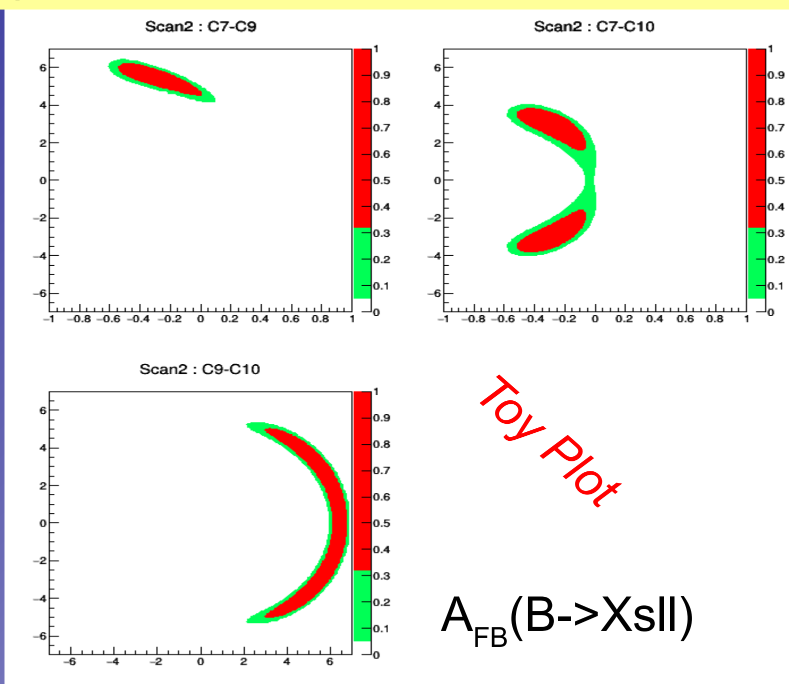
c) Discussion on Theory code

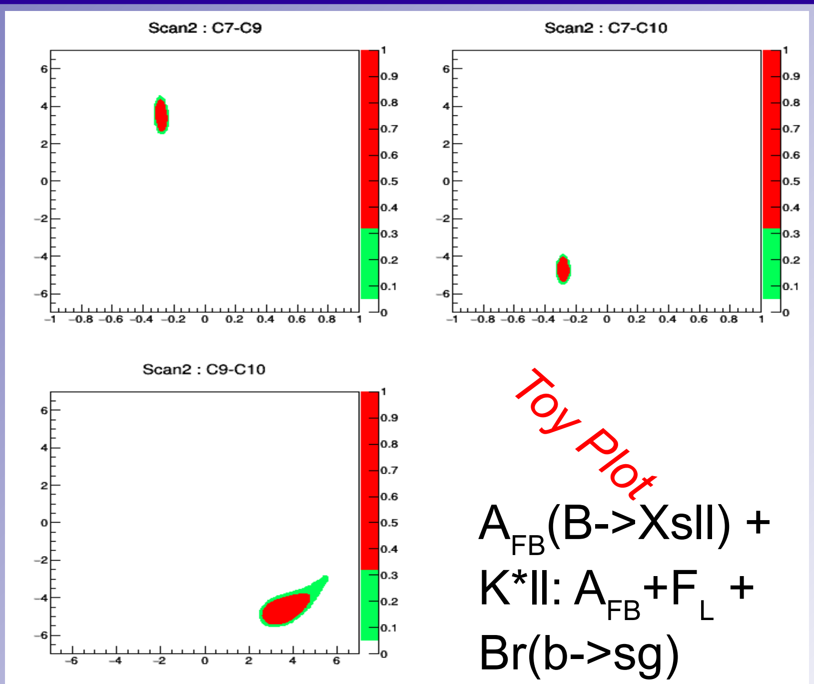
- For the detailed study of NP effects in the experiment, the NP effect has to be simulated in various measurements by Monte Carlo.

- Computer coded NP theories are essential tools to be implemented in MC.

- Currently we are evaluating
a) SuperIso
b) EOS
c) HEPfit
d) FormFlavor

EOS used in the test of global fit to have constraints on Wilson Coeff.





Competitiveness to LHCb

Observable	Expected th. accuracy	Expected exp. uncertainty	Facility
CKM matrix			
$\lvert V_{us}\rvert$ $[K \to \pi\ell\nu]$	**	0.1%	K-factory
$\lvert V_{cb}\rvert$ $[B \to X_c\ell\nu]$	**	1%	Belle II
$\lvert V_{ub}\rvert$ $[B_d \to \pi\ell\nu]$	*	4%	Belle II
$\sin(2\phi_1)$ $[c\bar{c}K_S^0]$	***	$8 \cdot 10^{-3}$	Belle II/LHCb
ϕ_2		1.5°	Belle II
ϕ_3	***	1.5°	LHCb
CPV			
$S(B_s \to \psi\phi)$	**	0.01	LHCb
$S(B_s \to \phi\phi)$	**	0.05	LHCb
$S(B_d \to \phi K)$	***	0.02	Belle II/~~LHCb~~
$S(B_d \to \eta' K)$	***	0.02	Belle II
$S(B_d \to K^*(\to K_S^0\pi^0)\gamma))$	***	0.03	Belle II
$S(B_s \to \phi\gamma))$	***	0.05	LHCb
$S(B_d \to \rho\gamma))$		0.15	Belle II
A_{SL}^d	***	0.001	LHCb
A_{SL}^s	***	0.001	LHCb
$A_{CP}(B_d \to s\gamma)$	*	0.005	Belle II
rare decays			
$\mathcal{B}(B \to \tau\nu)$	**	3%	Belle II
$\mathcal{B}(B \to D\tau\nu)$		3%	Belle II
$\mathcal{B}(B_d \to \mu\nu)$	**	6%	Belle II
$\mathcal{B}(B_s \to \mu\mu)$	***	10%	LHCb
zero of $A_{FB}(B \to K^*\mu\mu)$	**	0.05	LHCb
$\mathcal{B}(B \to K^{(*)}\nu\nu)$	***	30%	Belle II
$\mathcal{B}(B \to s\gamma)$		4%	Belle II
$\mathcal{B}(B_s \to \gamma\gamma)$		$0.25 \cdot 10^{-6}$	Belle II (with 5 ab^{-1})
$\mathcal{B}(K \to \pi\nu\nu)$	**	10%	K-factory
$\mathcal{B}(K \to e\pi\nu)/\mathcal{B}(K \to \mu\pi\nu)$	***	0.1%	K-factory
charm and τ			
$\mathcal{B}(\tau \to \mu\gamma)$	***	$3 \cdot 10^{-9}$	Belle II
$\lvert q/p\rvert_D$	***	0.03	Belle II
$arg(q/p)_D$	***	1.5°	Belle II

4. Summary

- The operation of SuperKEKB has been started and the machine is being tuned for the start of physics data taking in 2018.

- The Belle II detector construction is in a good shape.

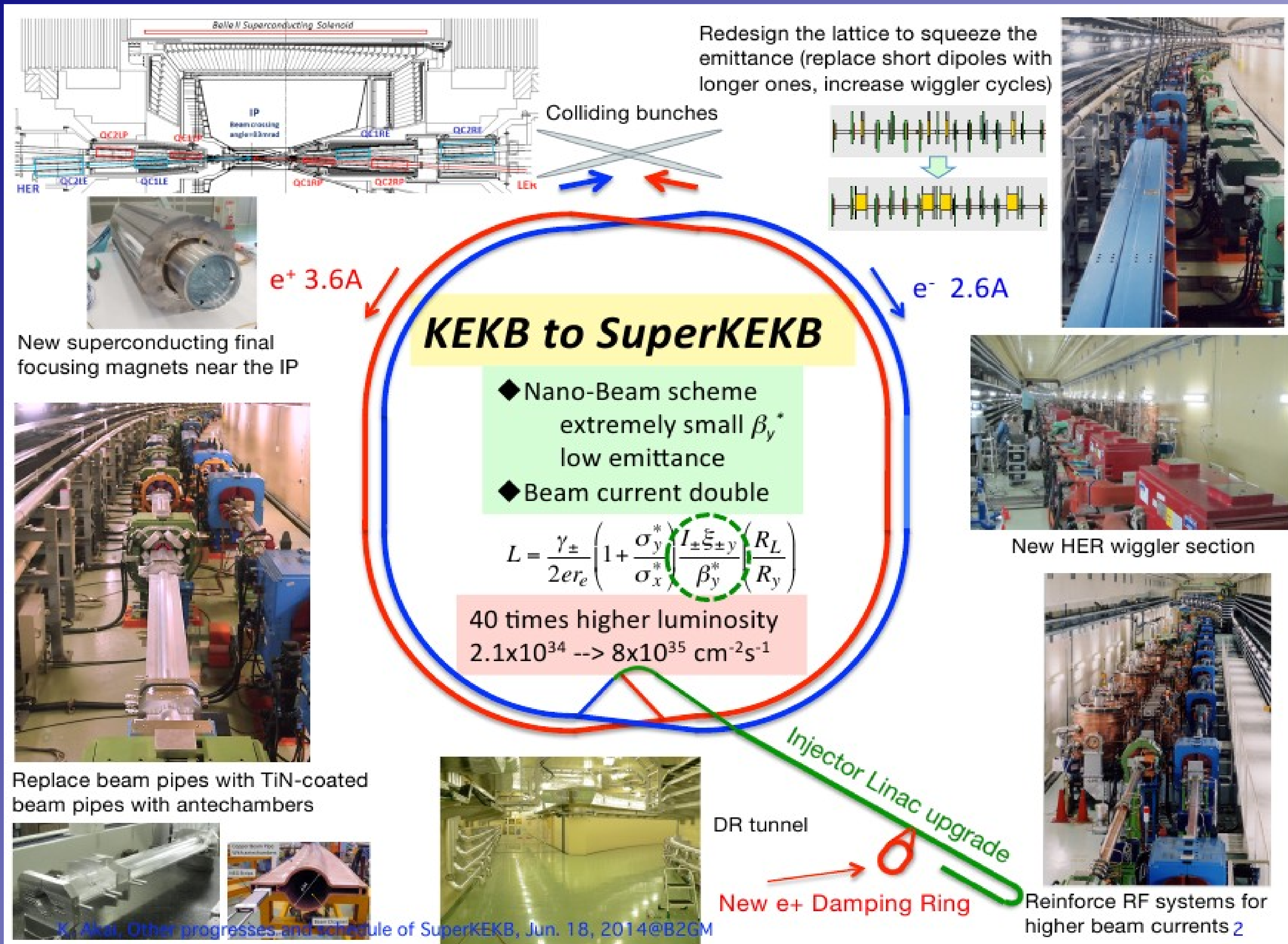
- The physics program of Belle II is now being discussed in B2TIP framework aiming at the early discovery of New Physics.

- We need more closer collaboration with theorists to enrich the physics program at Belle II.

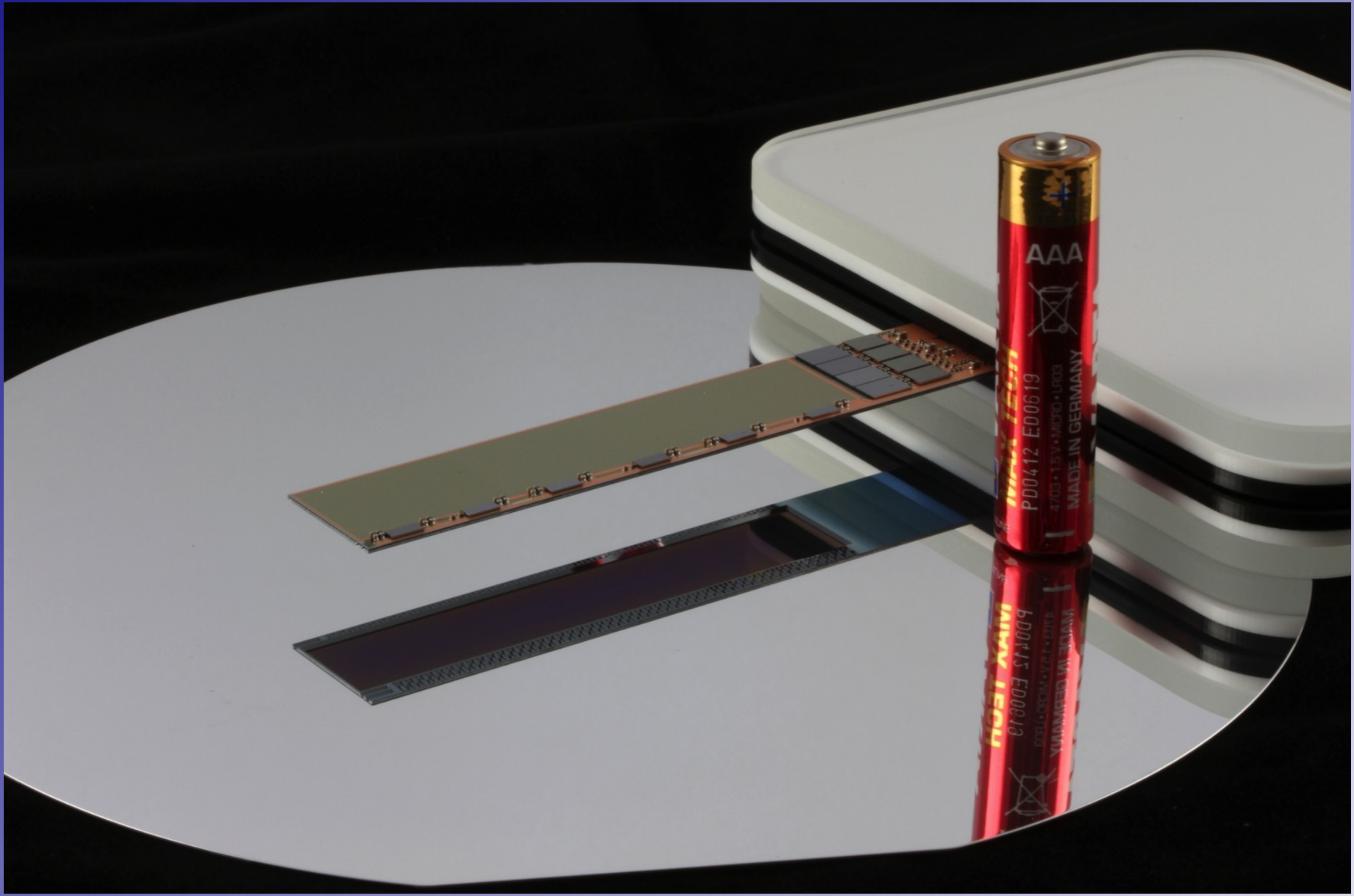
- Your participation is very much welcome!

Backup Slides

The SuperKEKB accelerator



“Full sized” pixel detector module 0



75 µm thick

Pixel detector group from many institutes and universities in Germany, also Czech Republic and Spain.

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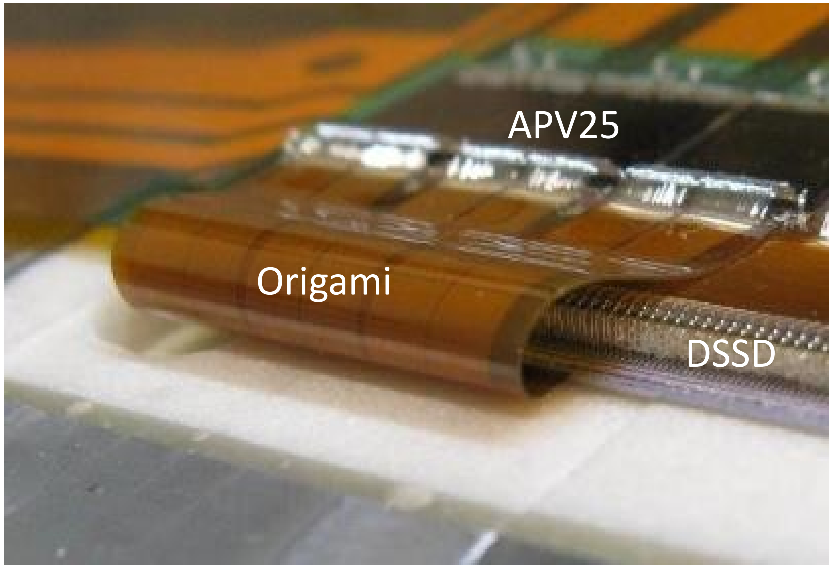
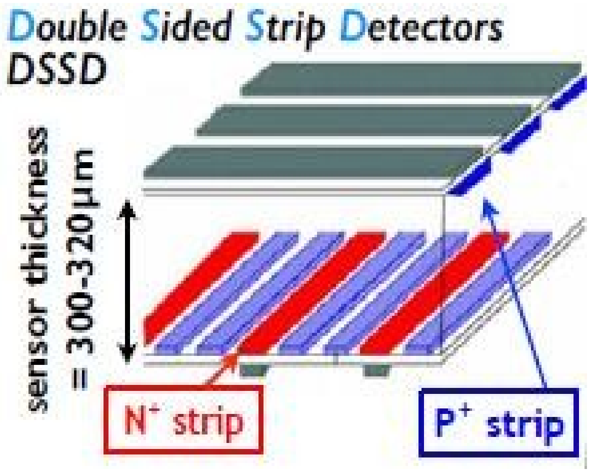
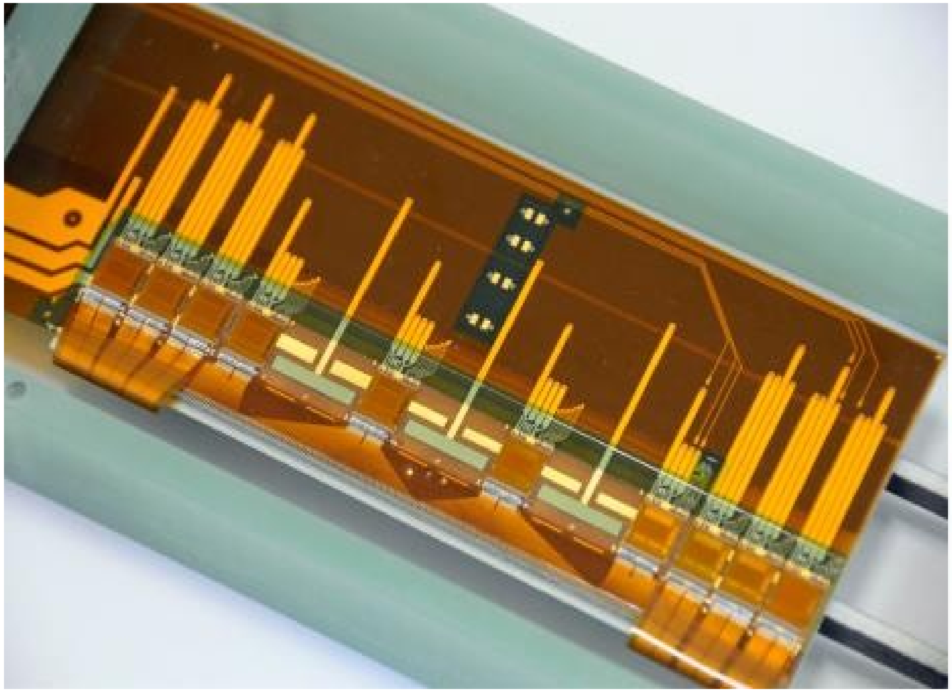
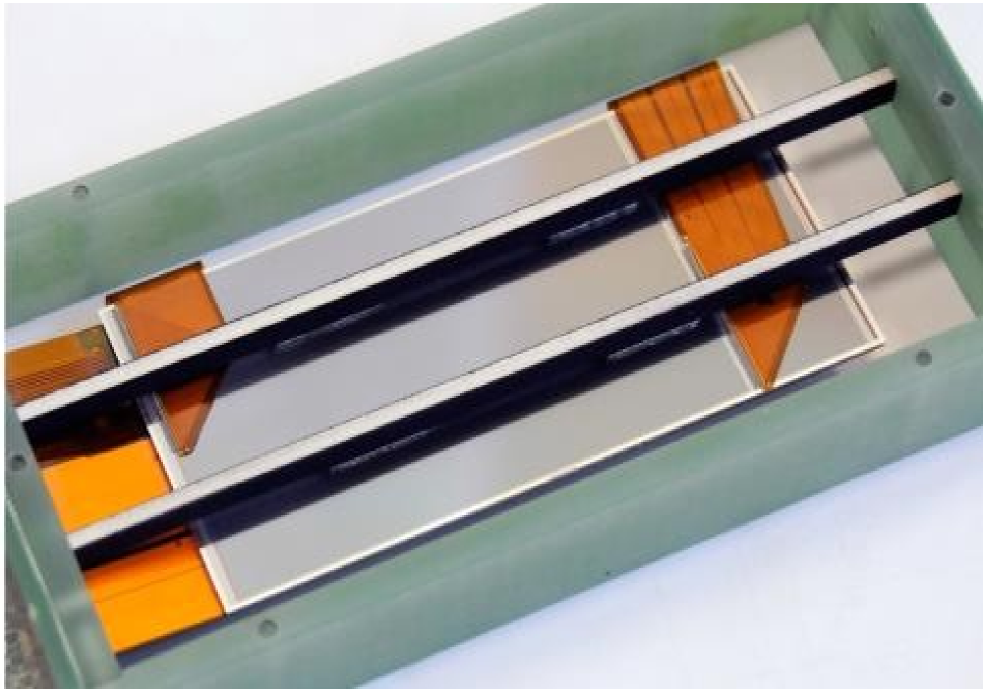
Belle II SVD Module

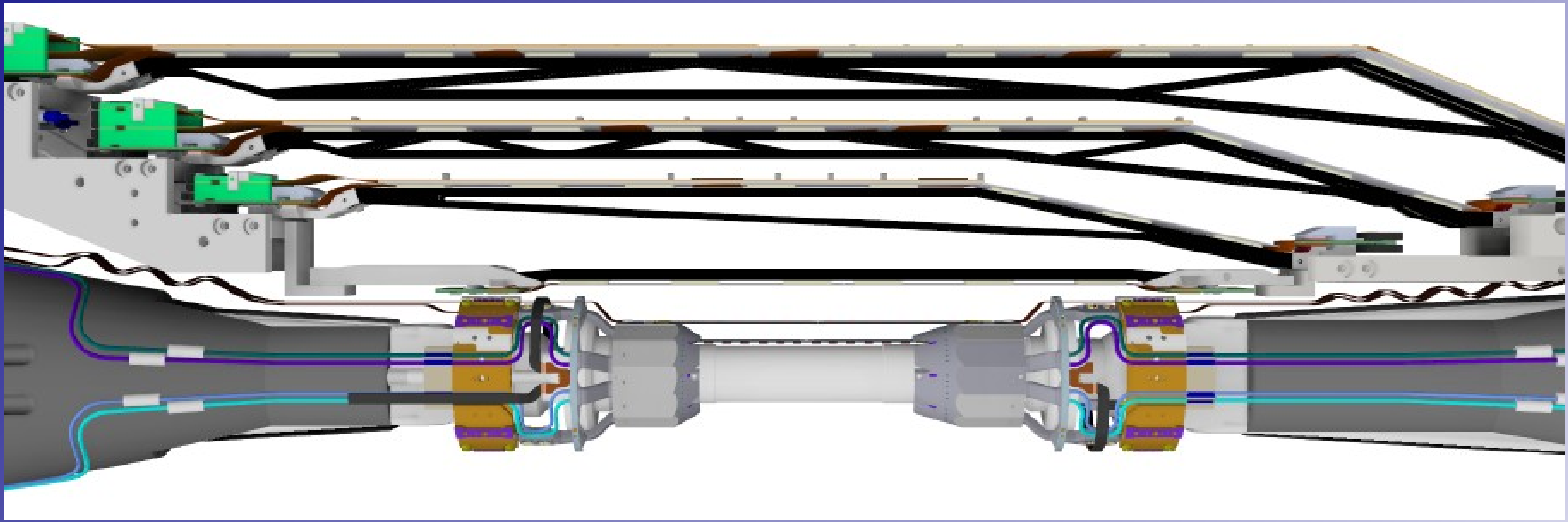




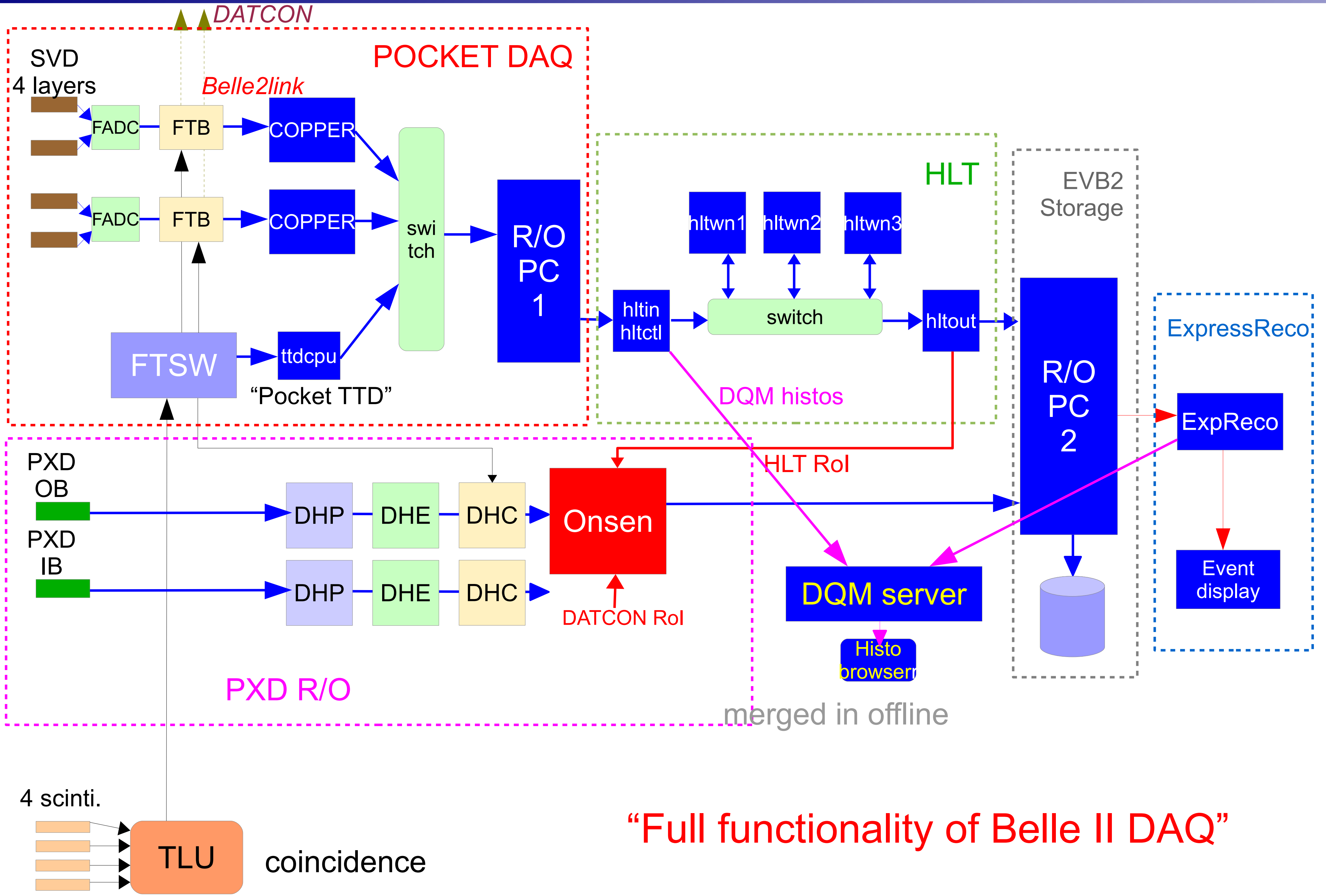




Innner detector structure (SVD+PXD)



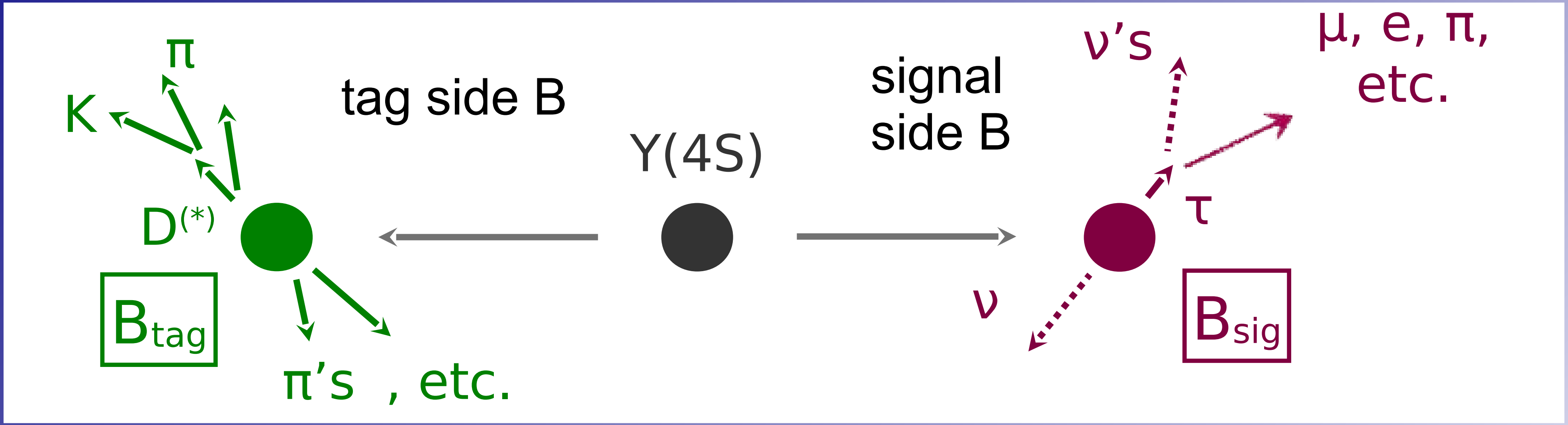
DAQ for DESY beam test



"Full functionality of Belle II DAQ"

Event reconstruction using "FullRecon" at B-factory

- The central technique : full reconstruction of tag-side B meson decay



- reconstructed from
  * Hadronic tag: hadronic decays: $B \rightarrow D^{(*)}\pi$ etc, eff. ~ 0.2%, purity ~20%
  * SL tag: semi-leptonic decays : $B \rightarrow D^{(*)}l\nu$ eff. ~1.5%, more BG.

WG1: Other Exclusive decays

Precision measurements of CKM matrix elements.

had. tagged

$$B \to D^* \ell \bar{\nu}_\ell$$

Error on $|V_{cb}|$	stat.	tot.
B-Factories	0.6%	3.6%
Belle II 5/ab	0.2%	1.8%
Belle II 50/ab	0.1%	**1.4%**

had. tagged

$$B \to \pi \ell \bar{\nu}_\ell$$

Error on $|V_{ub}|$	stat.	tot.
B-Factories	5.8%	10.8%
Belle II 5/ab	2.2%	4.7%
Belle II 50/ab	0.7%	**2.4%**

untagged

$$B \to \pi \ell \bar{\nu}_\ell$$

Error on $|V_{ub}|$	stat.	tot.
B-Factories	2.7%	9.4%
Belle II 5/ab	1.0%	4.2%
Belle II 50/ab	0.3%	**2.2%**

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* Not so much gain.
* Important to study the difference between inclusive and exclusive measurements.

$$B \to X_c \ell \bar{\nu}_\ell$$

Error on $|V_{cb}|$	stat.	tot.
B-Factories	1.5%	1.8%
Belle II 50/ab	0.5%	**1.2%**

$$B \to X_u \ell \bar{\nu}_\ell$$

Error on $|V_{ub}|$	stat.	tot.
B-Factories	4.5%	6.5%
Belle II 5/ab	1.1%	3.4%
Belle II 50/ab	0.4%	**3%**

B→Xsll

Another example of sensitivity estimation:

$B \to X_s \ell\ell$ C_7/C_9 ratio

Error	tot.
B-Factories	19%
Belle II 5/ab	9%
Belle II 50/ab	**6%**

WG4 : ϕ_3

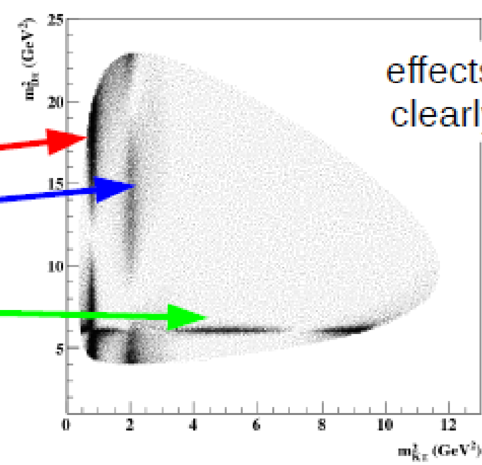
- LHCb dominates, though.
- There could be a new idea on the measurement.

Extension to $B \rightarrow D\pi K$ decays

TG PRD 79 (2009) 051301(R)
TG & M. Williams PRD 80 (2009) 092002

- Powerful extension of the method exploits additional sources of interference that occur in multibody decays
  - $B^0 \rightarrow D(\pi^- K^+)$ decays can have CP violation
  - $B^0 \rightarrow (D\pi^-)K^+$ decays have no CP violation
    - Provides ideal reference amplitude from which to determine relative phases via interference between different resonances on the Dalitz plot

Toy example containing
$K^*(892)^0$
$K_2^*(1430)^0$
$D_2^*(2460)^-$



effects of spin clearly visible

Tim Gershon
γ from $B \rightarrow DK$

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WG5 : Charmless hadronic decays

$B \to K\pi$: $\mathcal{B}$ and A_{CP} @ Belle II

$\mathcal{B}$

Mode	BABAR	Belle				Belle II (σ_{total})	
			Ref.	fb^{-1}	σ_{total}	5 ab^{-1}	50 ab^{-1}
$K^0\pi^+$	$23.9 \pm 1.1 \pm 1.0$	$23.97 \pm 0.53 \pm 0.71$	90	772	0.89	0.35	0.11
$K^+\pi^0$	$13.6 \pm 0.6 \pm 0.7$	$12.62 \pm 0.31 \pm 0.56$	90	772	0.64	0.25	0.08
$K^+\pi^-$	$19.1 \pm 0.6 \pm 0.6$	$20.0 \pm 0.34 \pm 0.60$	90	772	0.69	0.27	0.09
$K^0\pi^0$	$10.1 \pm 0.6 \pm 0.4$	$9.68 \pm 0.46 \pm 0.50$	90	772	0.68	0.27	0.08

A_{CP}

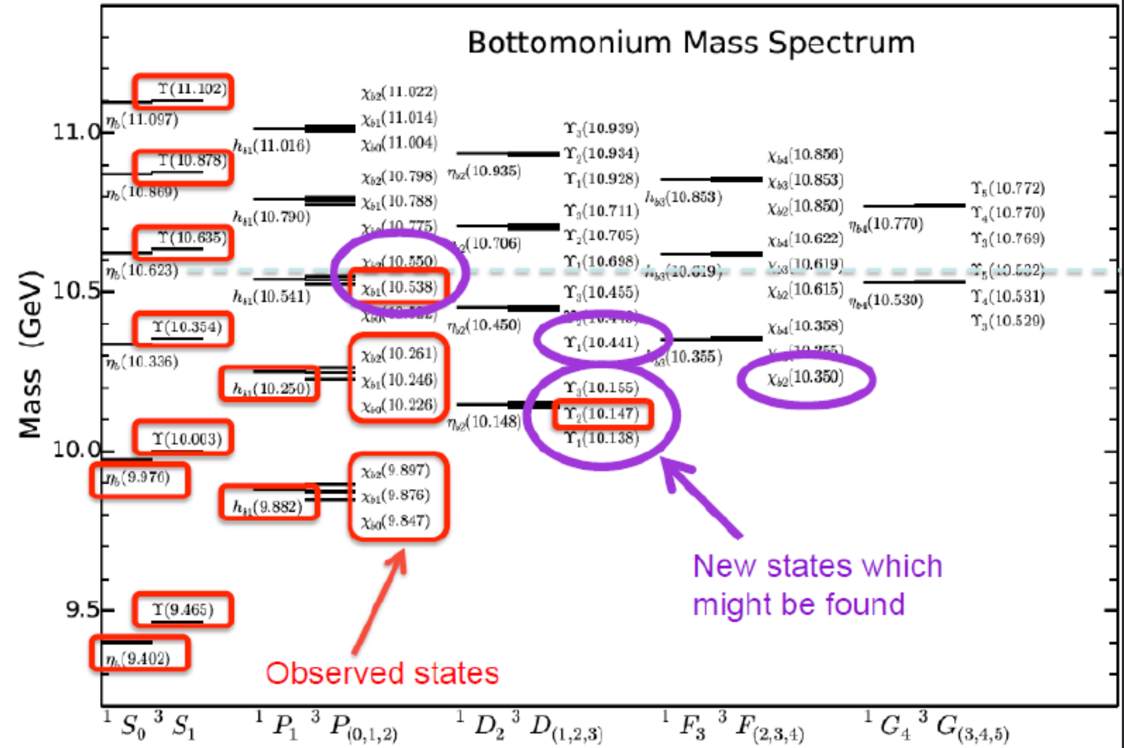
Mode	BABAR	Belle				Belle II (σ_{total})	
			Ref.	fb^{-1}	σ_{total}	5 ab^{-1}	50 ab^{-1}
$K^0\pi^+$	$-0.029 \pm 0.039 \pm 0.010$	$-0.011 \pm 0.021 \pm 0.006$	76	772	0.022	0.009	0.003
$K^+\pi^0$	$0.030 \pm 0.039 \pm 0.010$	$0.043 \pm 0.024 \pm 0.002$	76	772	0.024	0.009	0.003
$K^+\pi^-$	$-0.107 \pm 0.016^{+0.006}_{-0.004}$	$-0.069 \pm 0.014 \pm 0.007$	76	772	0.016	0.006	0.002

WG7: Exotic Particles

B.Fulsom's slide in B2TIP WS (Pitts)

S.Godfrey

- Work in PRD92, 054034 (2015)
- Potential model approach
- Focus on Belle II
  - States to discover
  - Radiative decay pathways
  - Predictions of rates

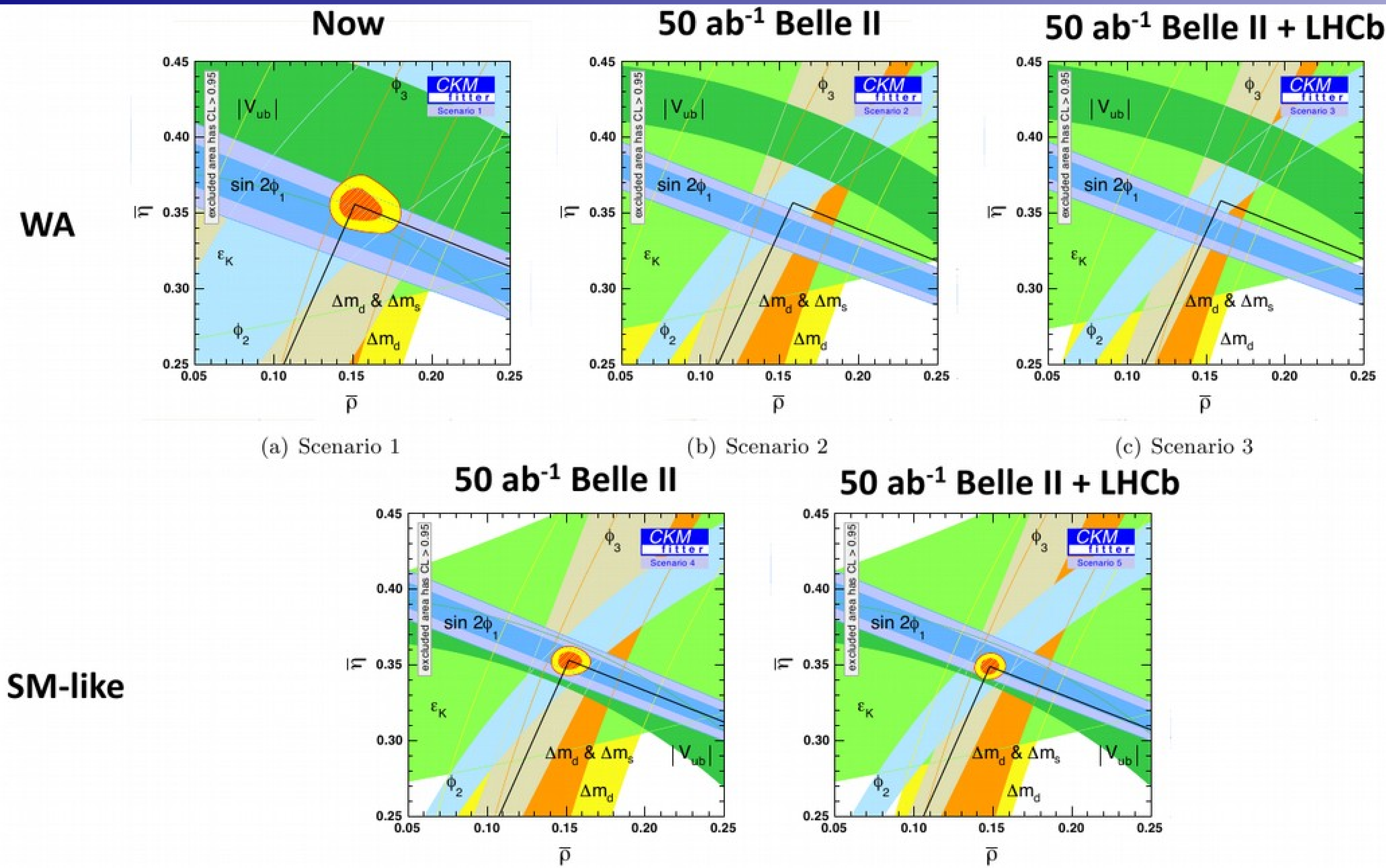


•We calculated mass and decay properties of bottomonium states to identify promising measurements:

- •Sitting on $\Upsilon(3S)$ should see 1^3D_1, 1^3D_2, 1^3D_3
- •Sitting on $\Upsilon(4S)$ should see 3^3P_1, 3^3P_2 and 1^3D_1, 2^3D_1
- •Could produce 1^3D_1 and 2^3D_1 by an energy scan
- •Might be able to see 1^3F_2 in radiative transitions of the 2^3D_1

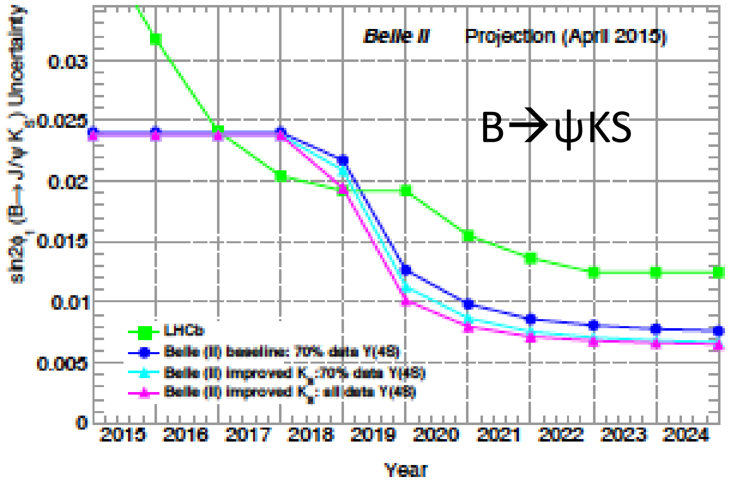
* $\Upsilon(6S)$?

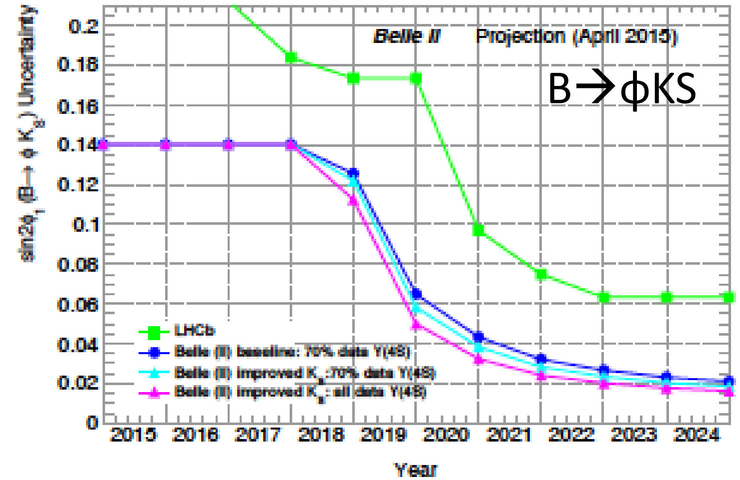
CKM constraint with and without LHCb



(a) Scenario 1 (b) Scenario 2 (c) Scenario 3

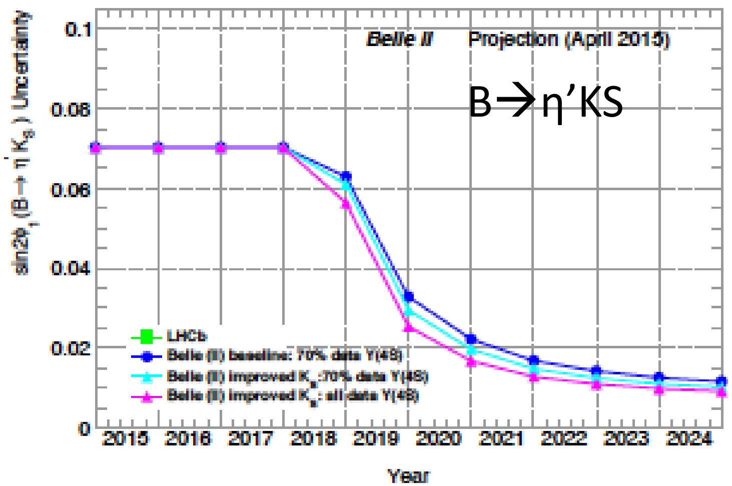
Tight race





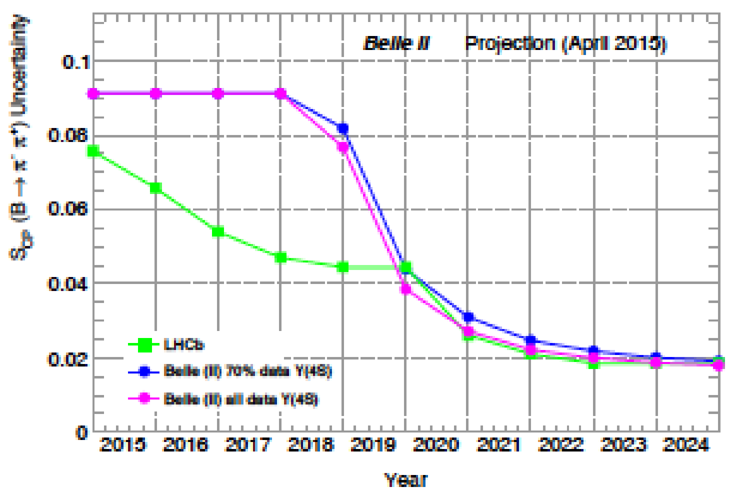
Belle II ahead

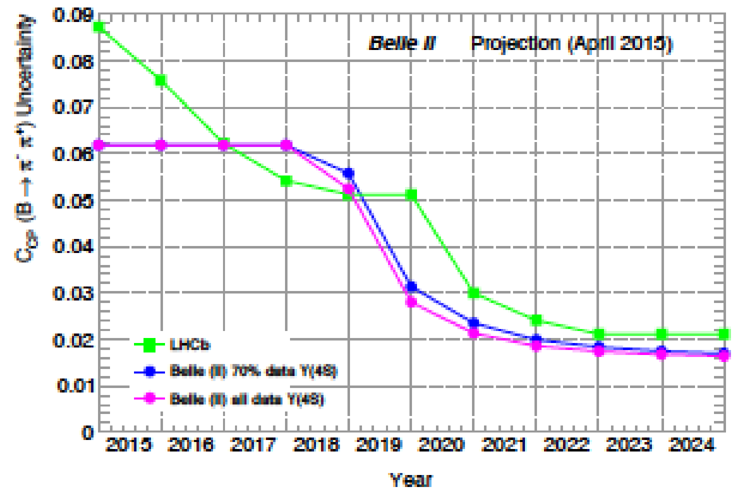
Belle II dominates here



Tight race

B→π+ π- CPV



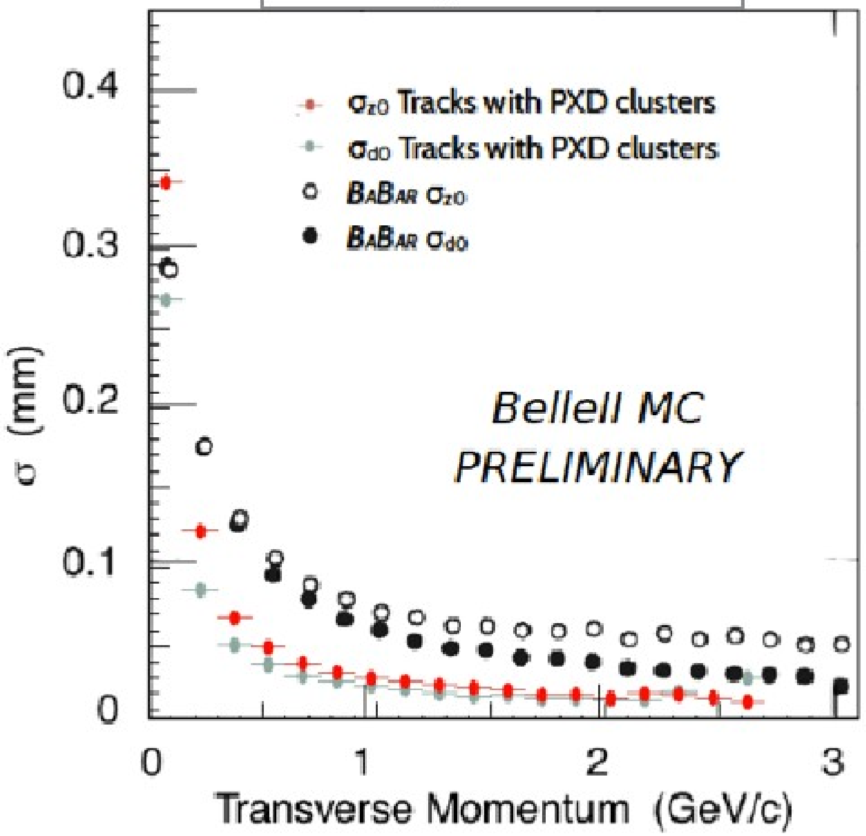


Readiness of Belle II data analysis software

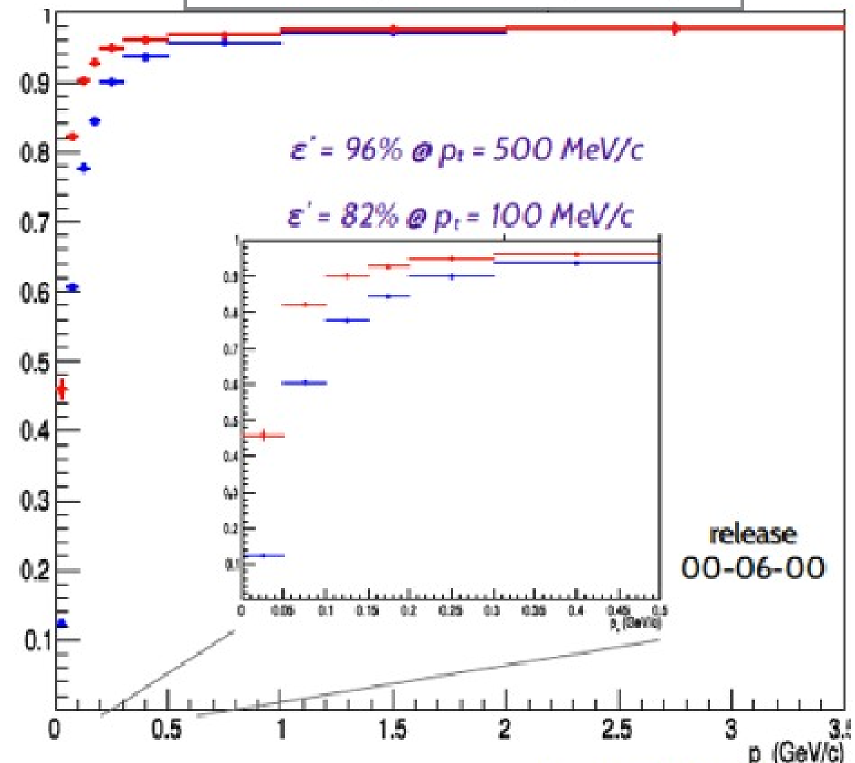
▸Vertexing	Suite of fitting methods ✓ - working on Tree-Fitter.
▸Event Topology	Continuum (*q anti-q*) suppression ✓
▸B-reconstruction	B hadronic & semileptonic tagging with MVA classifiers ✓
▸Rest of Event	Missing energy analysis ✓
▸Flavour Tagging	Categorised tag side flavour tagging✓
▸Tag-vertex	Fit tag side vertex for Δt measurement ✓
▸Charm-tag	Inclusive and exclusive prompt charm tagging ✓

Tracking Performance

Tracking IP resolution



Tracking efficiency vs. p_T



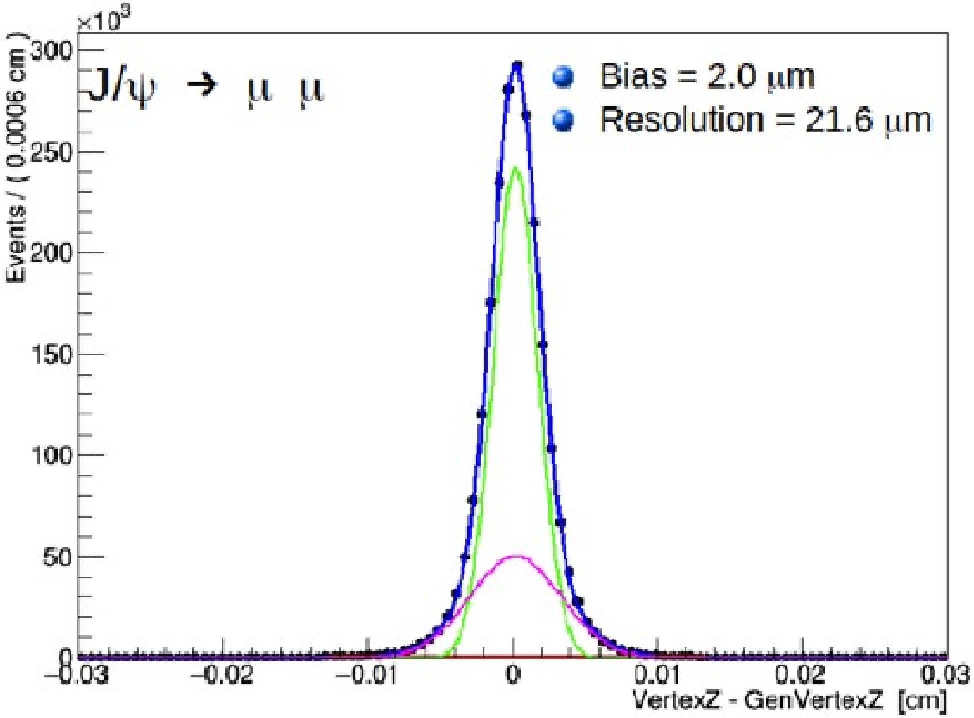
*release-6 (December 2015)

• physical efficiency

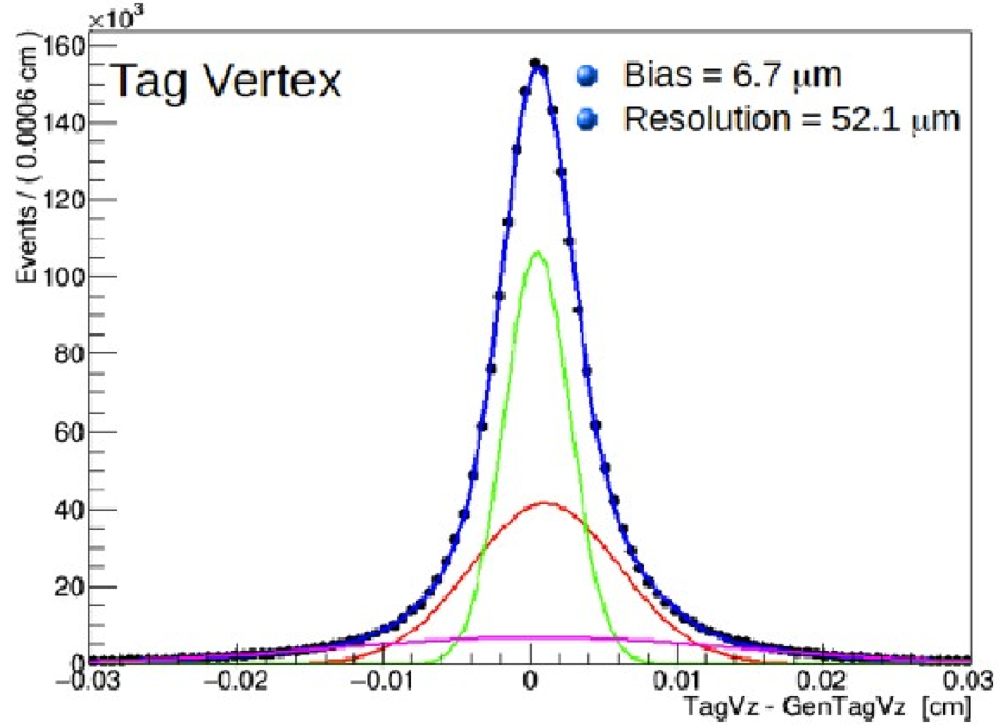
• geometrical acceptance and detector efficiency factored out

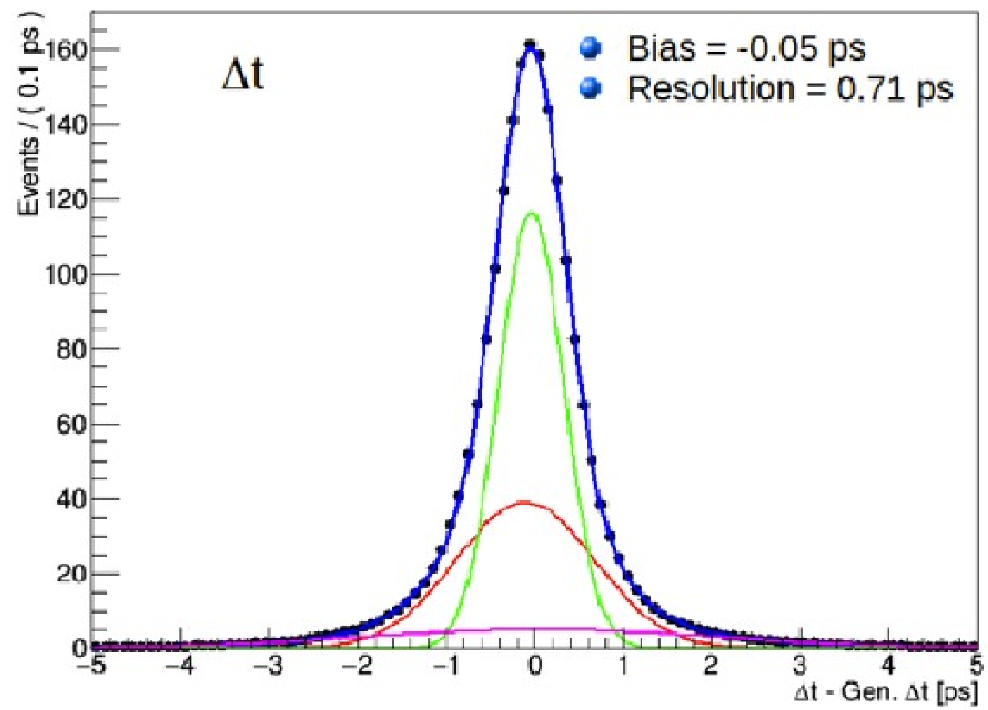
Vertex fitting

- $B^0 \rightarrow J/\psi\ K_S$
  - MC5 (0.8 ab^{-1}) sample (no bkg.)
  - Slightly more recent analysis tools



*release-5-3 (October 2015)





The importance of NP theory code from experimentalist's viewpoint

- To search for the evidence of new physics in the measurements obtained in the Belle II data analysis, the comparison with theoretical predictions which includes NP effects is essential.

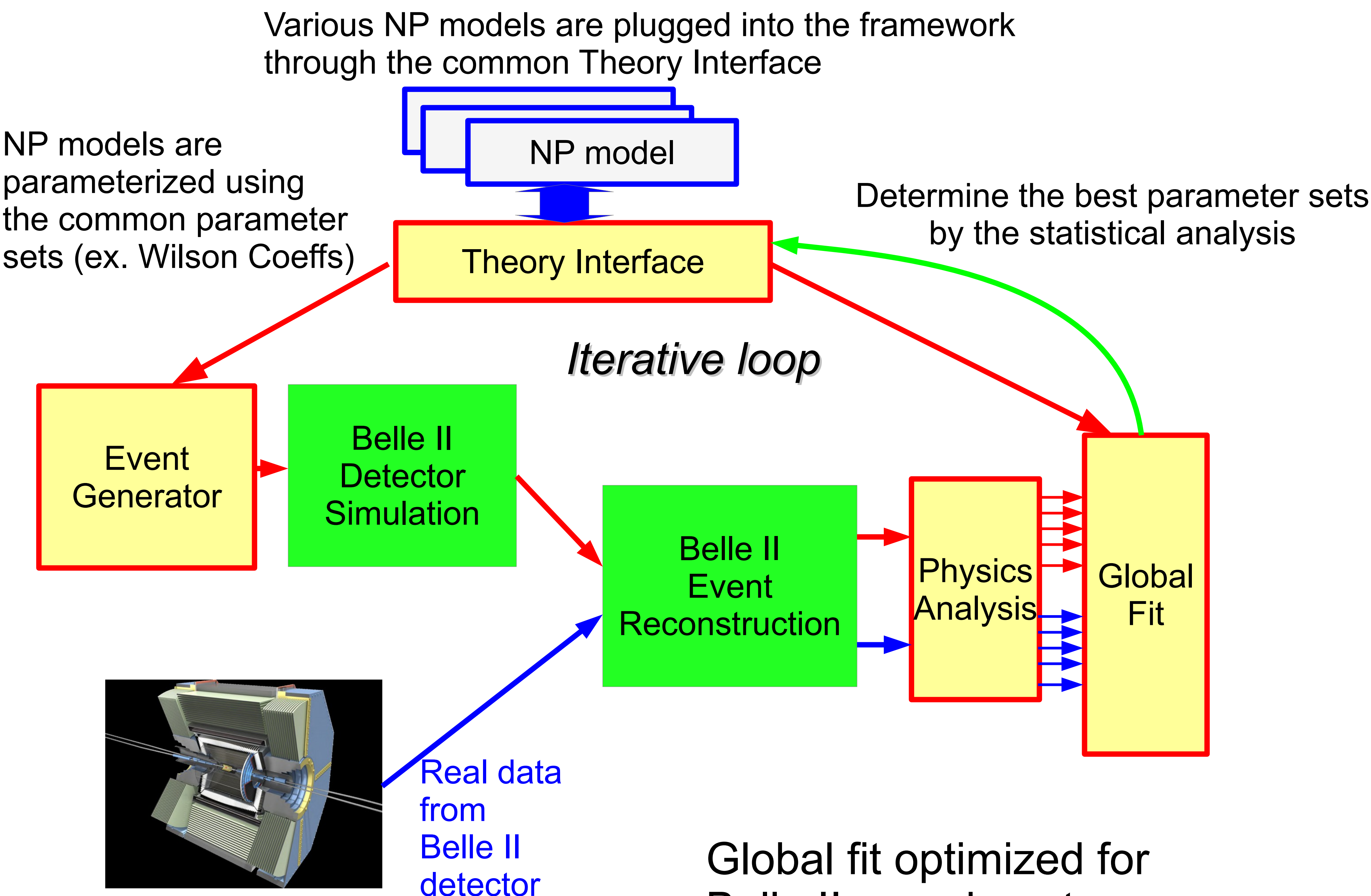
- In the past, such predictions are given by theorists independently of experiments, like predictions of branching fractions with NP effects.

- But the recent analyses in experiments are quite complicated and a simple comparison tends to become difficult.

- For the detailed study of NP effects in the experiment, the NP effect has to be simulated in various measurements by Monte Carlo.

- In such simulations, the NP effects have to be coded in the Event Generator which simulates the physics process B decays.
  <- Necessity of theory codes of NP models

- The theory codes are desired to be public so that event generator developer can implement them freely.

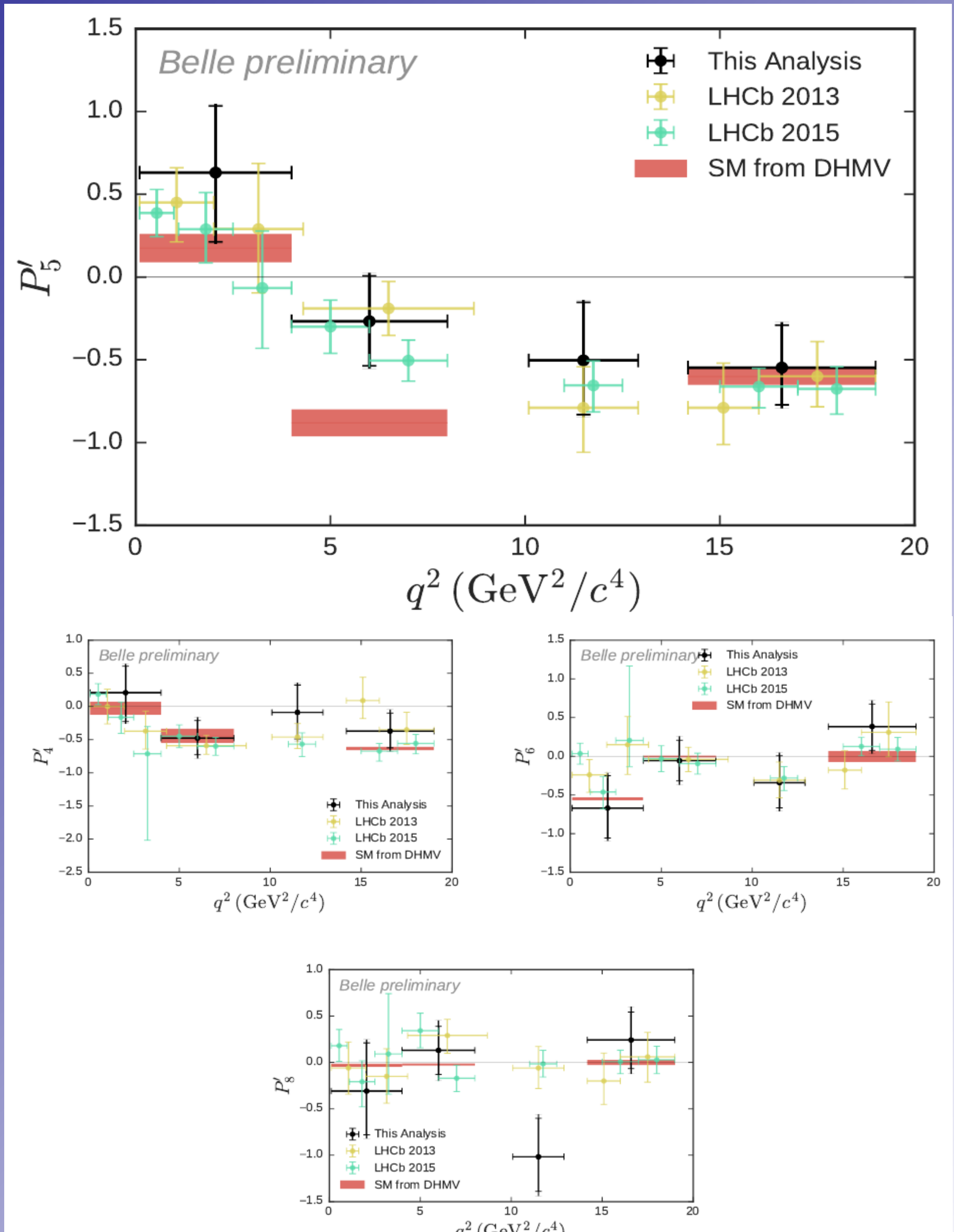


Global fit optimized for Belle II experiment

Belle : B→K*l⁺l⁻ update

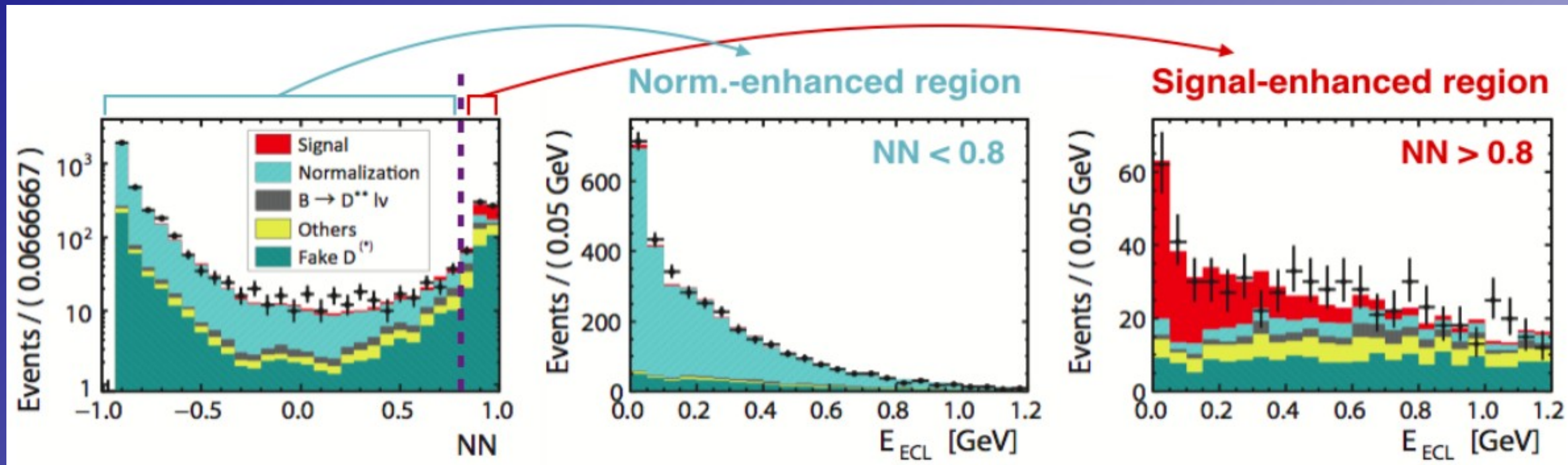
shown at LHCSki workshop 2016

* ~2.1 σ dicrepancy from SM in bin 2 of P_5'



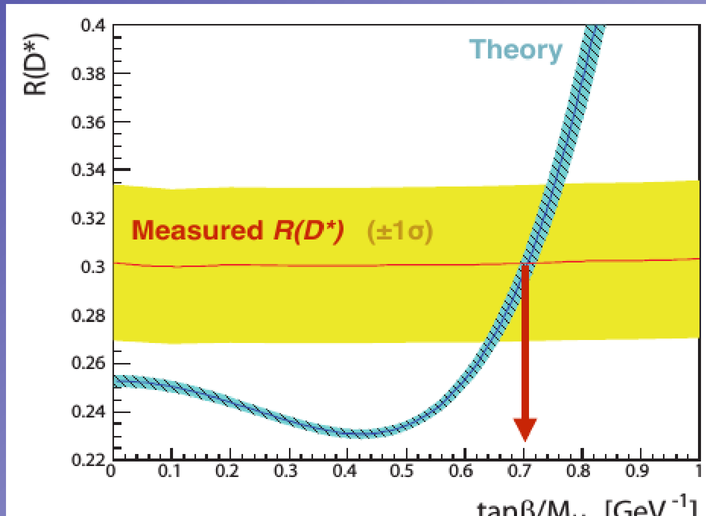
Belle : B→D*τν by semi-leptonic tag

shown at Moriond'16



$$\mathcal{R}(D^*) = 0.302 \pm 0.030(\mathrm{stat}) \pm 0.011(\mathrm{syst}) \quad (13.8\sigma)$$

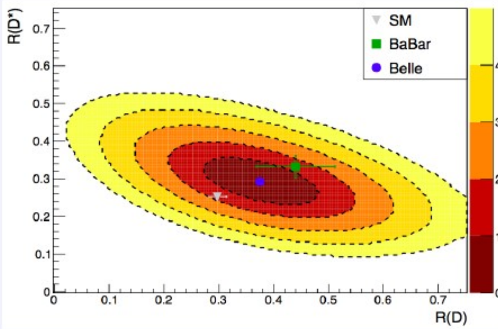
$$\mathcal{R}(D^*) \quad = \quad 0.311 \pm 0.038 \pm 0.013 \ \ (\ell^{\mathrm{sig}} = e)$$
$$\mathcal{R}(D^*) \quad = \quad 0.304 \pm 0.051 \pm 0.018 \ \ (\ell^{\mathrm{sig}} = \mu)$$



consistent

had. tag result

$$R(D) = 0.375 \pm 0.064 \pm 0.026$$
$$R(D^*) = 0.293 \pm 0.038 \pm 0.015$$



Belle result lies between the SM prediction (1.4σ away) and BaBar's hadronic tag result (1.8σ away) Phys. Rev. D 88, 072012 (2013)