The Belle II experiment at SuperKEKB

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on behalf of the **Belle II Collaboration**
2 Dec 2014

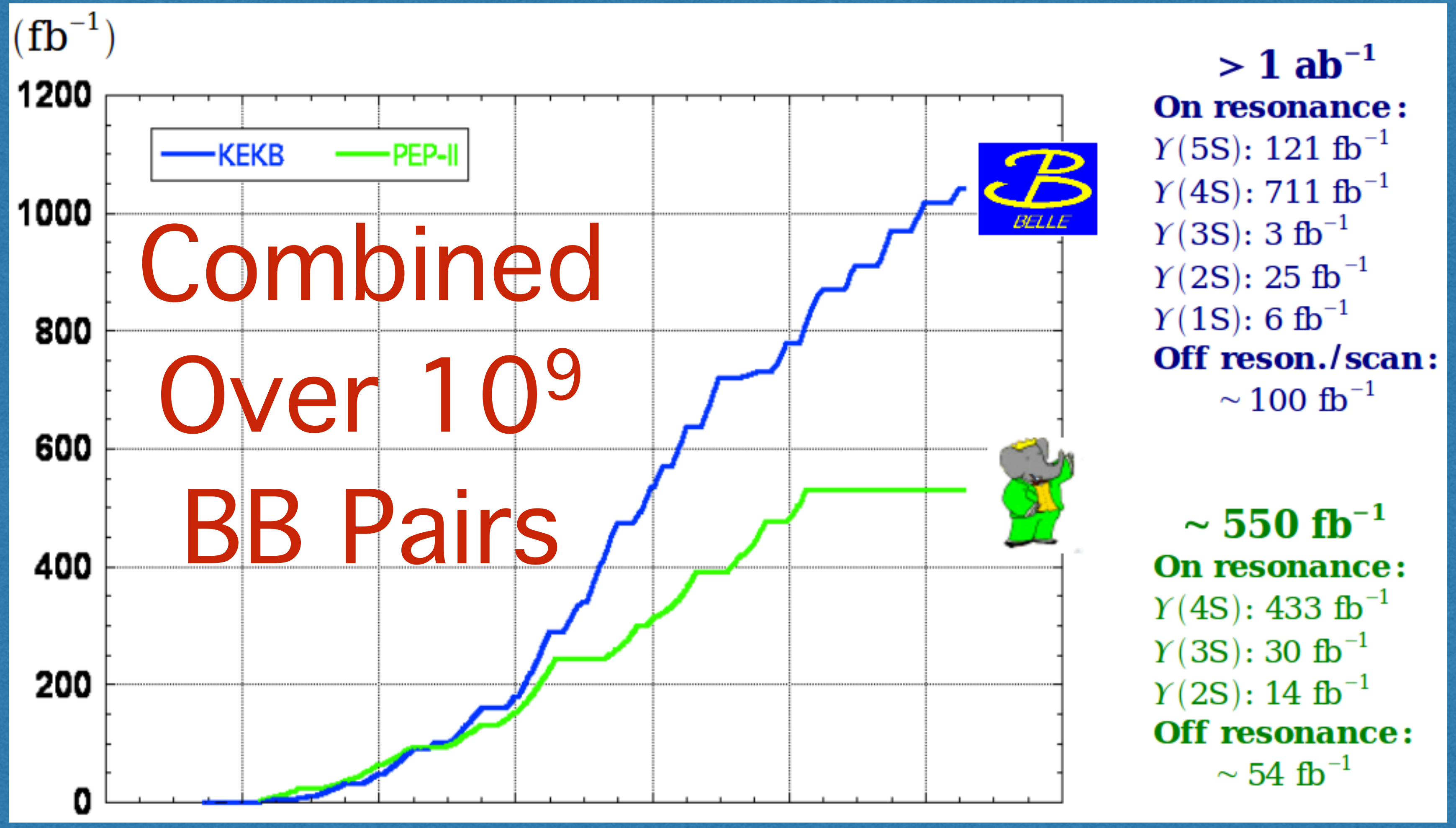
DISCRETE 2014: Fourth Symposium on Prospects in the Physics of Discrete Symmetries

2-6 December 2014
King's College London, Strand Campus
Europe/London timezone

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

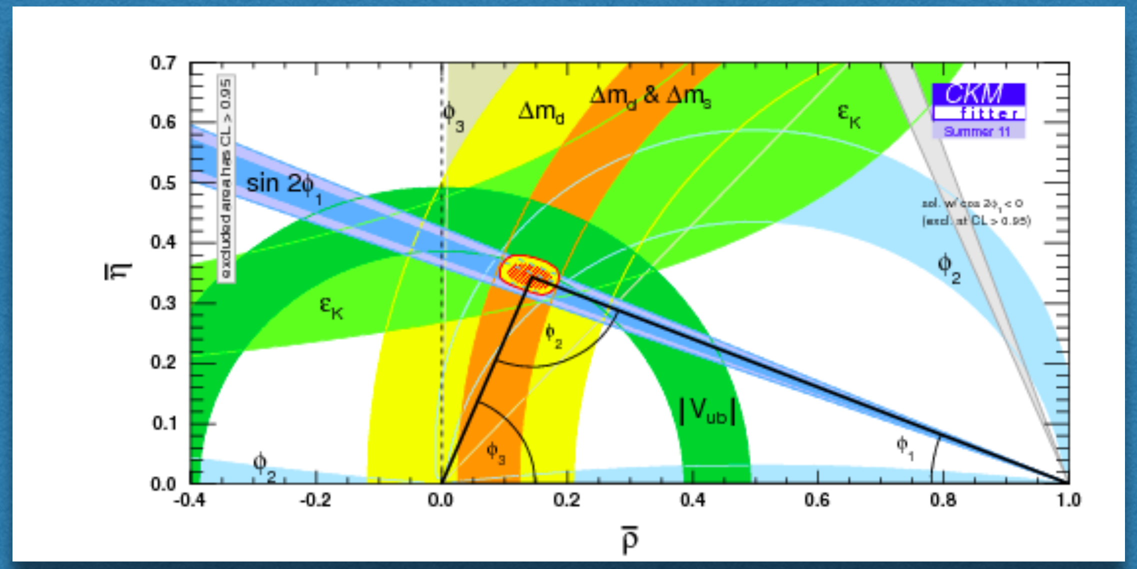
Outline

- B-Factory achievements
- WHY: **Motivation** for Super B factories
- HOW: **SuperKEKB** & **Belle II**
- WHAT: **Physics program** at Belle II
- WHEN: Current **schedule**

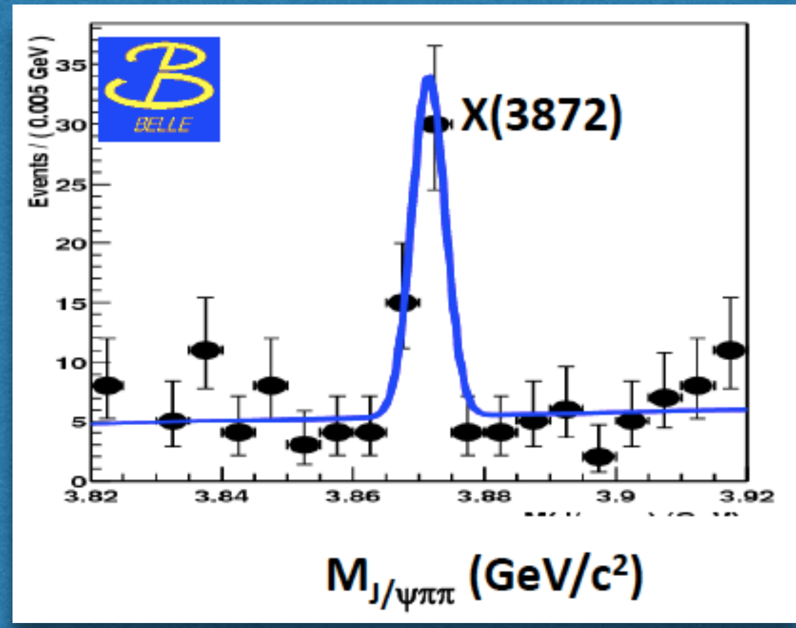


- Discovery of CPV in B mesons

- Rare B decays
- Measurements of UT sides and angles



- Mixing in charm
- New hadrons



- …many, many others

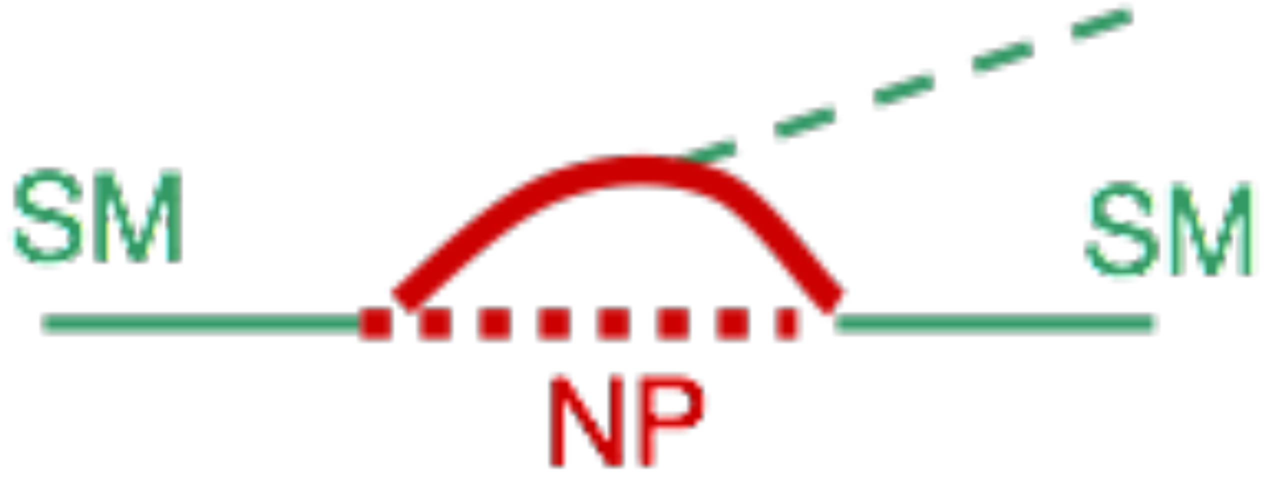
WHY: Motivation for Super B Factories

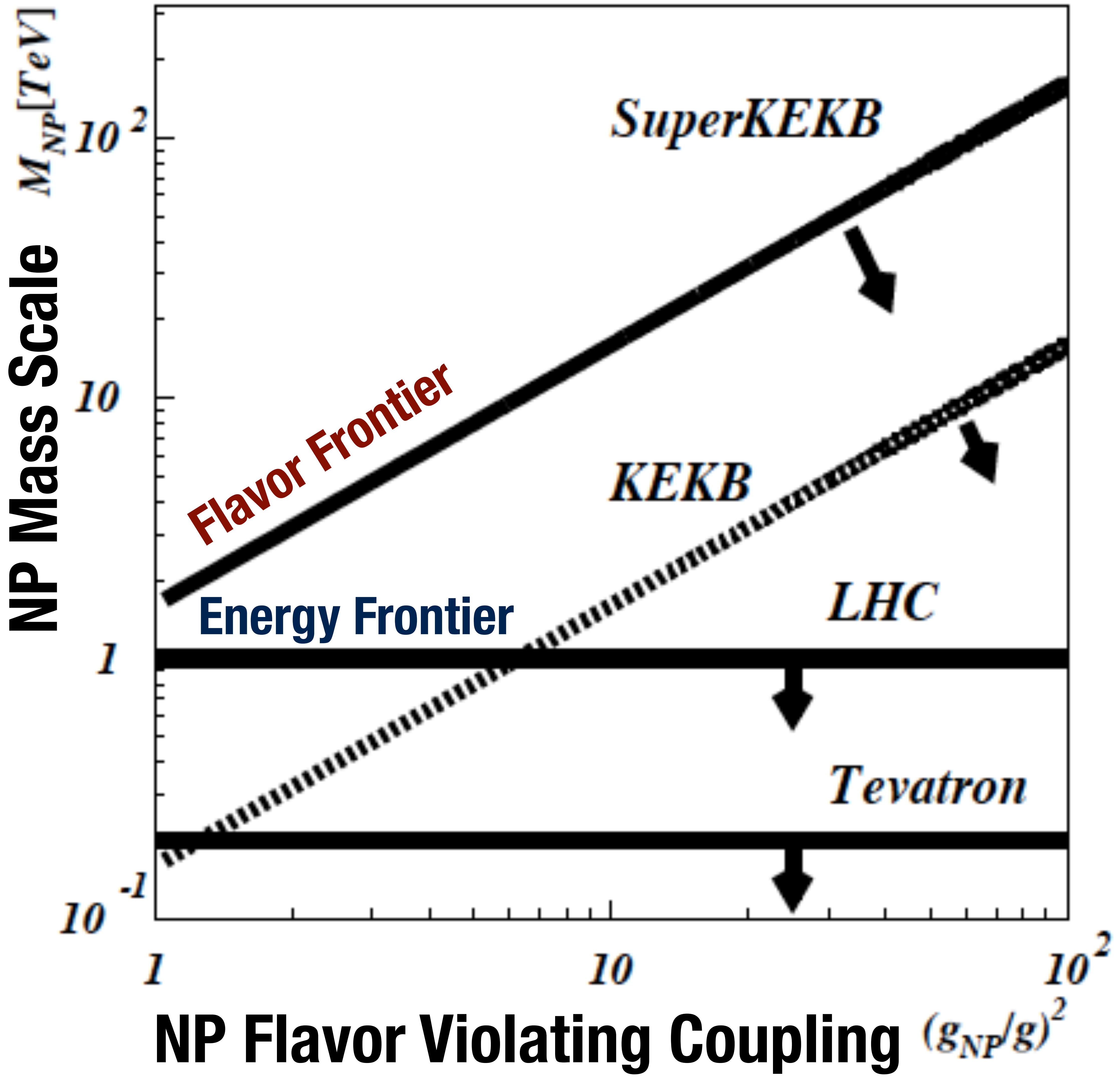
Motivation

Why do we need a flavor factory when we have the LHC?

- **Energy Frontier**: Production of new particles from collisions
  - *Limited by beam energy*

- **Flavor Frontier**: Virtual production can probe scales to ~10 TeV or more





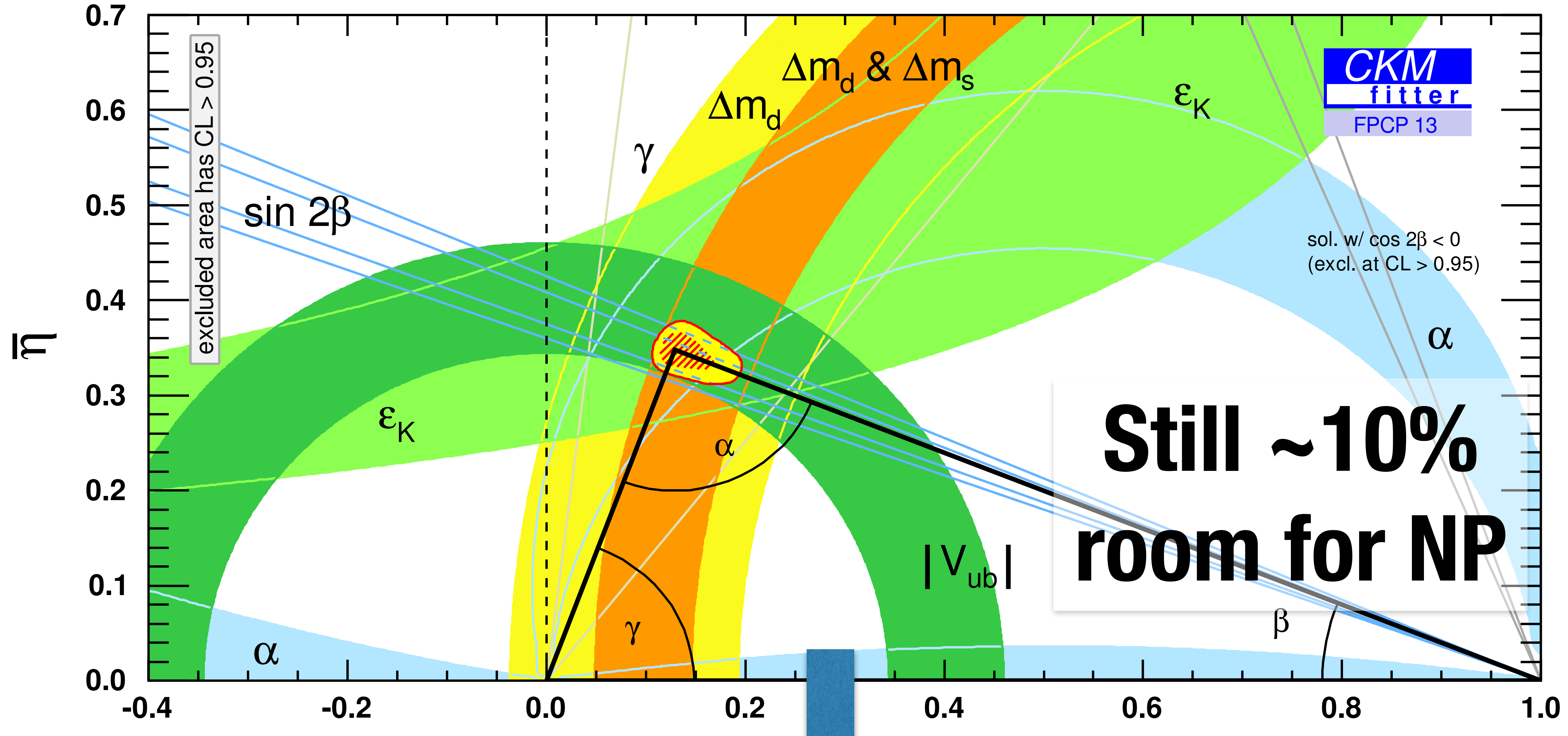
If supersymmetry is found at the LHC, a crucial question will be: how is it broken? By studying flavor couplings, a flavor factory can address this.

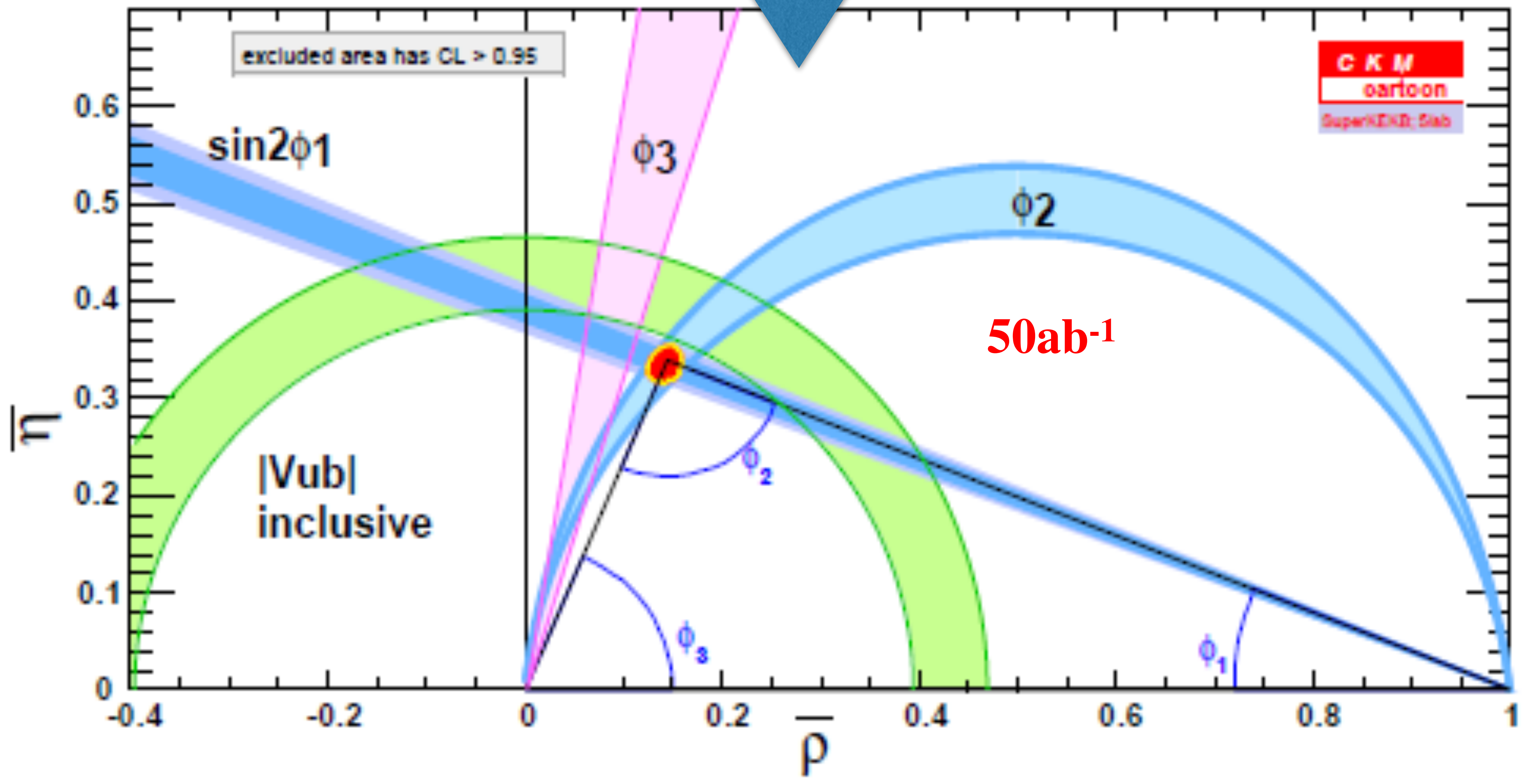
Motivation

Issues addressable at Belle II

- CP asymmetry in cosmology
  - ***CPV in quarks and charged leptons***
- Quark and lepton flavor and mass hierarchy
  - ***Higher symmetry***
- No candidates for Dark Matter yet
  - ***Hidden dark sector***
- Finite neutrino masses
  - ***Tau LFV***

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





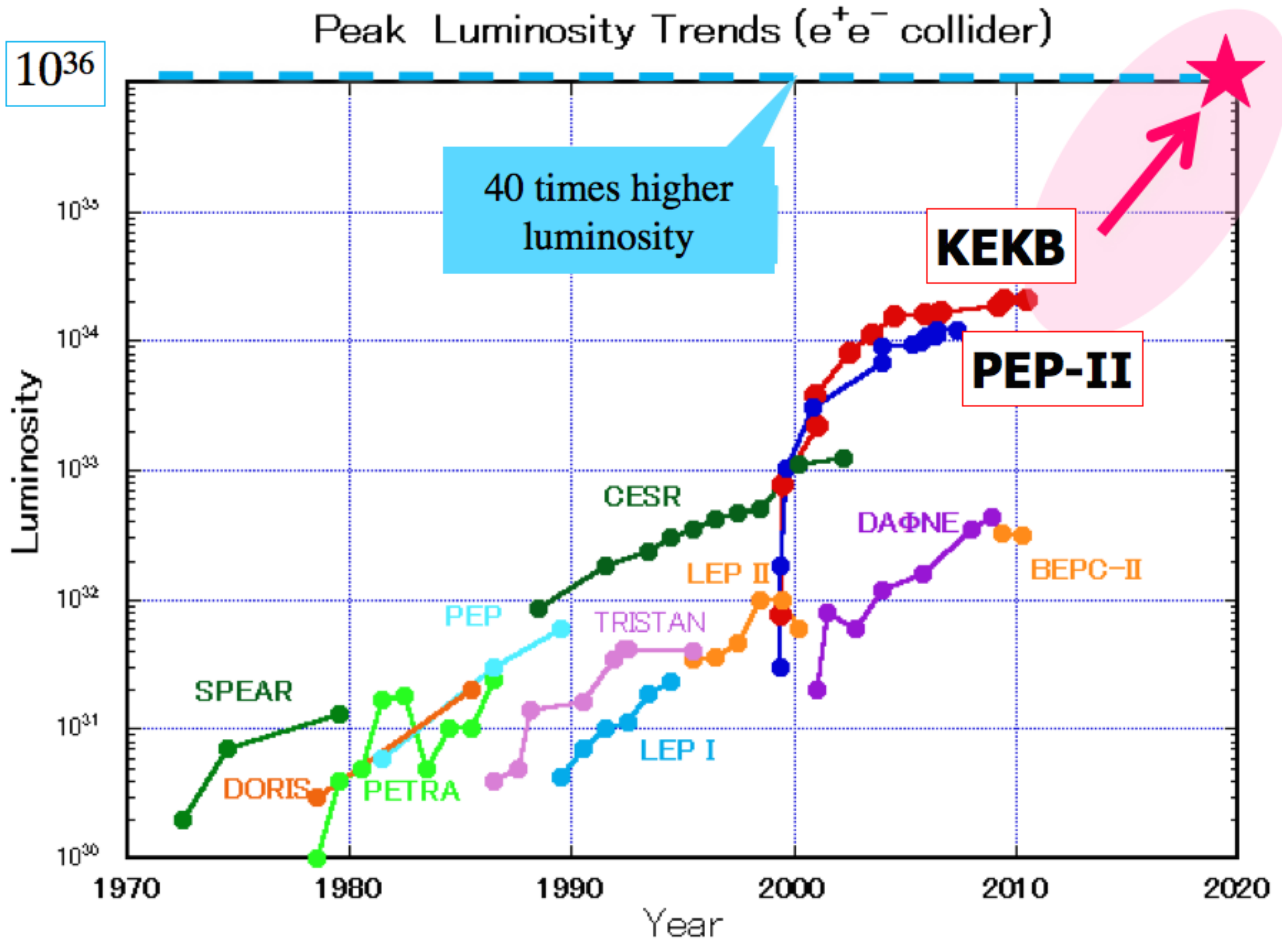
HOW: SuperKEKB Collider & Belle II

SuperKEKB

Target Luminosity

- L_{int} > 50 ab^{-1} by 2020s (50x Belle)
- $L_{peak} = 8 \times 10^{35}$cm^{-2}s^{-1} (40x KEKB)

Channel	Belle	BaBar	Belle II (per year)
$B\bar{B}$	7.7×10^8	4.8×10^8	1.1×10^{10}
$B_s^{(*)}\bar{B}_s^{(*)}$	7.0×10^6	–	6.0×10^8
$\Upsilon(1S)$	1.0×10^8		1.8×10^{11}
$\Upsilon(2S)$	1.7×10^8	0.9×10^7	7.0×10^{10}
$\Upsilon(3S)$	1.0×10^7	1.0×10^8	3.7×10^{10}
$\Upsilon(5S)$	3.6×10^7	–	3.0×10^9
$\tau\tau$	1.0×10^9	0.6×10^9	1.0×10^{10}



SuperKEKB

How to achieve 8x10^35 ?

- **High current** or **small beams**?
- High current (5-10x)
  - *Expensive and dangerous*
- "Nano-beam"
  - *Small current increase (2-3x)*
  - *Smaller β_y* (20x)* via superconducting focus magnets

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

Lorentz factor

Beam current

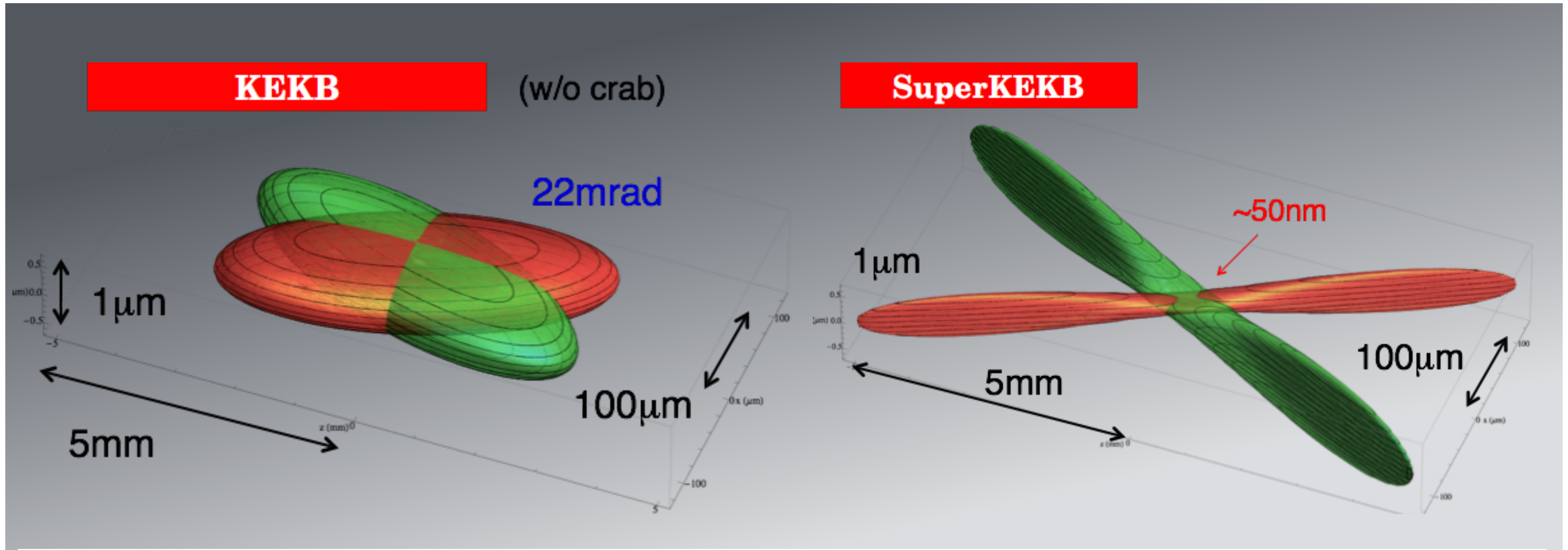
Beam-Beam parameter

Geometrical reduction factors (crossing angle, hourglass effect)

Beam aspect ratio at IP

Vertical beta function at IP

Minimum value is limited by hourglass effect



	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 x 10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80 x 10^{34}

SuperKEKB

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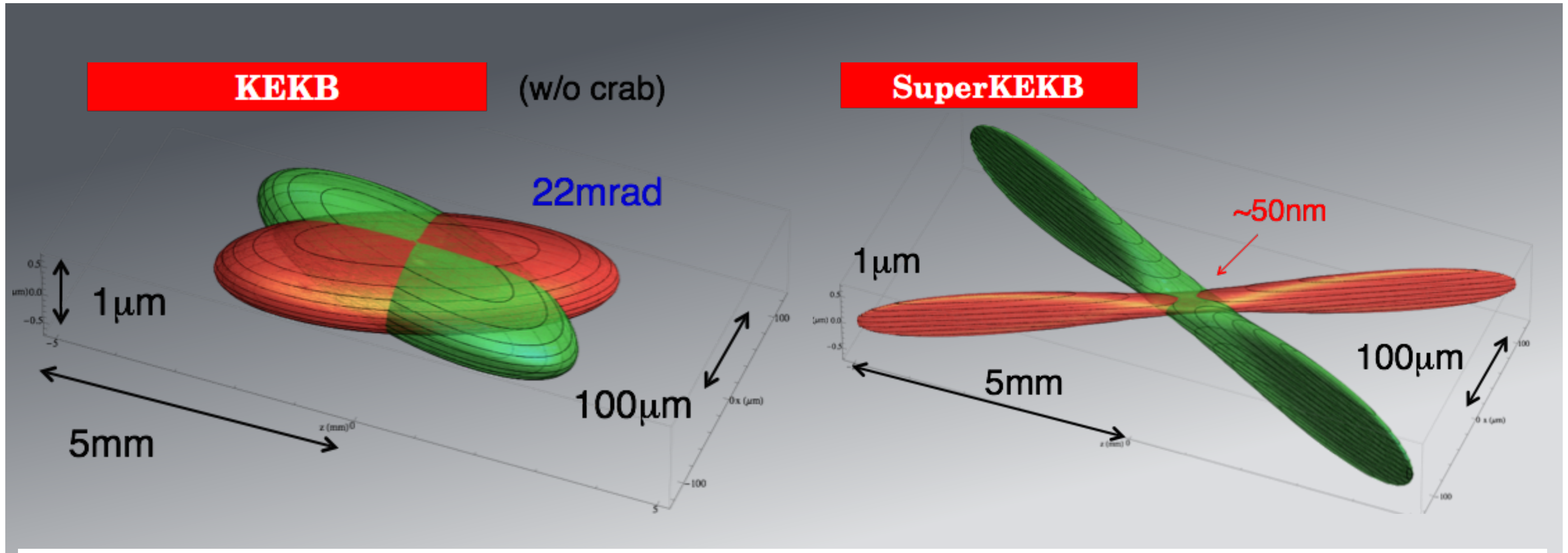

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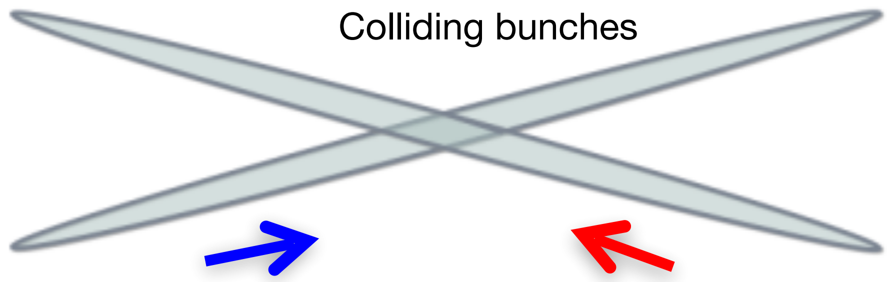
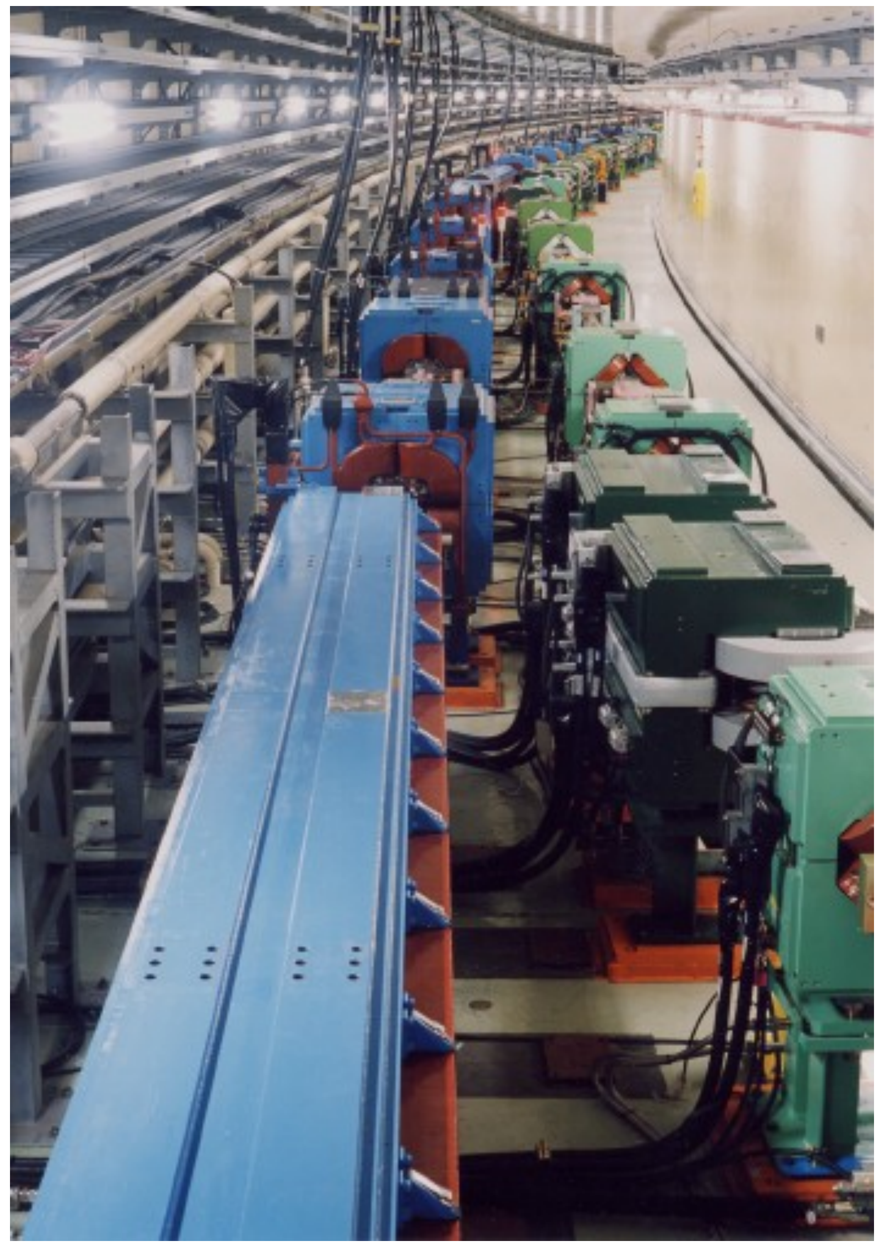
SuperKEKB

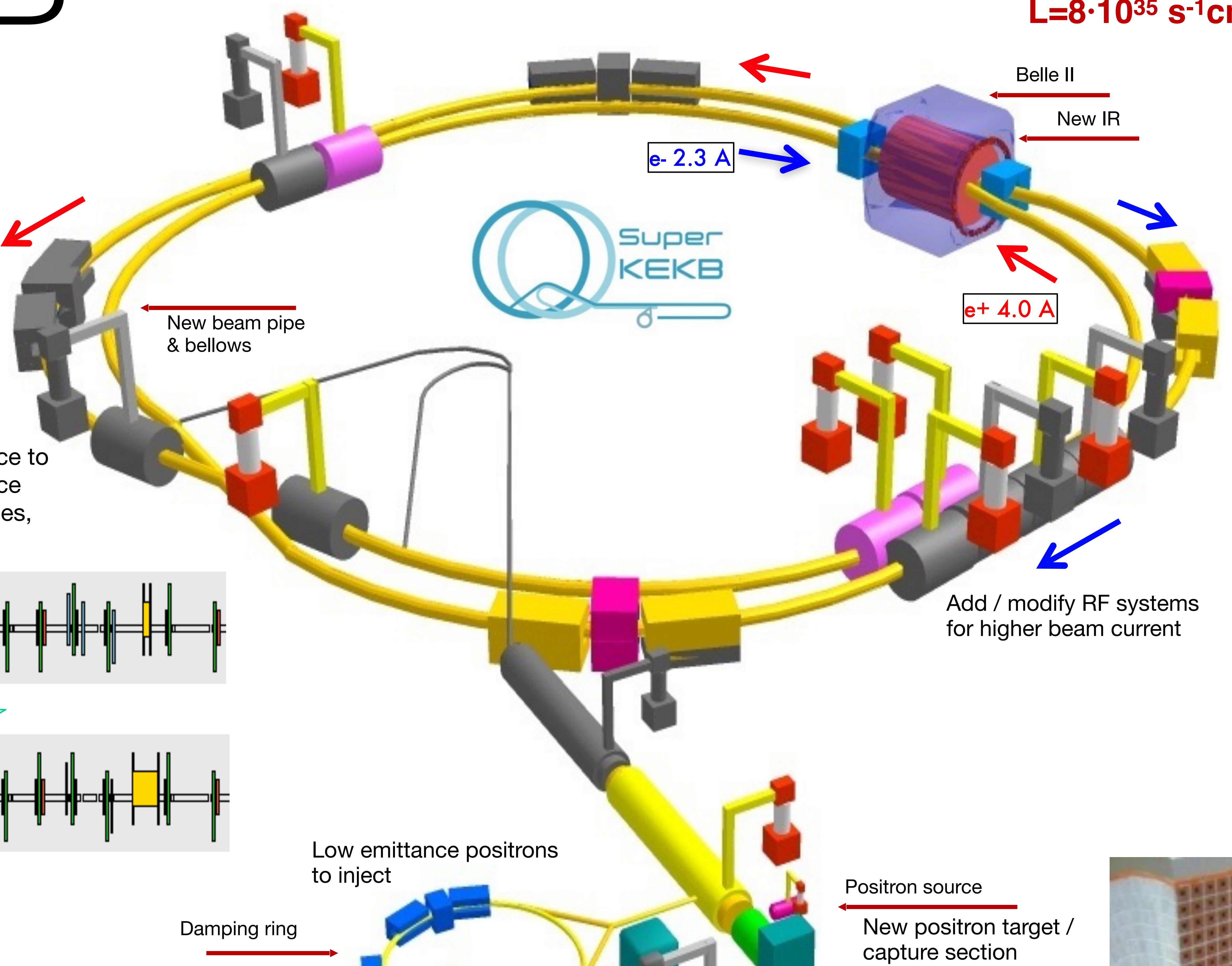
KEKB ⟹ SuperKEKB

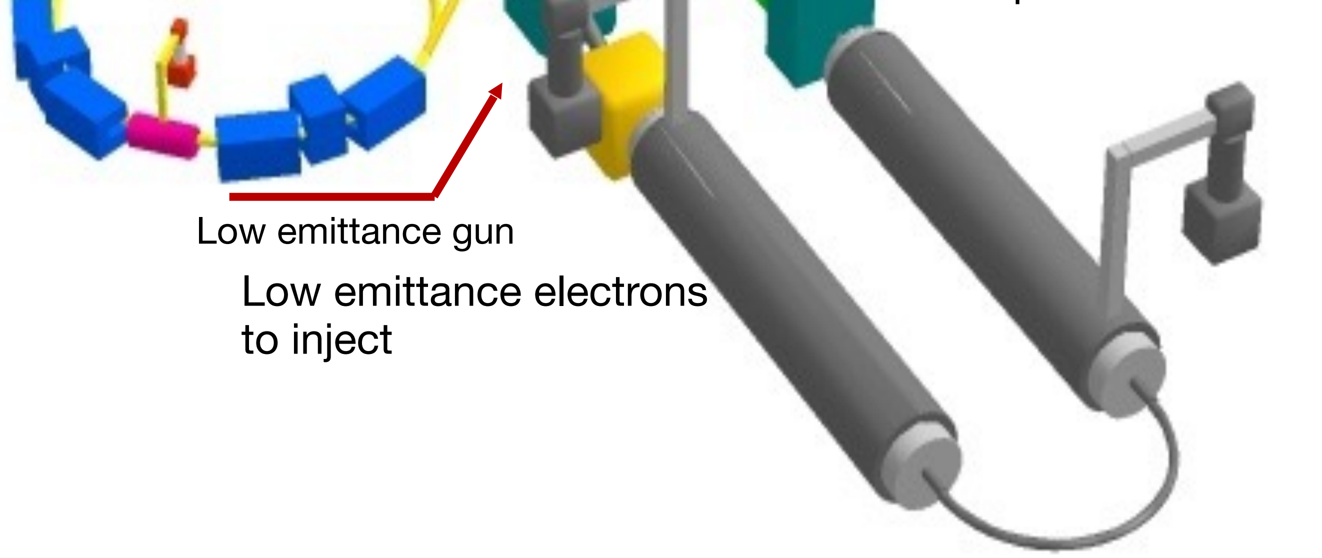
L=8·10^{35} s^{-1}cm^{-2}

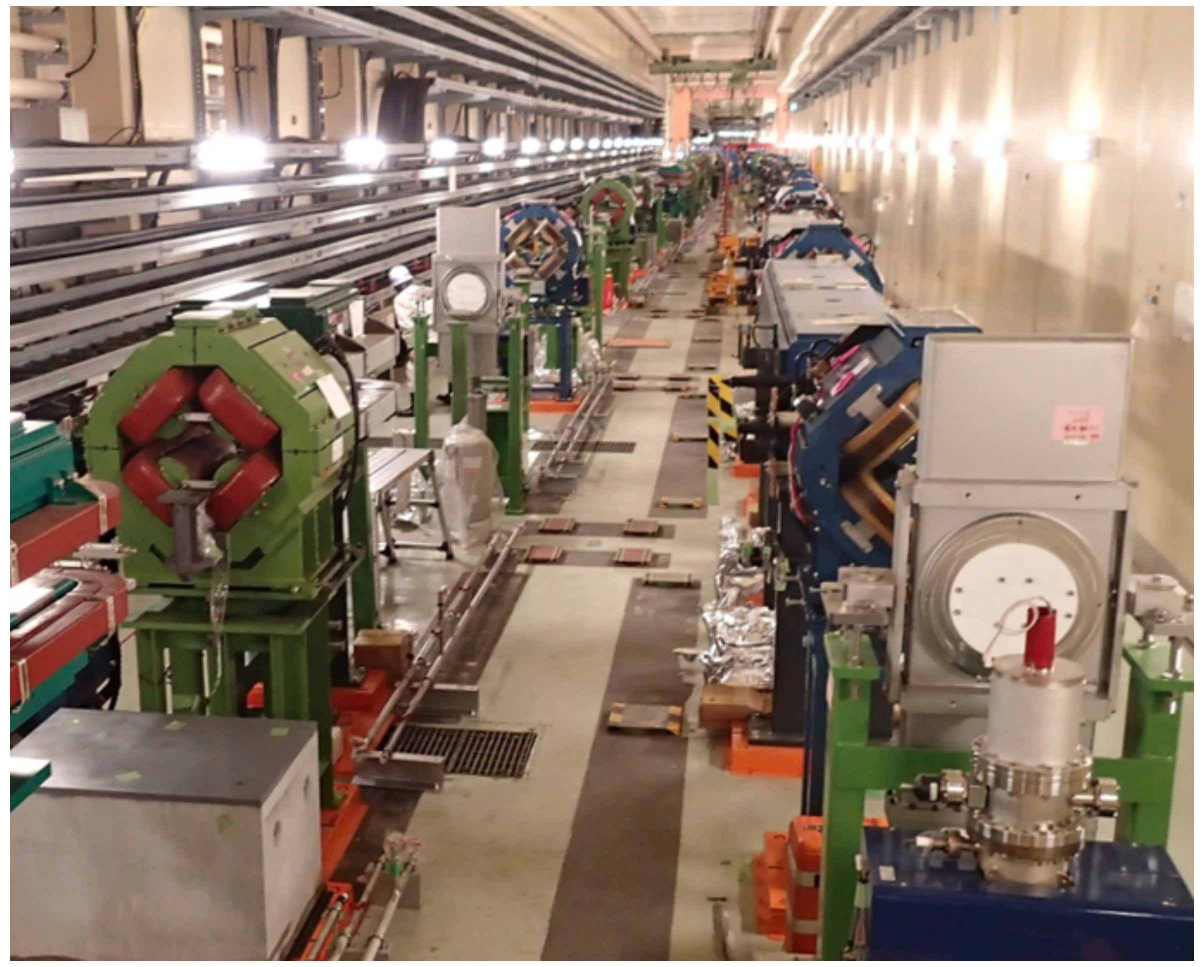


New superconducting / permanent final focusing quads near the IP

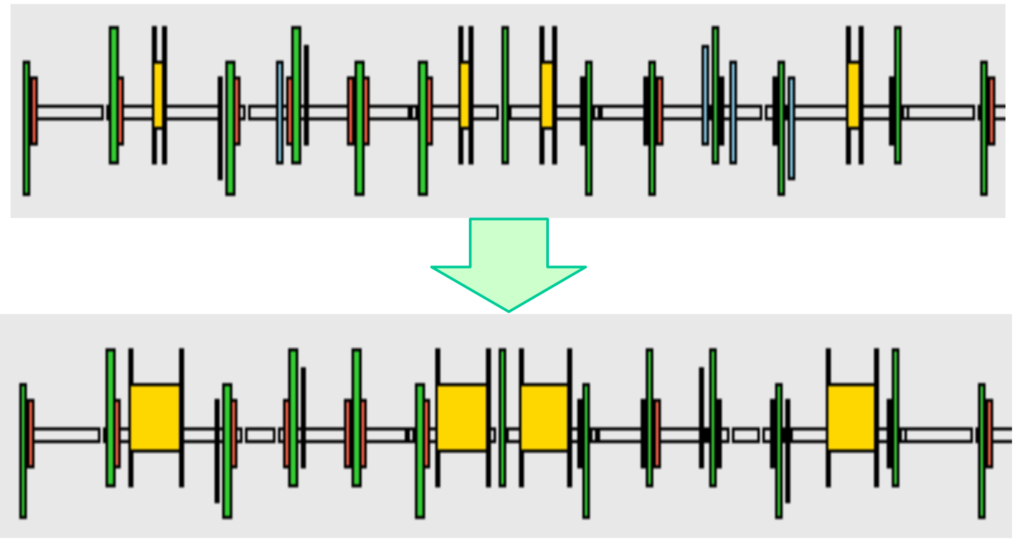




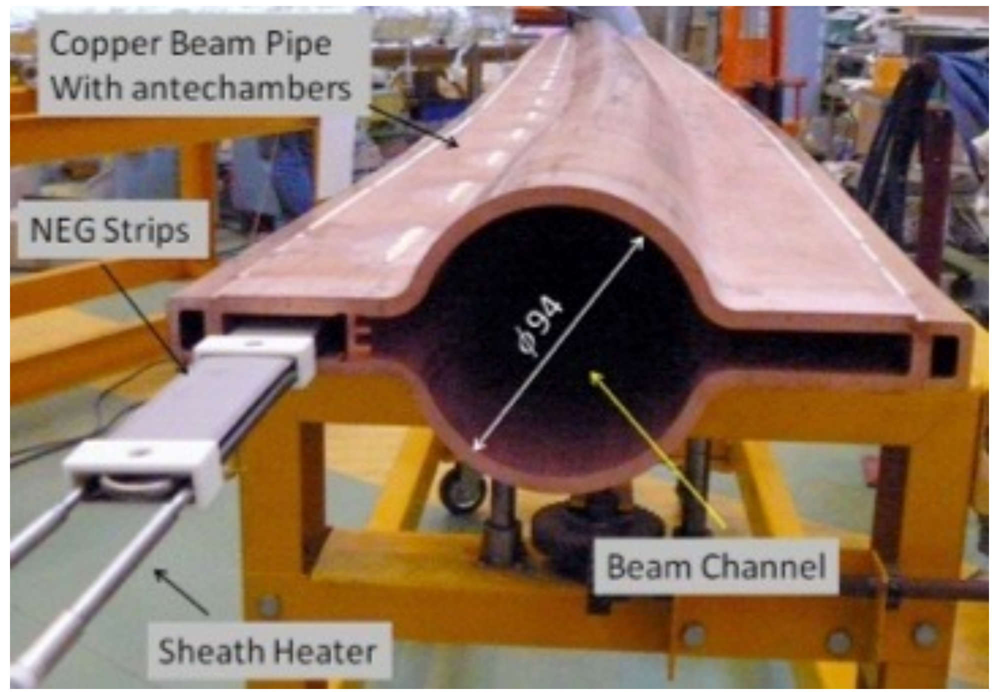


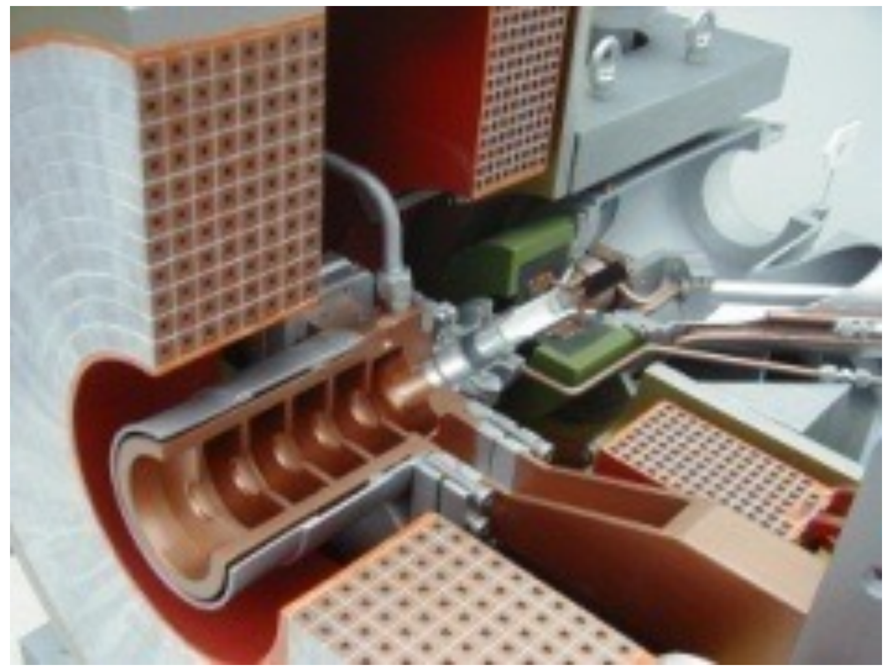


Redesign the magnetic lattice to reduce the emittance (replace short dipoles with longer ones, increase wiggler cycles)



Replace beam pipes with TiN-coated beam pipes with antechambers (reduced Sync Rad.)





Completion end of Japanese FY 2014

x 40 Gain in Luminosity

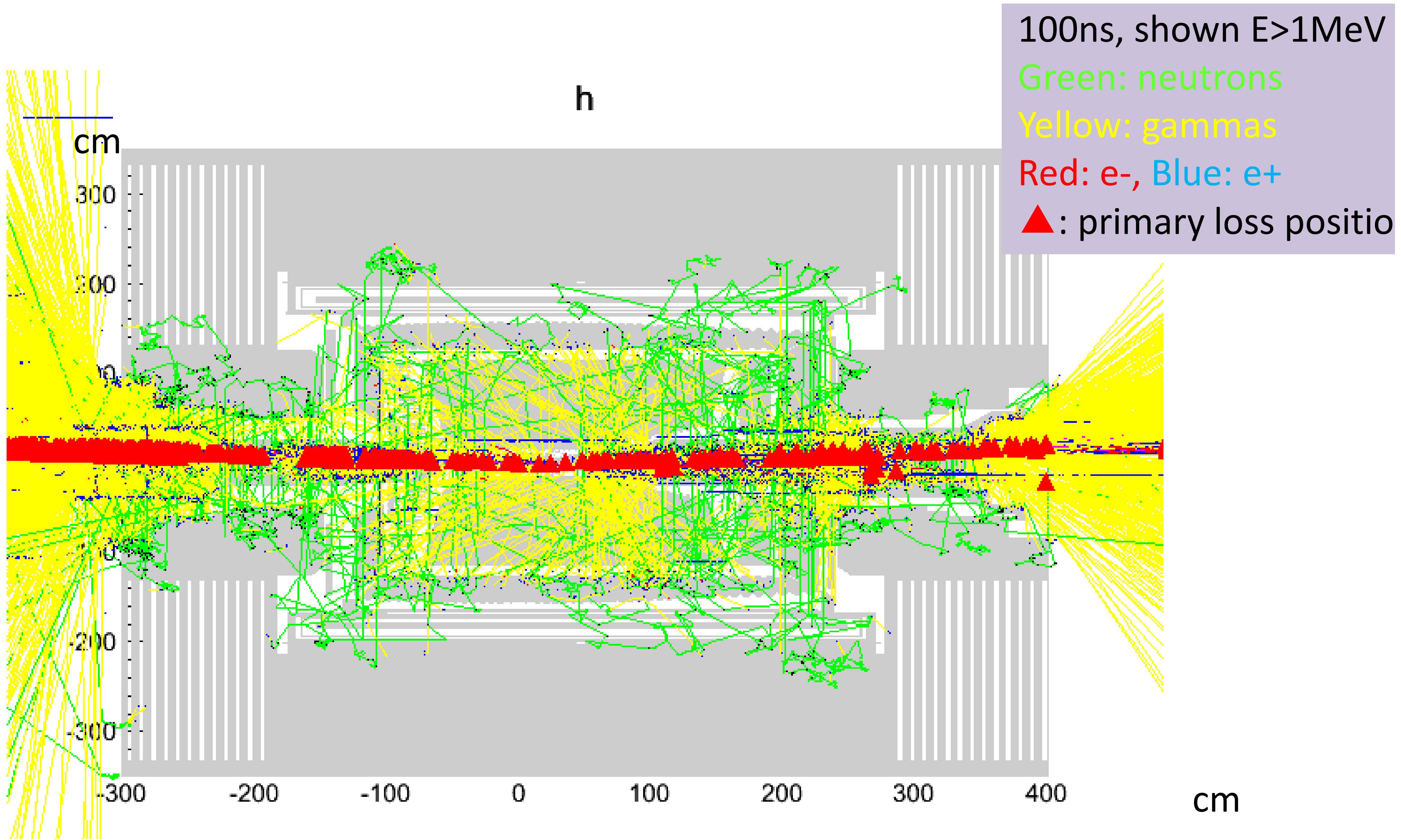
Belle II

Beam-related backgrounds are 10-20 x KEKB

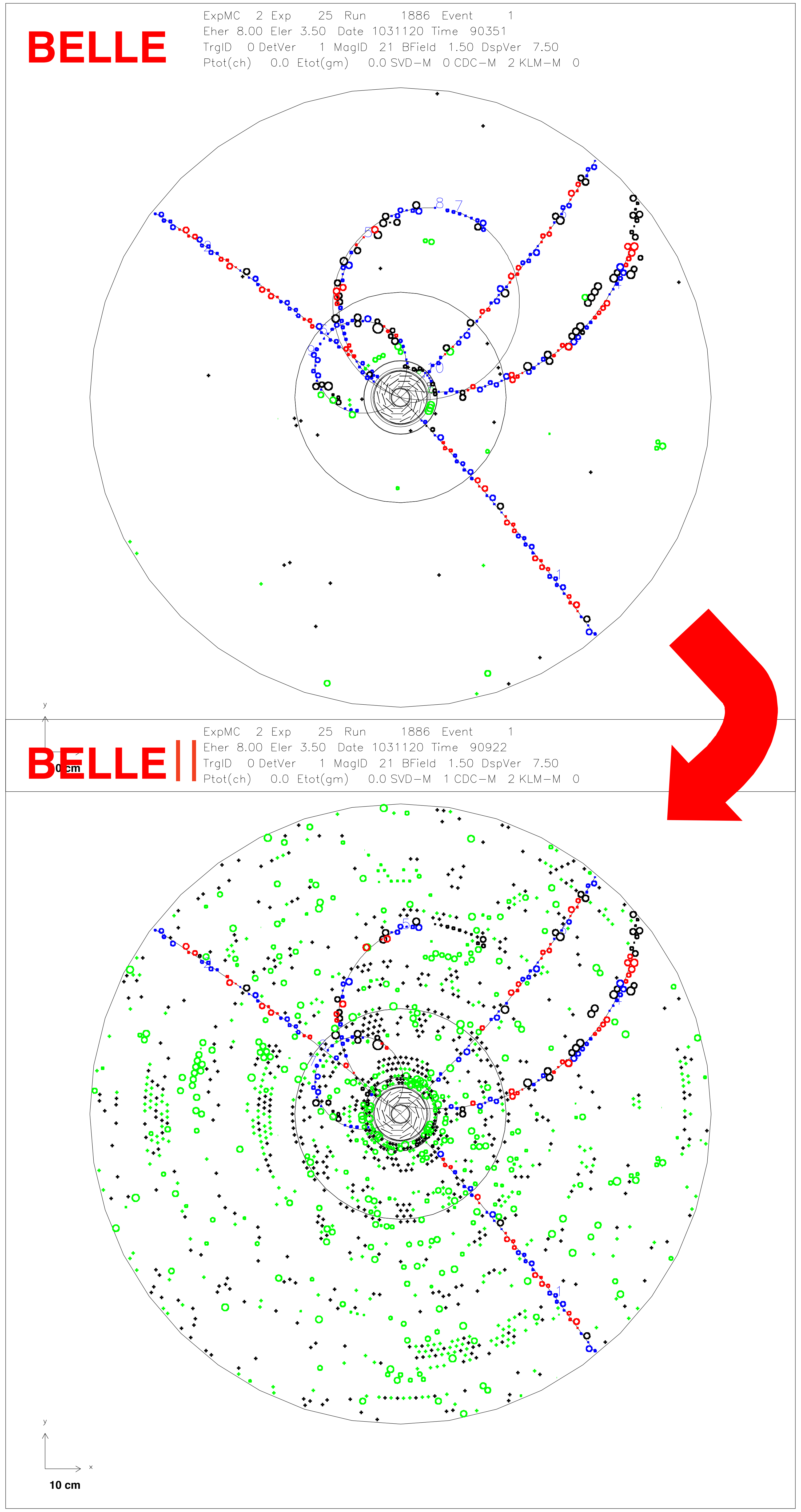
- Touschek scattering
- Radiative Bhabha
- 2-photon

Higher trigger rate:

L1 trigger rate: ~20 kHz



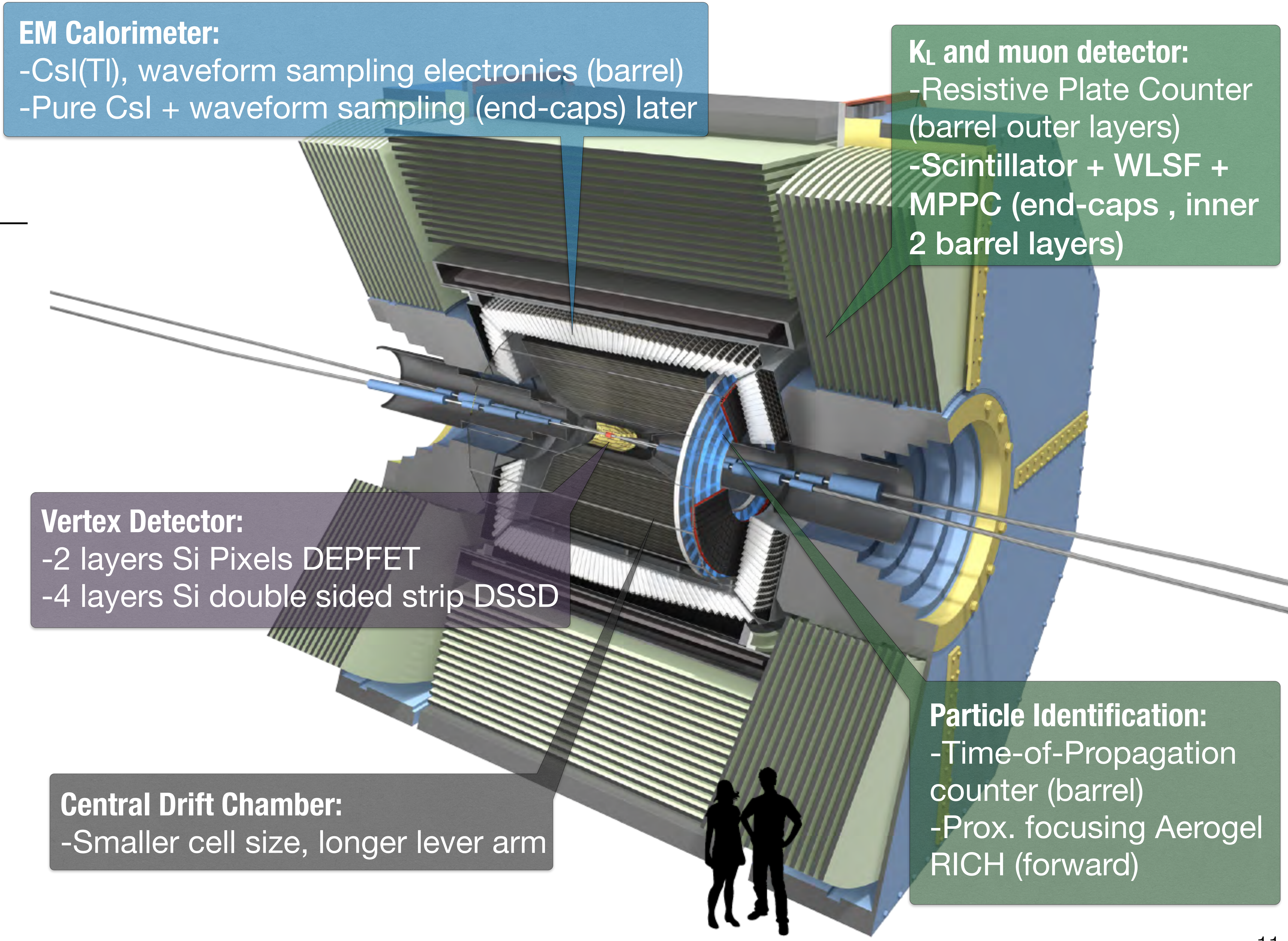
Fake hits, pile up, radiation damage



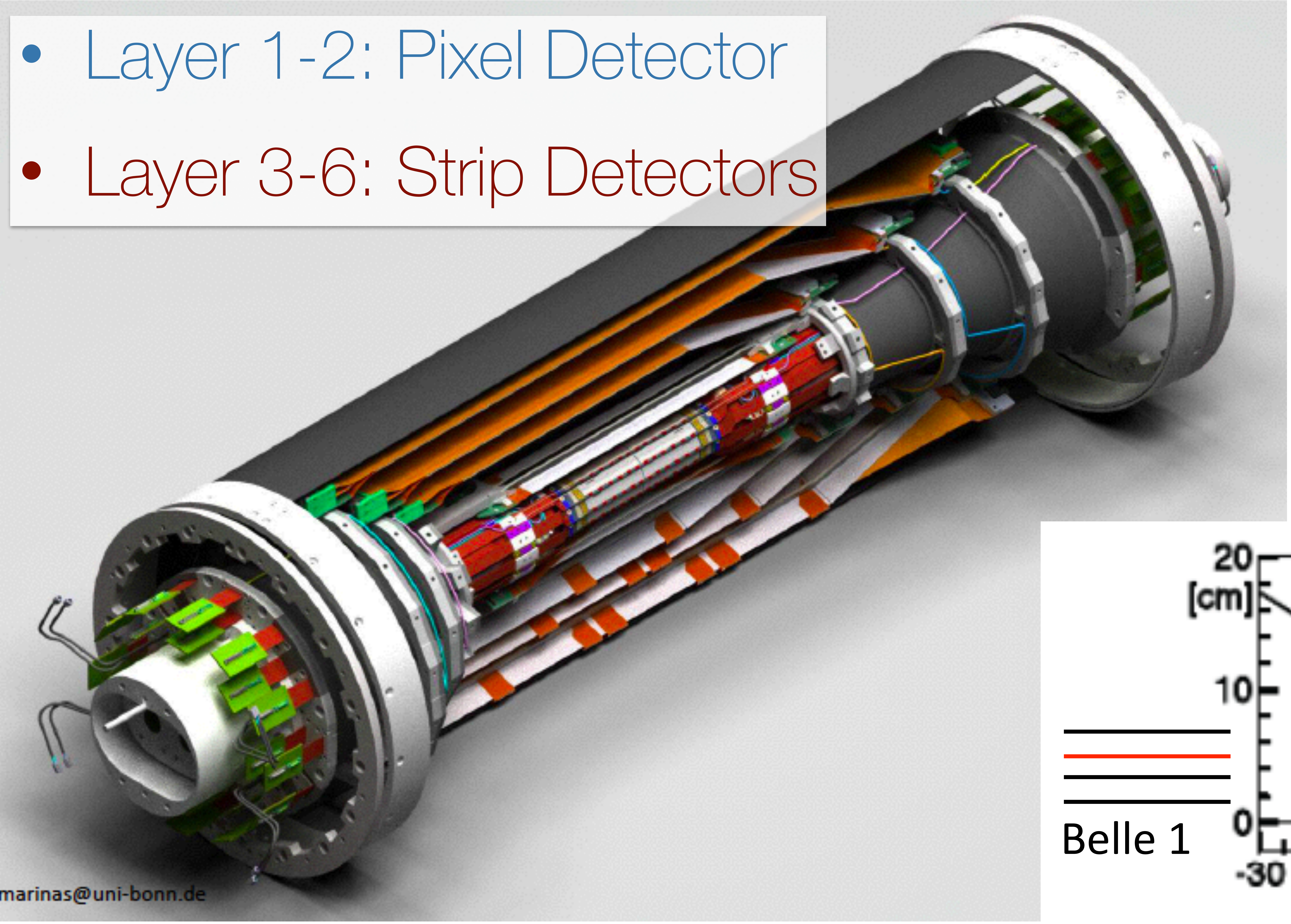
Belle II

Targeted improvements:

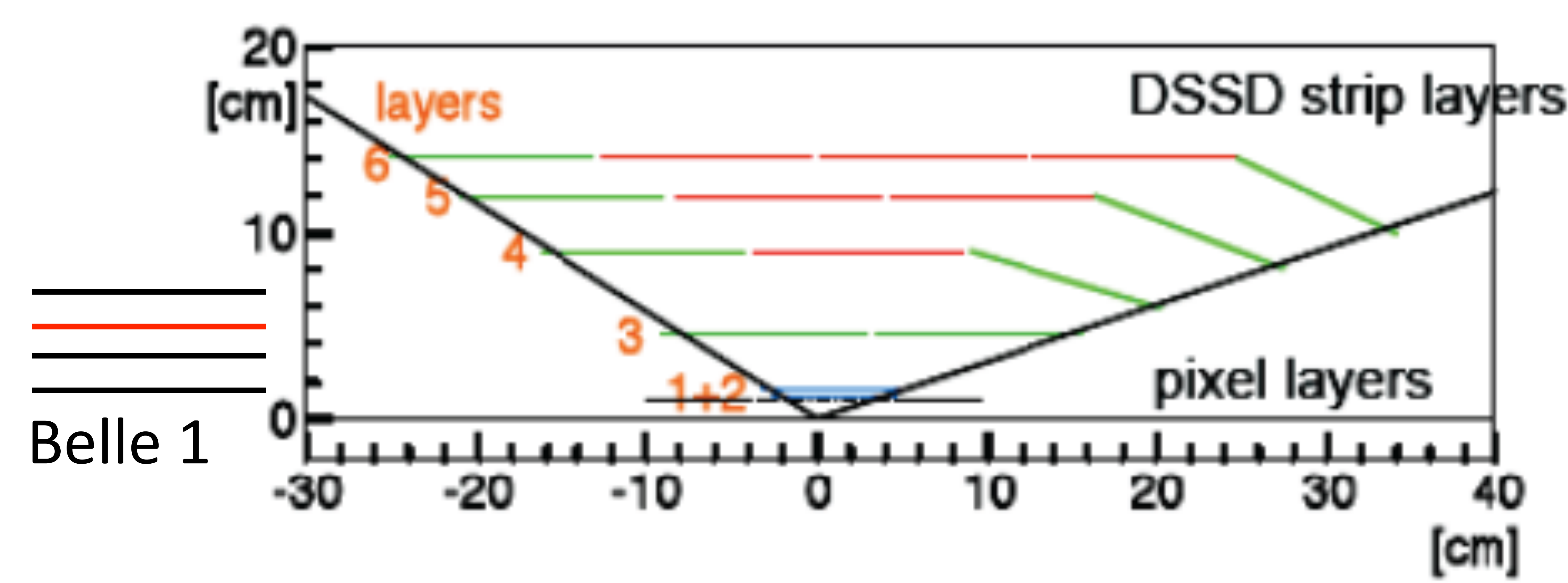
- **Increase hermeticity**
  - Add **PID** in **endcaps**
  - Add **μ ID** in **endcaps**
- Increase **K_S efficiency**
- Improve **IP** and **secondary vertex** resolution
- Improve **π/K** separation
- Improve π^0 efficiency



Belle II: Vertex Detector

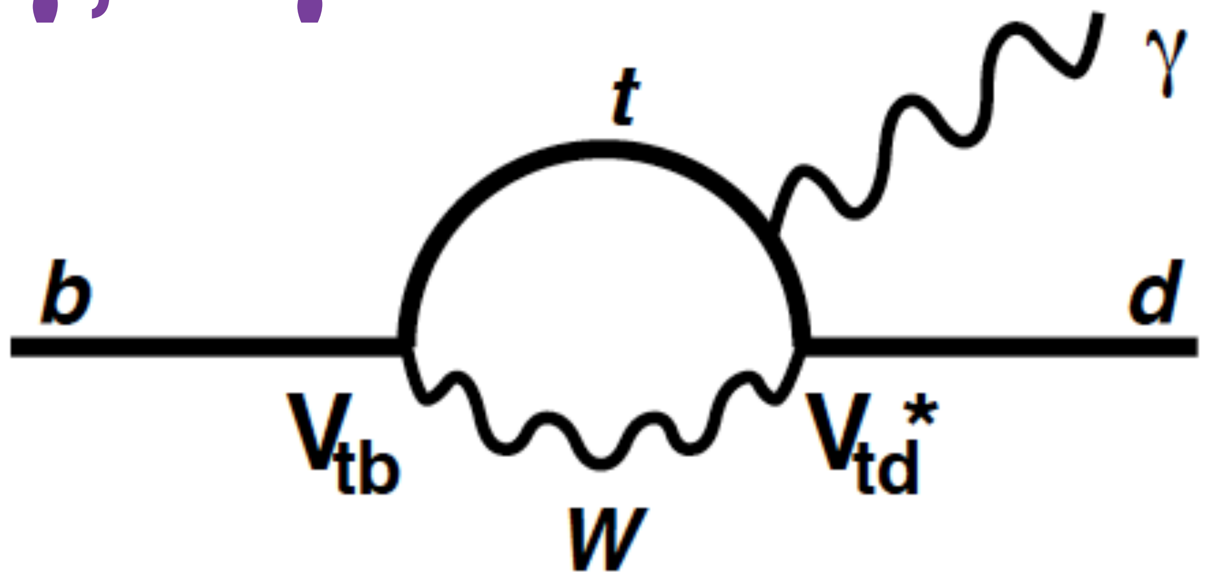


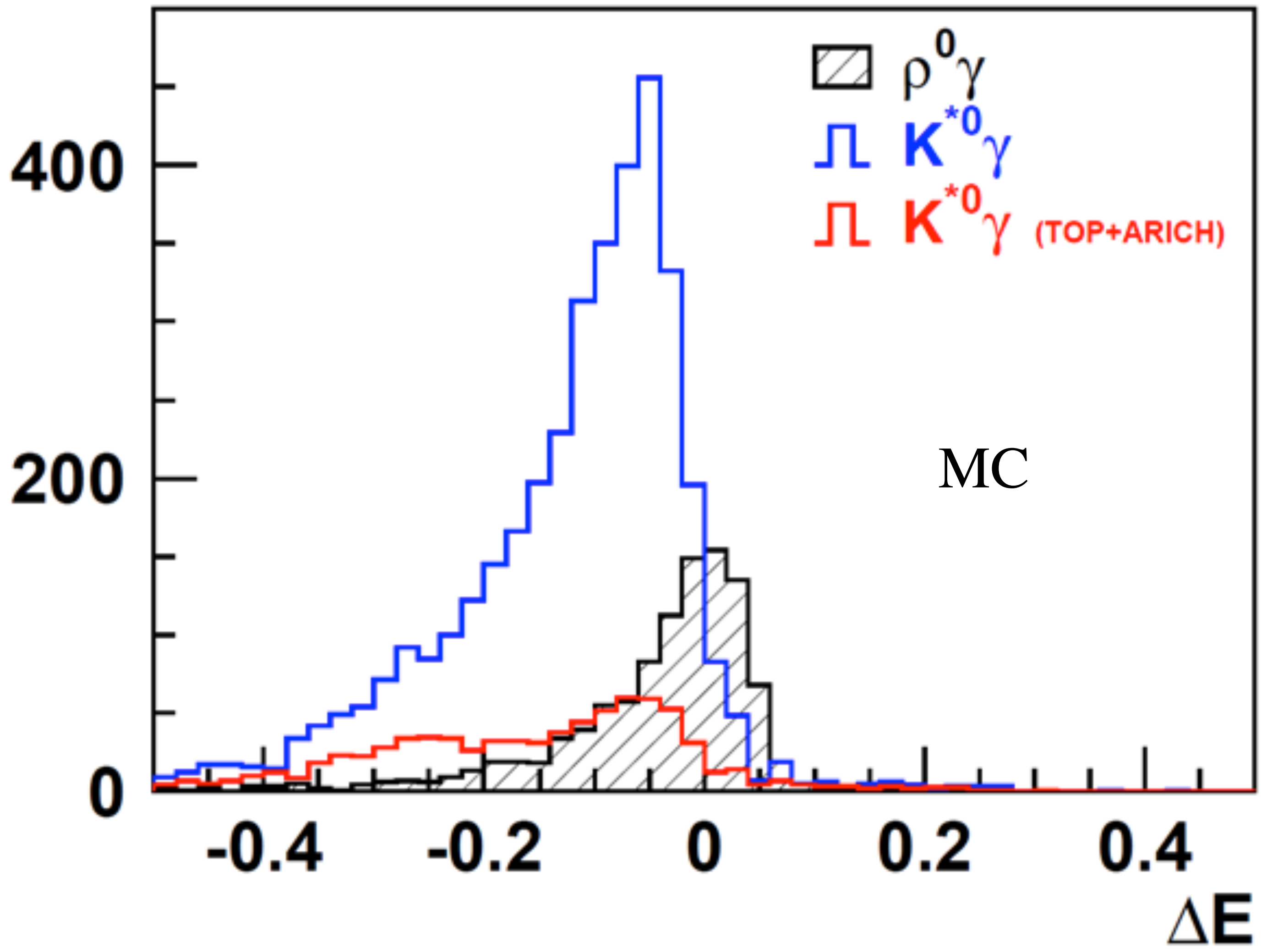
- For K_S vertexing, at least 2 VTX hits needed
  - Radius of 2nd outer most VTX layer is 2 times larger : **6 cm (B1) vs 11.5 cm (B2)**
  - **~30% higher acceptance** for K_S
    - Improves **time dependent CPV** measurement in **$S(K_S\pi^0\gamma)$**



Belle II: PID

PID impact on Rare b→d Penguins: B→ργ, K*γ



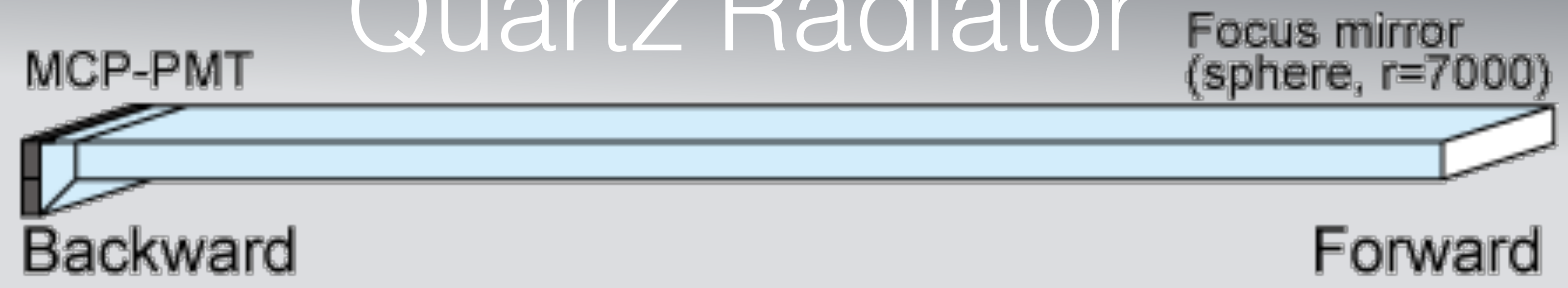


Dominate background

B→K* γ greatly suppressed

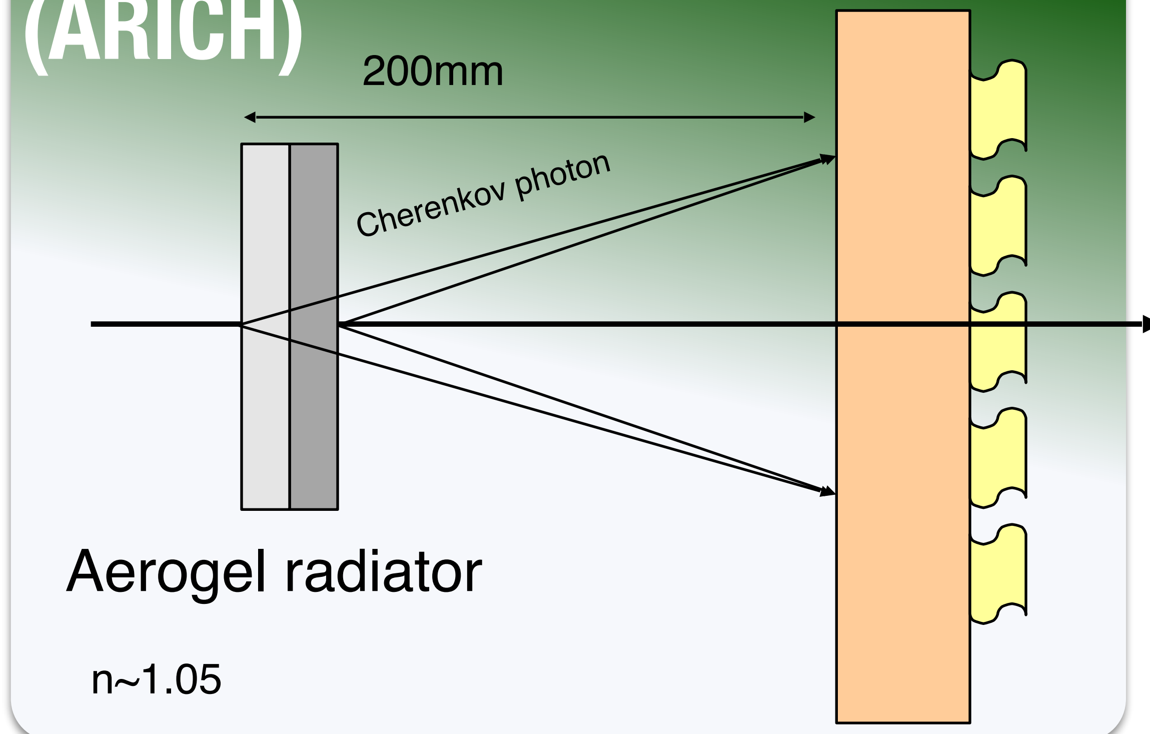
One of the key requirements is improved Particle ID (K/π separation)

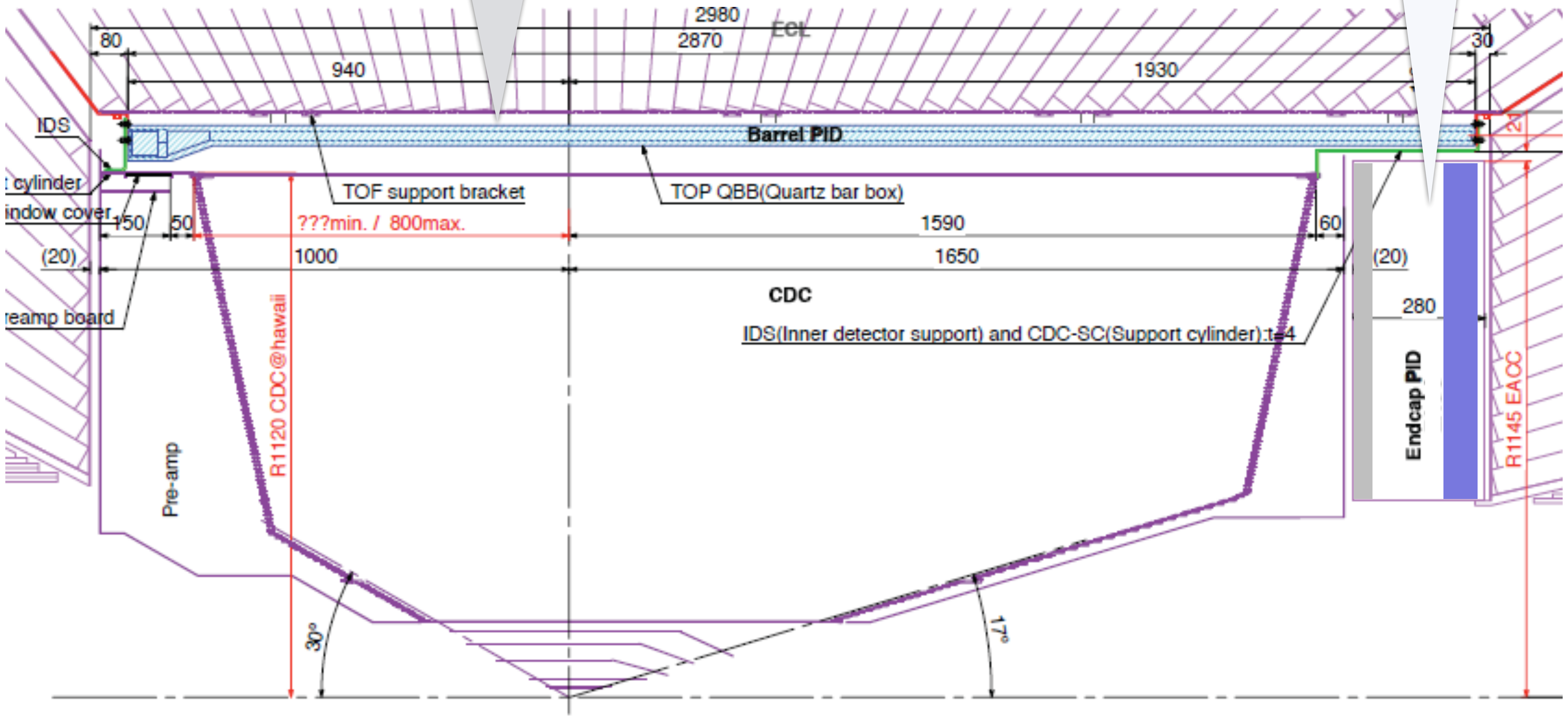
Barrel PID: Time of Propagation Counter (TOP)



Measures t, x, y

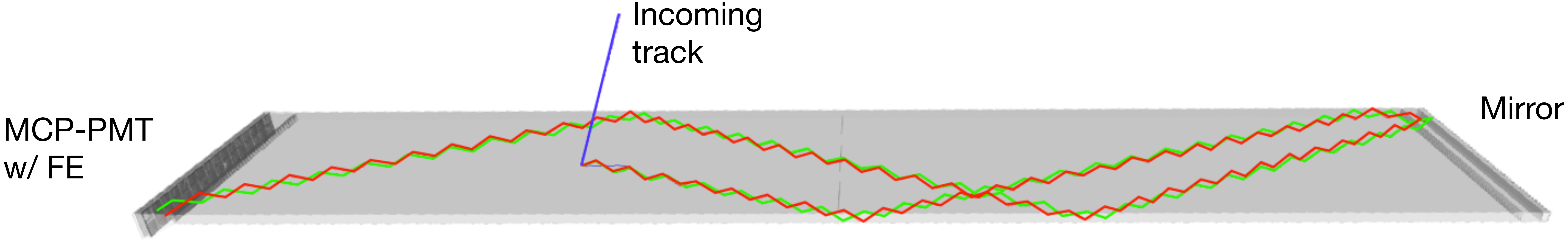
Endcap PID: Areogel RICH (ARICH)

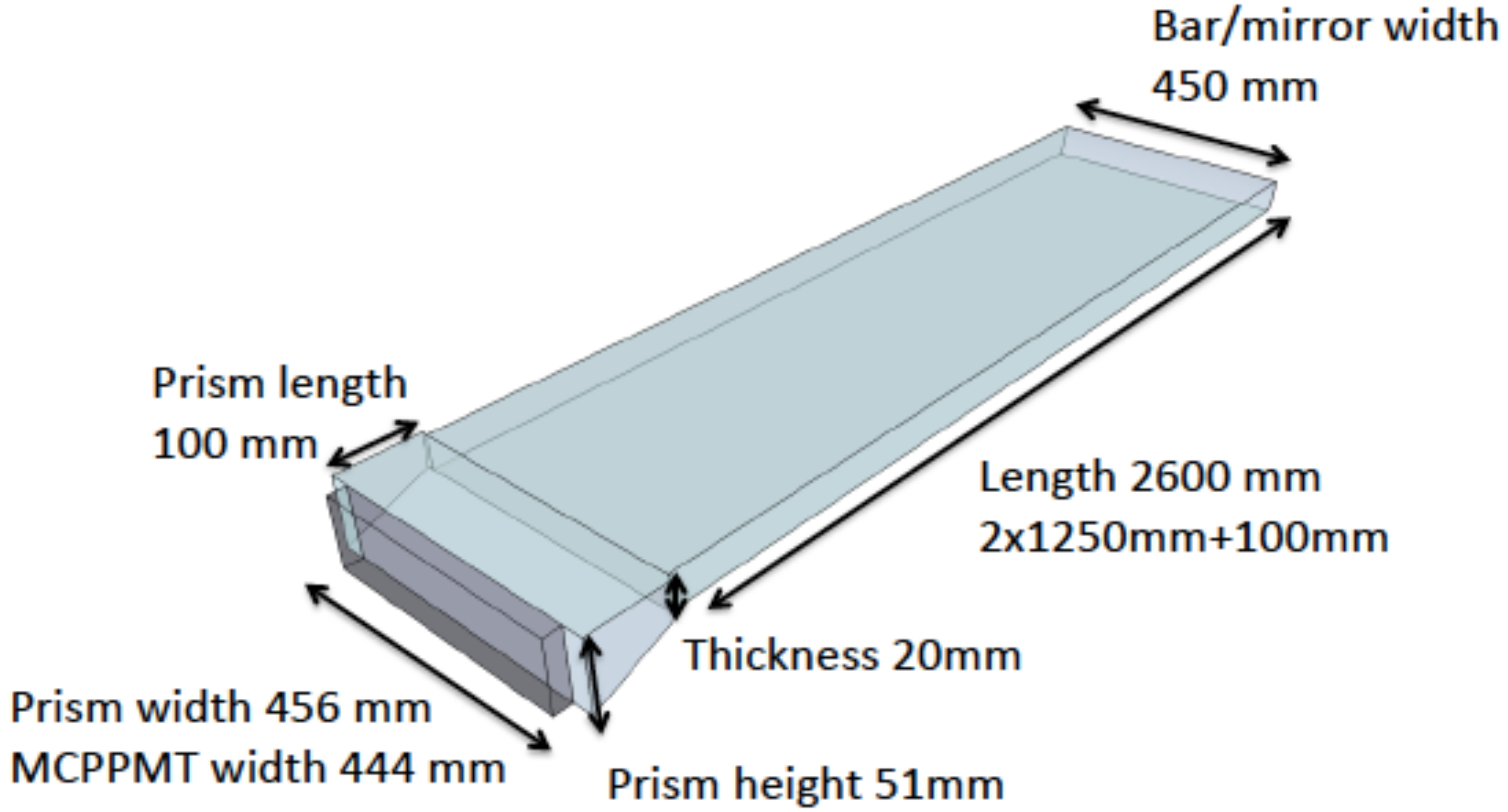


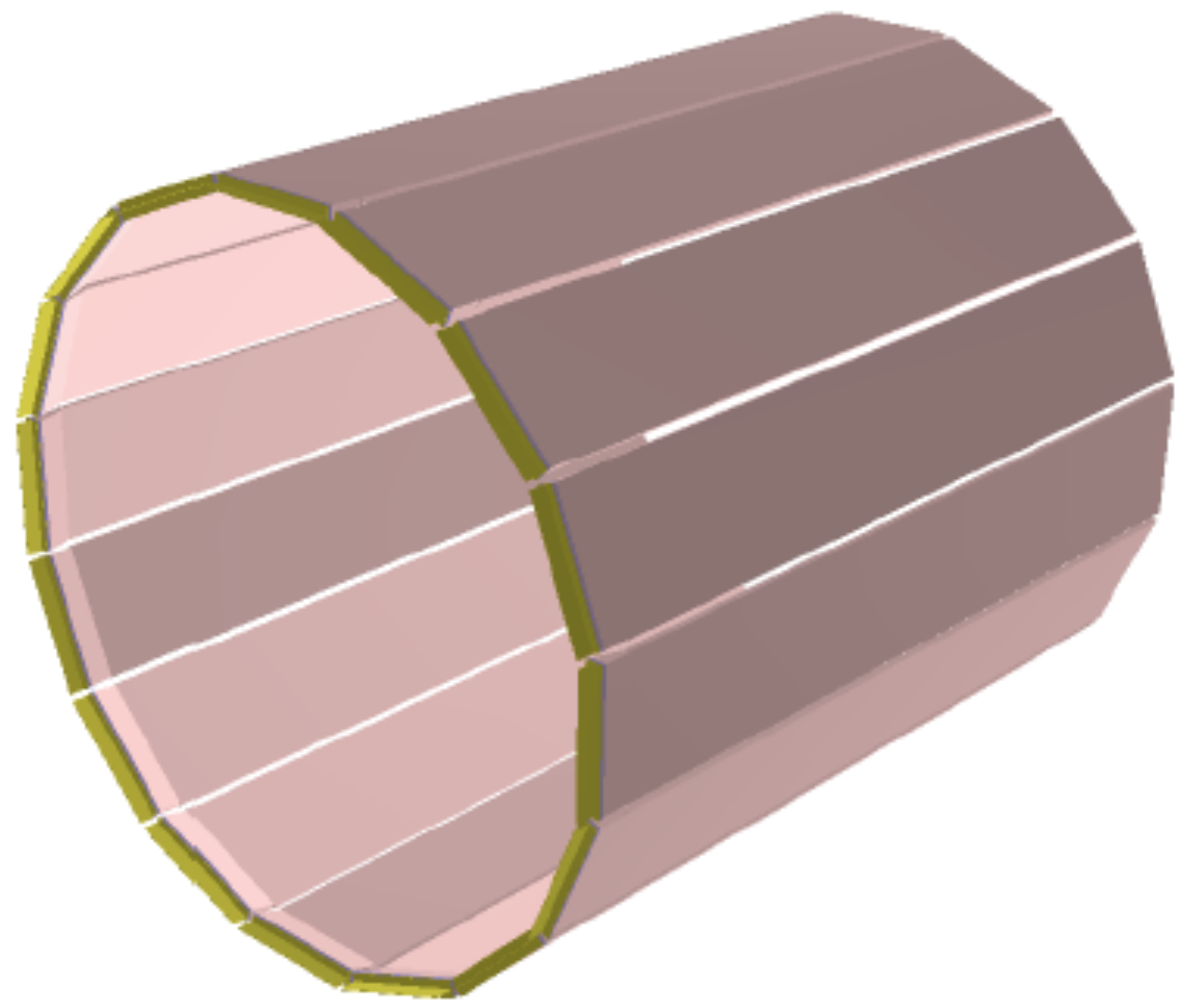


PID: TOP Detector

Simulation of a 2 GeV pion and kaon interacting in a quartz bar



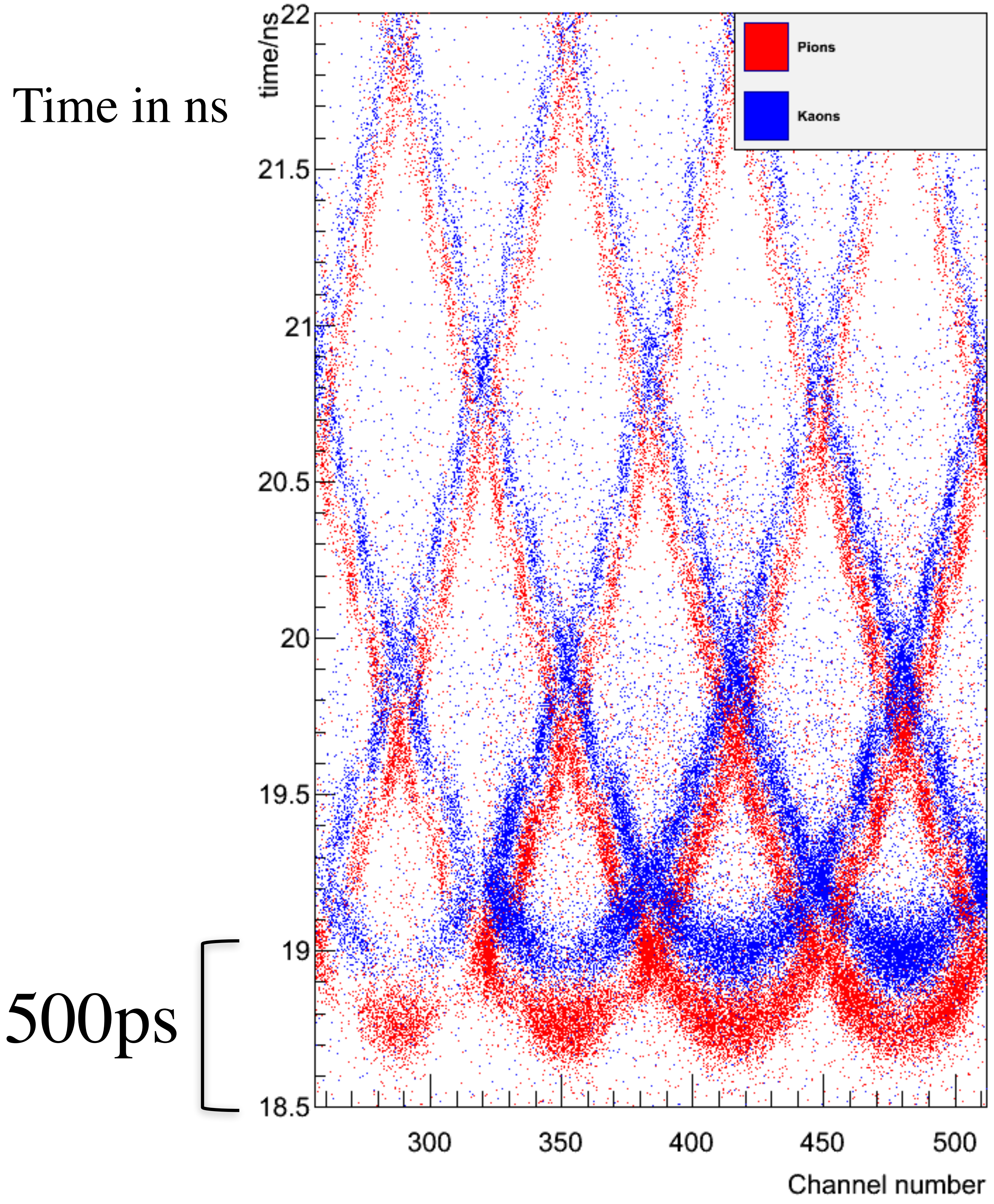


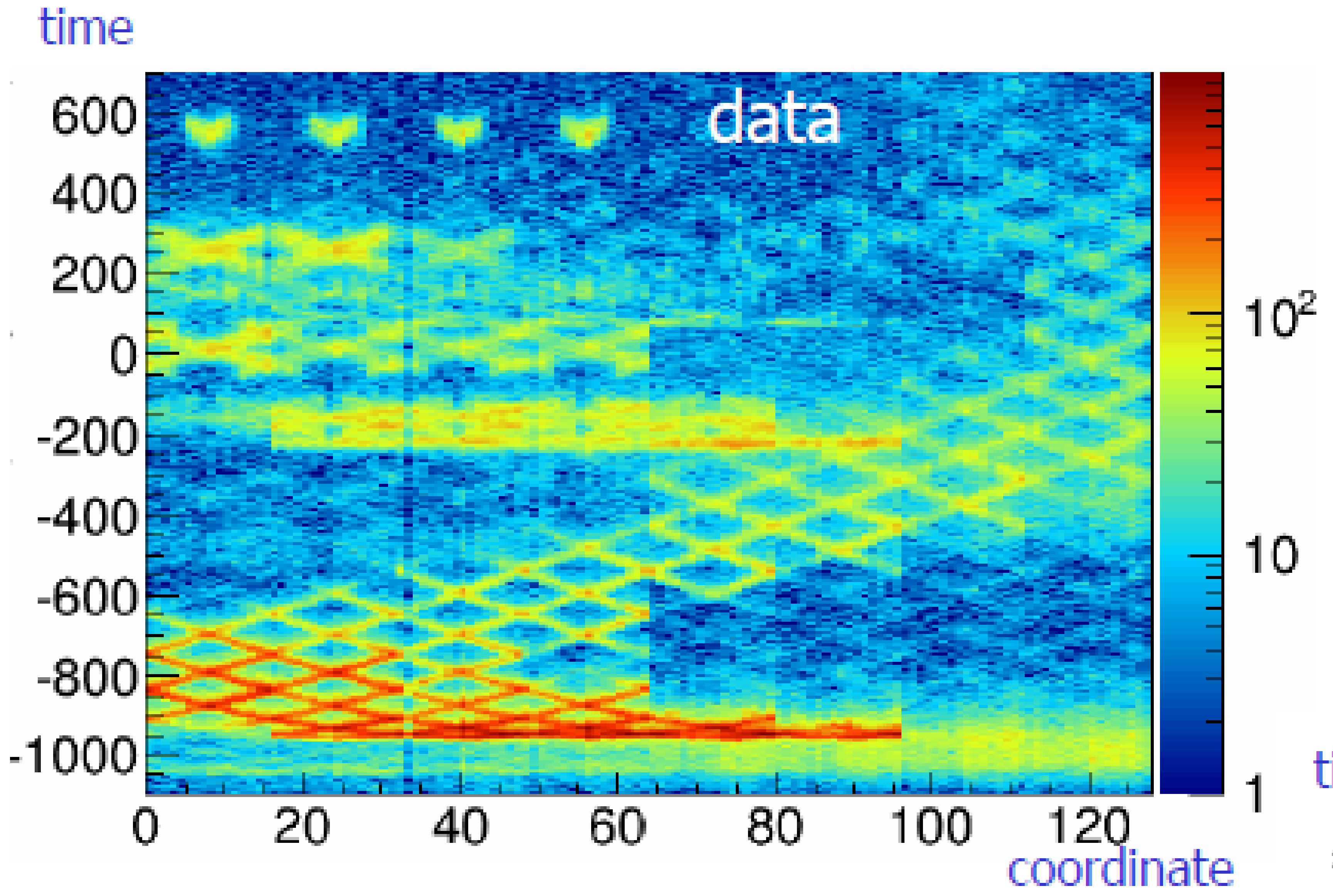


16 bar modules arranged in a "roman arch"

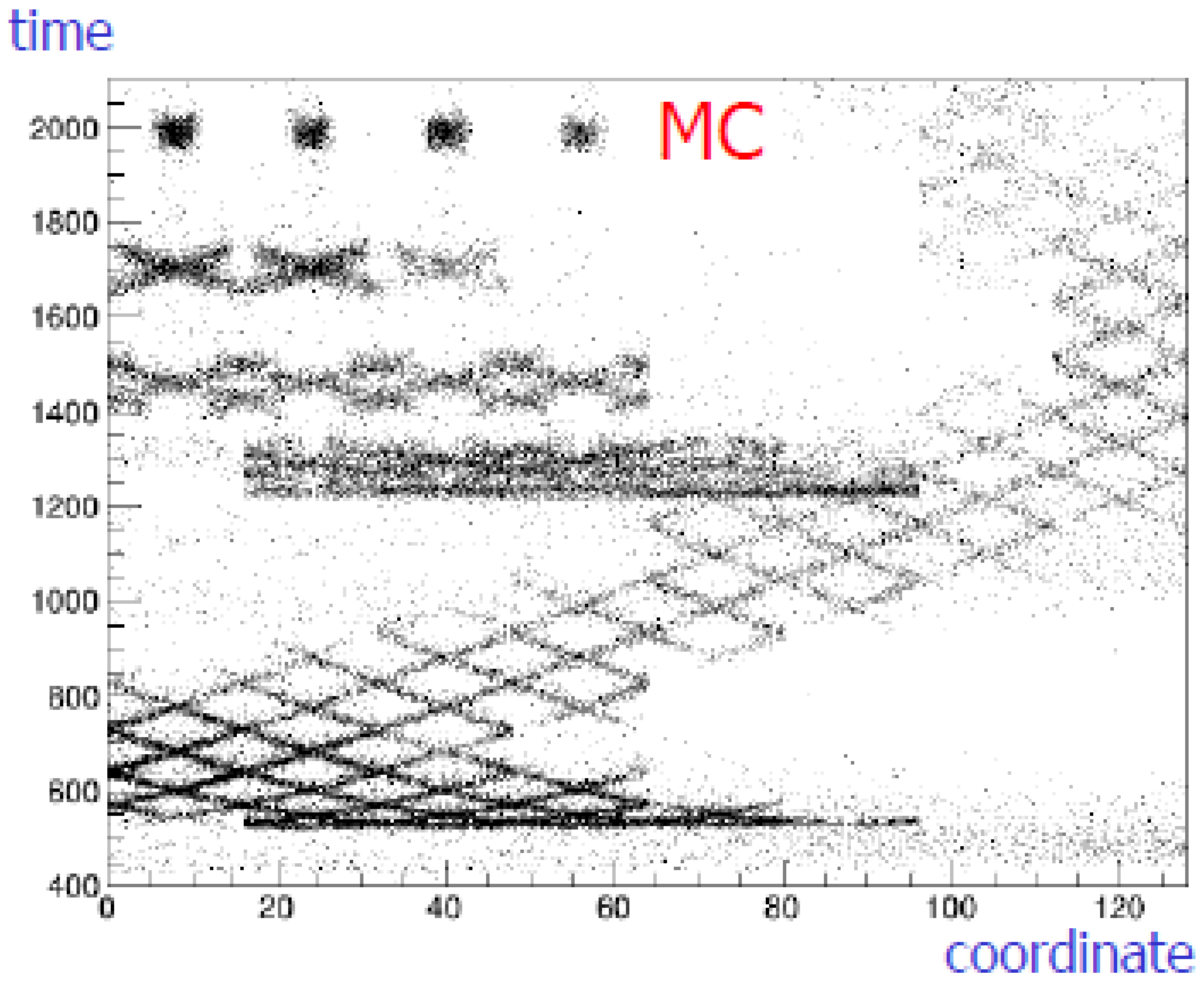
TOP: Kaons vs Pions (Integrated distributions)

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





Excellent agreement between the test beam data and MC simulation



Belle II: Collaboration

- Belle (~400 Collaborators, 15 nations)
- Belle II (~600 Collaborators, 99 Institutions, 23 nations)

Collaboration: Saudi Arabia, Australia, Austria, Canada, China, Czech, Germany, India, Italy, Japan, Korea, Malaysia, Mexico, Vietnam, Poland, Russia, Slovenia, Spain, Taiwan, Thailand, Turkey, USA, Ukraine

WHAT: Physics Program at Belle II

Belle II Physics Program

Leverage Advantages of e^+e^- and Belle II

- Exactly 2 B mesons produced at Υ(4S)
  - High flavor tag efficiency
- Excellent γ and π^0 reconstruction (and thus η, η', ρ+, etc. reconstruction)
- Clean: Able to analyze decays with multiple neutrinos
- Will have Υ(1S) Υ(2S) Υ(3S) Υ(5S)
- Complements LHCb: Systematics quite different. Can use neutrals (K^0, π^0). If NP is seen by one of the experiments, confirmation by the other is important.

"Golden" Modes!

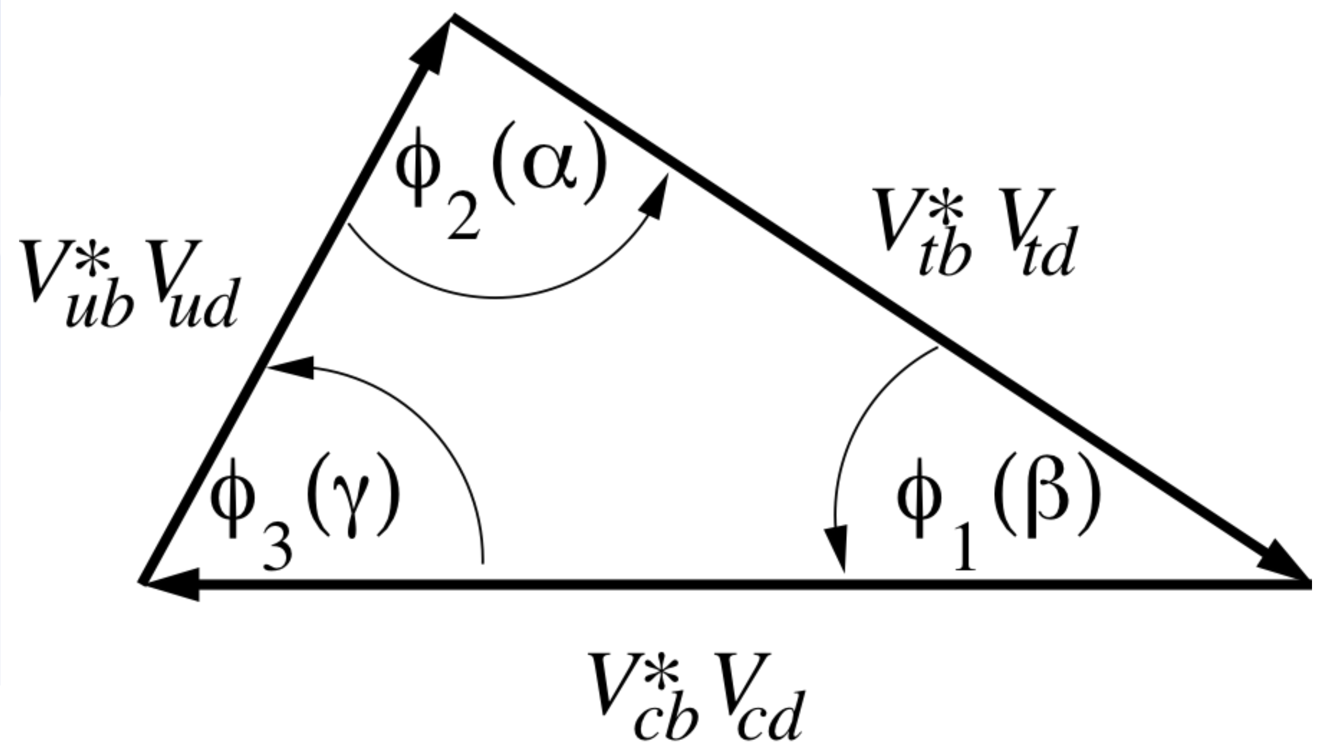
Sensitive to different New Physics (NP). Expected to improve by ***5-100x in precision***

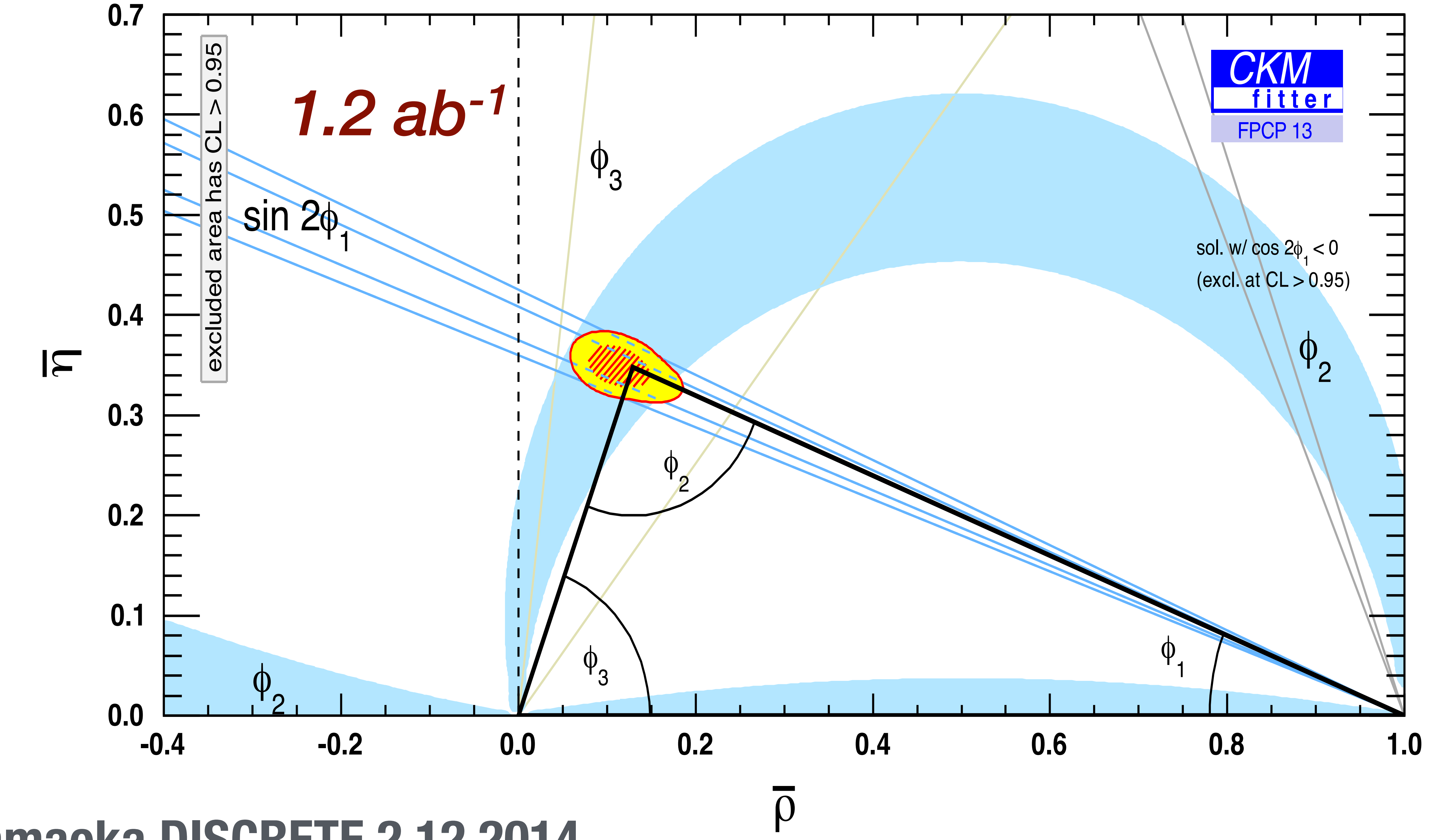
- Improved CKM elements
- CPV in tree level decays vs. penguins (inc. neutrals)
- Inclusive measurements, $b \to s\gamma$, $b \to sl^+l^-$
- A_{CP} in radiative decays, $S_{K_S\pi^0\gamma}$
- Missing Energy
  - $B \to l\nu$, $l=e,\mu,\tau$
  - $B \to D^*\tau\nu$, $B \to X_{u,c}l\nu$, $B \to K^{(*)}\nu\nu$
- Charged LFV, $\tau \to \mu\gamma$, $\tau \to eee$
- Dark matter, new QCD states, Light Higgs
- **…a few of these are discussed in the next slides**

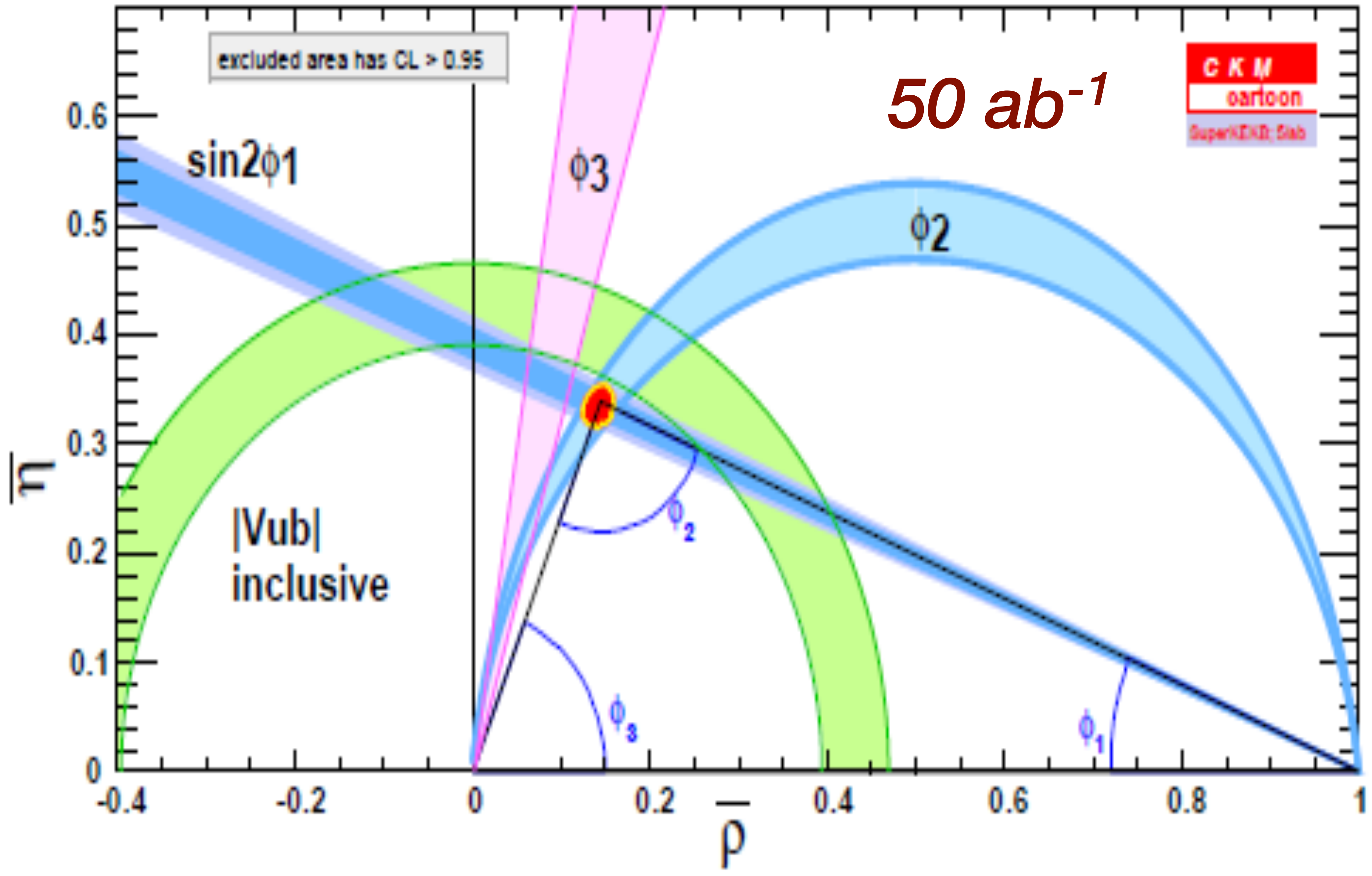
Constraining the CKM Unitarity Triangle

A main physics goal is to substantially reduce the uncertainties on the CKM UT

UT	2014	Belle II
α	4° (WA)	**1°**
β	0.8° (WA)	**0.2°**
γ	8.5° (WA) 14°(Belle)	**1-1.5°**





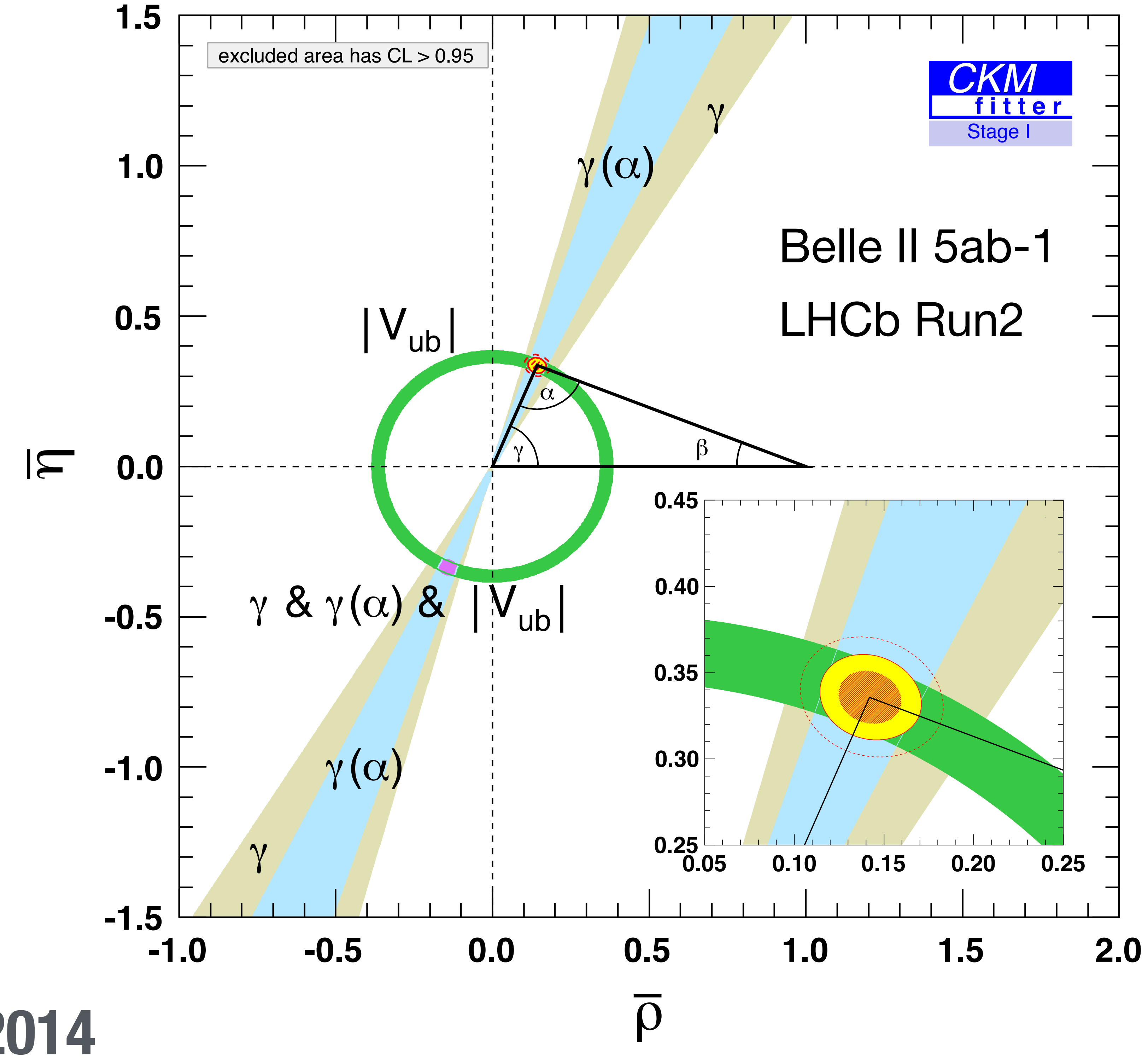


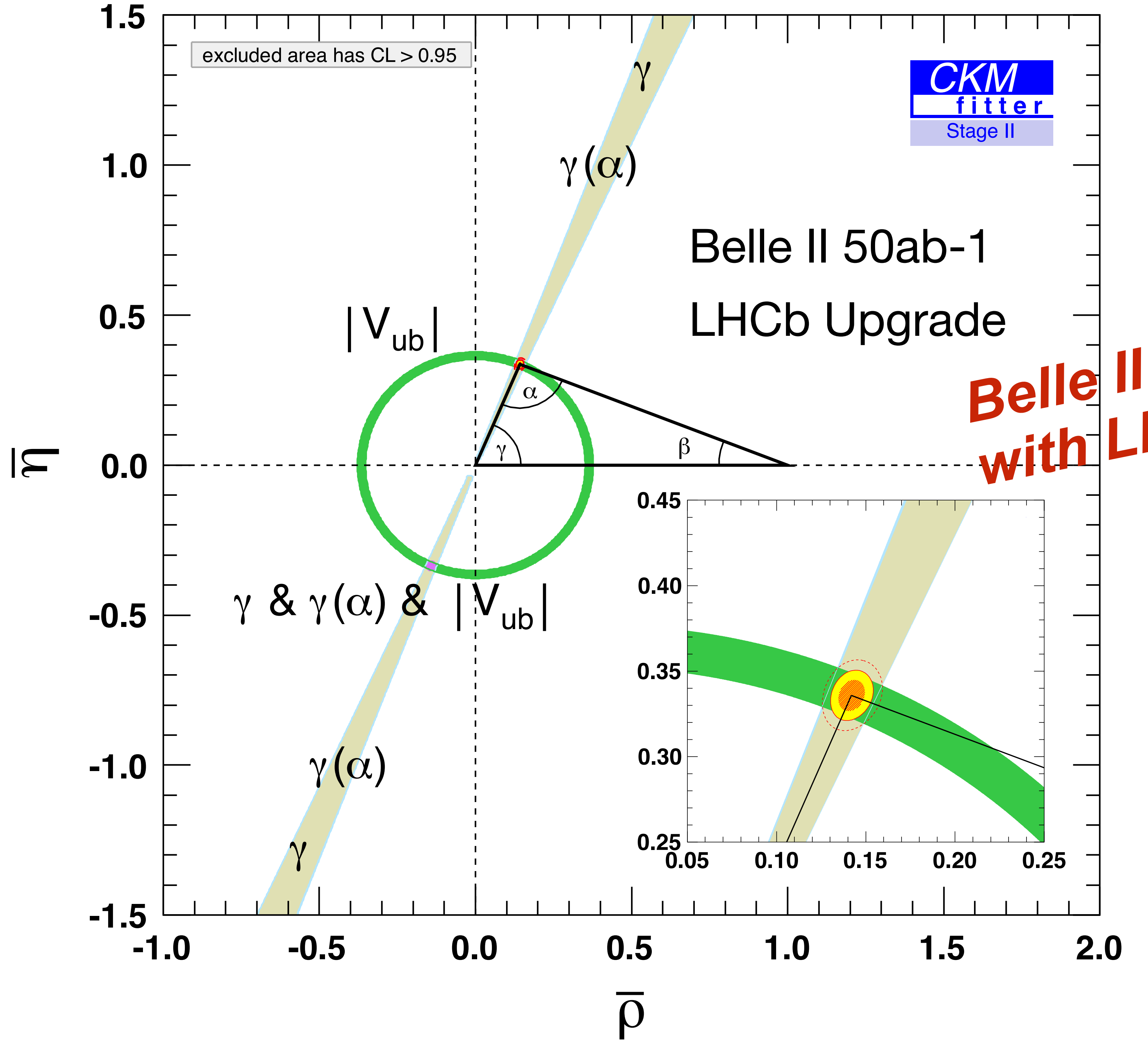
UT angle γ: Tree

Least well measured mode:
Based on Tree-Level B→DK methods

γ[BaBar] = (69 ± 17)°
γ[Belle] = (68 ± 14)°
γ[LHCb] = (69^{+11}_{-13})°
γ[combined] = $(68.0^{+8.0}_{-8.5})$°

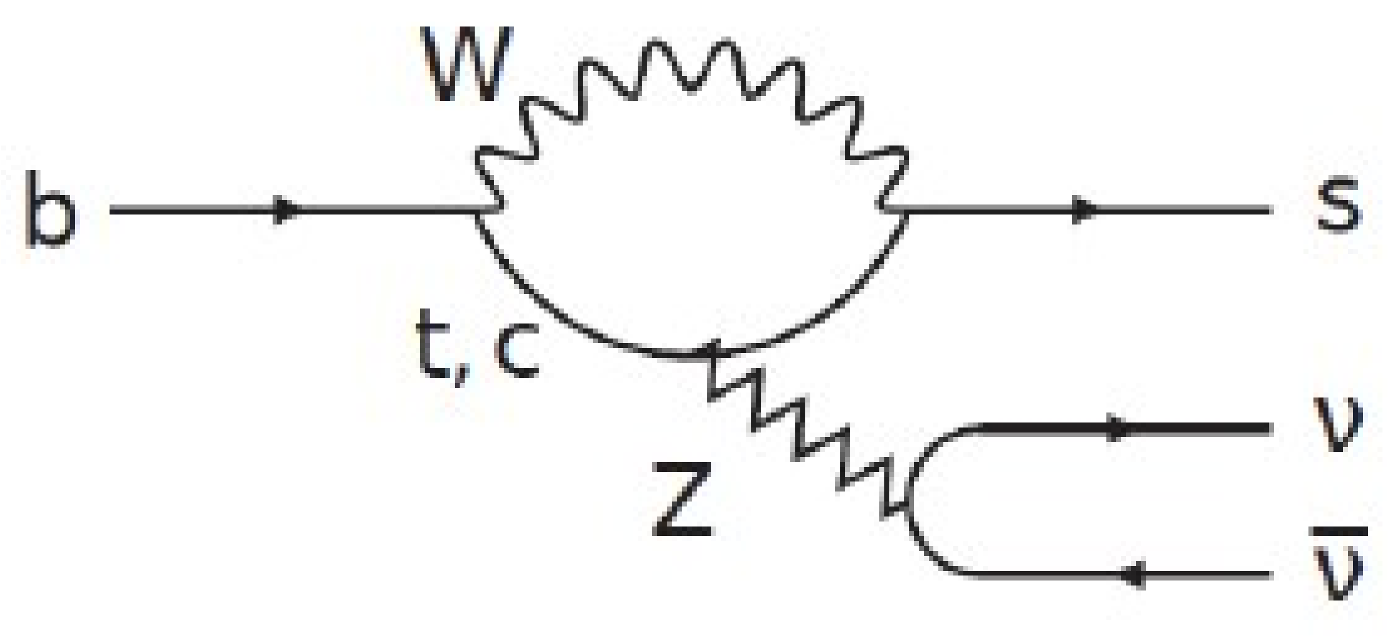
- No model error, stat. error dominates at 50 ab-1
- Combined with Dalitz, to obtain gamma precision of 1.5°





Belle II - Competitive with LHCb upgrade

Electroweak Penguin: Di-Neutrino

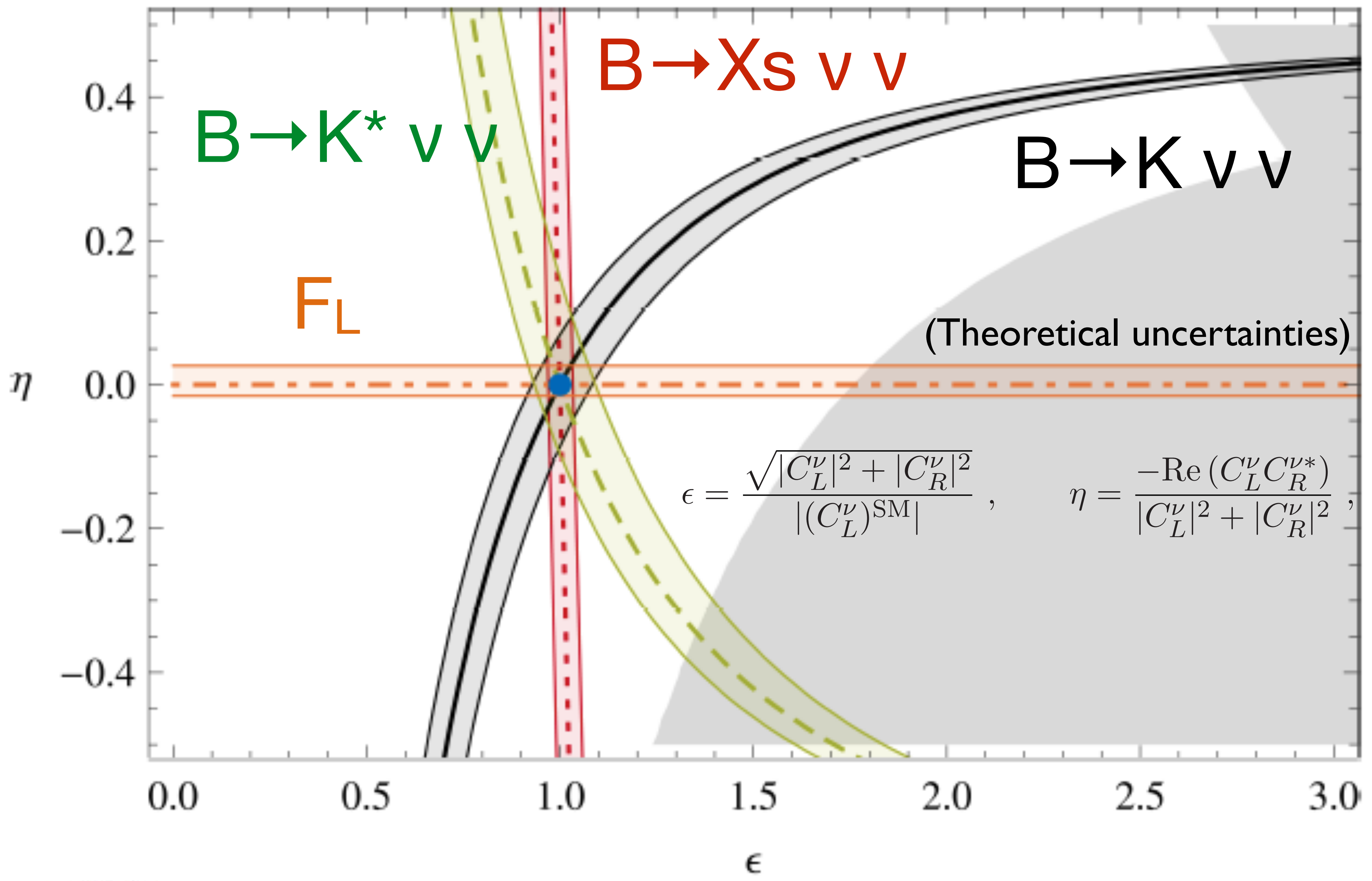


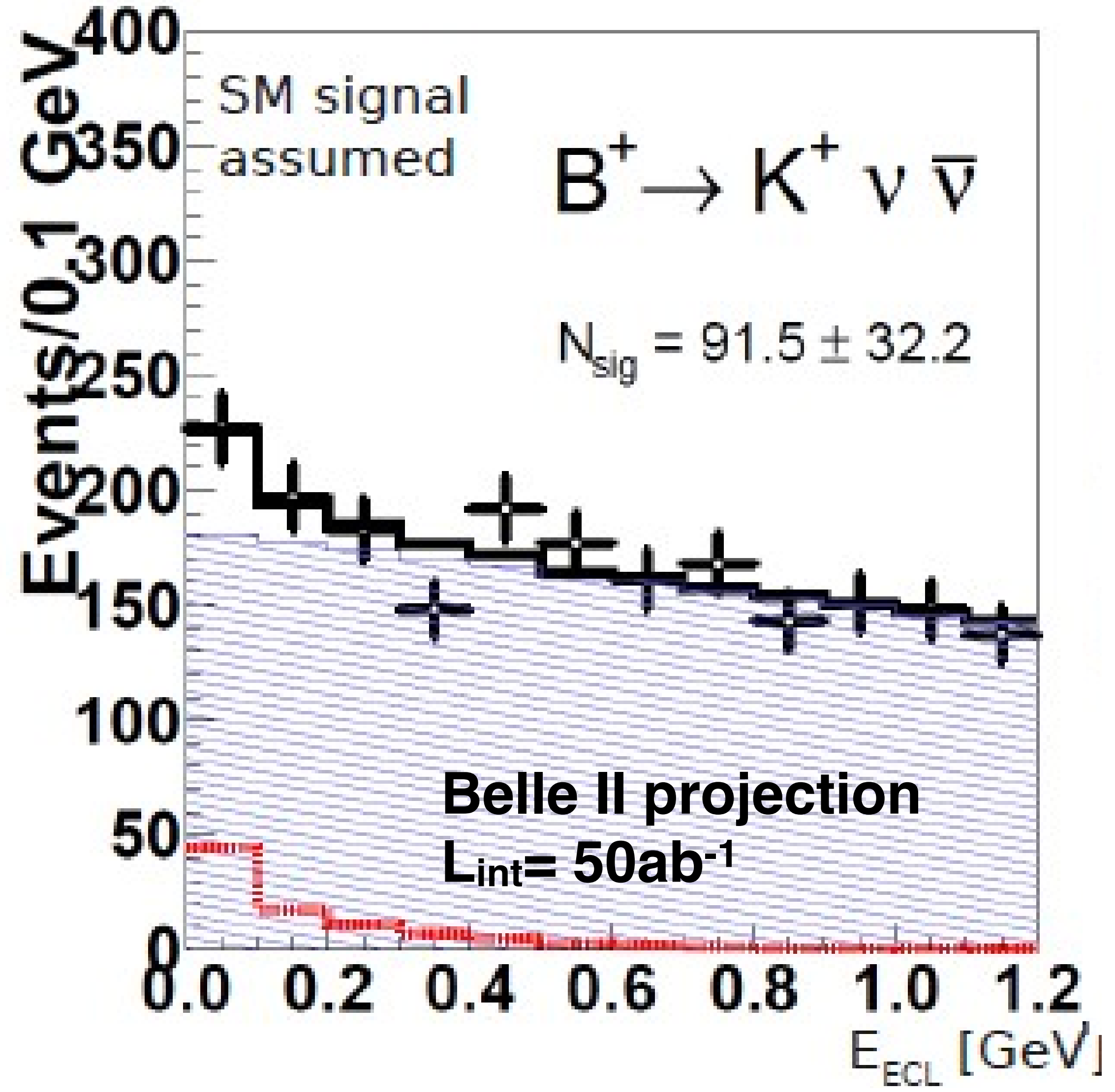
- BF($B^+ \to K^+ \nu \nu$)=$(4.4\pm0.7)10^{-6}$
  [Buchalla, NPPS 209, 137]
- BF($B^+ \to K^{*+} \nu \nu$)=$(6.8^{+1.0}_{-1.1})10^{-6}$
  [Altmannshofer, JHEP 0904, 022]

Ultimate test of Belle II

Further improvements to consider: tag efficiency, calorimeter timing, better K_L ID

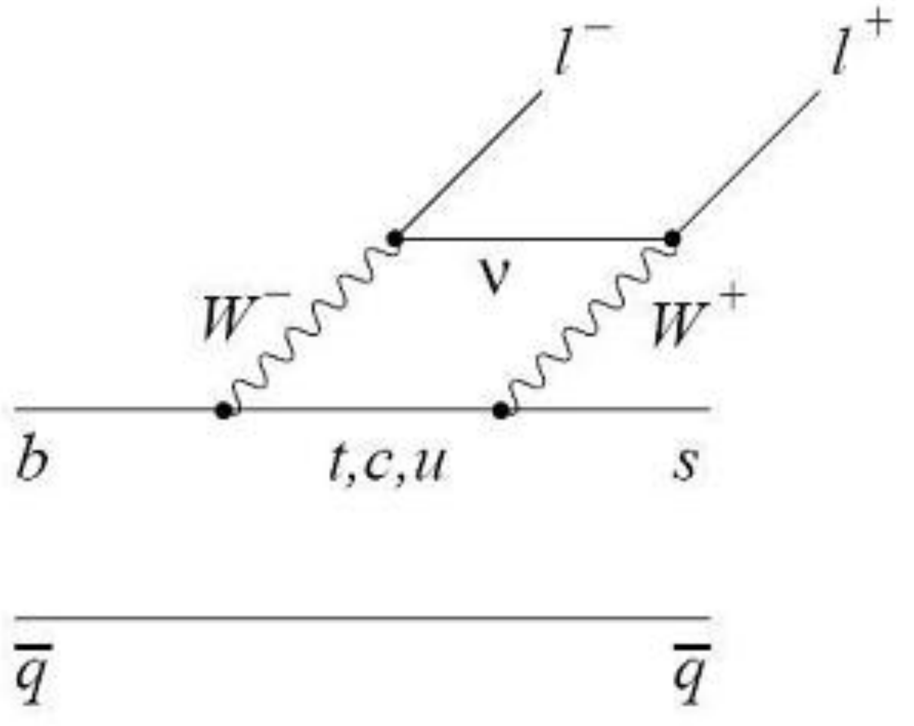
Altmannshofer et.al. JHEP 0904:022,2009

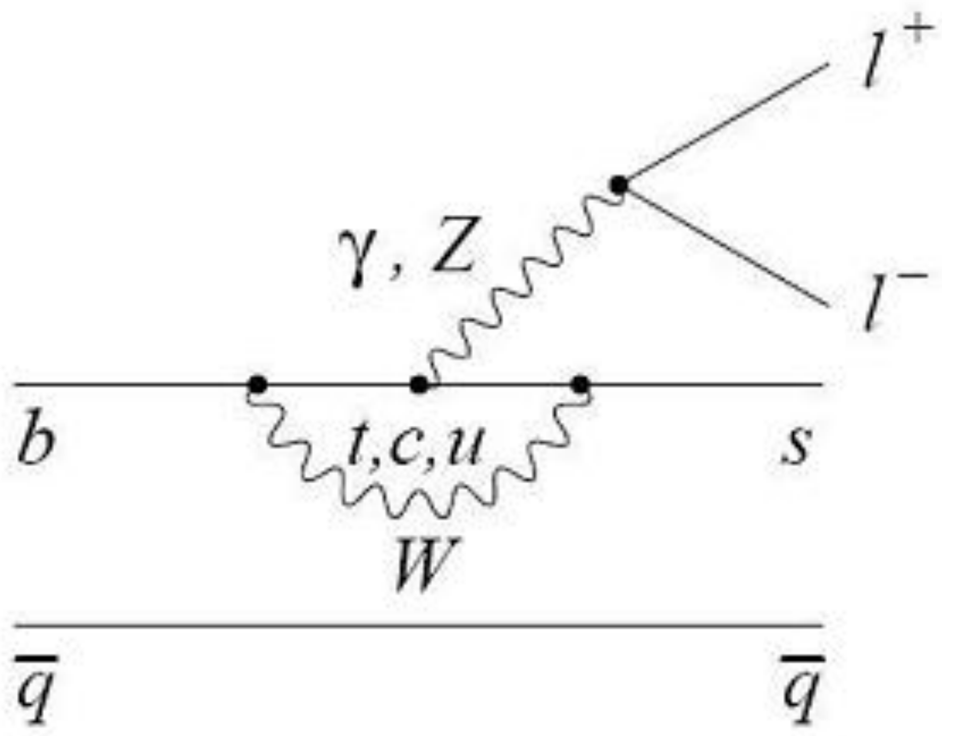




Nsig at Belle II ~90±30 based on Belle 2013 (hadronic tag only)

Electroweak Penguin: Leptons

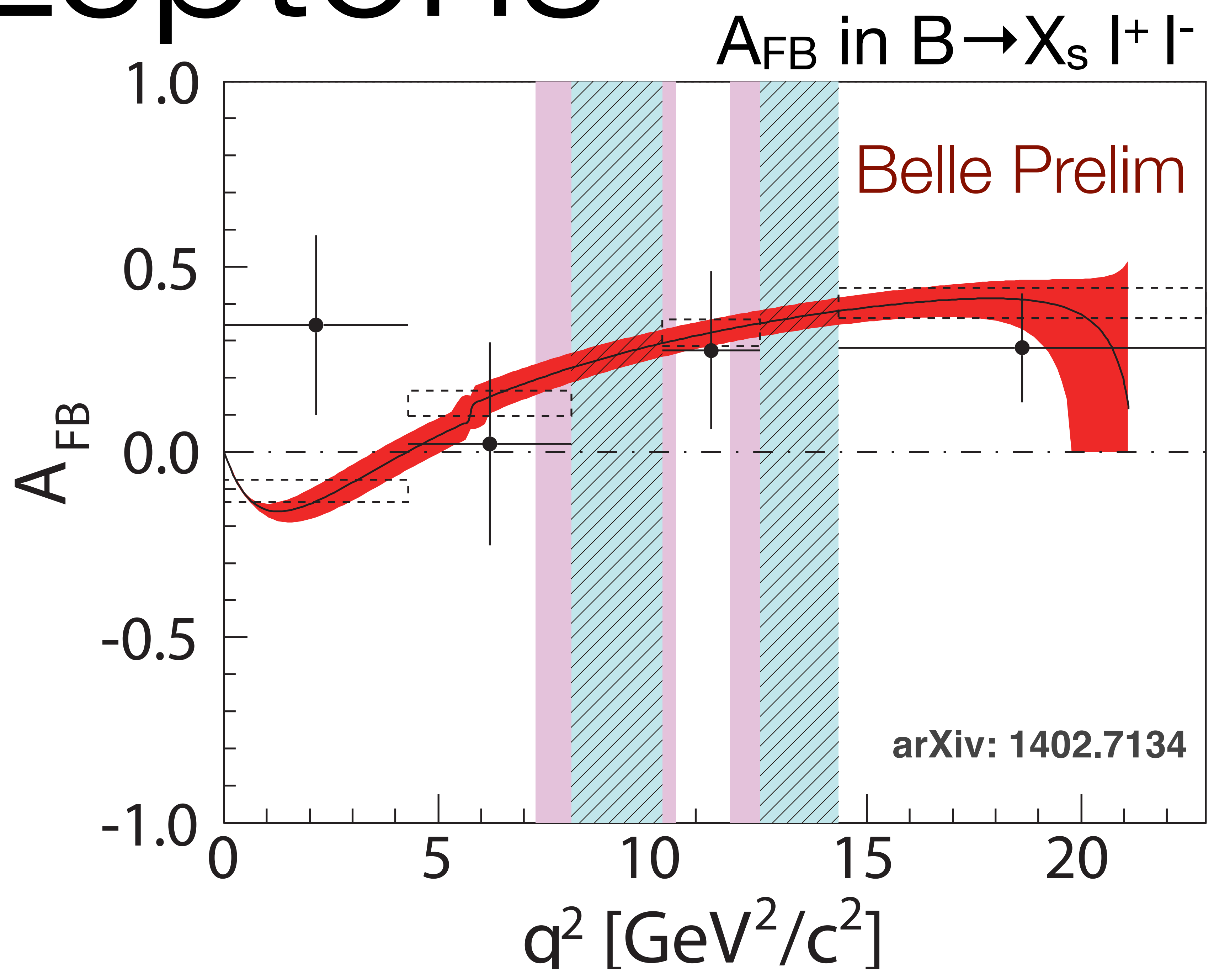


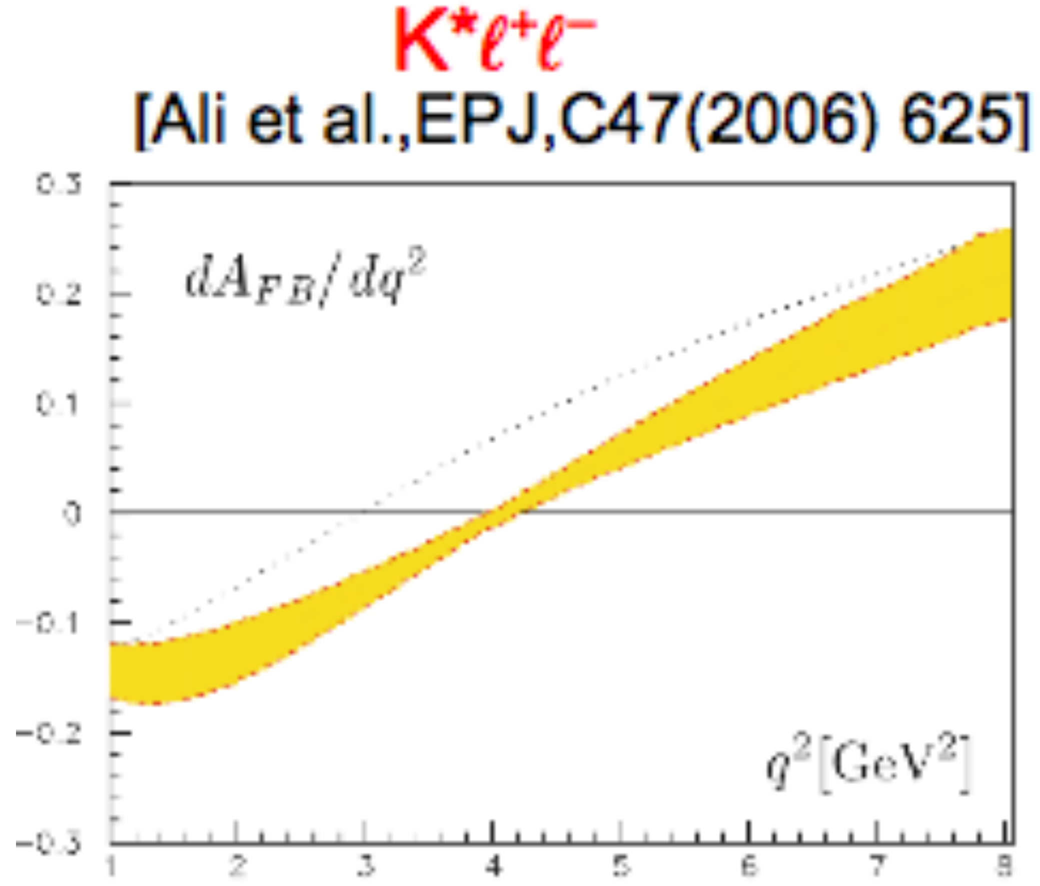


1. **Inclusive $B \to X_s\ l^+ l^-$, l=e,μ**
   - More precise theory
   - Sum of exclusive hadronic final states (BF, A_{CP}, A_I , F_L, A_{FB})

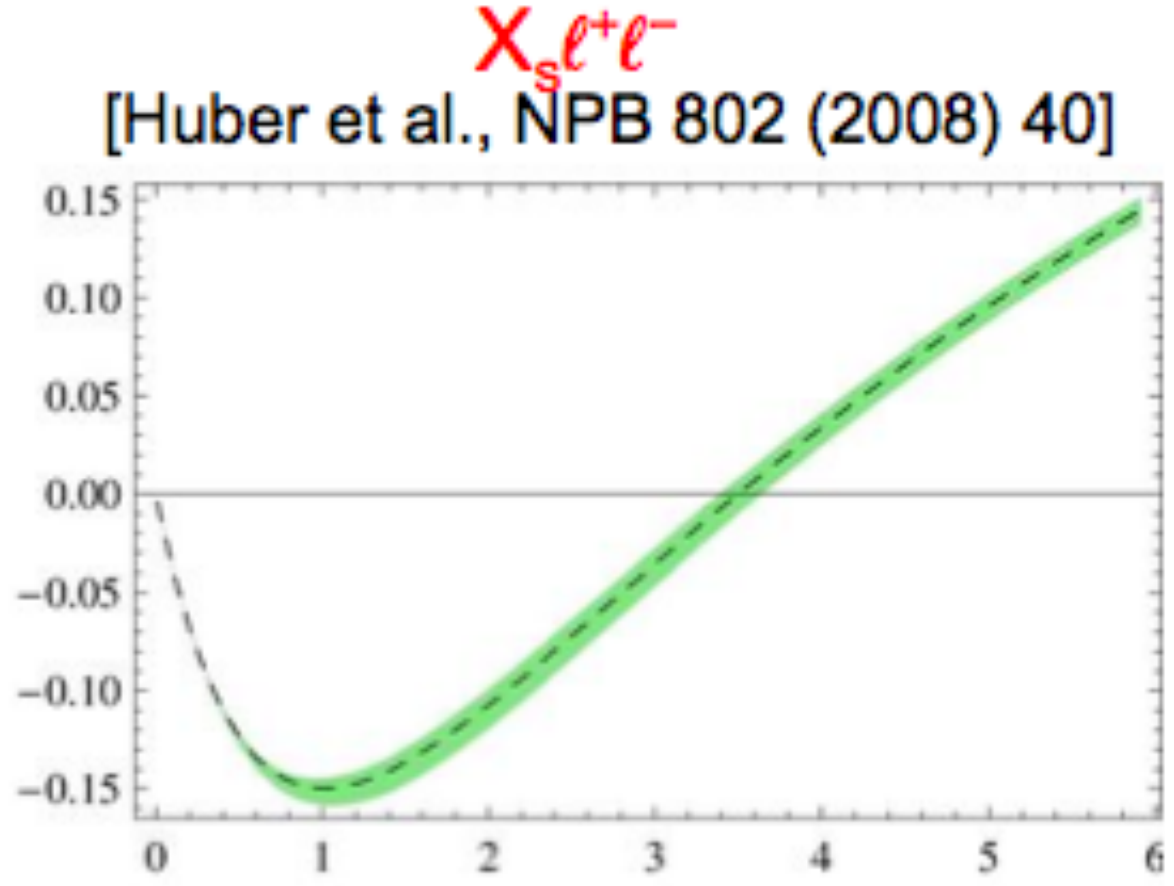
2. **$B \to \{K^*,K\}\ e^+ e-$**
   - Lepton Universality
   - Photon Polarization (low q^2)

3. **Third generation**
   - **$B \to K\tau\tau$** $<3 \times 10^{-4}$ in 50/ab





$$q_0^2 = \left(4.07^{+0.16}_{-0.13}\right)\ \mathrm{GeV}^2$$

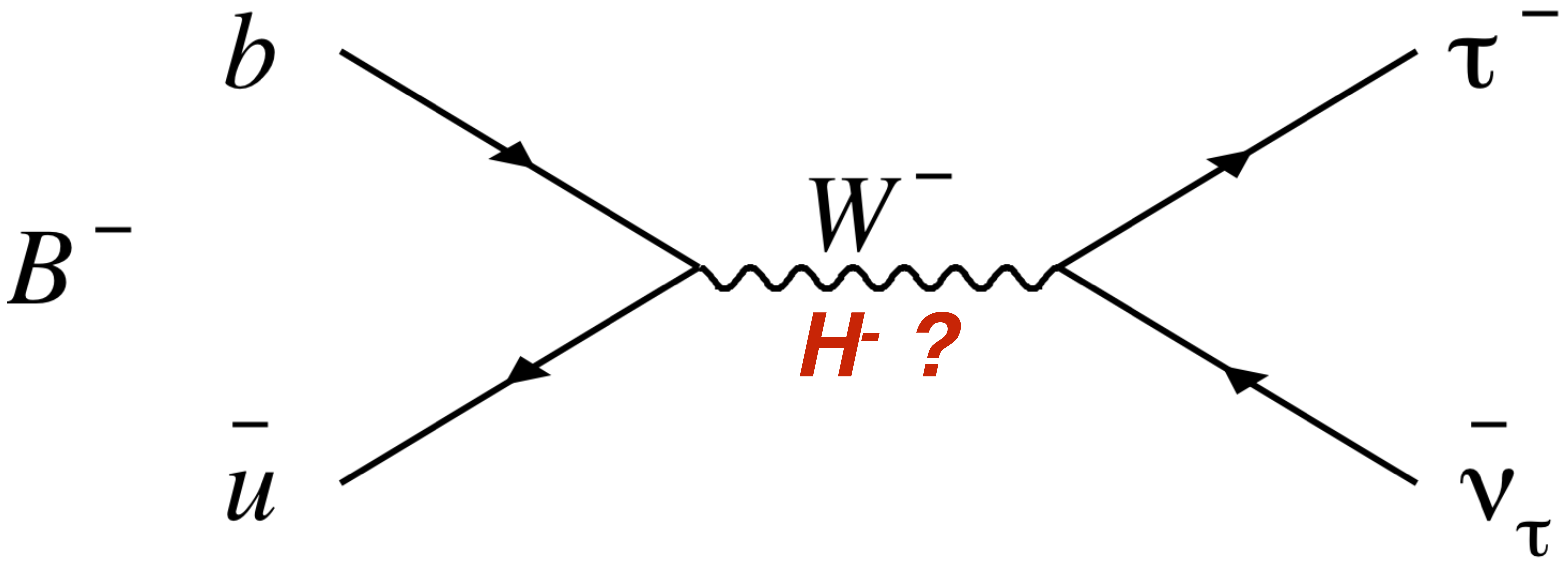


$$(q_0^2)_{\mu\mu} = (3.50 \pm 0.12)\ \mathrm{GeV}^2$$

$$(q_0^2)_{ee} = (3.38 \pm 0.11)\ \mathrm{GeV}^2$$

Charged Higgs

- H^+ Search: $B^+ \to \tau\nu$, $\mu\nu$
  - Large missing energy



Helicity suppressed - very small in SM.
NP could interfere *e.g.* **charged Higgs**,
and *change* the branching fraction

BF_{SM} $\quad r_H$

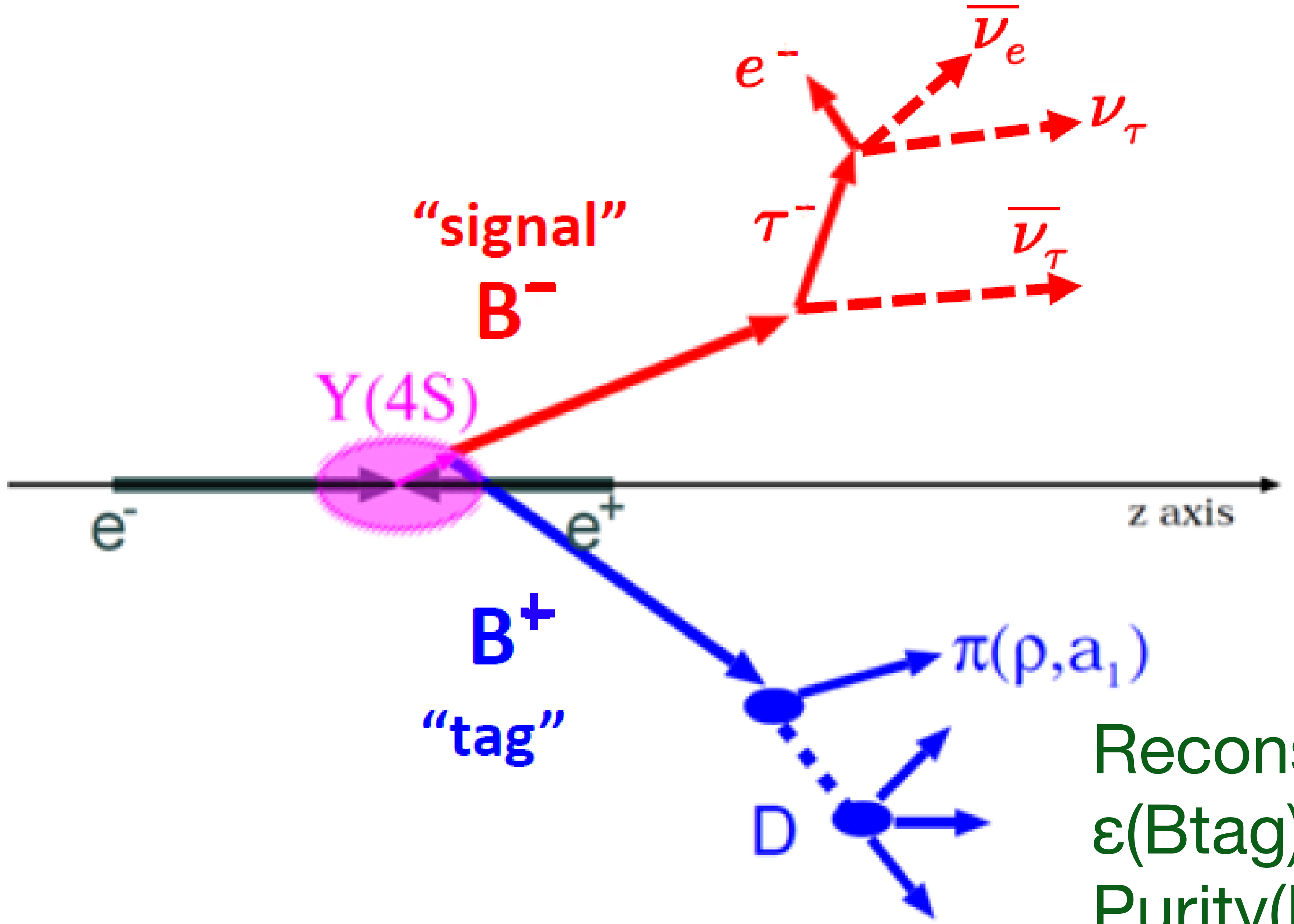
$$\mathrm{BR}(B_u \to \tau\nu_\tau) = \frac{G_F^2 f_B^2 |V_{ub}|^2}{8\pi}\tau_B m_B m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \left[1 - \left(\frac{m_B^2}{m_{H^+}^2}\right)\lambda_{bb}\lambda_{\tau\tau}\right]^2$$

Hara et al., PRD 82, 071101(R) (2010) ***[605 fb^{-1} , semilept tag]] (3.6σ evidence)***
Hara et al., PRL 110 131801 (2013) ***[772 fb^{-1} , full recon tag] (3.0σ evidence)***

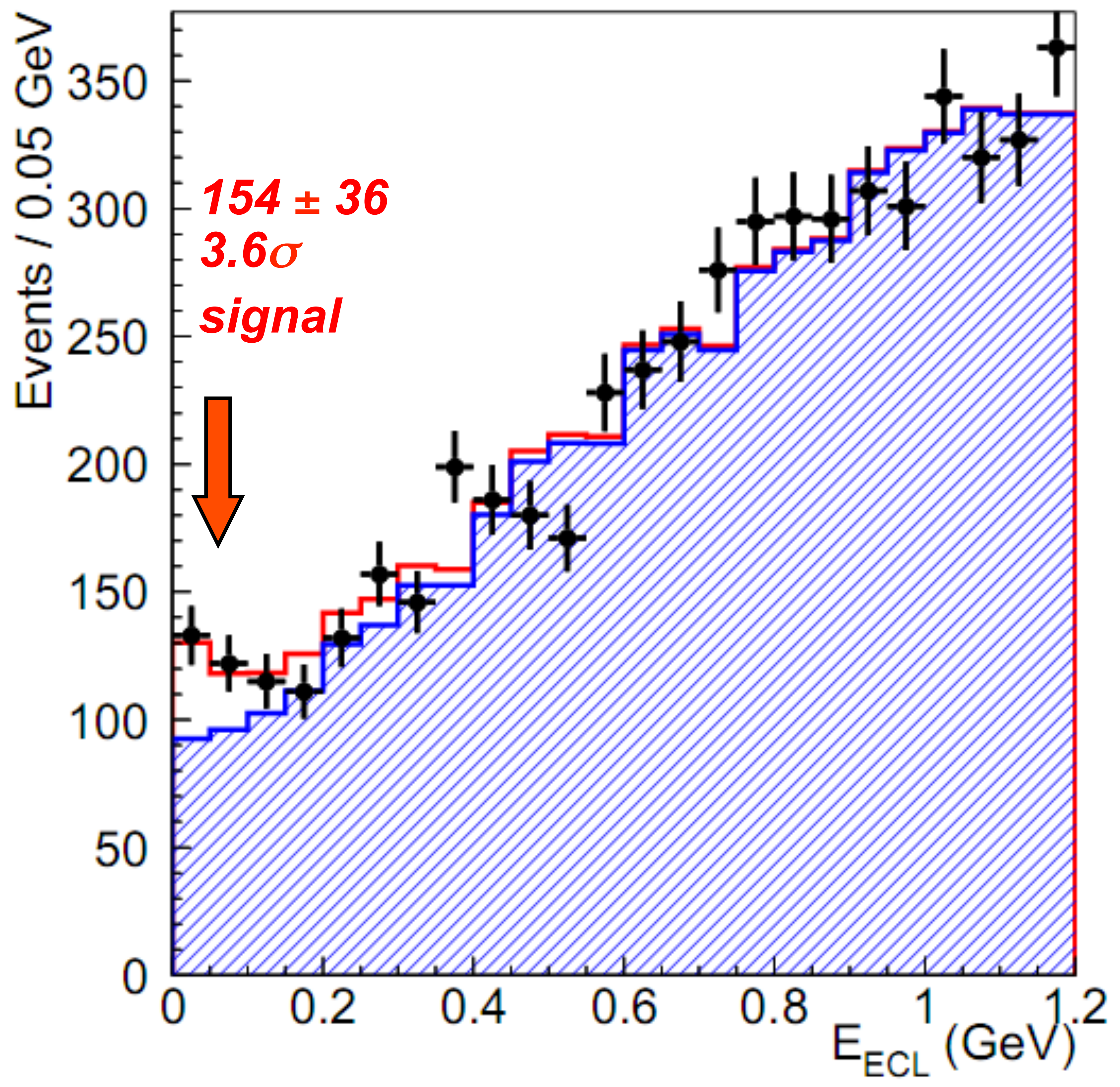
Aubert et al., PRD 77 011107(R)(2008);
PRD 81, 051101(R), 2010 [418 fb^{-1}] (2.8σ excess)

Charged Higgs: B–>τν

- **Very challenging to isolate: two ν's in final state**
  - Use fully reconstructed hadronic and semileptonic decays on tagging side
  - Signal side is τ→μνν, eνν, πν (1 charged track). Yield is obtained by fitting the ECL (electromagnetic calorimeter energy) distribution: peak near zero indicates τ→ lνν, πν decay.



Reconstruct one B meson (Btag)
ε(Btag) = 0.20 - 0.25% @
Purity(Btag) = 20%

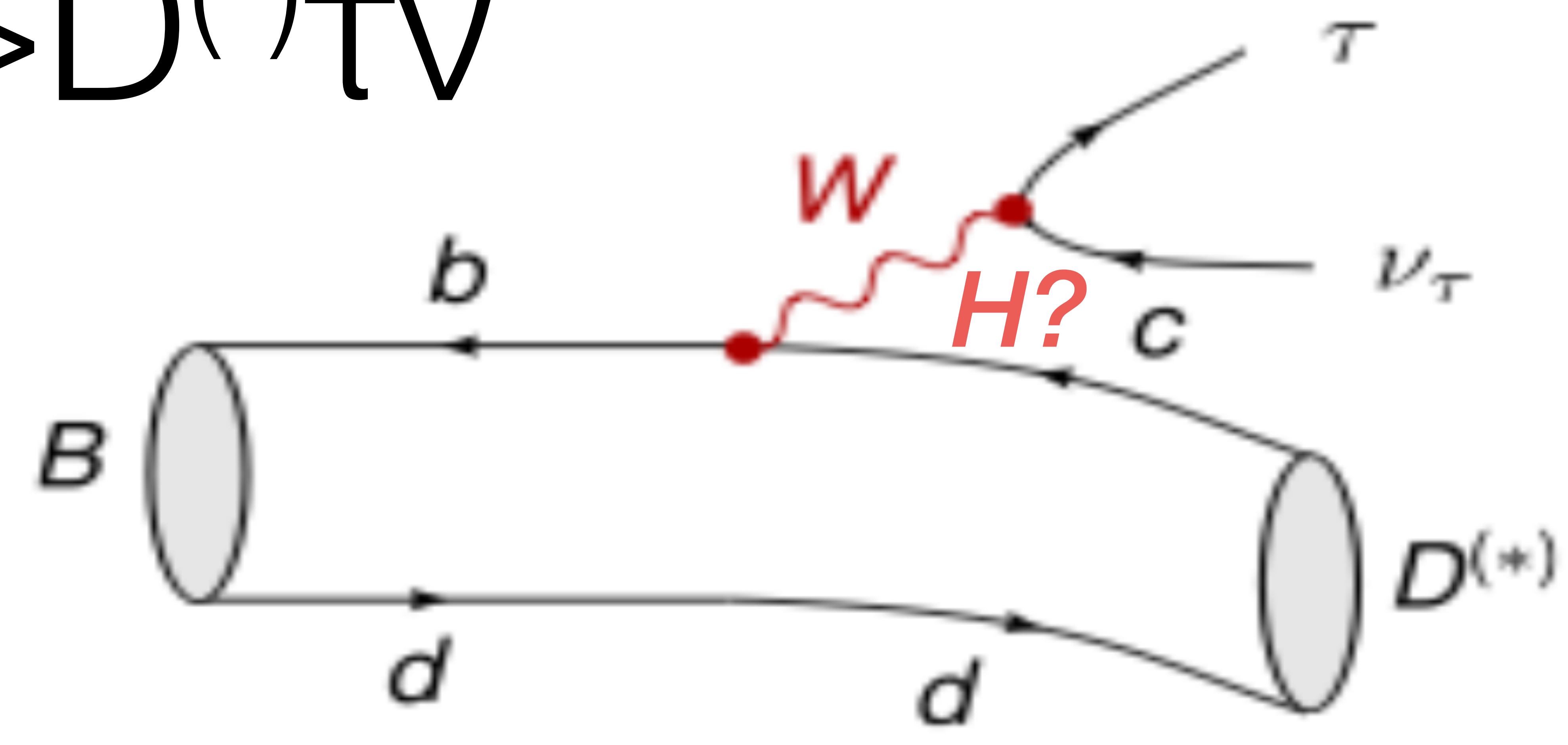


$\mathcal{B}(B \to \tau^+\nu)$ = (1.14 ± 0.22) x 10^{-4} (HFAG 2013)

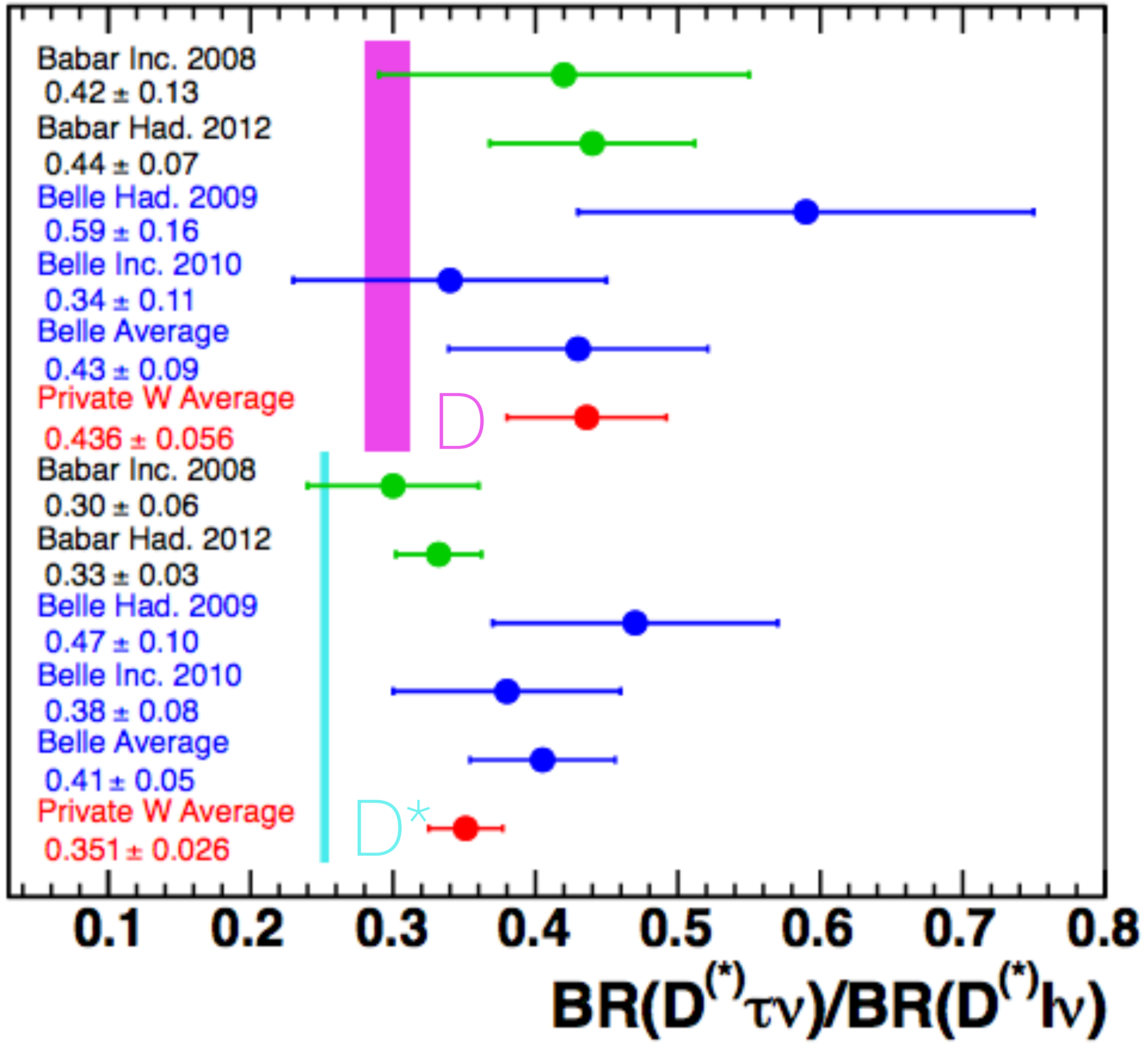
Charged Higgs: B–>D$^{(*)}$τν

2-Higgs Doublet Model:

$$\mathcal{B}(B\to D^{(*)}\tau\nu) \;\propto\; \mathcal{B}_{SM}\cdot m_W \left(\frac{\tan\beta}{m_H}\right)$$



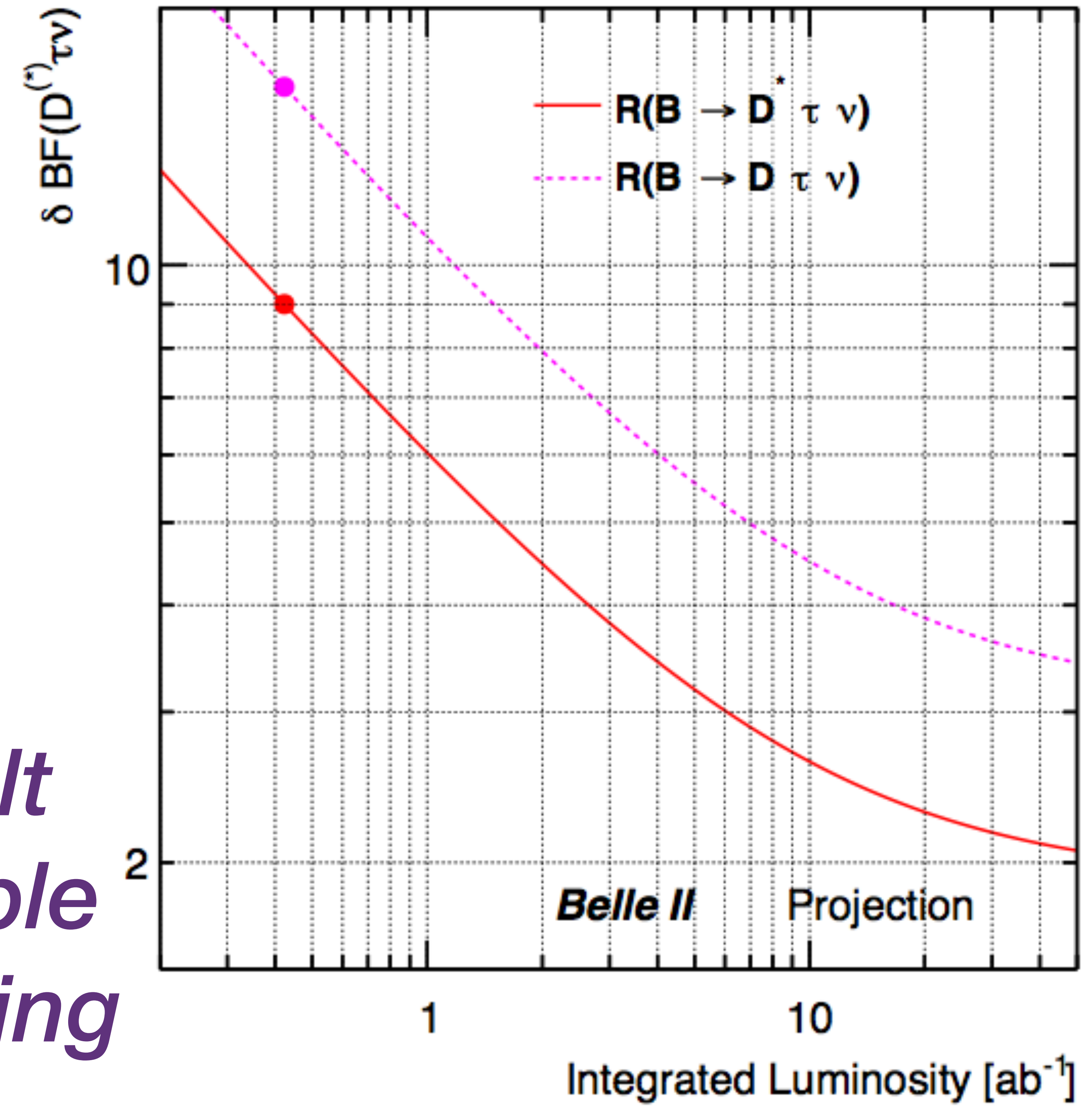
Missing energy from at least 2 neutrinos



Current B→ D$^{(*)}$τ $^{+}$ν is > 4σ above SM (SM)

Belle II should resolve this discrepancy

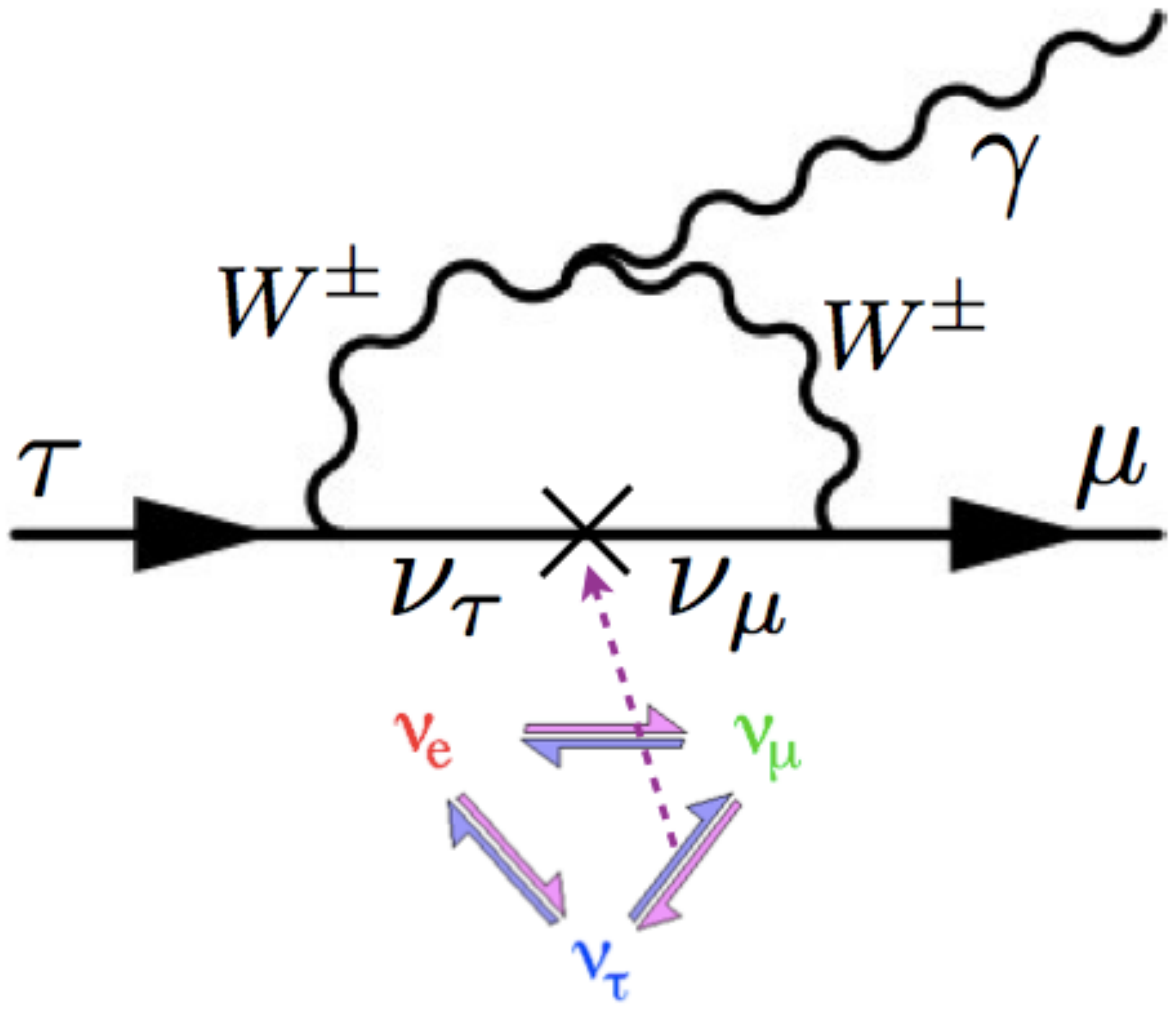
Strong result within a couple of years running

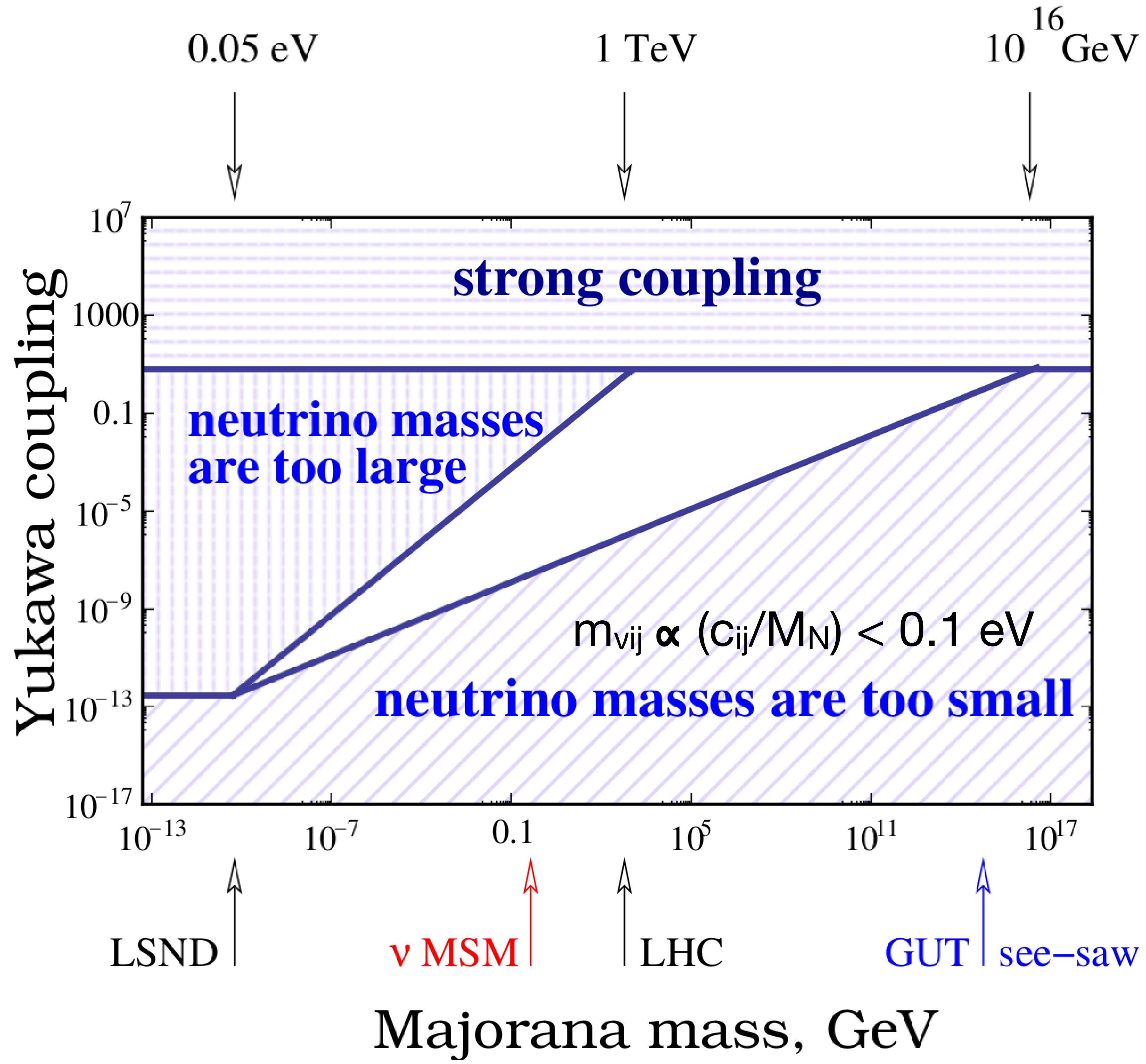


τ Lepton Flavor Violation (LFV)

- LFV is a theoretically clean null test of the **SM (BF ~10^{-25})**
- 2/3 lepton "mixing" types studied at Belle II

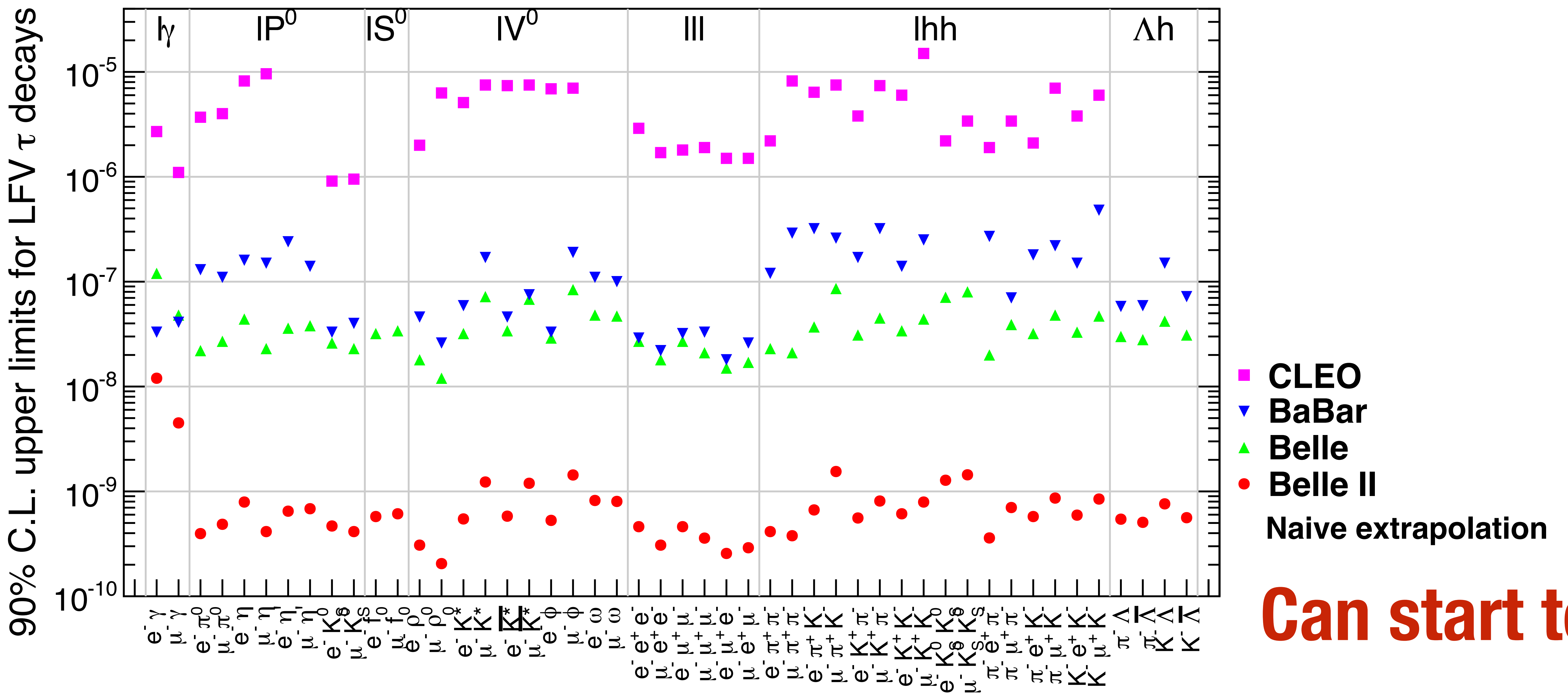
	reference	$\tau\to\mu\gamma$	$\tau\to\mu\mu\mu$
SM + heavy Maj ν_R	PRD 66(2002)034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547(2002)252	10^{-9}	10^{-8}
SUSY SO(10)	PRD 68(2003)033012	10^{-8}	10^{-10}
mSUGRA+seesaw	PRD 66(2002)115013	10^{-7}	10^{-9}
SUSY Higgs	PLB 566(2003)217	10^{-10}	10^{-7}

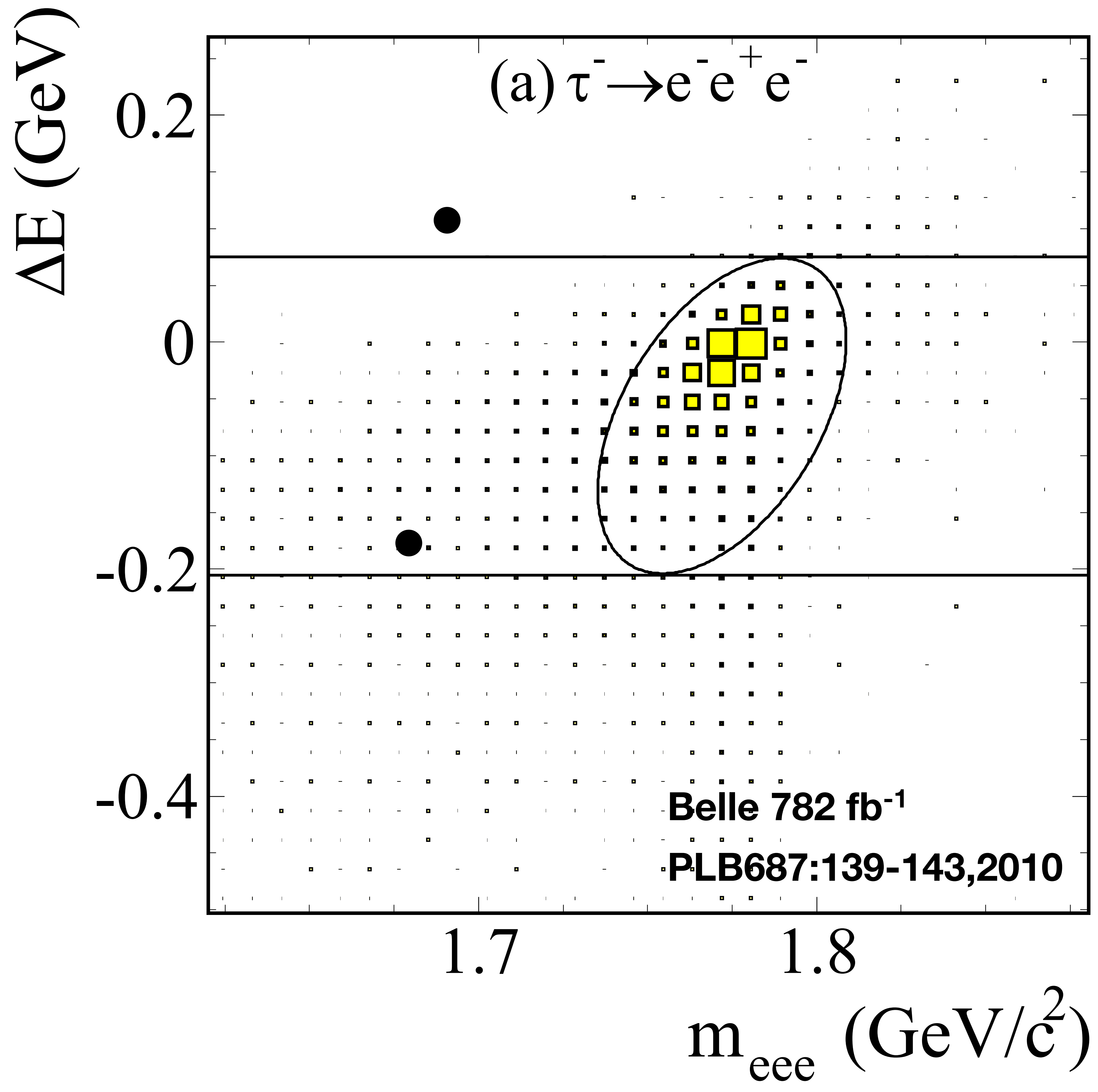




τ LFV

- **$\tau^+ \to \mu^+ \mu^+ \mu^-$**
  - Up to 50x improvement: Very clean, **essentially background free to 50 ab-1**
  - LHC not so competitive (trigger and track p_T limiting (even μμμ)





Can start to probe NP at 10^{-8}

CPV search in D^0-$\bar{D}^0$

Expected Uncertainties (*M. Staric, KEK FFW14*)**:**

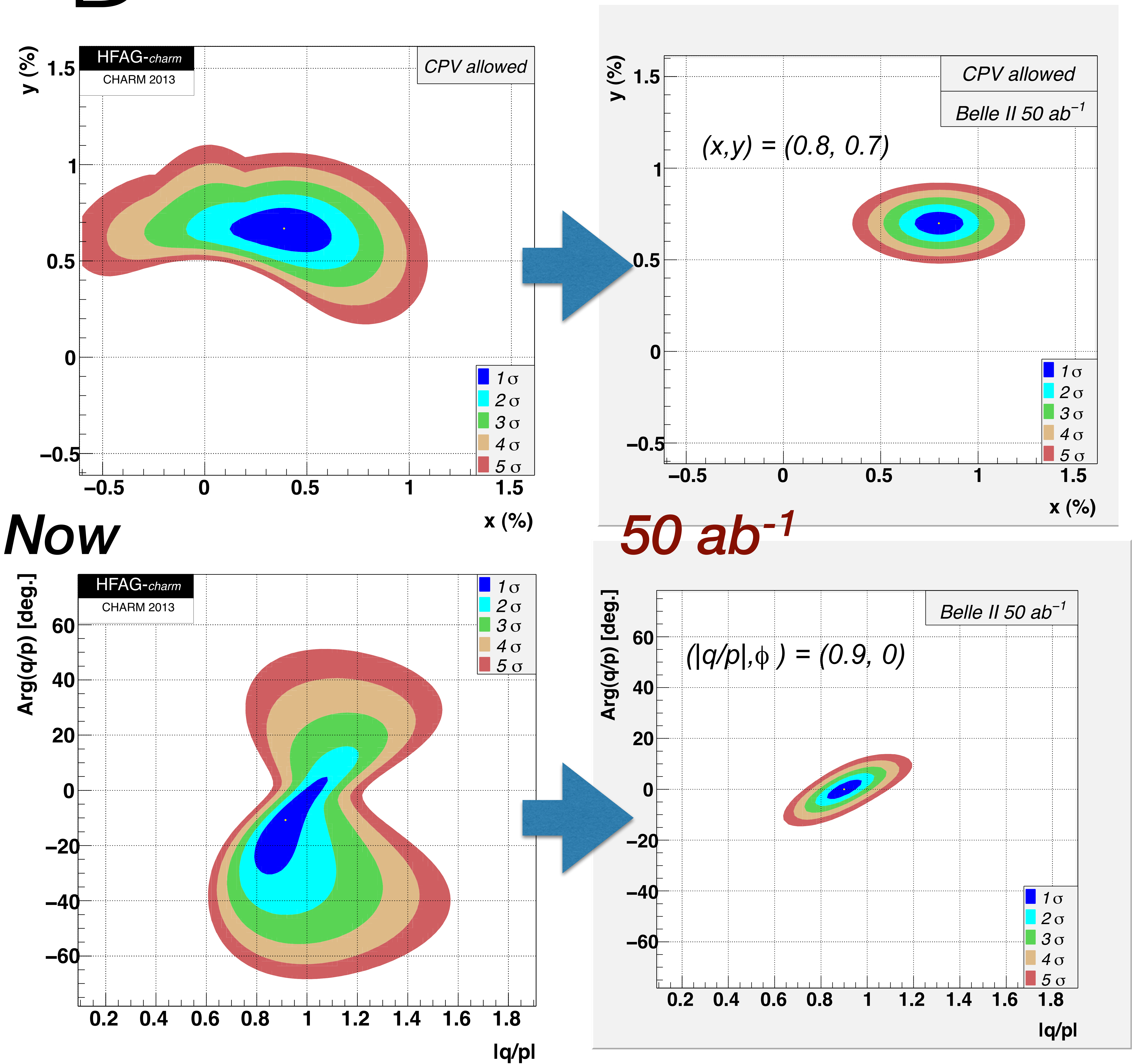
Analysis	Observable	Uncertainty (%)	
		Now ($\sim$1 ab^{-1})	$\mathcal{L} = 50$ ab^{-1}
$K_S^0\pi^+\pi^-$	x	0.21	0.08
	y	0.17	0.05
	$\lvert q/p\rvert$	18	6
	ϕ	0.21 rad	0.07 rad
$\pi^+\pi^-$, K^+K^-	y_{CP}	0.25	0.04
	A_Γ	0.22	0.03
$K^+\pi^-$	x'^2	0.025	0.003
	y'	0.45	0.04
	$\lvert q/p\rvert$	0.6	0.06
	ϕ	0.44	0.04 rad

Note: statistical error and some systematics scale by luminosity, but other systematics do not.

CPV search in D^0-$\bar{D}^0$

Current measurements of x, y give many constraints on NP models

[see Golowich et al., PRD76, 095009 (2007); 21 models considered, e.g., 2-Higgs doublets, left-right models, little Higgs, extra dimensions, of which 17 give constraints]

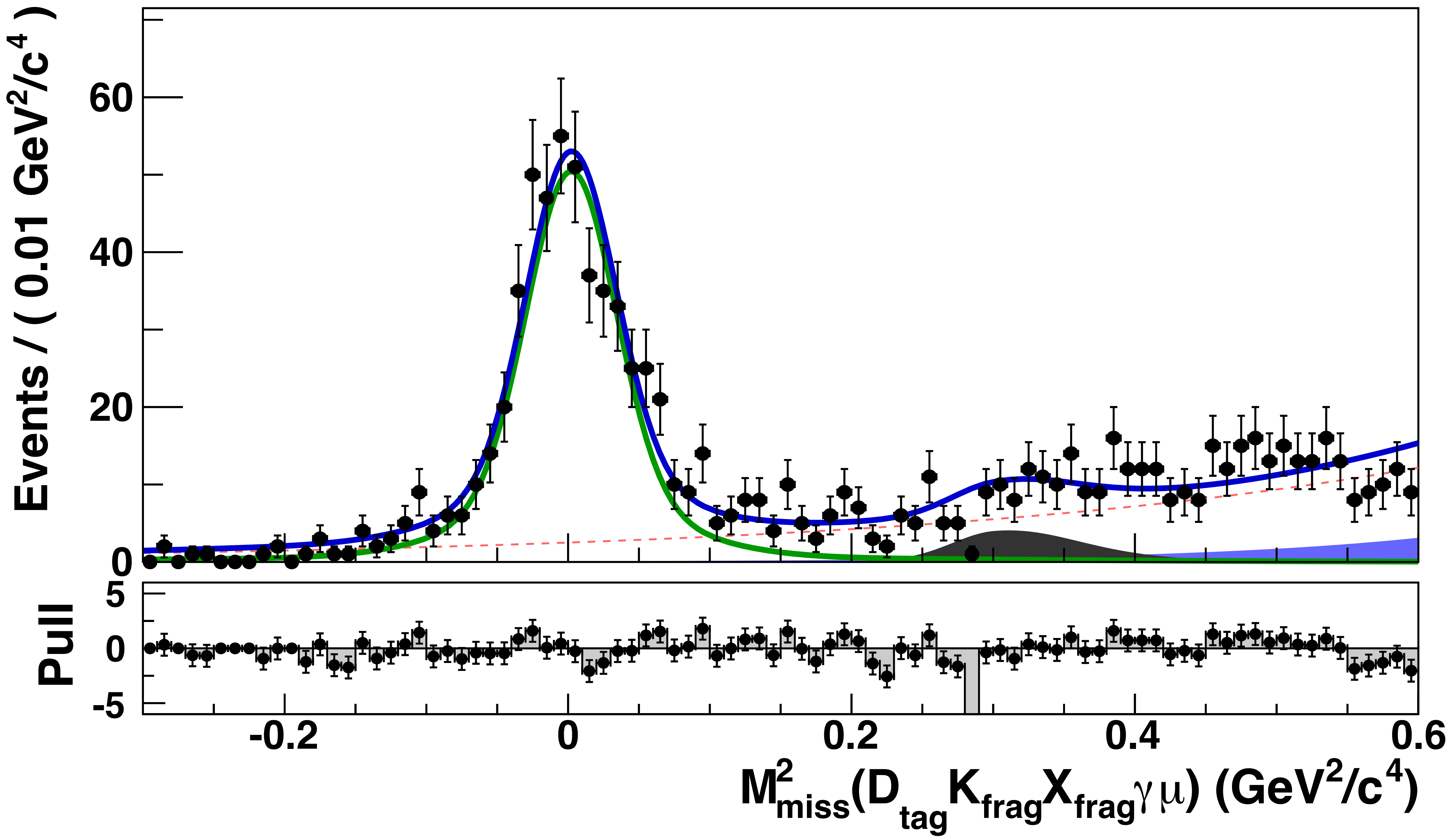


***Note:** LHCb will dominate most of these measurements, but Belle II should be competitive in y_{CP} and possibly in x'2, y', |q/p|, φ (see Staric, KEK FFW14). If LHCb sees new physics, it would be important for Belle II to independently confirm.*

Charm Recoil Techniques

- Based on B-beam techniques
- Powerful, precise test of LQCD and NP in (semi)leptonic modes
- Many modes to explore, e.g.
  - **$D_s \to \mu\nu$** (@1%), **$\tau\nu$** (@3%) precision
  - **$D \to \nu\nu$**: New scalars (e.g. Dark Matter).
  - **$D \to \gamma\gamma$**: Expect to reach ~10^{-7} (Measures long distance contributions to 2-μ mode)

$$e^+e^- \to c\bar{c} \to \overline{D}_{\mathrm{tag}} X_{\mathrm{frag}} D^{(*)}_{\mathrm{recoil}}$$

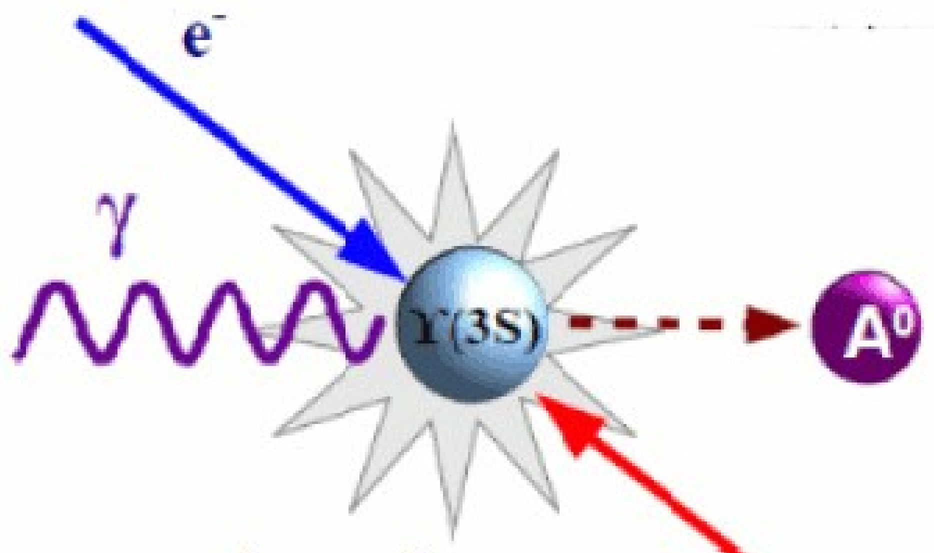


Rare modes: ργ, Φγ → 1% (NP up to 10%)

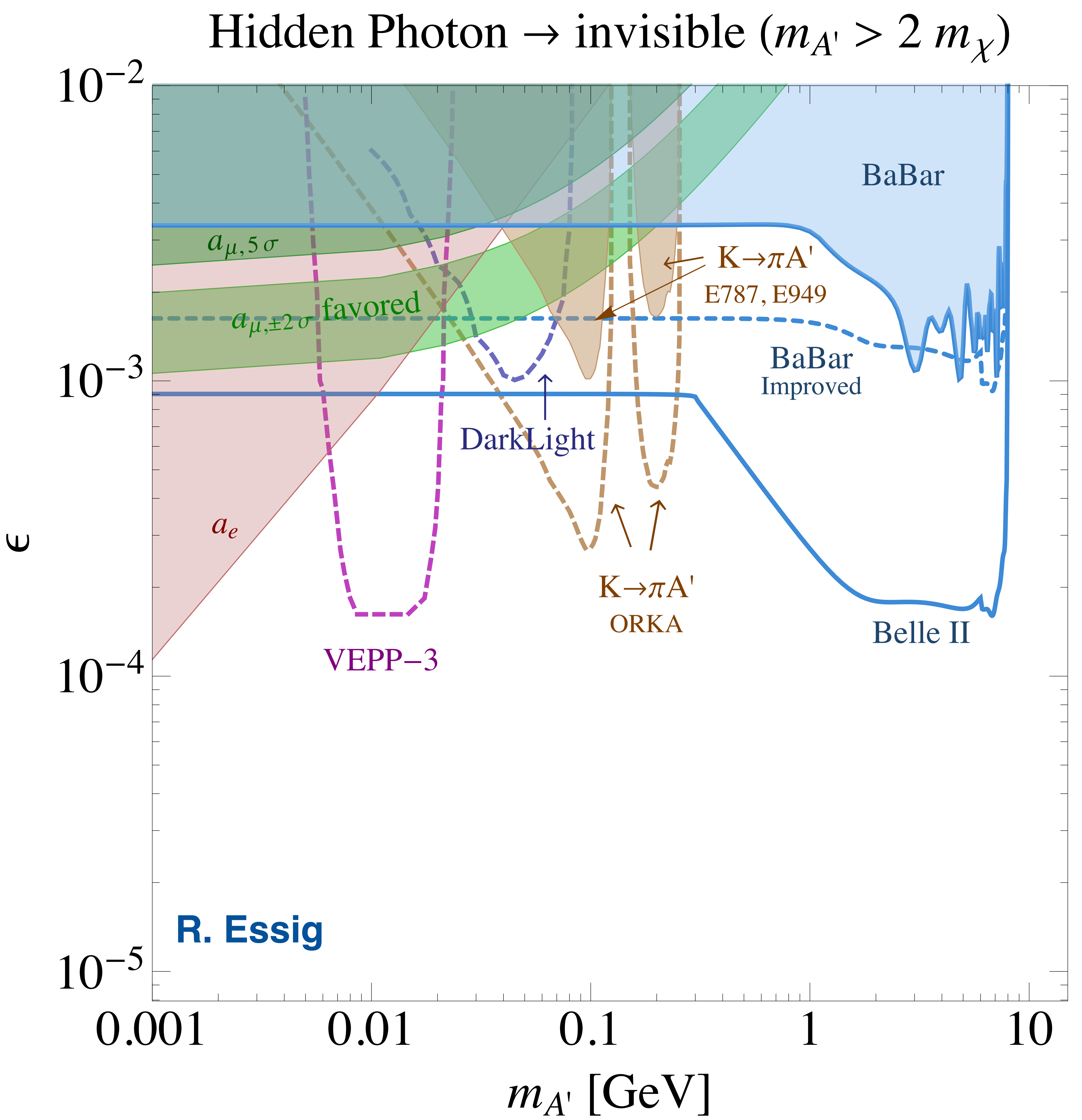
Dark Sector

- To maximize the impact of early data, Belle II may run at **Y(1S), Y(2S), Y(3S), or Y(5S)** for first few ~100fb^{-1}
  - Unique data sets much larger than Belle/ Babar
- One interesting search in these data sets: **Dark photon A', motivated be in MeV – GeV mass**
  - Probe leptonicaly decaying dark photons through mixing
  - Probe sub-GeV dark matter in invisible decays

Radiative decays of Y(2S), Y(3S)



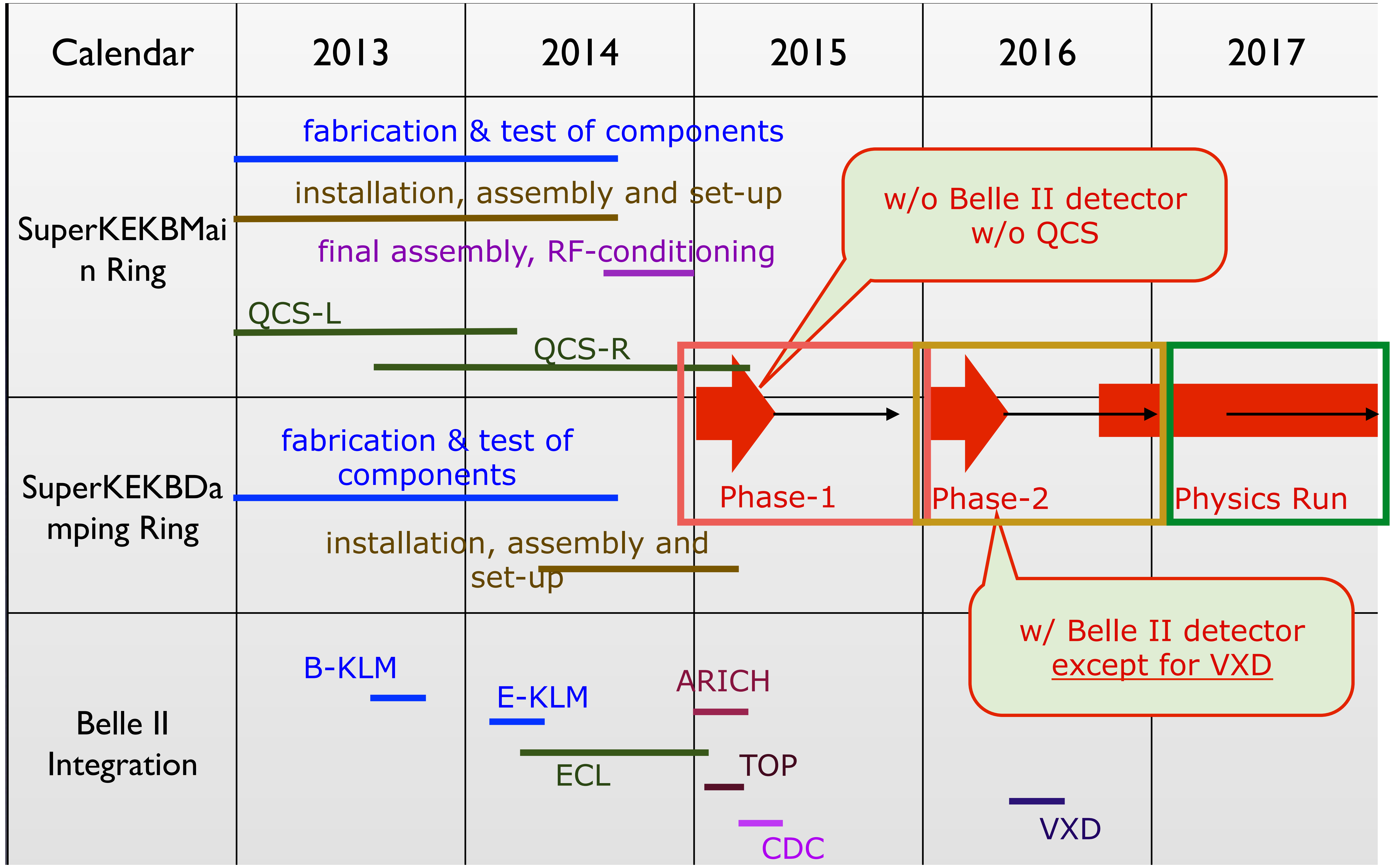
$$E^*_\gamma = \frac{m^2_\Upsilon - m^2_{A^0}}{2m_\Upsilon}$$

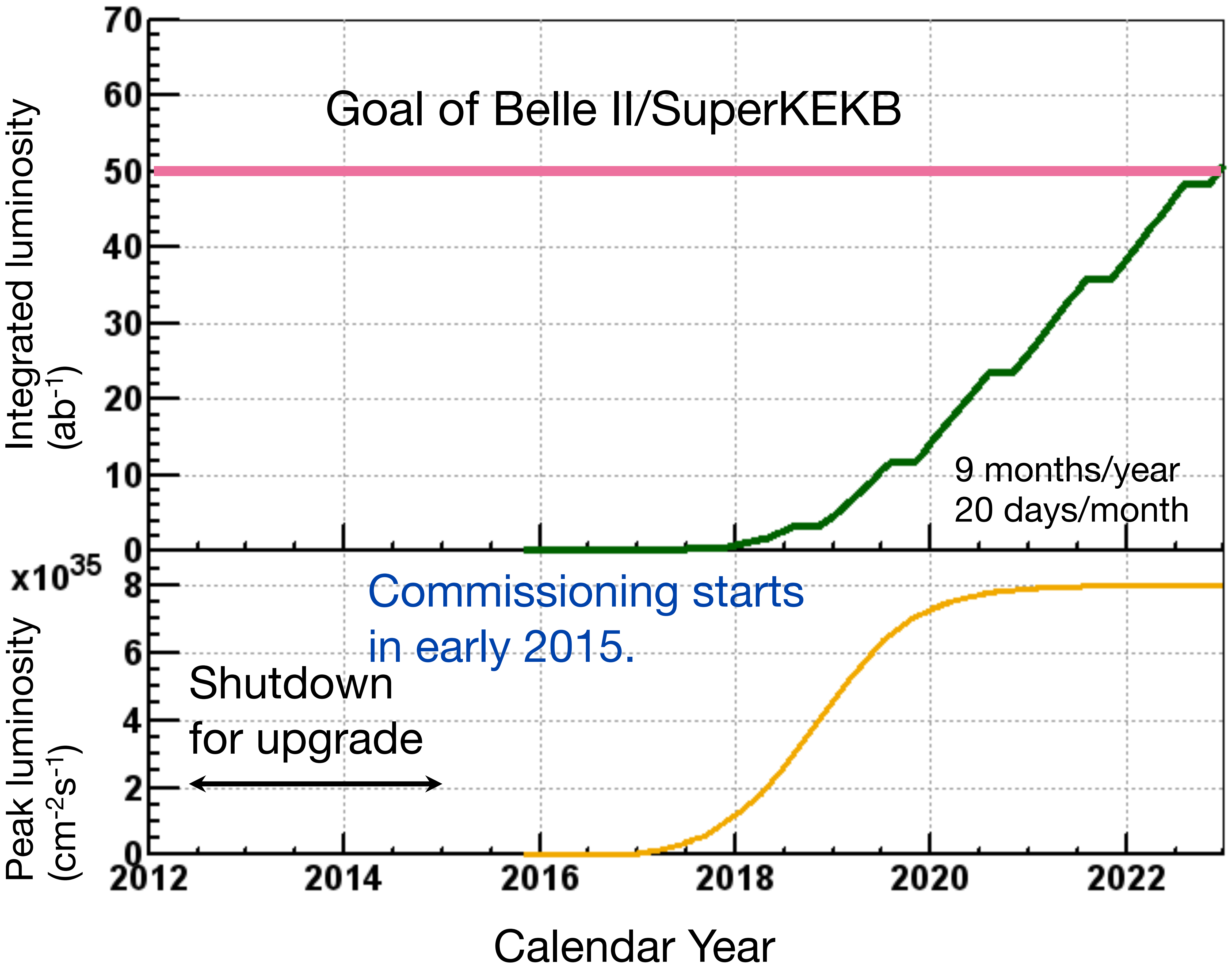


WHEN: Current Schedule

SuperKEKB & Belle II Schedule

	approximate	
Phase-1	end 2015	Accelerator commissioning
Phase-2	end 2016	Belle II “Beast” and partial detector commissioning
Phase-3	end 2017	First runs with full detector





Current schedule **First Physics Run end 2017 (beginning 2018)** calendar year

SuperKEKB

Magnets have been installed

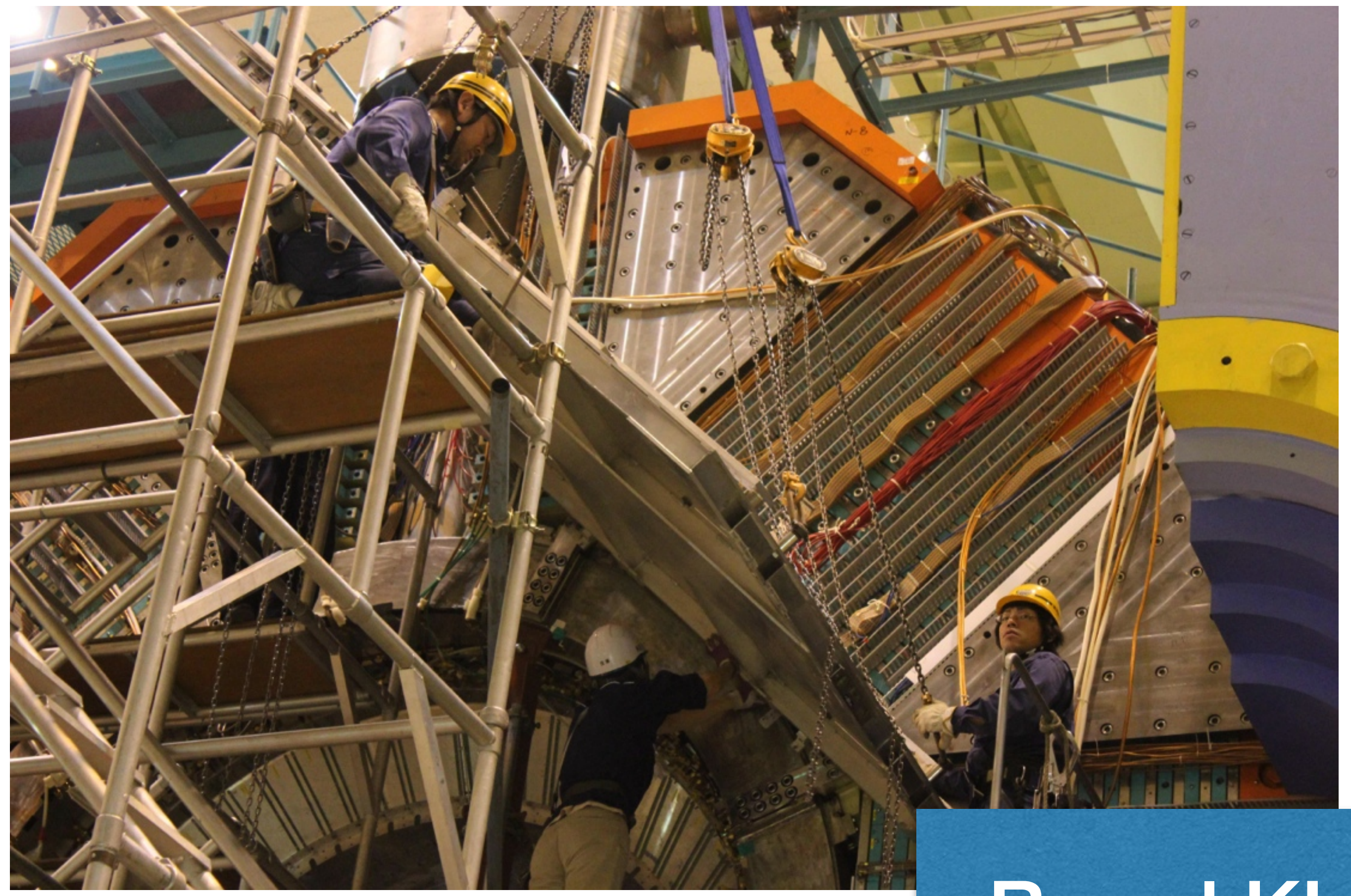
D2(Oho-side)

D1(Nikko-side)

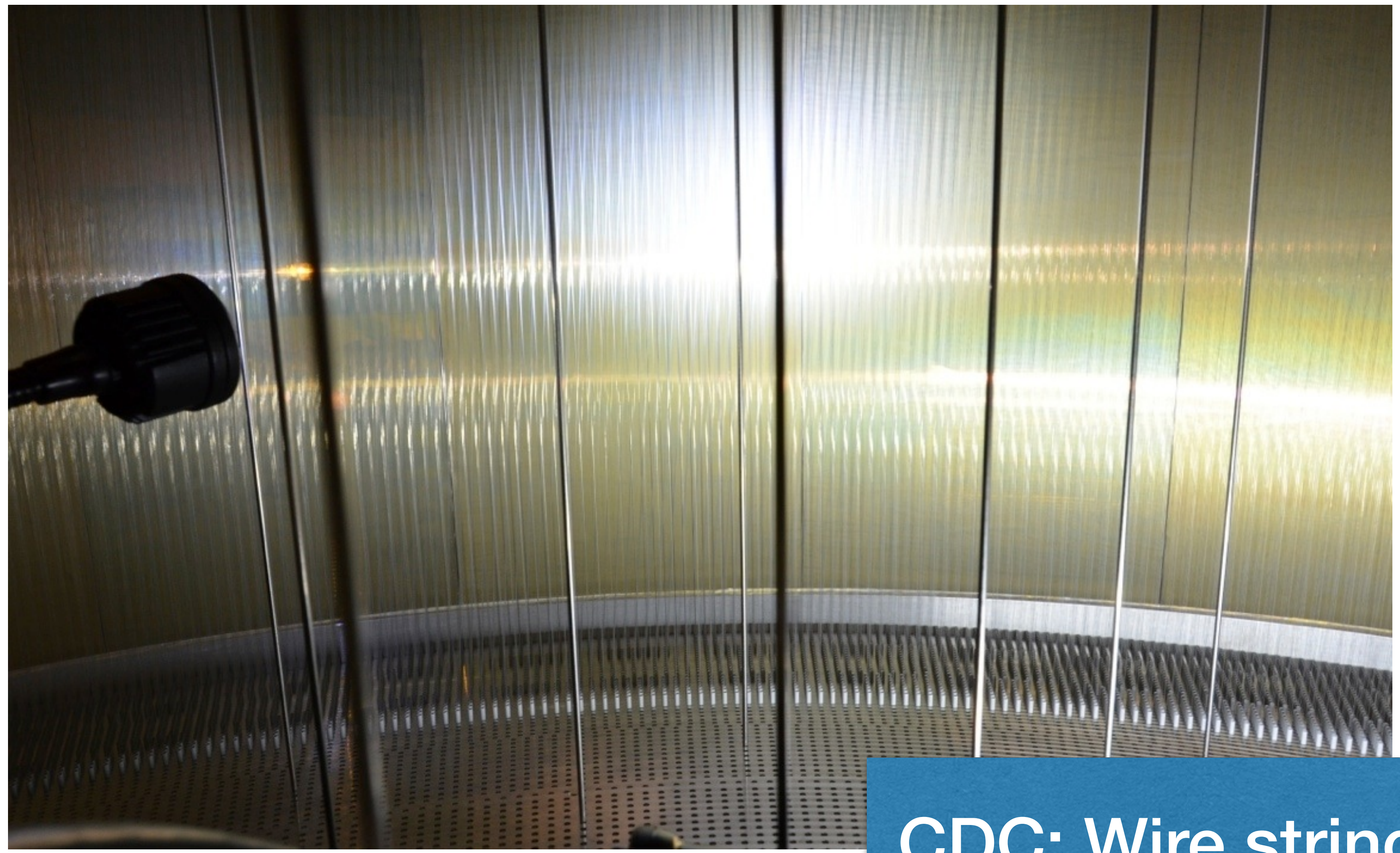
Damping ring built

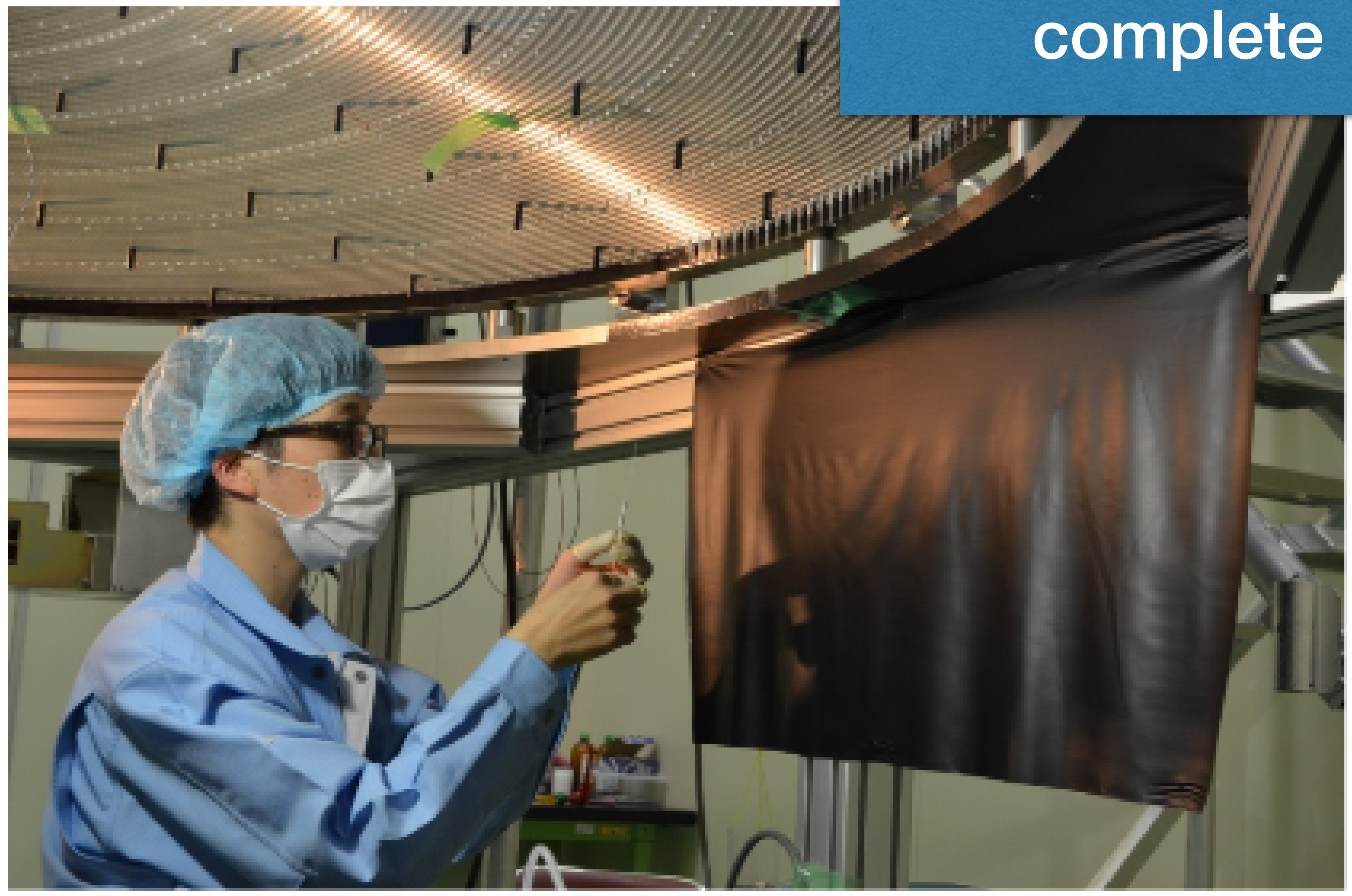
On schedule to be completed by JFY 2014

Belle II

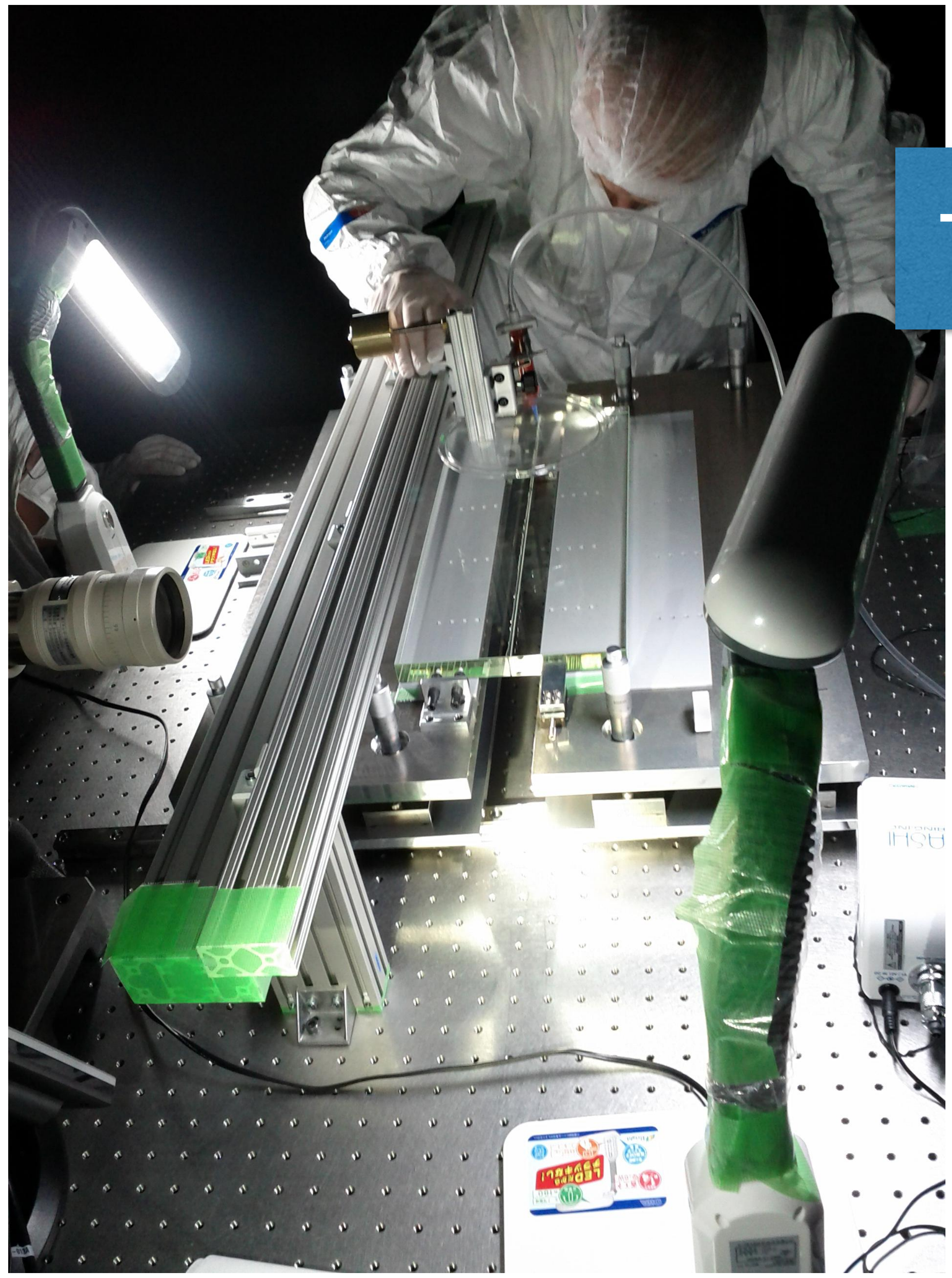


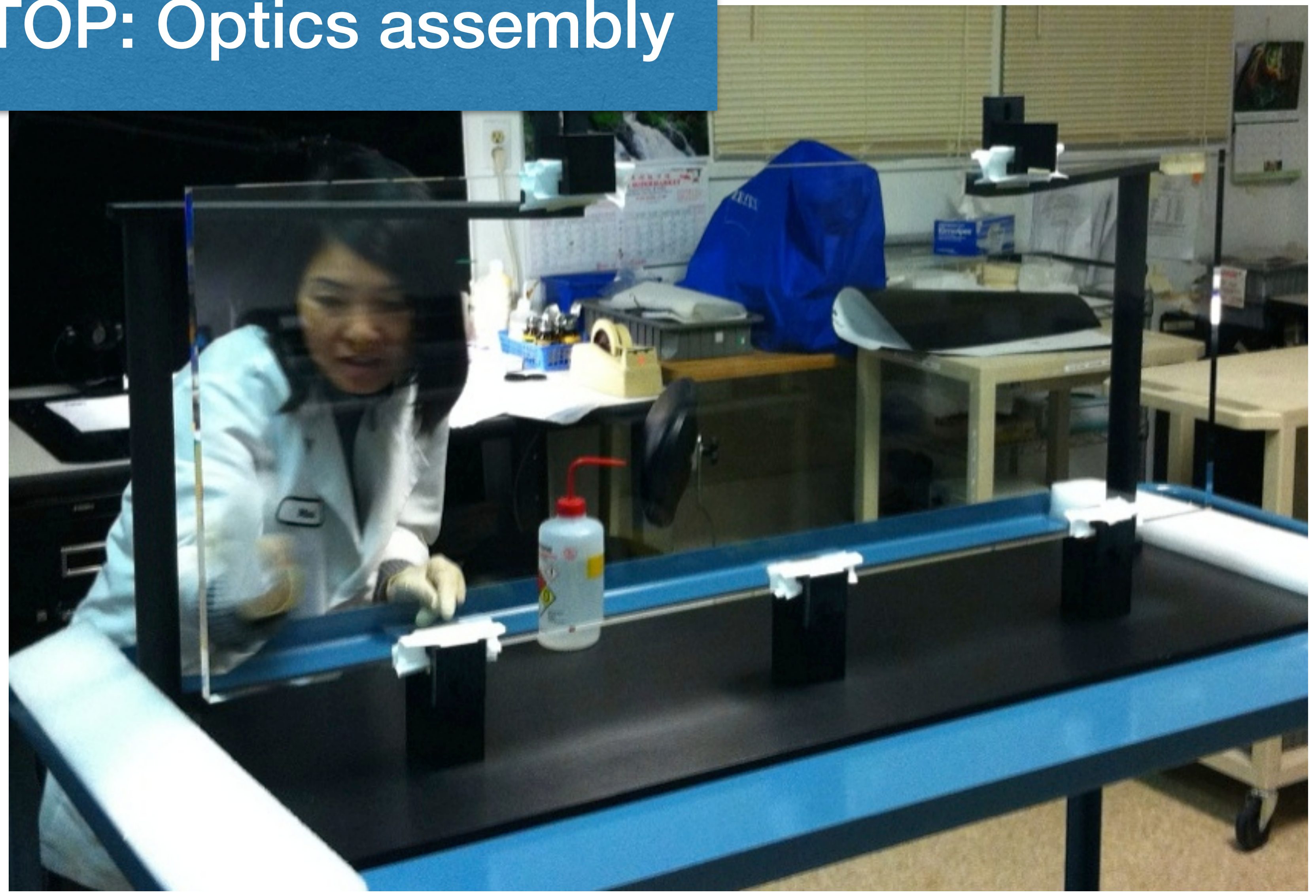
Barrel KLM: Installation complete - *first Belle II sub-detector ready!*





CDC: Wire stringing complete





TOP: Optics assembly

Belle II Theory Interface Platform

ADVERT

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

Inviting Theorist Participation: ***Next Meeting 27-29 April 2015, Krakow Poland***

Help plan the Belle II physics program and ensure a coordinated experiment/theory effort to maximize the discovery power of Belle II

Belle II Theory Interface Platform (B2TIP)

Overview

The "Belle II-Theory Interface Platform" is an initiative to coordinate a joint theory-experiment effort to study the potential impacts of the Belle II program.

We plan to organize meetings twice a year gathering theory experts and Belle II members, starting from June 2014 until the end of 2016.

One of the expected outcomes of the project is a "KEK Report", summarizing all the important observables which will be measured at Belle II, their experimentally achievable precision and their impact on our understanding of the theory (Standard Model and New Physics). This report should also include a "milestones table" clarifying the targets for the first 5 to 10 ab-1 of data as well as for the final goal at 50 ab-1.

See the table of golden modes (link).

This project is an official activity of Belle II, approved by the executive board of the Belle II Collaboration, in February 2014.

Workshop Dates

The 2014 meetings will be held at KEK in June and November, as a satellite meeting of the Belle and Belle II General meetings. There is a possibility of holding one workshop in 2015 at an external location. Individual working groups may choose to hold additional meetings. Please register for the meetings on the linked indico pages.

B2TIP Meeting	Meeting Agenda	Belle (II) associated meetings
2014 June 16-17 @ KEK	workshop indico	B2GM June 18-21, BGM June 22-23
2014 October 30-31, merged with KEKFF October 28-29. @ KEK	workshop indico	B2GM November 3-6, BGM November 7-8
2015 April 27-29 @ Krakow (Local organiser A. Bozek)		
2015 November (KEK)		
2016 April/May (North America)		

Committees

Organising Commitee

Toru Goto	KEK
Emi Kou	LAL
Phillip Urquijo (B2 Physics Coord.)	Melbourne

Ex Officio

Hiroaki Aihara (B2 EB Chair)	Tokyo
Thomas Browder (B2 Spokesperson)	Hawaii
Marco Ciuchini (KEK FF Advisory)	Rome
Thomas Mannel (KEK FF Advisory)	Siegen

Report Editors

Christoph Schwanda	HEPHY Vienna
Theory TBC	

Advisory Committee

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Bostjan Golob	IJS Ljubljana
Shoji Hashimoto	KEK
Francois Le Diberder	LAL
Zoltan Ligeti	LBL
Hitoshi Murayama	IPMU
Matthias Neubert	Mainz
Yoshihide Sakai	KEK
Junko Shigemitsu	Ohio

Summary

- **Rich physics program at Belle II**
  - Precision CKM
  - Radiative EWP decays
  - Extended Higgs sector
  - Lepton Flavor Violation
  - Charm
  - Dark Sector
  - **…MANY OTHERS!**

- Work is on schedule on the SuperKEKB accelerator: Implementing nano beams.
  - **Completion JFY 2014**

- Belle II upgrade is progressing

- **Belle II full physics program to start ~end 2017! precision 5-100 time better than previous B-factories**

♓: Back Up :♓

Belle II

Belle II Physics Program

errors.

	Observables	Belle (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
UT angles	$\sin 2\beta$	$0.667 \pm 0.023 \pm 0.012$ [64]	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
	$S(B \to \eta' K^0)$	$0.68 \pm 0.07 \pm 0.03$ [65]	0.028	0.011
	$S(B \to K_S^0 K_S^0 K_S^0)$	$0.30 \pm 0.32 \pm 0.08$ [17]	0.100	0.033
	$\mathcal{A}(B \to K^0 \pi^0)$	$-0.05 \pm 0.14 \pm 0.05$ [66]	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.	$37.5 \cdot 10^{-3}(1 \pm 3.0\%_{\rm ex.} \pm 2.7\%_{\rm th.})$ [10]	1.8%	1.4%
	$\lvert V_{ub}\rvert$ incl.	$4.47 \cdot 10^{-3}(1 \pm 6.0\%_{\rm ex.} \pm 2.5\%_{\rm th.})$ [5]	3.4%	3.0%
	$\lvert V_{ub}\rvert$ excl. (had. tag.)	$3.52 \cdot 10^{-3}(1 \pm 8.2\%)$ [7]	4.7%	2.4%
Missing E decays	$\mathcal{B}(B \to \tau\nu)$ [10^{-6}]	$96(1 \pm 27\%)$ [26]	10%	3%
	$\mathcal{B}(B \to \mu\nu)$ [10^{-6}]	< 1.7 [67]	20%	7%
	$R(B \to D\tau\nu)$	$0.440(1 \pm 16.5\%)$ [29]†	5.2%	2.5%
	$R(B \to D^*\tau\nu)^\dagger$	$0.332(1 \pm 9.0\%)$ [29]†	2.9%	1.6%
	$\mathcal{B}(B \to K^{*+}\nu\bar{\nu})$ [10^{-6}]	< 40 [30]	< 15	30%
	$\mathcal{B}(B \to K^{+}\nu\bar{\nu})$ [10^{-6}]	< 55 [30]	< 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}]	$2.2 \pm 4.0 \pm 0.8$ [68]	1	0.5
	$S(B \to K_S^0 \pi^0 \gamma)$	$-0.10 \pm 0.31 \pm 0.07$ [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% [36]	10%	5%
	$\mathcal{B}(B_s \to \gamma\gamma)$ [10^{-6}]	< 8.7 [42]	0.3	–
	$\mathcal{B}(B_s \to \tau\tau)$ [10^{-3}]	–	< 2 [44]‡	–

	Observables	Belle (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
Charm Rare	$\mathcal{B}(D_s \to \mu\nu)$	$5.31 \cdot 10^{-3}(1 \pm 5.3\% \pm 3.8\%)$ [46]	2.9%	0.9%
	$\mathcal{B}(D_s \to \tau\nu)$	$5.70 \cdot 10^{-3}(1 \pm 3.7\% \pm 5.4\%)$ [46]	3.5%	3.6%
	$\mathcal{B}(D^0 \to \gamma\gamma)$ [10^{-6}]	< 1.5 [49]	30%	25%
Charm CP	$A_{CP}(D^0 \to K^+K^-)$ [10^{-2}]	$-0.32 \pm 0.21 \pm 0.09$ [69]	0.11	0.06
	$A_{CP}(D^0 \to \pi^0\pi^0)$ [10^{-2}]	$-0.03 \pm 0.64 \pm 0.10$ [70]	0.29	0.09
	$A_{CP}(D^0 \to K_S^0\pi^0)$ [10^{-2}]	$-0.21 \pm 0.16 \pm 0.09$ [70]	0.08	0.03
Charm Mixing	$x(D^0 \to K_S^0\pi^+\pi^-)$ [10^{-2}]	$0.56 \pm 0.19 \pm {}^{0.07}_{0.13}$ [52]	0.14	0.11
	$y(D^0 \to K_S^0\pi^+\pi^-)$ [10^{-2}]	$0.30 \pm 0.15 \pm {}^{0.05}_{0.08}$ [52]	0.08	0.05
	$\lvert q/p\rvert(D^0 \to K_S^0\pi^+\pi^-)$	$0.90 \pm {}^{0.16}_{0.15} \pm {}^{0.08}_{0.06}$ [52]	0.10	0.07
	$\phi(D^0 \to K_S^0\pi^+\pi^-)$ [°]	$-6 \pm 11 \pm {}^{4}_{5}$ [52]	6	4
Tau	$\tau \to \mu\gamma$ [10^{-9}]	< 45 [71]	< 4.6	< 0.5
	$\tau \to e\gamma$ [10^{-9}]	< 120 [71]	< 12	< 1.2
	$\tau \to \mu\mu\mu$ [10^{-9}]	< 21.0 [72]	< 4.5	< 0.5

Some Golden Modes with expected sensitivities for the Belle II program

arXiv:1002.5012 Belle II

Beam Backgrounds

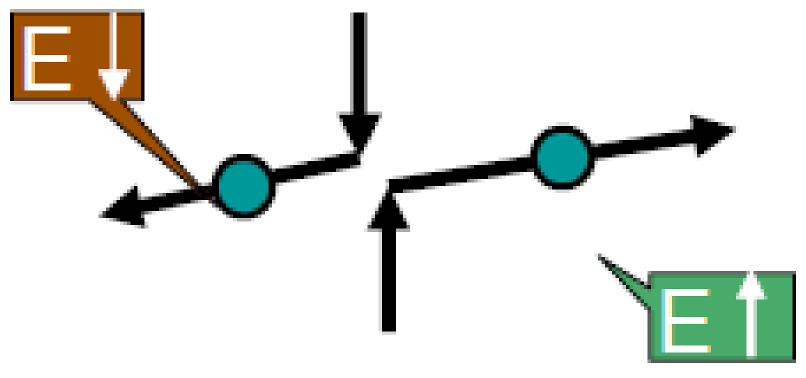
At SuperKEKB with x40 larger Luminosity, beam background will also increase drastically.

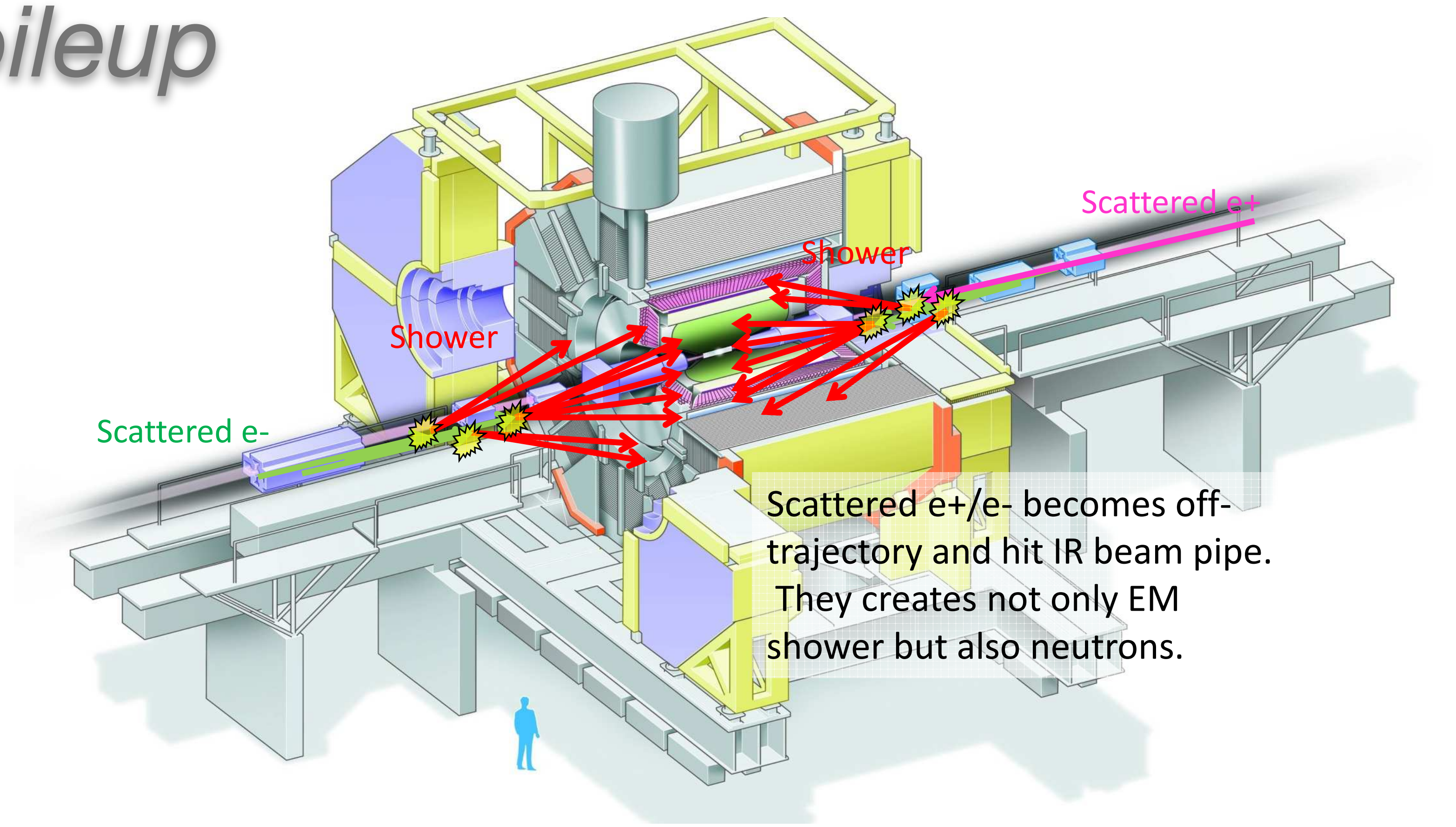
radiation damage, photosensor aging, pileup

Touschek scattering

Beam-gas scattering

Synchrotron radiation

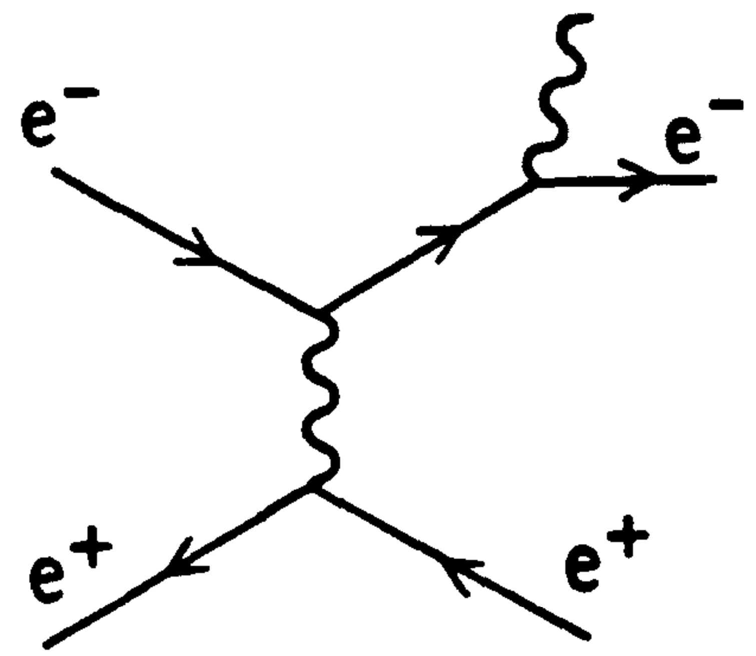


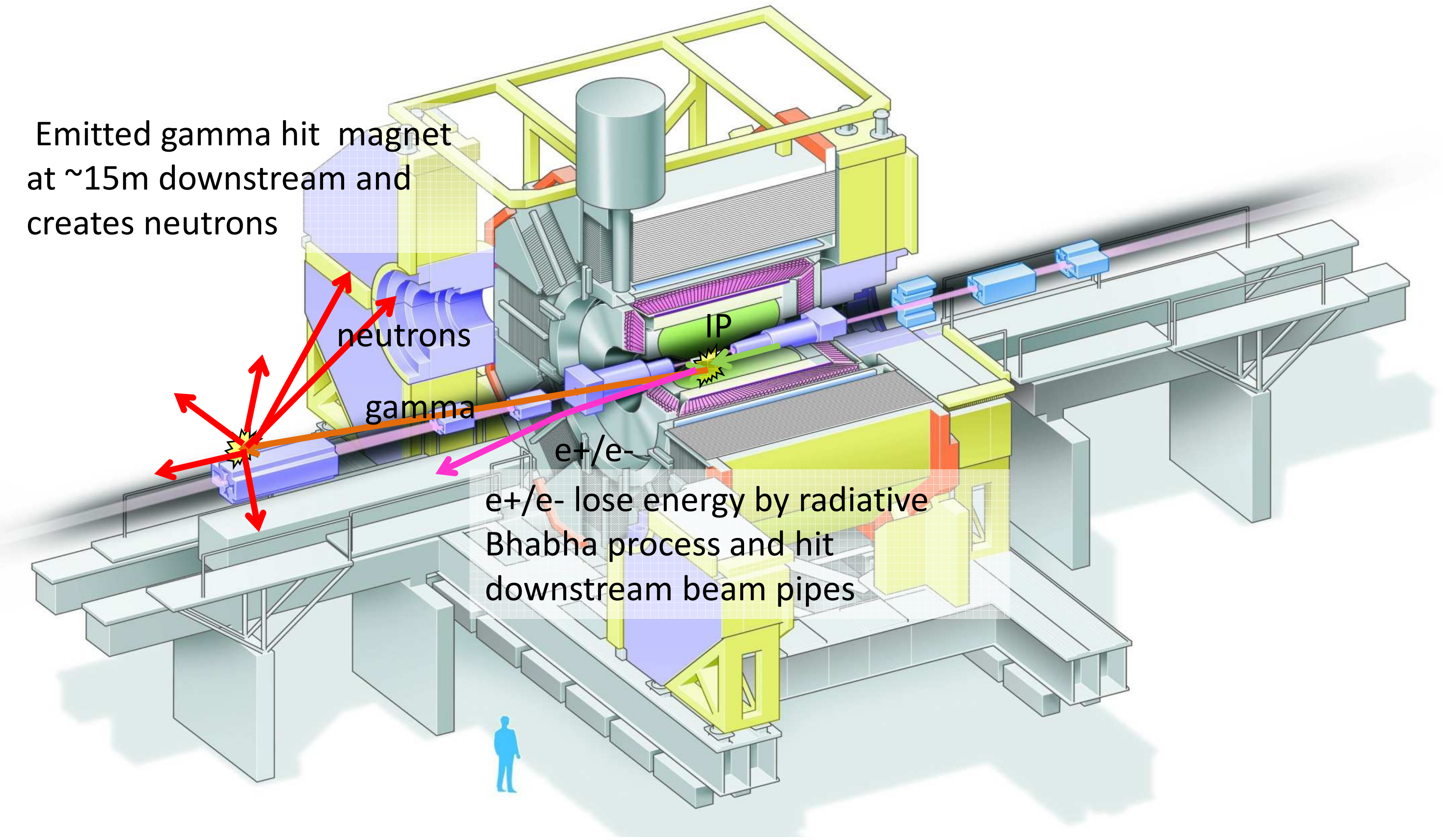


Radiative Bhabha:

emitted photons

spent electrons





2-photon process: $e^+e^- \to e^+e^-e^+e^-$

Belle II vs Belle