Charm CPV and Mixing prospects at the Belle II Experiment

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(for the Belle II Collaboration)

Outline :

- Introduction
- Charm CPV prospects at the Belle II
- Charm Mixing prospects at the Belle II
- Conclusions

2nd Flavour Physics Conference

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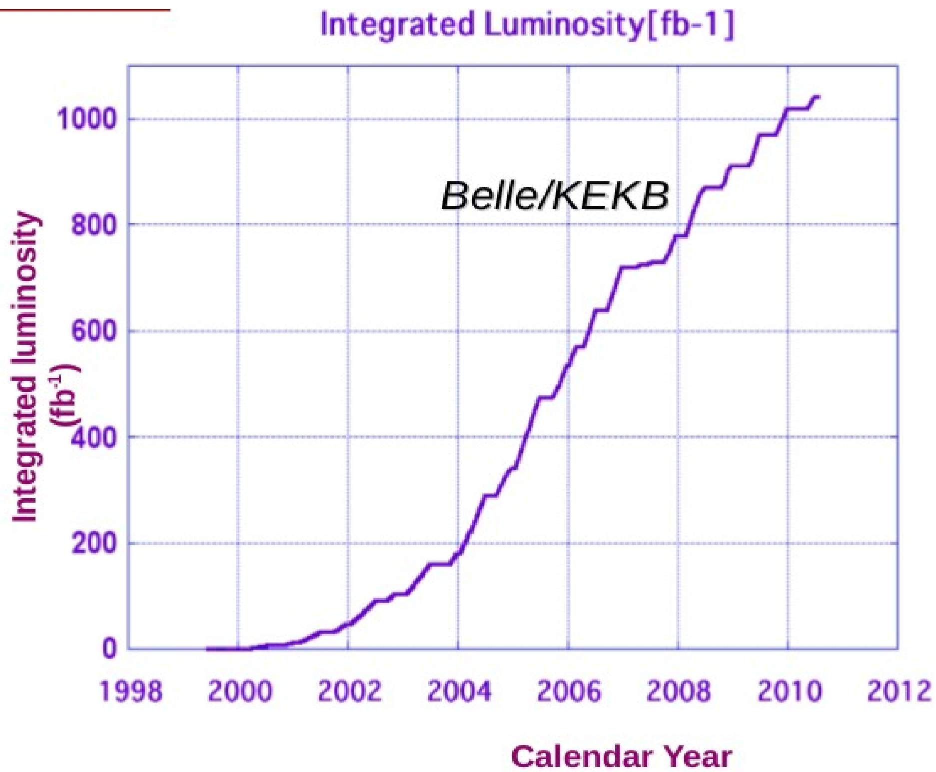
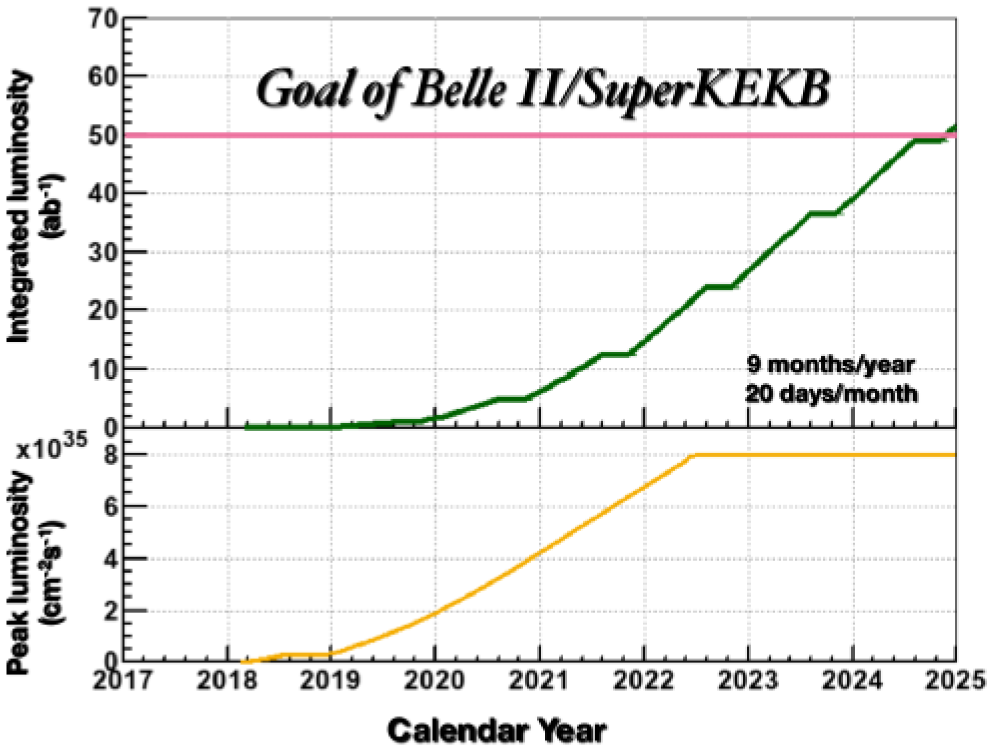
Introduction





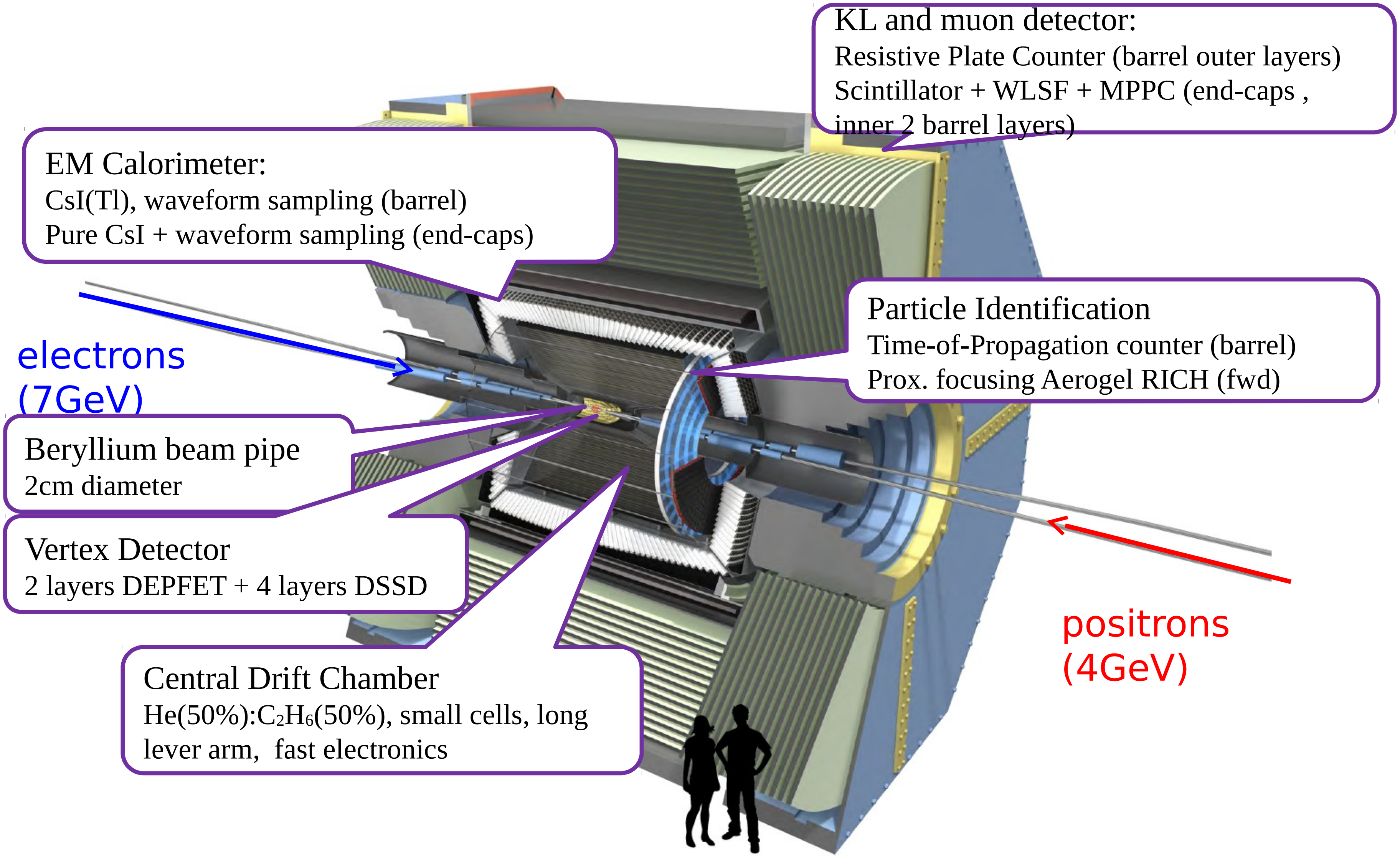
➢ New physics opportunities :

L_{int} = 50 ab^{-1} (50 X KEKB)

L_{peak} = 8 X 10^{35} $cm^{-2}s^{-1}$ (40X KEKB)

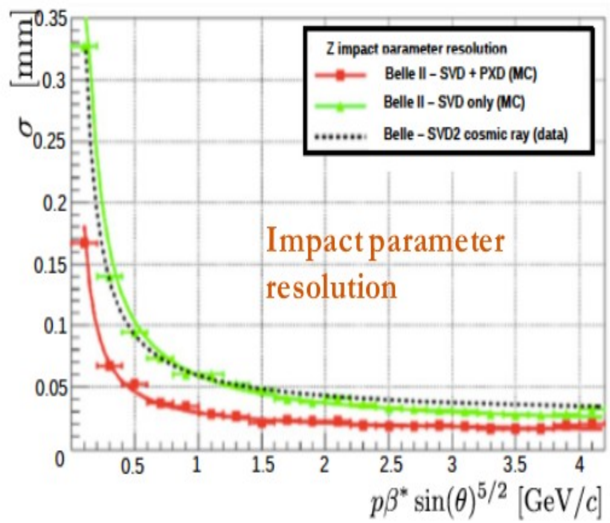
- Precise measurement of UT parameters
- New sources of CP violation
- Belle II will have a rich charm physics program: it should improve precision of mixing/CPV parameters, direct CP asymmetries etc..
- Lepton Flavour Violation in B and τ decays
- New physics search in missing energy modes of B decays, Dark matter, charged Higgs , etc..

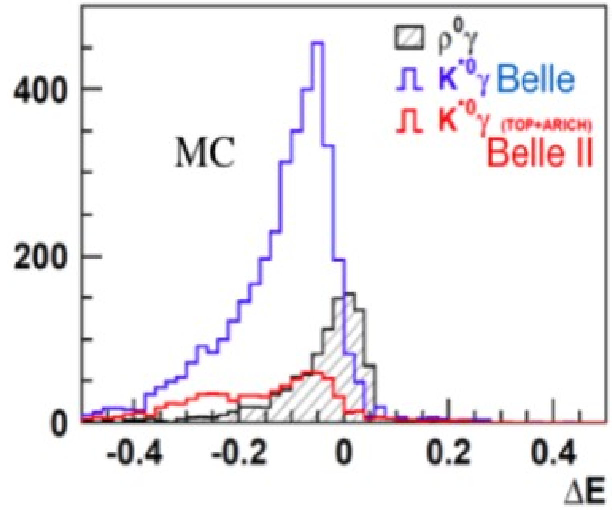
Belle II Detector

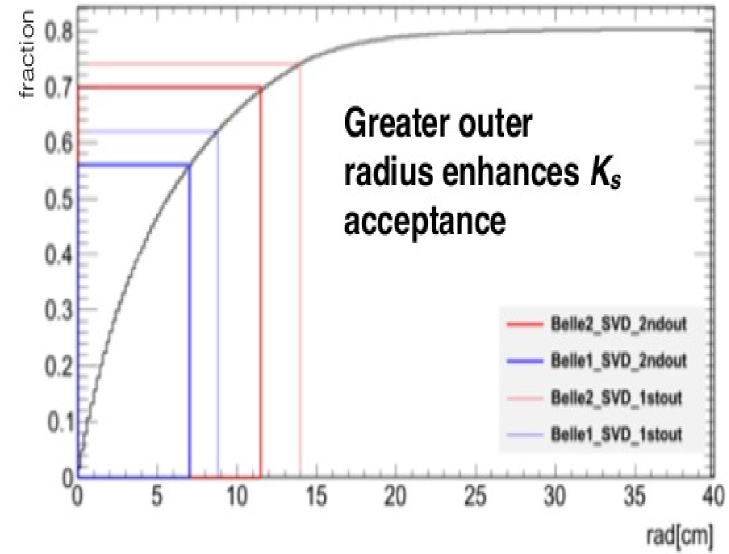


*** See the talk by Tadeas**

B Factory Improvements

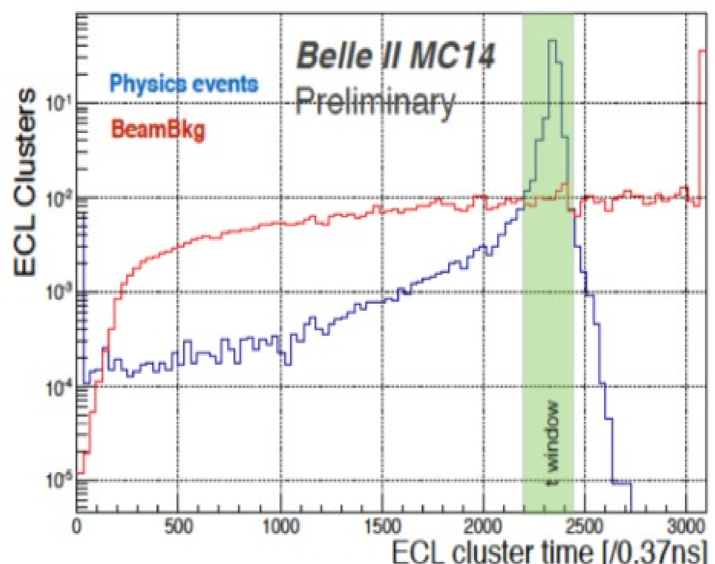






Improvements:

- IP and secondary vertex resolution
- K/π separation and flavour tagging
- machine background rejection
- K_s , π^0 and slow pions reconstruction efficiency
- Clean experimental environment, low track multiplicity and detector occupancy (w.r.t hadron collider)
  - High B, D, K, tau reconstruction efficiency
  - open trigger ~99% efficient

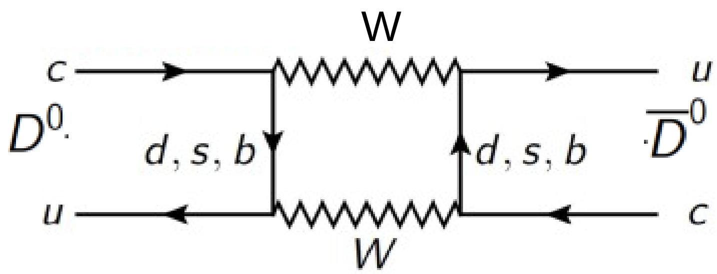


Mixing & CP violation

- **Indirect CP Violation :**

  Mixing in the up-quark sector only occurs for D meson

  mass eigenstates $|D^0_{1,2}\rangle = p|D^0\rangle \pm q|\overline{D}^0\rangle$



- CP violation observables in mixing/induced: A_Γ , y_{CP}
- A_Γ primarily probes indirect CP violation:

$$M = \frac{M1 + M2}{2}$$

$$\Gamma = \frac{\Gamma1 + \Gamma2}{2}$$

$$x = \frac{\Delta M}{\Gamma}$$

$$y = \frac{\Delta\Gamma}{2\Gamma}$$

CP violation in interference

$$A_\Gamma = \frac{\hat{\Gamma}(D^0 \to f) - \hat{\Gamma}(\bar{D}^0 \to f)}{\hat{\Gamma}(D^0 \to f) + \hat{\Gamma}(\bar{D}^0 \to f)} = \frac{1}{2}\left[\left(\left|\frac{q}{p}\right| - \left|\frac{p}{q}\right|\right) y\cos\phi - \left(\left|\frac{q}{p}\right| + \left|\frac{p}{q}\right|\right) x\sin\phi\right]$$

CP violation in mixing

It relates to A_{CP} (t) by

$$A_{CP}(t) \approx a^{\rm dir}_{CP} + a^{\rm ind}_{CP}\frac{t}{\tau_D}$$

with $a_{CP}^{ind} = - A_\Gamma$

- In the absence of direct CP violation, y_{CP} is given by

$$y_{CP} = \frac{\hat{\tau}(D^0 \to K^-\pi^+)}{\hat{\tau}(D^0 \to K^+K^-)} - 1 = \frac{1}{2}\left[\left(\left|\frac{q}{p}\right| + \left|\frac{p}{q}\right|\right) y\cos\phi - \left(\left|\frac{q}{p}\right| - \left|\frac{p}{q}\right|\right) x\sin\phi\right]$$

y_{CP} = y for no CPV

CP violation

- **Direct CP Violation**

Occurs when $A(D \to f) \neq = \bar{A}(\bar{D} \to \bar{f})$

- direct CPV is searched for through time- integrated asymmetries

$$A_{CP} = \frac{\Gamma(D \to f) - \Gamma(\bar{D} \to \bar{f})}{\Gamma(D \to f) + \Gamma(\bar{D} \to \bar{f})}$$

- ΔA_{CP} is mostly a measurement of direct CP violation:

$$\Delta a_{CP}^{dir} = \frac{|A_f|^2 - |\bar{A}_{\bar{f}}|^2}{|A_f|^2 + |\bar{A}_{\bar{f}}|^2}$$

$$|D^0_{1,2}\rangle = p|D^0\rangle \pm q|\overline{D}^0\rangle$$

q/p ≠ 1 => **indirect CP violation**

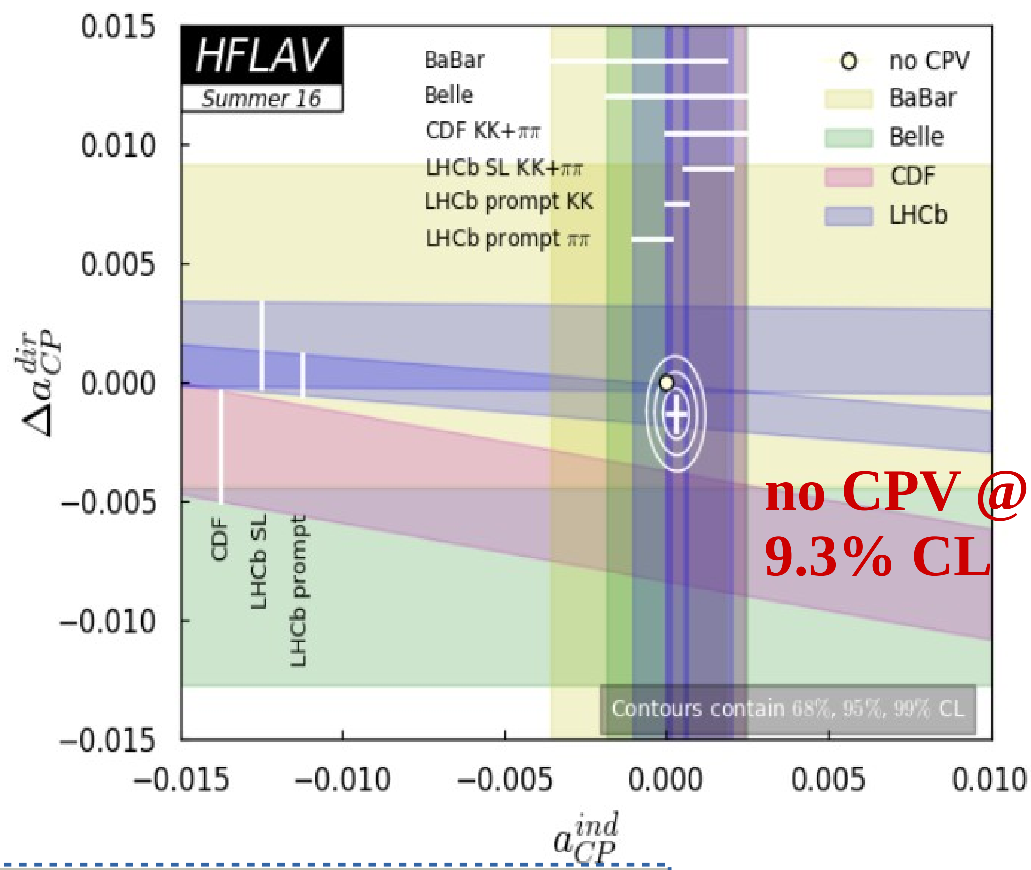
$q/p = |q/p| * e^{i\varphi}$:

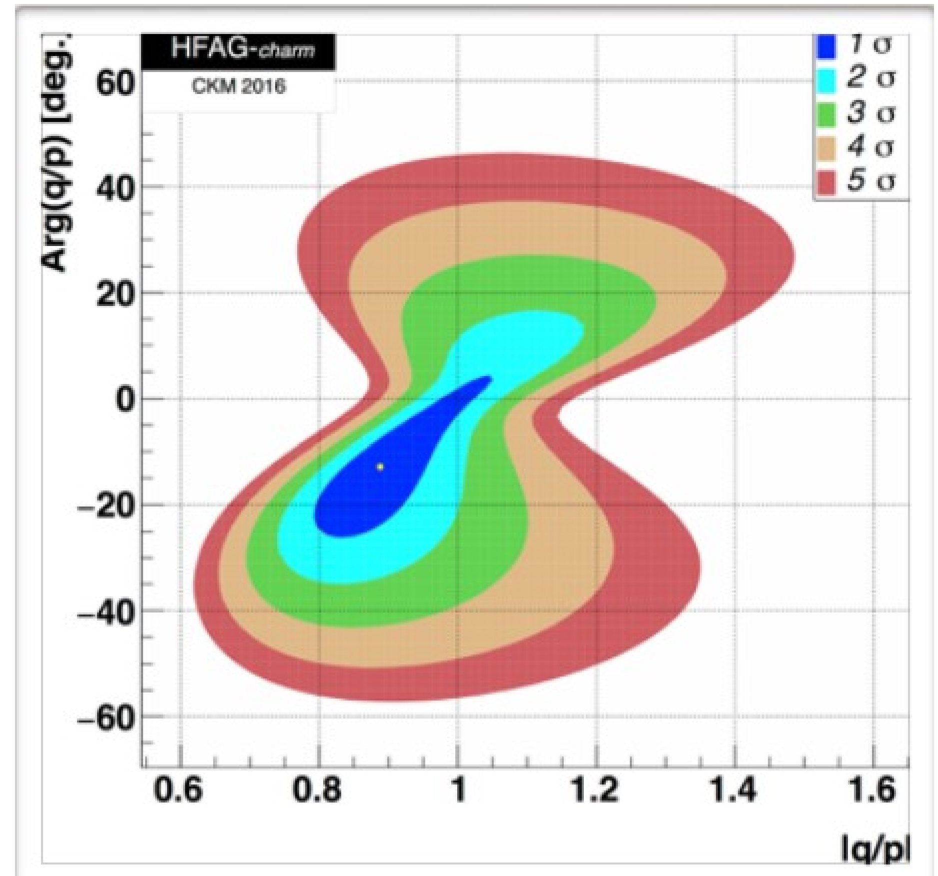
- $|q/p| \neq 1$ => CP violation in mixing
- $\varphi \neq 0(\pi) \Rightarrow$ CP violation in interference of decays w/ and w/o mixing
- D^0 only, common to all decay modes

- Level of CP violation in the SM hard to estimate. Expected asymmetries $\mathcal{O}(10^{-3})$ **(CHARM)**
- All three species (D^0 , D^+ , D_s^+), decay mode dependent

Charm CPV results

CPV in $D^0 \rightarrow h^+h^-$ decays , h= K, **π**





$a_{CP}^{ind} = (0.030 \pm 0.026)\%$

$\Delta a_{CP}^{dir} = (-0.134 \pm 0.070)\%$

- No clear evidence of direct CPV (no CP violation at 9.3% CL)
- No hints of indirect CPV, CL = 40%

Direct CPV in D Decays

Belle measurements extrapolated to 50 ab^{-1}

Extrapolation:

$$\sigma_{BelleII} = \sqrt{(\sigma_{stat}^2 + \sigma_{sys}^2)\frac{\mathcal{L}_{Belle}}{50\ \mathrm{ab}^{-1}} + \sigma_{ired}^2}$$

mainly due to K^0-$\bar{K}^0$ interaction asymmetry

Time-integrated measurements: Prospects

mode	$\mathcal{L}$ (fb^{-1})	A_{CP} (%)	Belle II at 50 ab^{-1}
$D^0 \to K^+K^-$	976	$-0.32 \pm 0.21 \pm 0.09$	± 0.03
$D^0 \to \pi^+\pi^-$	976	$+0.55 \pm 0.36 \pm 0.09$	± 0.05
$D^0 \to \pi^0\pi^0$	966	$-0.03 \pm 0.64 \pm 0.10$	± 0.09
$D^0 \to K_s^0\pi^0$	966	$-0.21 \pm 0.16 \pm 0.07$	± 0.03
$D^0 \to K_s^0\eta$	791	$+0.54 \pm 0.51 \pm 0.16$	± 0.07
$D^0 \to K_s^0\eta'$	791	$+0.98 \pm 0.67 \pm 0.14$	± 0.09
$D^0 \to \pi^+\pi^-\pi^0$	532	$+0.43 \pm 1.30$	± 0.13
$D^0 \to K^+\pi^-\pi^0$	281	-0.60 ± 5.30	± 0.40
$D^0 \to K^+\pi^-\pi^+\pi^-$	281	-1.80 ± 4.40	± 0.33
$D^+ \to \phi\pi^+$	955	$+0.51 \pm 0.28 \pm 0.05$	± 0.04
$D^+ \to \eta\pi^+$	791	$+1.74 \pm 1.13 \pm 0.19$	± 0.14
$D^+ \to \eta'\pi^+$	791	$-0.12 \pm 1.12 \pm 0.17$	± 0.14
$D^+ \to K_s^0\pi^+$	977	$-0.36 \pm 0.09 \pm 0.07$	± 0.03
$D^+ \to K_s^0K^+$	977	$-0.25 \pm 0.28 \pm 0.14$	± 0.05
$D_s^+ \to K_s^0\pi^+$	673	$+5.45 \pm 2.50 \pm 0.33$	± 0.29
$D_s^+ \to K_s^0K^+$	673	$+0.12 \pm 0.36 \pm 0.22$	± 0.05
$D^+ \to \pi^+\pi^0$			$\pm(0.2 - 0.4)$

LHCb Measurement	Now %	50fb^{-1} %
$D^0 \to K^+K^-$	0.15	0.03
$D^+ \to K_SK^+$	0.14	0.03
$D_s^+ \to K_S\pi^+$	0.17	0.03

ArXiv:1208.3355

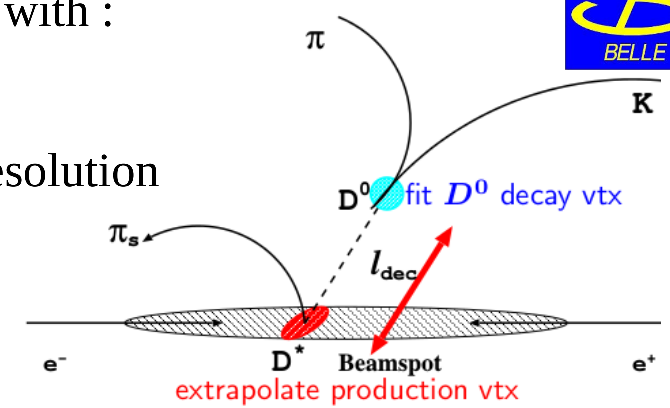
- Only D^* tagging method considered and A_{CP} precision will reach ***O*** (10^{-4}) better than the current theoretical predictions
- Belle II will provide best precision for **neutral particle final states**, but will be competitive with LHCb for charged particle final states as well
- **Both forthcoming experiments, Belle II and LHCb upgrade are complimentary to each other !!**

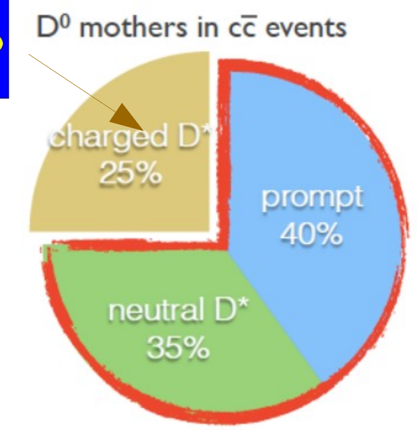
New flavour tagging method

- D^{*+} from B decays can be completely rejected with :

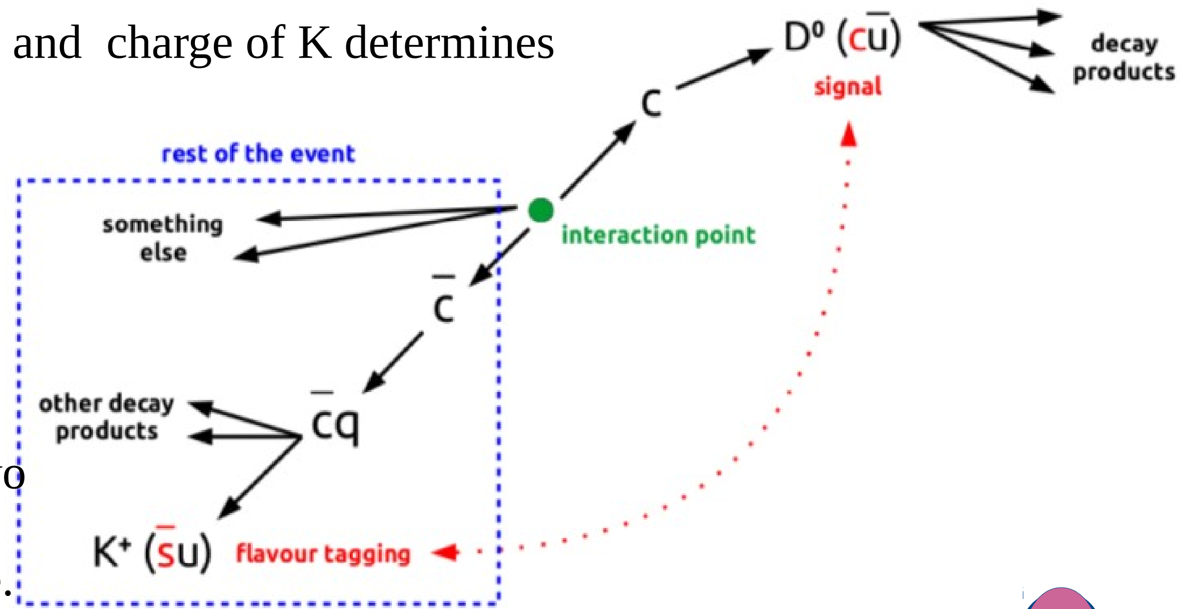
$$p_{D*}^{CMS} > 2.5\ GeV/c$$

- IP constrained refit of π slow to improve ΔM resolution





- Observables: $m(D^0)$, $\Delta M \equiv m(D^*) - m(D^0)$ or $Q \equiv \Delta M - m_\pi$
- Lose 75% of D^0 in cc-bar events at B-factories
- Rest of the event (ROE) D^0 flavour tagging [improve statistics]
- Select events with only one $K^\pm$ in the ROE and charge of K determines the flavour of D^0 at production
- Tagging K : a. BDT with a first loose cut to reject most of the background and count the number of charged kaons,
  b. tighter cut to reject fake kaons
- The expected improvement combining the two Flavour tagging techniques (D* & ROE) is **~15%,** depending on the purity of the sample.



$D^0 \to K_S\pi^0, \pi^0\pi^0, K_SK_S$

Expected precision for future measurements

$$A_{CP}(D^0 \to K_S^0\pi^0) = (-0.21 \pm 0.16 \pm 0.07)\%,$$

$$A_{CP}(D^0 \to \pi^0\pi^0) = (-0.03 \pm 0.64 \pm 0.10)\%,$$

$$A_{CP}(D^0 \to K_S^0K_S^0) = (-0.02 \pm 1.53 \pm 0.17)\%$$

@ 50ab^{-1}

$$\sigma_{\rm total}^{A_{CP}^{K_S^0\pi^0}} = \sqrt{(0.16^2 + 0.09^2) \times 0.996\ {\rm ab}^{-1}/\mathcal{L}_{\rm int} + 0.01^2}\ [\times 10^{-2}],\ \mathbf{0.03\%}$$

$$\sigma_{\rm total}^{A_{CP}^{\pi^0\pi^0}} = \sqrt{(0.64^2 + 0.10^2) \times 0.996\ {\rm ab}^{-1}/\mathcal{L}_{\rm int} + 0.01^2}\ [\times 10^{-2}],\ \mathbf{0.09\ \%}$$

$$\sigma_{\rm total}^{A_{CP}^{K_S^0K_S^0}} = \sqrt{(1.53^2 + 0.17^2) \times 0.921{\rm ab}^{-1}/\mathcal{L}_{\rm int} + 0.01^2}[\times 10^{-2}]\quad \mathbf{0.21\ \%}$$

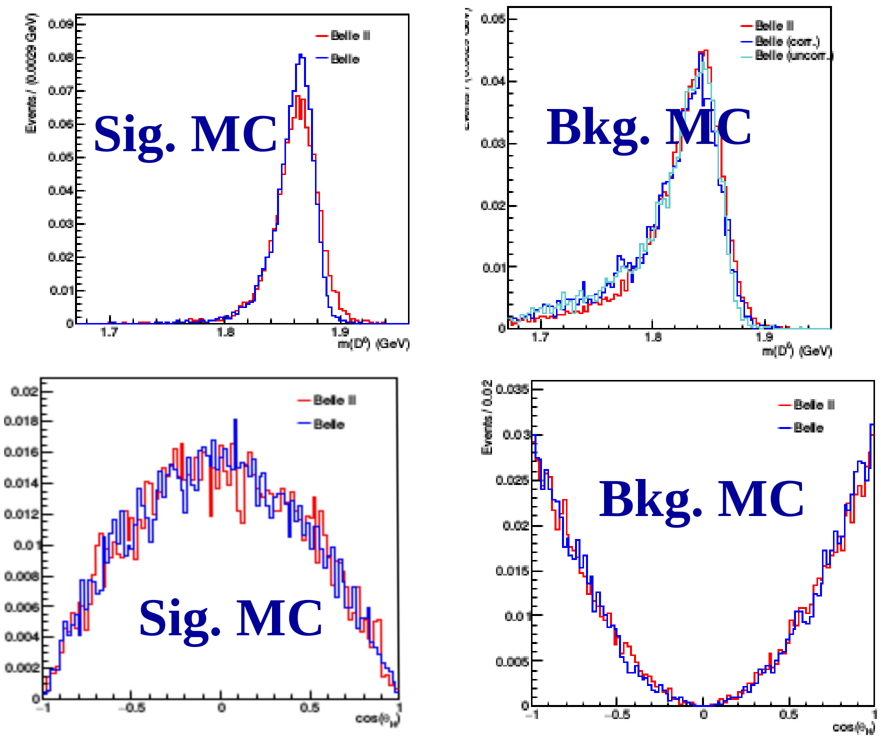
- The outer radius of the SVD detector has been significantly increased from 8.8 to 14.0 cm
- Large various of SVD will allow % more KS candidates whose daughters have associated SVD hits

- Expect similar systematic error in Belle II
- irreducible sys. err. due to the neutral K interactions in the material (0.01×10^{-2})
- Large fraction of systematics will be reduced With higher statistics

- Dominant error arises from ACP measurements of $K_s\pi^0$ errors on $K_s\pi^0$ will reduce with increased statistics at Belle II

$D^0 \to V\gamma$

	Int. luminosity	$A_{CP}(D^0 \to \rho^0\gamma)$
Belle result	1 ab^{-1}	$+0.056 \quad \pm0.152 \quad \pm0.006$
	5 ab^{-1}	±0.07
Belle II statistical error	15 ab^{-1}	±0.04
	50 ab^{-1}	±0.02
		$A_{CP}(D^0 \to \phi\gamma)$
Belle result	1 ab^{-1}	$-0.094 \quad \pm0.066 \quad \pm0.001$
	5 ab^{-1}	±0.03
Belle II statistical error	15 ab^{-1}	±0.02
	50 ab^{-1}	±0.01
		$A_{CP}(D^0 \to \overline{K}^{*0}\gamma)$
Belle result	1 ab^{-1}	$-0.003 \quad \pm0.020 \quad \pm0.000$
	5 ab^{-1}	±0.01
Belle II statistical error	15 ab^{-1}	±0.005
	50 ab^{-1}	±0.003



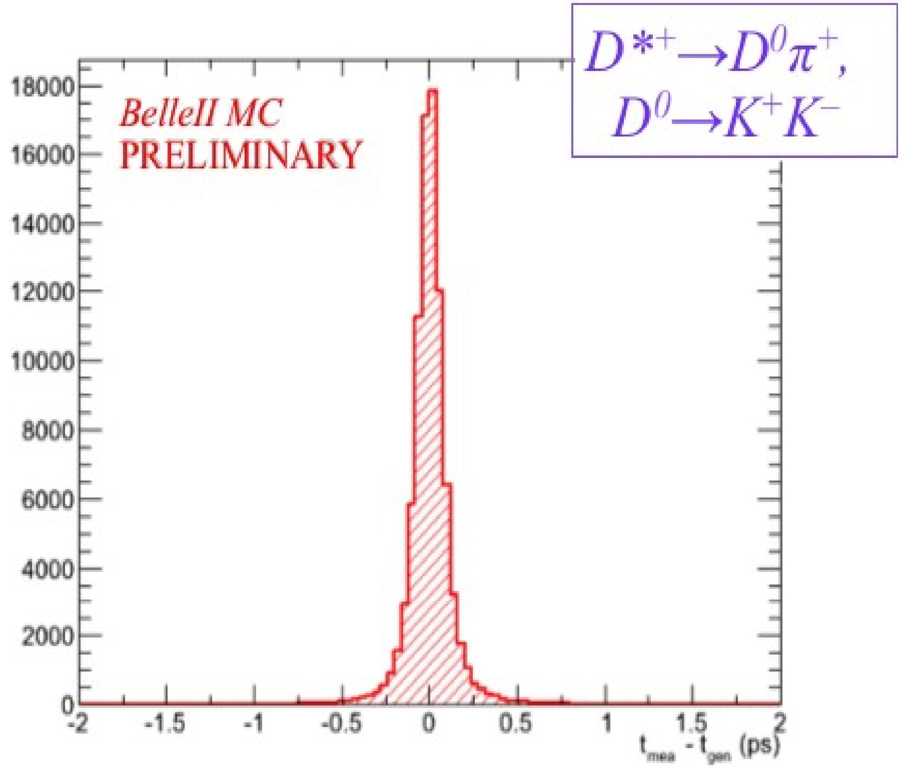
	Belle	Belle II
Signal efficiency	9.8%	7.2%
Signal Mean	1.8645±0.0003	1.8642±0.0003
Signal width	0.0122±0.0001	0.0164±0.0002
π^0 bkg. mean	1.8428±0.0007	1.8421±0.0005
π^0 bkg. width	0.0187±0.0003	0.0194±0.0003

- Same selection criteria used for Belle II sensitivity study as in Belle
- The resolution looks similar on the Belle II sample, compared to Belle, but background is a challenge .

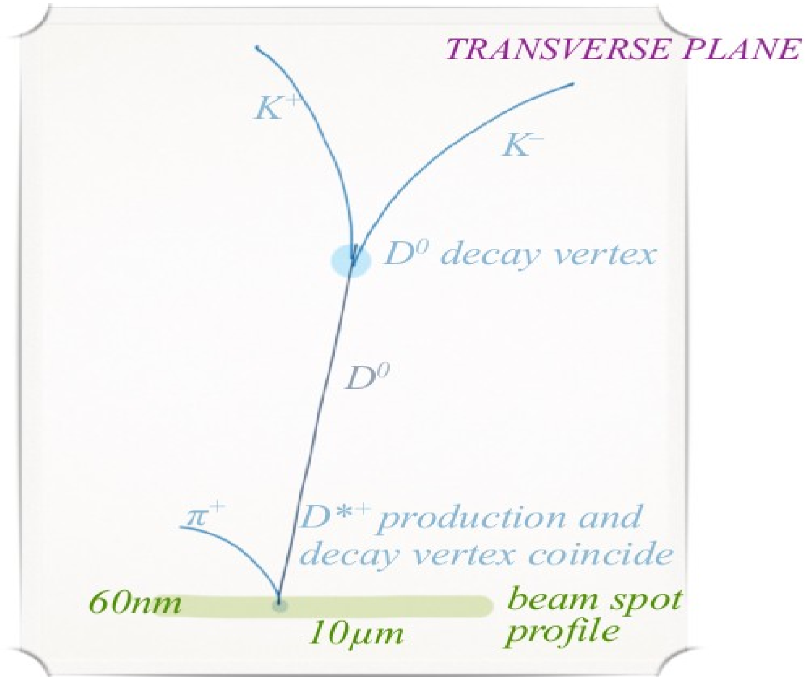
D^0 proper time resolution

proper time :

$$t = \frac{\ell}{\beta\gamma c} = \frac{\ell}{c}\frac{m_D}{|\vec{p}|}$$



Proper time resolution



experiment	σ_t		t resolution	
	mean	RMS	mean	RMS
Belle II	73 fs	41 fs	6.5 fs	135 fs
BaBar	245 fs	95 fs	-0.48 fs	271 fs

- vertex detector allows to reconstruct the D^0 decay vertex with a precision of **∼ 40μm**
- benefit from this improved the precision of the determination of the D^0 proper time is improved by **a factor two**

Mixing in D Decays: Prospects w Belle II

Analysis	Observable	Uncertainty(%)		
		Now (~ 1 ab^{-1})	$\mathcal{L}$ = 50ab^{-1}	Improved t resol. (ToyMC)
$D^0 \to K_S\pi^+\pi^-$	x y |q/p| φ	0.20 0.16 17.8 12.2	0.11 0.05 7.0-7.4 4.0-4.2	
$D^0 \to \pi^+\pi^-, K^+K^-$	y_{cp} A_Γ	0.24 0.22	0.05-0.08 0.03-0.05	
$D^0 \to \pi^-K^+$	x' x'^2 y' |q/p| φ	 0.022 0.34 0.6 0.44 rad	 0.003 0.04 0.06 0.04 rad	0.15 - 0.10 0.051 0.09

do better on x' and y' than just scaling

N.B. statistical error and some systematics scale by luminosity, but other systematics do not.

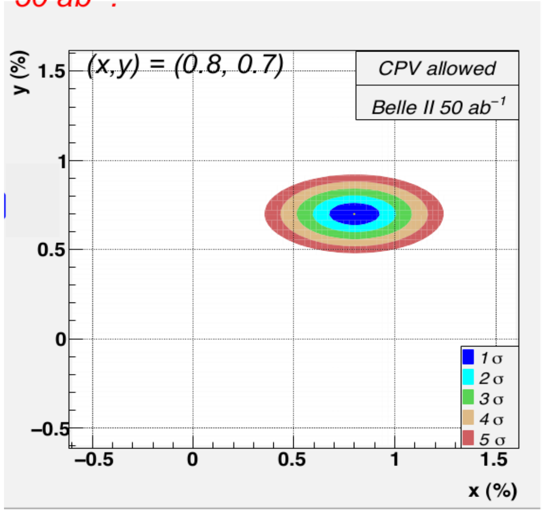
[Belle2-PUB-DRAFT-2016-012] (LHCb: arXiv:1208.3355)

Conclusions

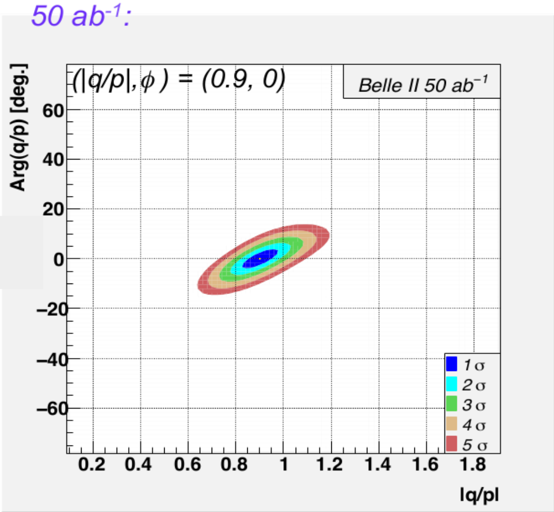
- B factories have proven to be an excellent tool for charm physics, producing a wealth of physics results
- CP violation was searched in many decay modes
- No evidence found for CPV in the charm sector
- Prospects for these measurements at Belle II were also discussed in some cases the sensitivity would reach a 0.03% level.
- Belle II will have a rich charm physics program: it should improve precision of mixing/CPV parameters, direct CP asymmetries.

- Belle II will implement novel tagging method (ROE) to increase statistics and The expected improvement combining the two Flavour tagging techniques (D* & ROE) is **~15%,** depending on the purity of the sample.
- CPV in D decays is a challenge for the upcoming upgrades of LHCb and Belle ; Belle II will provide results competitive and complementary to LHCb.

50 ab^{-1}:



50 ab^{-1}:



only estimated in $D^0 \to K_s \pi \pi$ @ Belle II

Thank You…!!

BACK UP

Rare decays

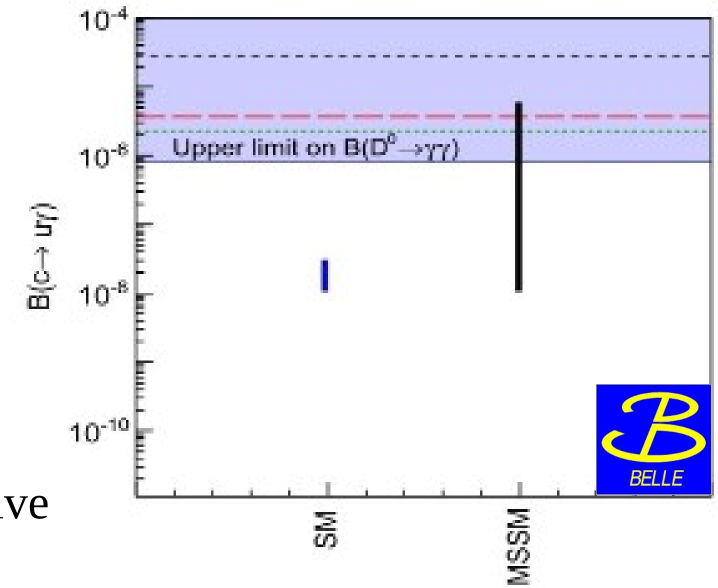
Rare charm decays, e.g. $D^0 \rightarrow \gamma\gamma$

predicted BF a few x 10^{-8}

Belle result 8.5×10^{-7} @ 90% C.L.

(PRD 93, 051102(R), 2016; 832 fb-1 data)

expected to reach 10^{-7}~10^{-8}(with full Belle II data)



dominate the precision of the BF($D^0 \rightarrow \gamma\gamma$) with $50ab^{-1}$, to a relative accuracy of around 20%-30%

	Observables	Belle or LHCb* (2014)	Belle II $5\ ab^{-1}$	Belle II $50\ ab^{-1}$	LHCb 2018 $50\ fb^{-1}$
Charm Rare	$\mathcal{B}(D_s \rightarrow \mu\nu)$	$5.31 \cdot 10^{-3}(1 \pm 5.3\% \pm 3.8\%)$	2.9%	0.9%	
	$\mathcal{B}(D_s \rightarrow \tau\nu)$	$5.70 \cdot 10^{-3}(1 \pm 3.7\% \pm 5.4\%)$	3.5%	2.3%	
	$\mathcal{B}(D^0 \rightarrow \gamma\gamma)$ $[10^{-6}]$	< 1.5	30%	25%	

$D^+ \to K_S K^+,\ K_S \pi^+$)

$A_{CP}^{K_S^0 K^+} = (-0.25 \pm 0.28 \pm 0.14)\%$

$A_{CP}^{K_S^0 \pi^+} = (-0.363 \pm 0.094 \pm 0.067)\%$

PRL 109, 021601 (2012) , JHEP 02, 98(2013)

Source	$A_\epsilon^{K^+}$	$\cos\theta_{D^+}^{\text{CMS}}$ binning	Fitting	A_D correction
Value	0.133	0.021	0.008	0.010

- consistent with zero
- consistent also with expected CPV due to K^0-mixing $(-0.345 \pm 0.008)\%$
- no evidence for CPV in charm sector

- 3.2σ away from zero
- consistent with expected CPV due to K^0-mixing $(-0.345 \pm 0.008)\%$

$$\sigma_{\text{total}}^{A_{CP}^{K_S^0 K^+}} = \sqrt{(0.275^2 + 0.124^2 + \rho 0.053^2) \times 0.976\ \text{ab}^{-1}/\mathcal{L}_{\text{int}} + (1-\rho)0.053^2}\ [\times 10^{-2}].$$

- KS efficiency associated charged pion silicon hits is improved by the upgrade of the silicon vertex detector by around 30%:

prospects for time-intergraded CPV

$D^0 \to KK, \pi\pi$

time-integrated $D^0 \to K^+K^-, \pi^+\pi^-$

977 fb^{-1} preliminary: BELLE $\Delta A \equiv A_{KK} - A_{\pi\pi} = (-0.87 \pm 0.41 \pm 0.06)\%$

Source	$\Delta A_{CP}^{K^+K^-}$ $[10^{-2}]$	$\Delta A_{CP}^{\pi^+\pi^-}$ $[10^{-2}]$
Signal counting	0.055	0.023
Slow pion correction	0.065	0.067
A_{CP} extraction	0.006	0.050
total syst. error	0.085	0.087
stat. error	0.210	0.360

- Slow π correction uncertainty: Flavor od D*,
- scales with integrated luminosity
- ACP extraction: Calculation of final CP asymmetry in the bins of different kinematic variable
- higher statistics, uncertainty becomes negligible

Irreducible errors:
Signal counting: Possible difference between the background
shape in signal and sideband intervals of **Q**

Expected precision for future measurements

$$\sigma_{\text{total}}^{A_{CP}^{K^+K^-}} = \sqrt{(0.220 + 0.066^2) \times 0.976\ \text{ab}^{-1}/\mathcal{L}_{\text{int}} + 0.055^2}\ [\times 10^{-2}]$$

$$\sigma_{\text{total}}^{A_{CP}^{\pi^+\pi^-}} = \sqrt{(0.370 + 0.085^2) \times 0.976\ \text{ab}^{-1}/\mathcal{L}_{\text{int}} + 0.018^2}\ [\times 10^{-2}]$$

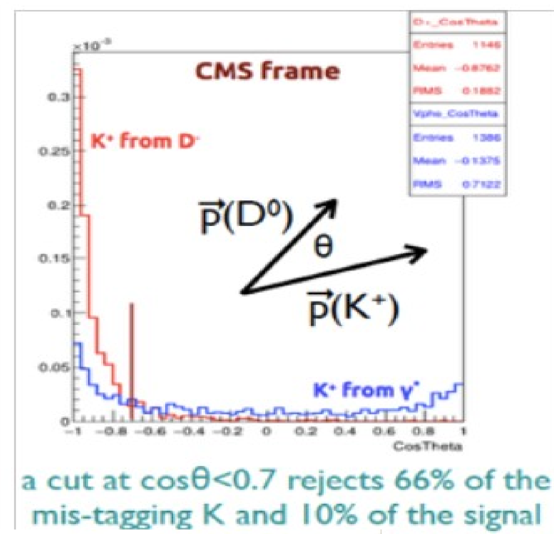
- Experiment better in charm 2-body decay ~30%

[Belle II Internal Note]

- Tagging kaons are mostly back-to-back

- Tagging efficiency (ε) = 15 %, mis-tagging level (w) < 5%, after vetoing presence of neutral kaons K_L and K_S in the ROE [from MC truth]

- A novel tagging method which will: increase statistics with an additional D^0 sample and will be very useful to evaluate systematics independently.

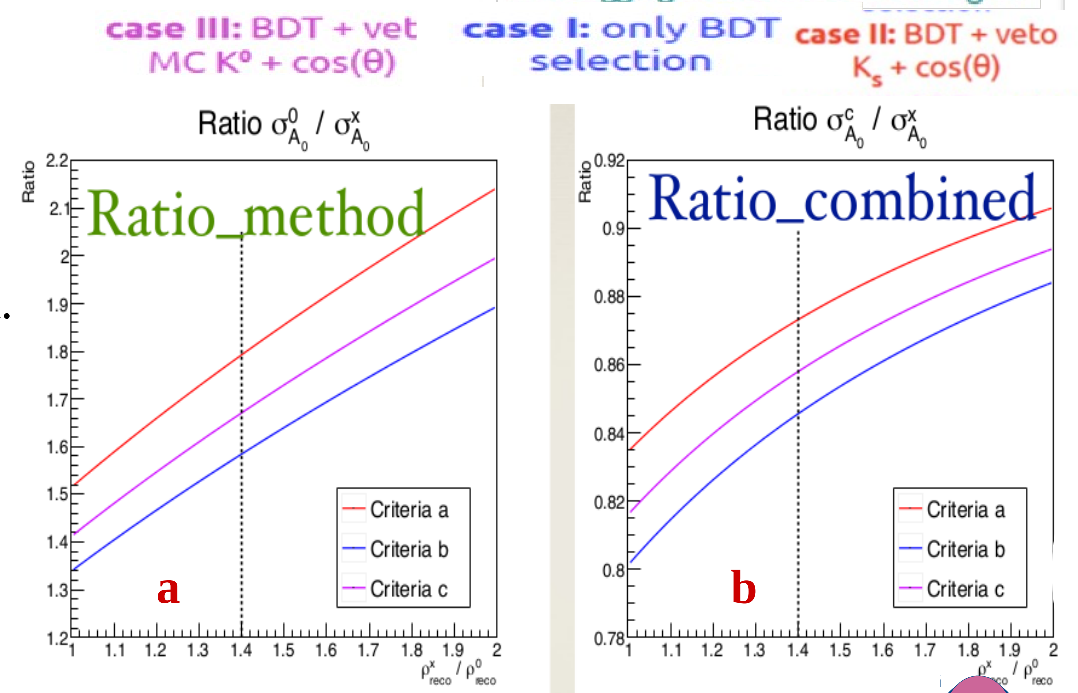


- a: Ratio between the statistical error on a A_{CP} measurement using the two different flavour tagging methods (D* and ROE, given by σ^X and σ^0) as a function of the purity of D^0 samples.

- b: Ratio between the combined statistical error (σ^C) and the statistical error from the D* method.

- Reference point for the ratio of the purity of D^0 samples: 1.4 **[PhysRevD.87.012004]**

- In the best case, assuming the value 1.4 for Belle II, we can expect a reduction of **~15%** of the statistical error on a A_{CP} measurement.



	KEKB Design	KEKB Achieved : with crab	SuperKEKB Nano-Beam
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	4.0/7.0
β_y^* (mm)	10/10	5.9/5.9	0.27/0.30
β_x^* (mm)	330/330	1200/1200	32/25
ε_x (nm)	18/18	18/24	3.2/5.3
$\varepsilon_y/\varepsilon_x$ (%)	1	0.85/0.64	0.27/0.24
σ_y(μm)	1.9	0.94	0.048/0.062
ξ_y	0.052	0.129/0.090	0.09/0.081
σ_z (mm)	4	6 - 7	6/5
I_{beam} (A)	2.6/1.1	1.64/1.19	3.6/2.6
$N_{bunches}$	5000	1584	2500
Luminosity (10^{34} cm^{-2} s^{-1})	1	2.11	80

Nano-beams are the key (vertical spot size is ~50nm !!)

Table of Belle II detector performance parameters

Component	Type	Configuration	Readout	Performance
Beam pipe	Beryllium double-wall	Cylindrical, inner radius 10 mm, 10 μm Au, 0.6 mm Be, 1 mm coolant (paraffin), 0.4 mm Be		
PXD	Silicon pixel (DEPFET)	Sensor size: 15×100 (120) mm^2 pixel size: 50×50 (75) μm^2 2 layers: 8 (12) sensors	10 M	impact parameter resolution $\sigma_{z_0} \sim 20\ \mu$m (PXD and SVD)
SVD	Double sided Silicon strip	Sensors: rectangular and trapezoidal Strip pitch: 50(p)/160(n) - 75(p)/240(n) μm 4 layers: 16/30/56/85 sensors	245 k	
CDC	Small cell drift chamber	56 layers, 32 axial, 24 stereo r = 16 - 112 cm $-83 \le z \le 159$ cm	14 k	$\sigma_{r\phi} = 100\ \mu$m, $\sigma_z = 2$ mm $\sigma_{p_t}/p_t = \sqrt{(0.2\% p_t)^2 + (0.3\%/\beta)^2}$ $\sigma_{p_t}/p_t = \sqrt{(0.1\% p_t)^2 + (0.3\%/\beta)^2}$ (with SVD) $\sigma_{dE/dx} = 5\%$
TOP	RICH with quartz radiator	16 segments in ϕ at $r \sim 120$ cm 275 cm long, 2 cm thick quartz bars with 4x4 channel MCP PMTs	8 k	$N_{p.e.} \sim 20$, $\sigma_t = 40$ ps K/π separation : efficiency > 99% at < 0.5% pion fake prob. for $B \to \rho\gamma$ decays
ARICH	RICH with aerogel radiator	4 cm thick focusing radiator and HAPD photodetectors for the forward end-cap	78 k	$N_{p.e.} \sim 13$ K/π separation at 4 GeV/c: efficiency 96% at 1% pion fake prob.
ECL	CsI(Tl) (Towered structure)	Barrel: $r = 125$ - 162 cm End-cap: $z =$ -102 cm and +196 cm	6624 1152 (F) 960 (B)	$\frac{\sigma_E}{E} = \frac{0.2\%}{E} \oplus \frac{1.6\%}{\sqrt[4]{E}} \oplus 1.2\%$ $\sigma_{pos} = 0.5$ cm/$\sqrt{E}$ (E in GeV)
KLM	barrel: RPCs	14 layers (5 cm Fe + 4 cm gap) 2 RPCs in each gap	θ: 16 k, ϕ: 16 k	$\Delta\phi = \Delta\theta = 20$ mradian for K_L ~ 1 % hadron fake for muons
	end-caps: scintillator strips	14 layers of $(7-10) \times 40$ mm^2 strips read out with WLS and G-APDs	17 k	$\Delta\phi = \Delta\theta = 10$ mradian for K_L $\sigma_p/p = 18\%$ for 1 GeV/c K_L

SuperKEKB/Belle II is the intensity frontier facility for B mesons, charm mesons and tau leptons.

SuperKEKB TDR parameters

		LER (e+)	HER (e-)	units
Beam Energy	E	4	7	GeV
Half Crossing Angle	ϕ	41.5		mrad
Horizontal Emittance	ε_x	3.2(2.7)	2.4(2.3)	nm
Emittance ratio	$\varepsilon_y/\varepsilon_x$	0.40	0.35	%
Beta Function at the IP	β_x^*/β_y^*	32 / 0.27	25 / 0.41	mm
Horizontal Beam Size	σ_x^*	10.2(10.1)	7.75(7.58)	μm
Vertical Beam Size	σ_y^*	59	59	nm
Betatron tune	ν_x/ν_y	45.530/45.570	58.529/52.570	
Momentum Compaction	α_c	2.74×10^{-4}	1.88×10^{-4}	
Energy Spread	σ_ε	$8.14(7.96) \times 10^{-4}$	$6.49(6.34) \times 10^{-4}$	
Beam Current	I	3.60	2.62	A
Number of Bunches/ring	n_b	2503		
Energy Loss/turn	U_0	2.15	2.50	MeV
Total Cavity Voltage	V_c	8.4	6.7	MV
Synchrotron Tune	ν_s	-0.0213	-0.0117	
Bunch Length	σ_z	6.0(4.9)	5.0(4.9)	mm
Beam-Beam Parameter	ξ_y	0.0900	0.0875	
Luminosity	L	8×10^{35}		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$

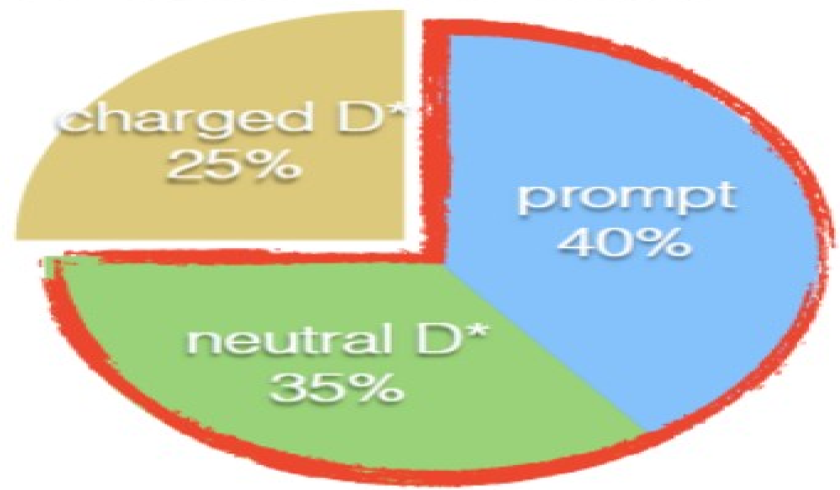
Table 2.2: Machine Parameters of SuperKEKB. Values in parentheses denote parameters at zero beam currents.

Source	$\pi^0\pi^0$	$K_S^0\pi^0$
Signal shape	±0.03	±0.01
Slow pion correction	±0.07	±0.07
A_{CP} extraction method	±0.07	±0.02
$K^0/\overline{K}^0$-material effects	–	±0.01
Total	±0.10	±0.07

$K_S K_S$

Source	Systematic uncertainty, in %
Signal shape	±0.01
Peaking background	±0.01
$K^0/\bar{K}^0$ material effects	±0.01
A_{CP} measurement of $K_S^0\pi^0$	±0.17
Total	±0.17

D^0 mothers in $c\bar{c}$ events



Typical Correctly Tagging Events

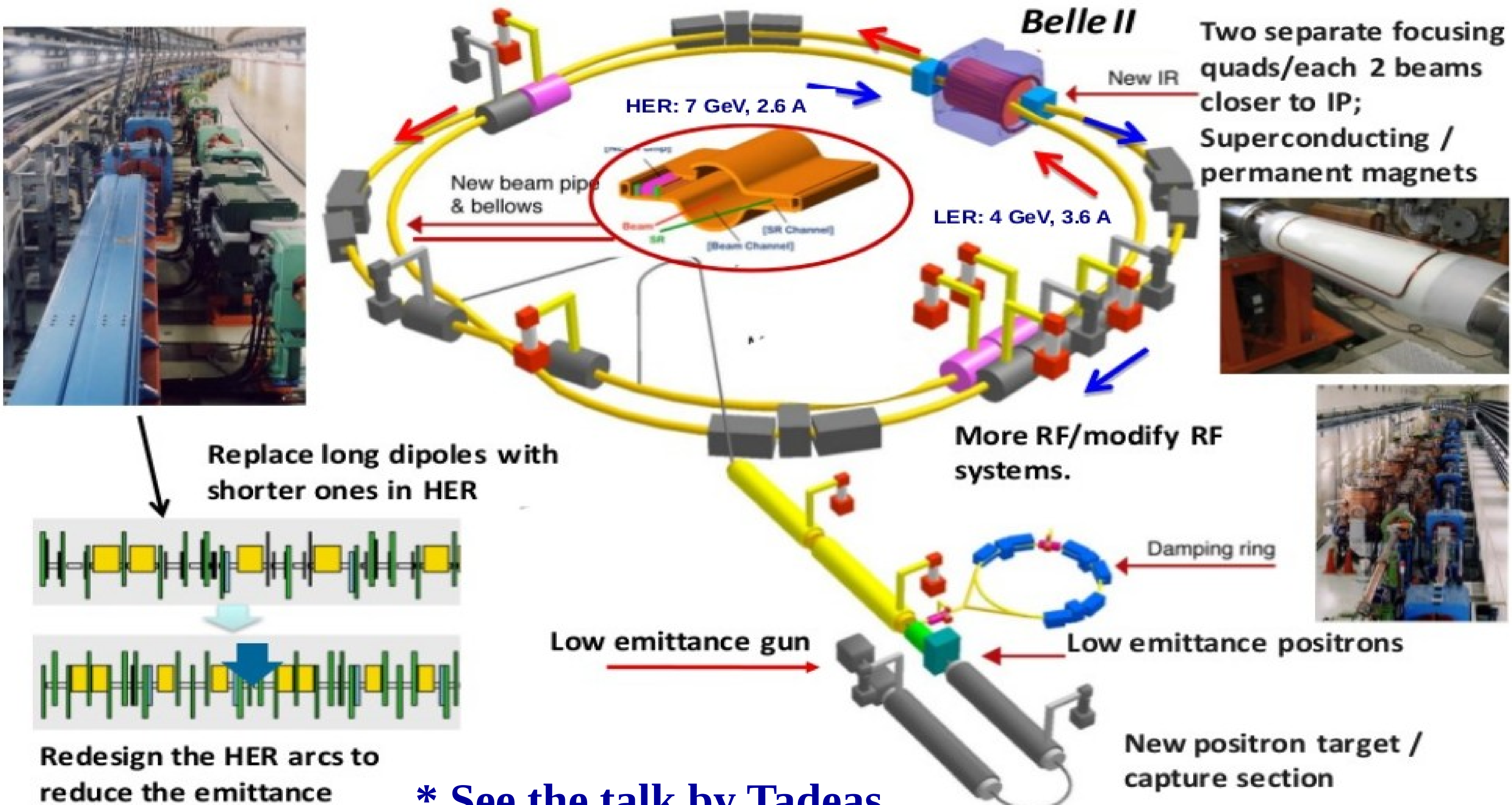
$cc \to D^0 D^- X$, $D^0 \to$ signal ch

$D^- \to K^{*0} e^- \nu$; $K^{*0} \to K^+\pi^-$

$cc \to D^0 \Lambda_c^- X$, $D^0 \to$ signal ch

$\Lambda_c^- \to \Delta^{--} K^{*+}$; $K^{*+} \to K^+\pi^0$

KEKB upgrade → SuperKEKB(nano-beam)



*** See the talk by Tadeas**

estimated error on	current	Belle + BaBar	scaled	Toy MC with improved σ_t PRELIMINARY	
	HFAG	1.5/ab	50/ab	50/ab, no CPV	50/ab, CPV
x' (%)	–	(*) 0.98	(*) 0.45	(*) 0.22	0.15
x'^2 (%)	–	0.0195	0.009	0.0044	–
y' (%)	–	0.321	0.16	0.047	0.10
|q/p|	0.1	–	–	–	0.051
Φ (deg)	10	–	–	–	5.7