Charm physics prospects at the Belle II experiment

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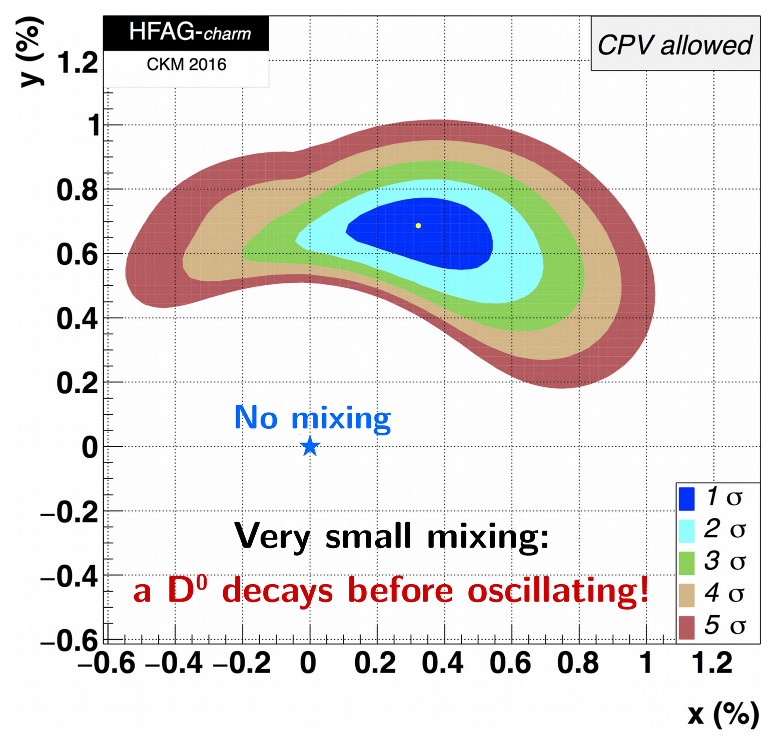
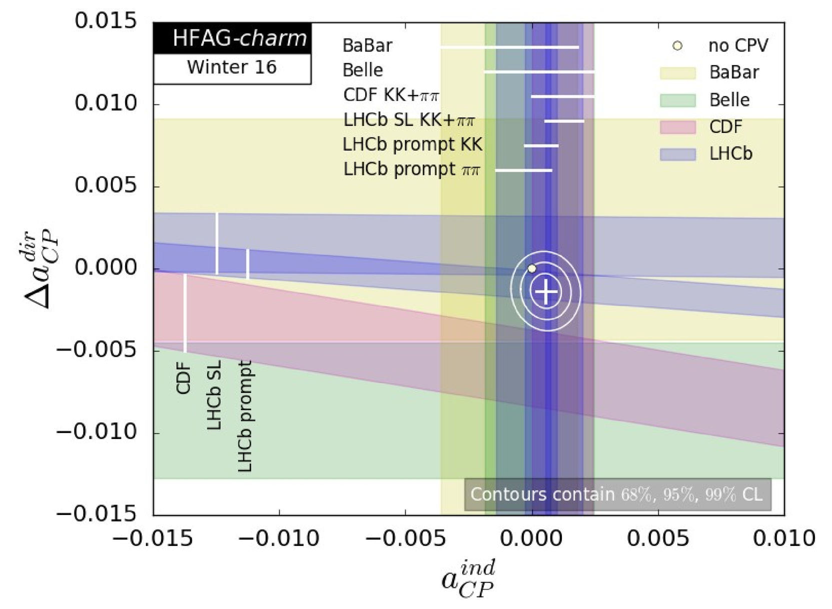
Charm physics: the state of the art





No CPV at 6.5% CL

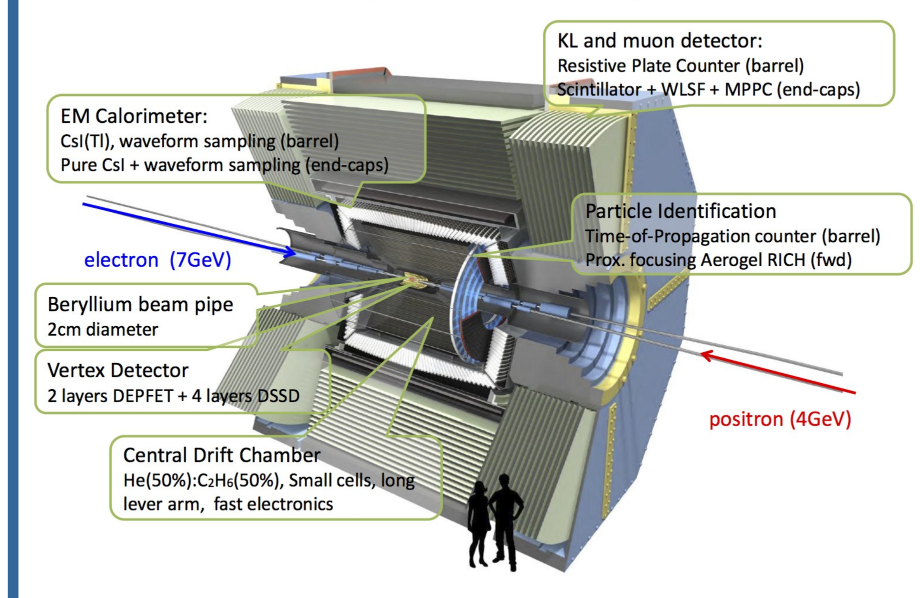
Unique system to study mixing and CPV in the **up-quark** sector

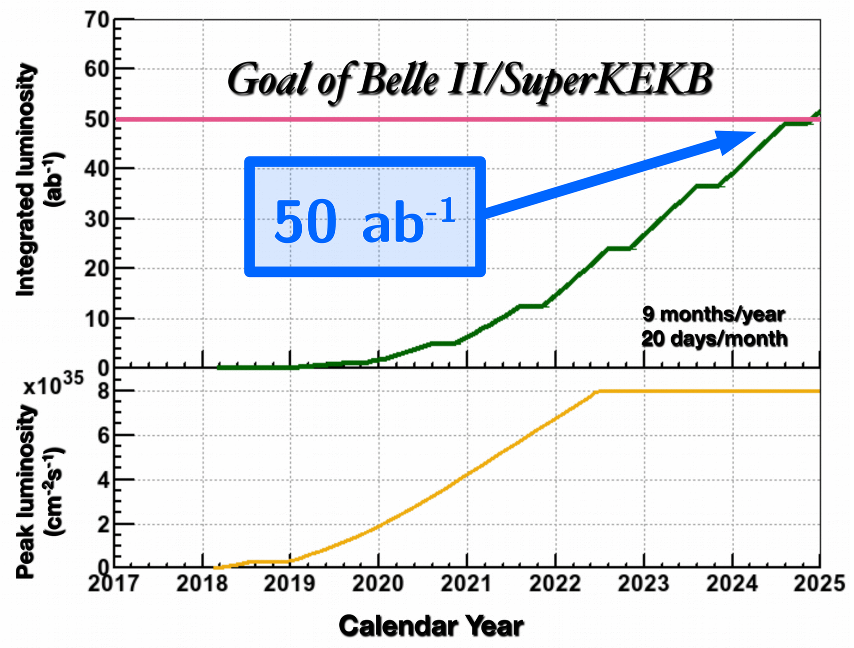
Measurements are achieving a **sub-percentage level** of precision

Difficult to make theoretical predictions (**non-perturbative effects**)

Belle II experiment @ SuperKEKB

Belle II Detector





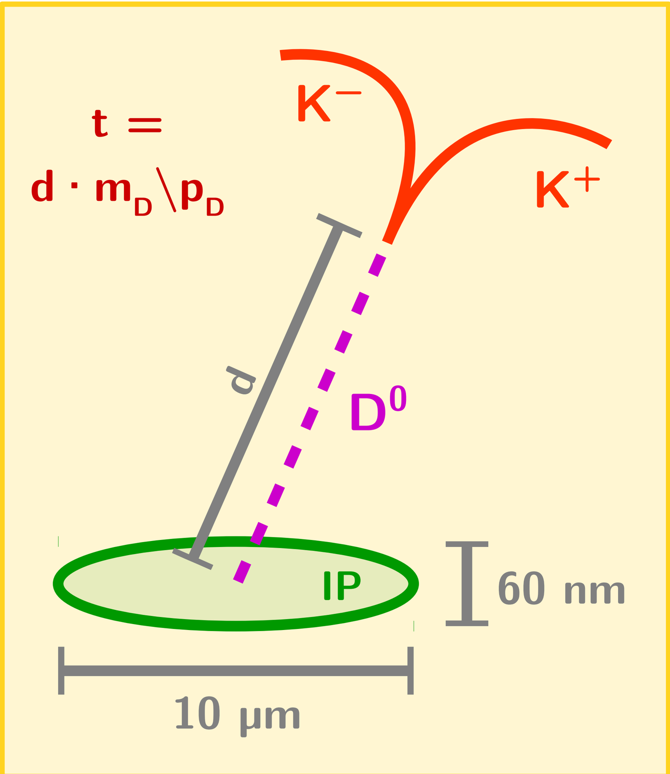
Innermost layer of the vertex detector is **2 times closer** to the IP w.r.t. Belle

Great performances expected in the reconstruction of

final states with neutrals and **missing energy**

First data taking (without vertex detector) will start in **2018**

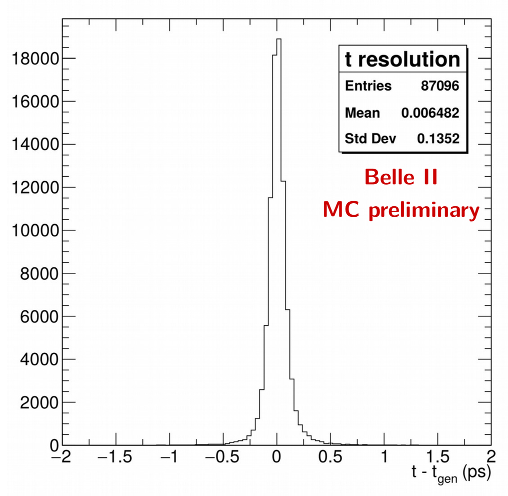
Proper time resolution and error



Proper time resolution:

2 times better

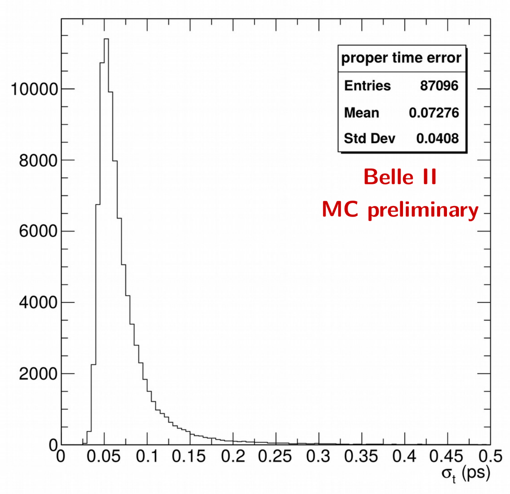
w.r.t. BaBar: **14 ps**



Proper time error:

3 times smaller

w.r.t. BaBar: **73 fs**

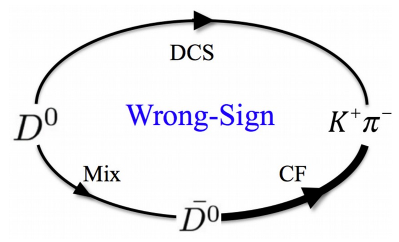


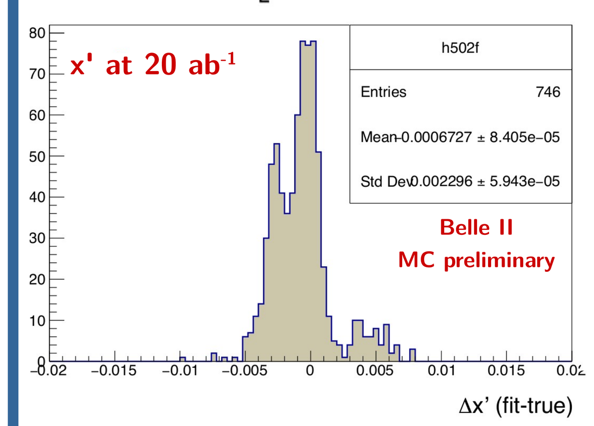
Impact on D^0-$\overline{D}^0$ mixing and CPV

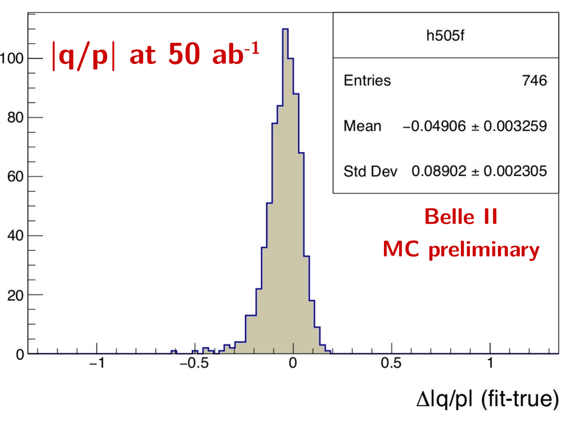
Toy MC study for the WS decay $D^0 \to K^+\pi^-$

(almost **background free** at the B-factories)

$$D^0(t) \propto e^{-\overline{\Gamma}t}\left[R_D + \left|\frac{q}{p}\right|\sqrt{R_D}(y'\cos\varphi - x'\sin\varphi)(\overline{\Gamma}t) + \left|\frac{q}{p}\right|^2 \frac{(x'^2+y'^2)}{4}(\overline{\Gamma}t)^2\right]$$







$|q/p|$ and φ are the CPV parameters; x' and y' are defined as:

$$x' = x\cos\delta + y\sin\delta$$

$$y' = y\cos\delta - x\sin\delta$$

where δ is the strong phase between $D^0 \to K^+\pi^-$ and $D^0 \to K^-\pi^+$

The expected sensitivity at 50 ab^{-1} is:

$\delta x' = 0.15\%$ $\delta y' = 0.10\%$ $\delta|q/p| = 0.05\%$ $\delta\varphi = 5.7°$

~ **1 order of magnitude better** than Belle ~ **1.6 times better** than the world average

Competitive with the upgrade of LHCb!

Impact on time-integrated CPV measurements

Current results from Belle for:

$$A_{CP} = \frac{\Gamma(D^0 \to X) - \Gamma(\overline{D}^0 \to \overline{X})}{\Gamma(D^0 \to X) + \Gamma(\overline{D}^0 \to \overline{X})}$$

Only correlations and sum rules

between A_{CP} for different final states

can be predicted precisely

(absolute values of A_{CP} have large uncertainties)

Channel	Current measurement $\mathcal{L}$ (fb^{-1})	value (%)	Scaled 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
$D^0 \to K^0_S\pi^0$	966	$-0.21 \pm 0.16 \pm 0.07$	±0.03
$D^0 \to K^0_S\eta$	791	$+0.54 \pm 0.51 \pm 0.16$	±0.07
$D^0 \to K^0_S\eta'$	791	$+0.98 \pm 0.67 \pm 0.14$	±0.09
$D^0 \to K^0_S K^0_S$	921	$-0.02 \pm 1.53 \pm 0.17$	±0.02
$D^0 \to \pi^+\pi^-\pi^0$	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
$D^0 \to \rho^0\gamma$	976	$+0.056 \pm 0.152 \pm 0.006$	±0.02
$D^0 \to \phi\gamma$	976	$-0.094 \pm 0.066 \pm 0.001$	±0.01
$D^0 \to \overline{K}^{*0}\gamma$	976	$-0.003 \pm 0.020 \pm 0.000$	±0.003
$D^+ \to \pi^0\pi^+$	ongoing analysis		±0.04
$D^+ \to \phi\pi^+$	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
$D^+ \to K^0_S\pi^+$	977	$-0.36 \pm 0.09 \pm 0.07$	±0.03
$D^+ \to K^0_S K^+$	977	$-0.25 \pm 0.28 \pm 0.14$	±0.05
$D^+_s \to K^0_S\pi^+$	673	$+5.45 \pm 2.50 \pm 0.33$	±0.29
$D^+_s \to K^0_S K^+$	673	$+0.12 \pm 0.36 \pm 0.22$	±0.05

$$\sigma_{\text{Belle II}} = \sqrt{(\sigma^2_{\text{stat}} + \sigma^2_{\text{syst}}) \cdot (\mathcal{L}_{\text{Belle}}/50\ \text{ab}^{-1}) + \sigma^2_{\text{irred}}}$$

Golden channels at Belle II:

$D^0 \to K_S K_S$ (CPV is enhanced in the SM predictions; limited by statistics at Belle)

$D^+ \to \pi^0\pi^+$ (No CPV in the SM: possible enhancement from NP)

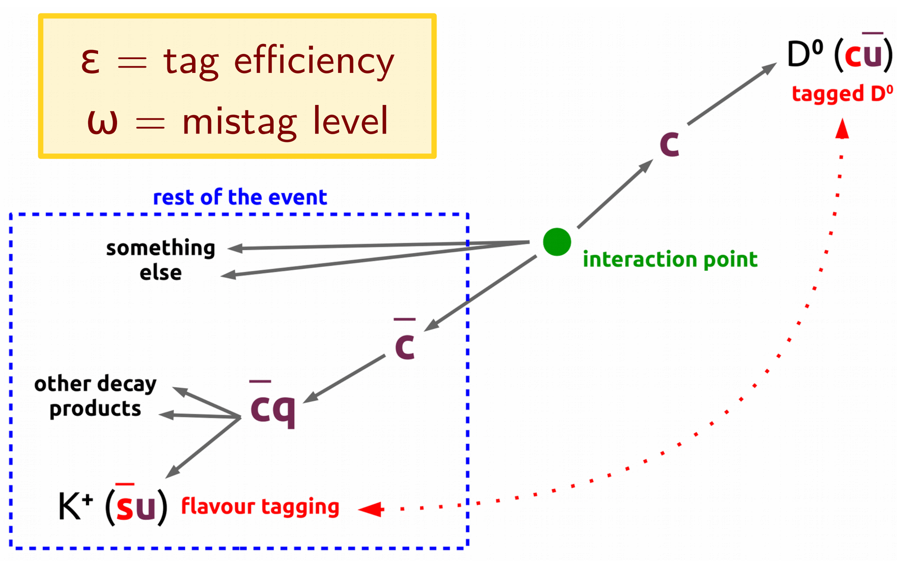
Flavour tagging: the ROE method

A new method: selecting events **with only 1 $K^\pm$ in the ROE**

to tag the flavour of D^0 at production

ε = tag efficiency

ω = mistag level



Expected perfomances:

ε ~ 27% ω ~ 13%

$Q^0 = \varepsilon \cdot (1 - 2\omega)^2$ ~ **20%**

(different selection criteria → different performances)

Performances for D^{*+} tag:

$Q^* = 0.8 \cdot (1 - 2 \cdot 0.02)^2$ ~ **80%**

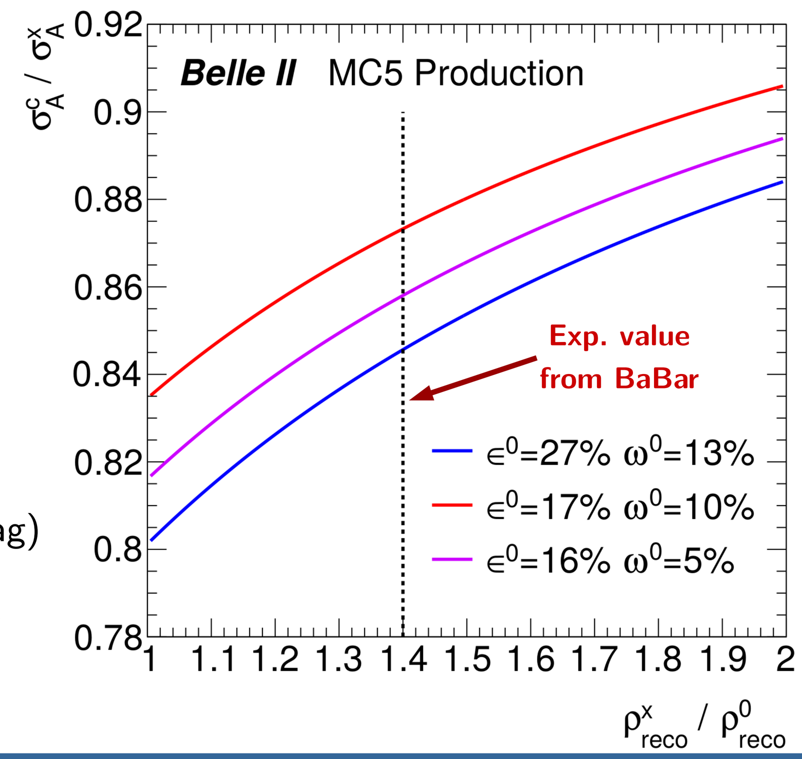
but only **25% of D^0 are from D^{*+}**

A fraction of D^0 can be doubly tagged: **measurement of Q^0 (ε,ω) on data**

15% reduction on statistical uncertainty of $A_{CP}(D^0 \to K^-\pi^+)$ combining the D^{*+} and ROE methods:

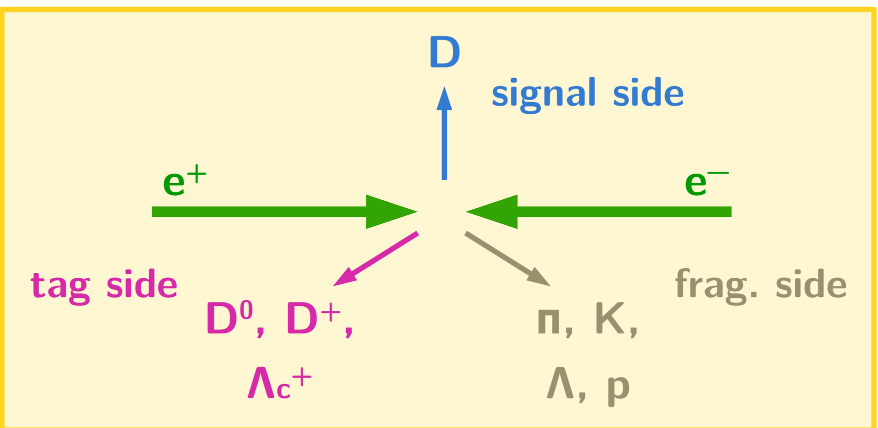
$$\frac{\sigma^c_{A_{CP}}}{\sigma^*_{A_{CP}}} = \frac{\alpha}{\sqrt{1+\alpha^2}} \; ; \quad \alpha \equiv \sqrt{\frac{1}{3} \cdot \frac{Q^*}{Q^0} \cdot \frac{\rho^*_{\text{reco}}}{\rho^0_{\text{reco}}}}$$

(where ρ^0 is the purity of the reconstructed D^0 tagged with the ROE method and ρ^* is the purity with the D^{*+} tag)



Enhancement of the effective luminosity by **35%** adding the ROE method

Leptonic and semileptonic decays



To study the (semi)leptonic decays, we look for configurations with **missing energy from the neutrino**:

$$P_{\text{miss}} = \sqrt{s} - P_{\text{tag}} - P_{\text{frag}} - P_l \; (- P_h)$$

M^2_{miss} peaks at 0 for the signal

Leptonic decays ($D_{(s)}^+ \to \mu^+\nu$)

Extracting $f_{D_q}|V_{cq}|^2$, the goals are:

- improve the most precise measurement of $|V_{cs}|$ (from Belle)
- measure $|V_{cd}|$ with **2%** of precision

Possibility to search for $D^0 \to$ invisibles

Semileptonic decays ($D \to hl^+\nu$)

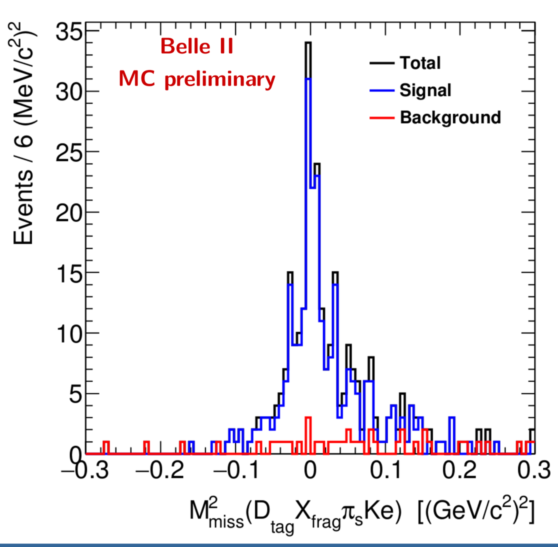
MC with 1 ab^{-1}

Signal: $l = \mu, e$; $h = K, \pi$; D^0 from D^{*+}

Tag: $D^0 \to K^-\pi^+$

Frag.: π^-

No background from continuum!



References

Belle II Theory Interface Platform (B2TiP) Report

(to be published on *Progress of Theoretical and Experimental Physics*)

ROMA TRE UNIVERSITÀ DEGLI STUDI — INFN Istituto Nazionale di Fisica Nucleare

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