Search for New Physics in CP-violating Phenomena at LHCb

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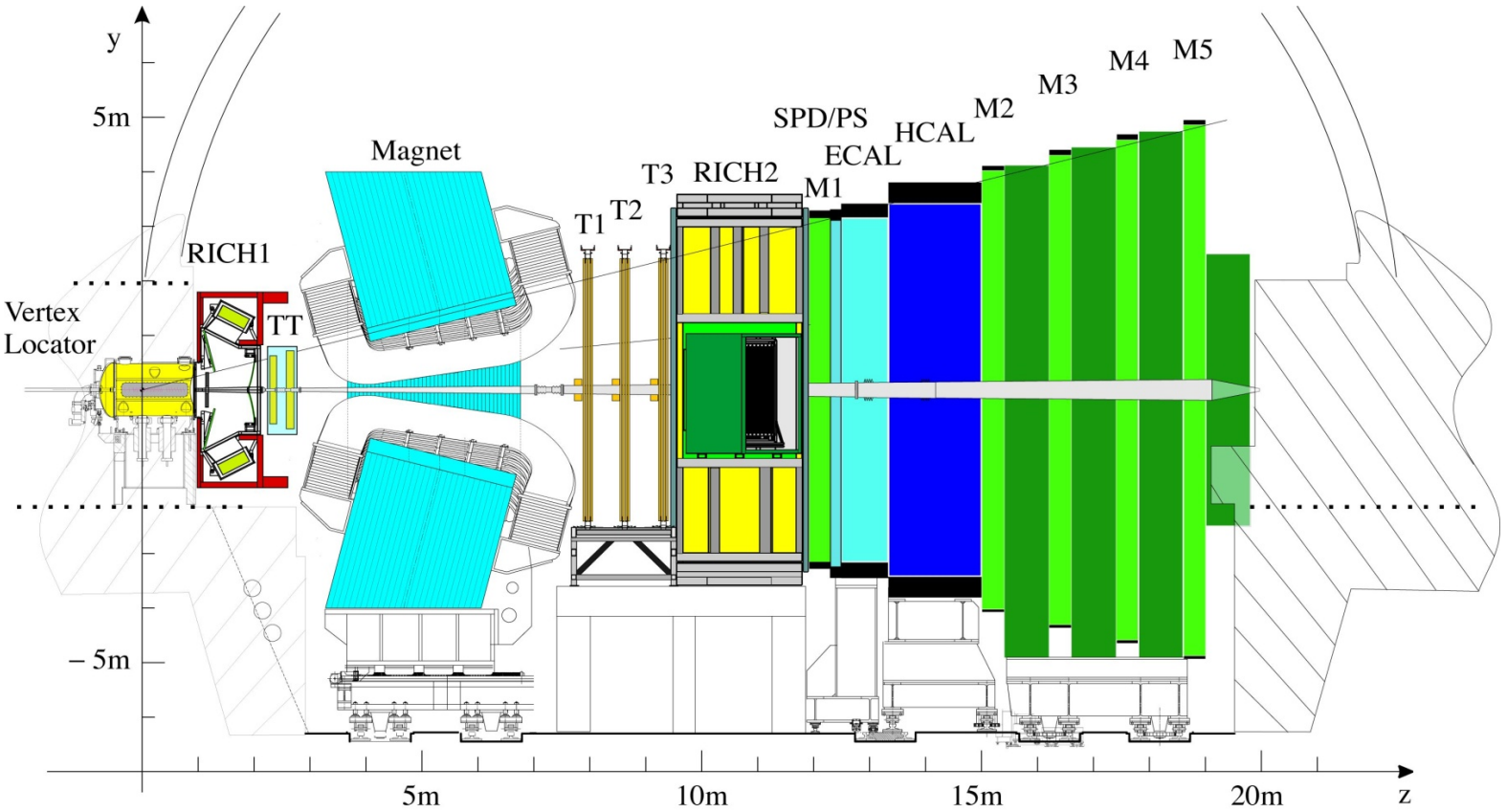
Contents

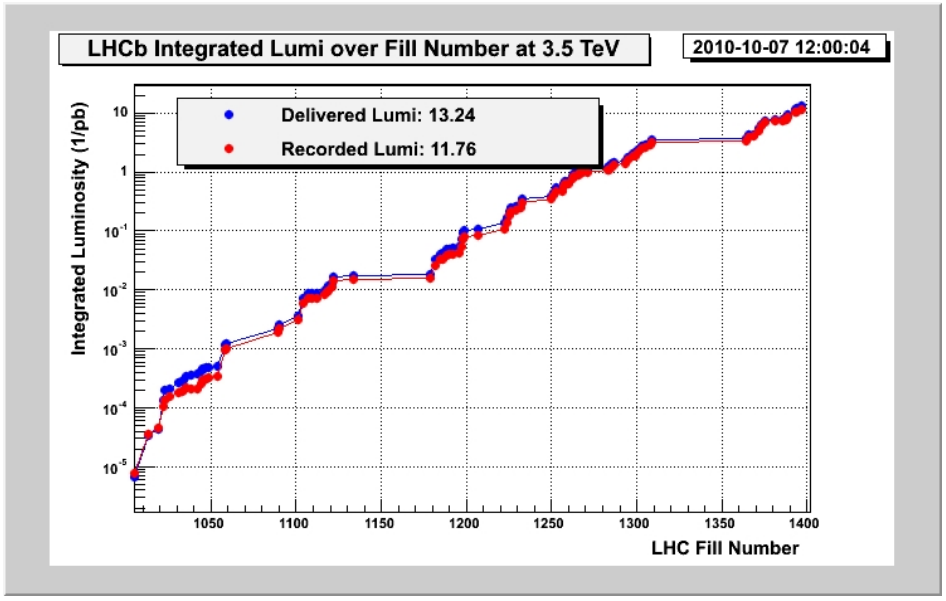
- The LHCb experiment.
- New Physics from CP-violation in the beauty sector.
- NP from CP-violation in the charm sector.
- Conclusions.

The LHCb experiment & performance

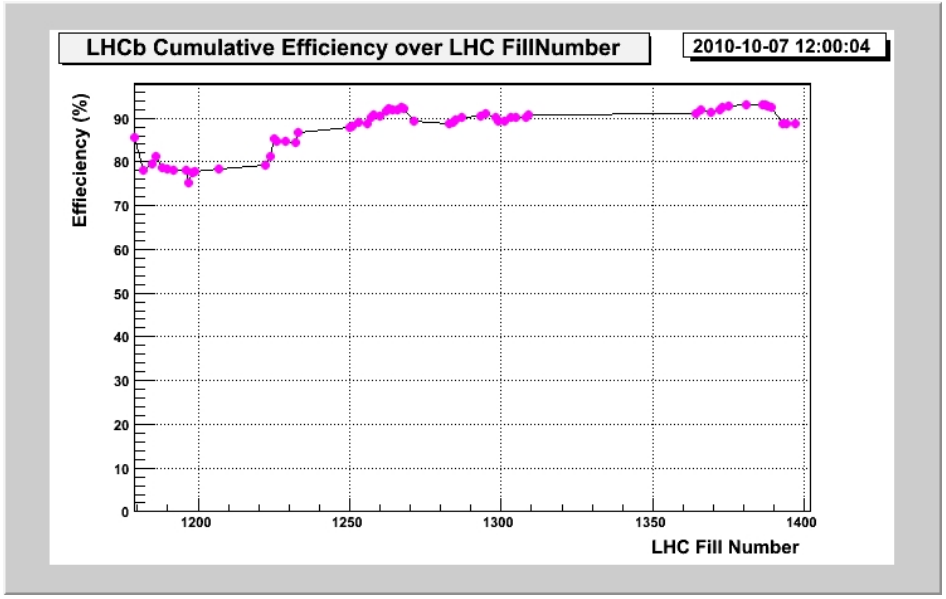


The LHCb experiment & performance

Integrated & and recorded luminosity:



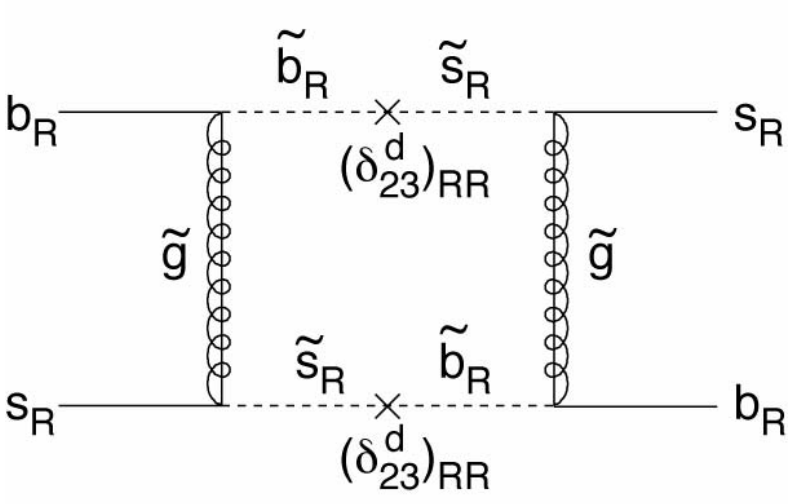
Data taking efficiency *vs.* run number:



- Excellent performance of LHC!
- Excellent start of data taking!
- hoping for 1 pb^{-1} per day...

New Physics in B meson sector

- CP-violation small in Standard Model $\phi_s = \mathcal{O}(0.04)$
- NP may appear through box-diagram



- determine CPV in B_s-$\bar{\mathrm{B}}_s$ mixing from $\mathrm{B}_s \to J/\Psi\ \phi$
- use $\mathrm{B}_s \to \mathrm{K}^+\mathrm{K}^-$ and $\mathrm{B}_d \to \pi^+\pi^-$
- with ϕ_s from $\mathrm{B}_s \to J/\Psi\ \phi\ \Rightarrow$:
- unambiguous determination of ϕ_s.
- CPV in $\mathrm{B}_d \to \mathrm{K}\pi$ and $\mathrm{B}_s \to \mathrm{K}\pi$

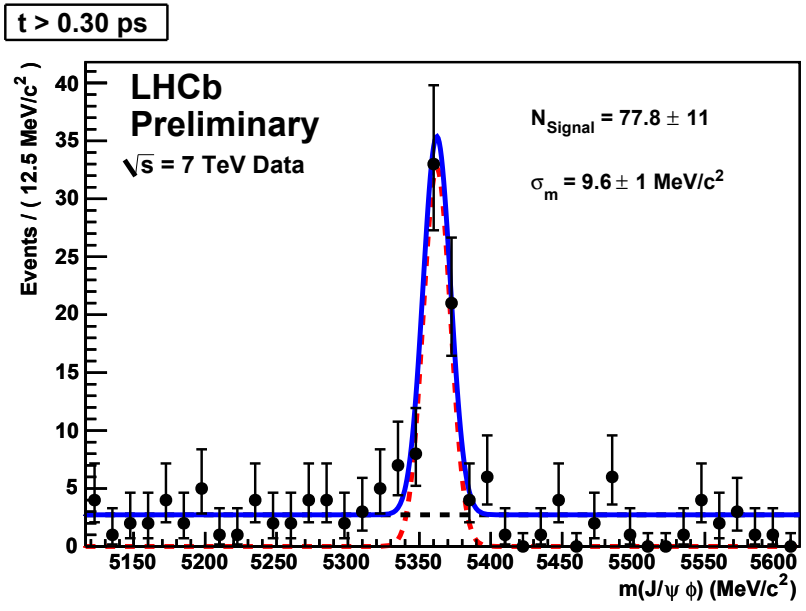
Ingredients for CPV in $B_s \to J/\Psi\,\phi$ channel

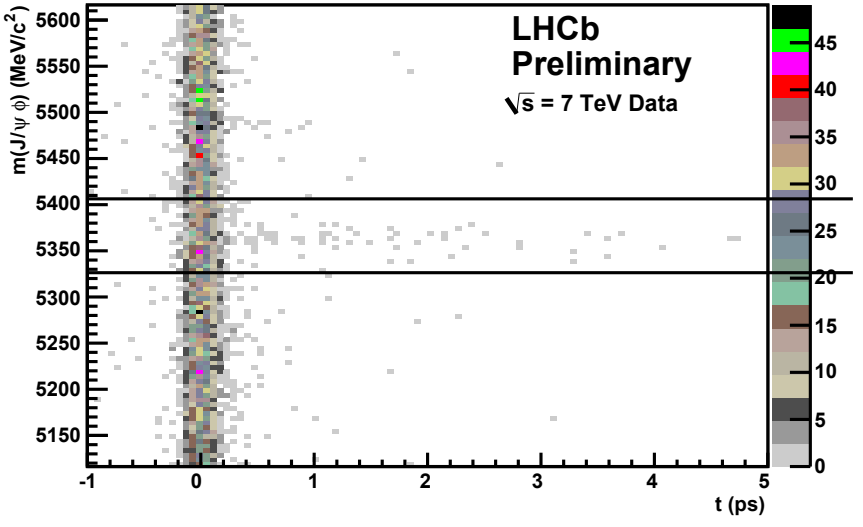
- select $B_s \to J/\Psi\,\phi$ events, and control samples ($B^+ \to J/\Psi K^+, B^0 \to J/\Psi K^*$)
- measure proper time resolution function ($B^+ \to J/\Psi K^+$)
- measure angular acceptance ($B^0 \to J/\Psi K^*$)
- determine CP of $J/\Psi\,\phi$ final state (even/odd?)
- tag reconstructed B_s meson (meson/anti-meson?)
- resolve oscillations of B_s meson into $\bar{B}_s$ ($\Delta\Gamma_s$, Δm_s)

Current Status of $B_s \to J/\Psi\ \phi$ analysis

B_s yield

$B_s \to J/\Psi\ \phi$ yield with $\mathcal{L} = 2\ \mathrm{pb}^{-1}$



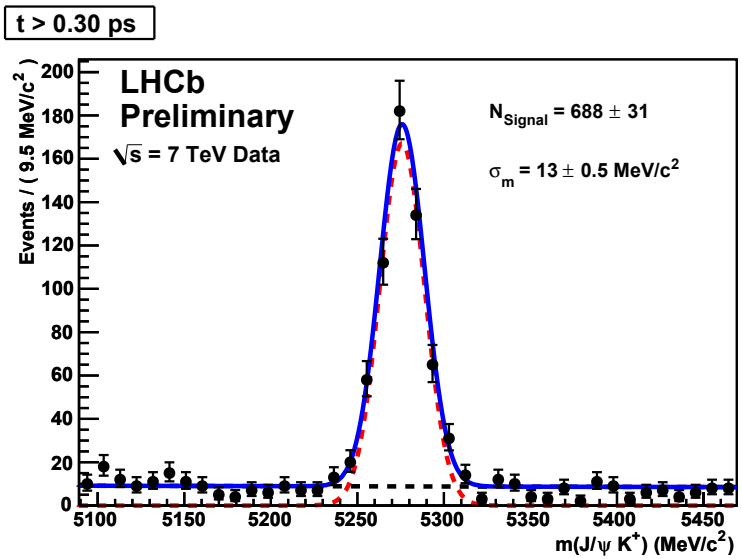


- $(38.9 \pm 5.5) B_s \to J/\Psi\ \phi$ per pb^{-1}
- Note: not yet reached performance predicted by MC

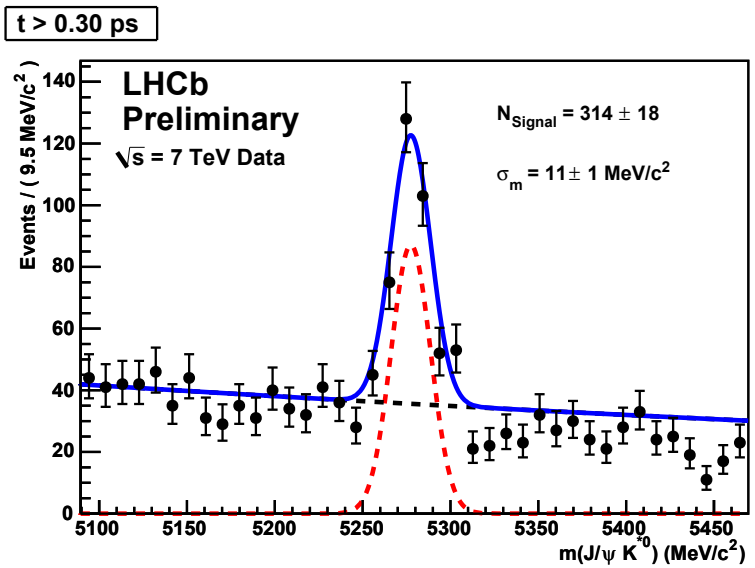
Current Status of $B_s \to J/\Psi\ \phi$ analysis

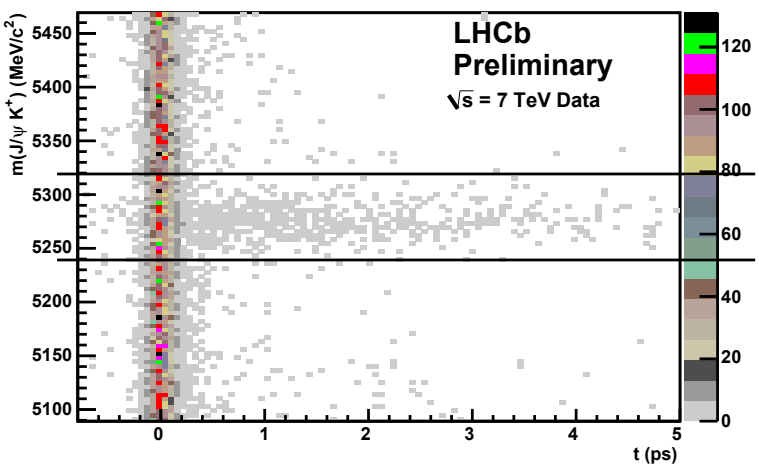
Control Channels

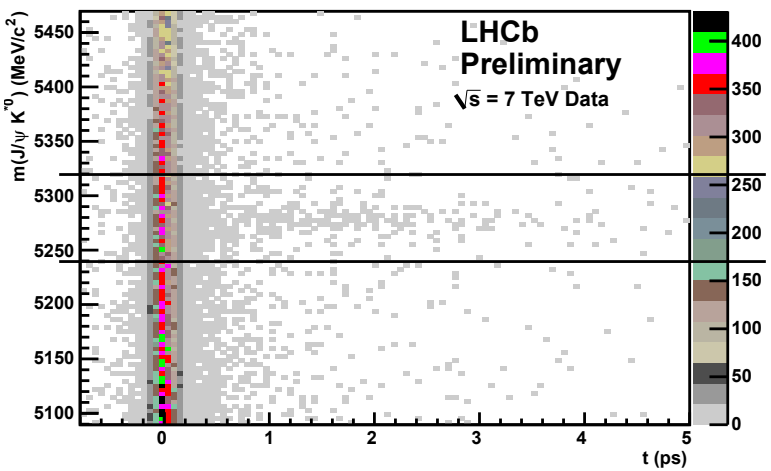
$B^+ \to J/\Psi K^+$ with $\mathcal{L} = 3\ pb^{-1}$;



$B^0_d \to J/\Psi K^{*0}$



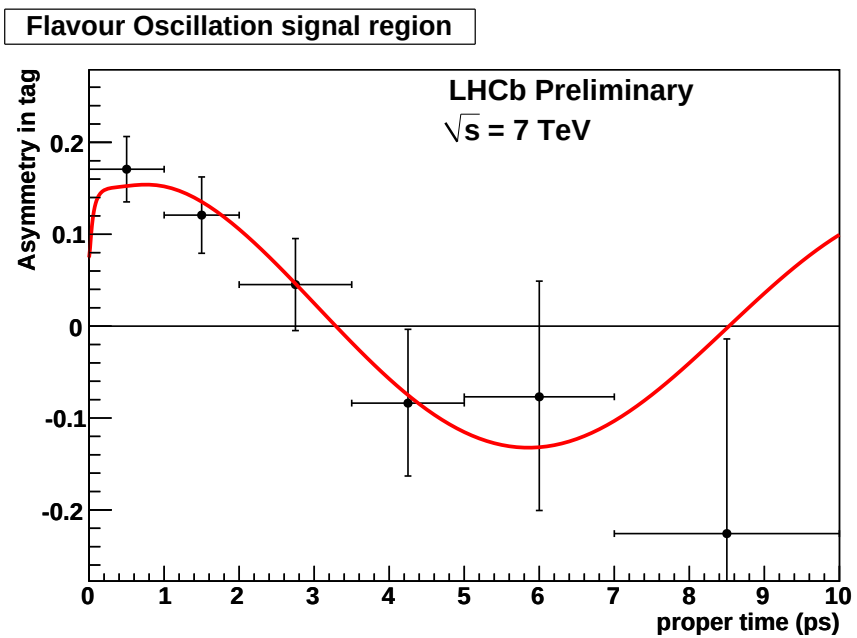




Current Status of $B_s \to J/\Psi\ \phi$ analysis

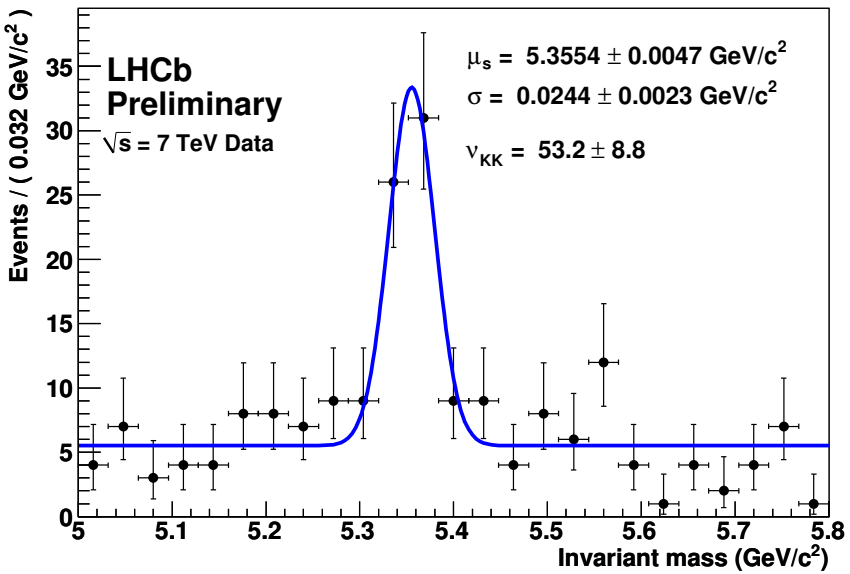
- Use opposite- and same-side taggers:
- on *e.g.* $B_d \to D^* \mu\nu$
- fit mass difference and B-proper-time

- B_d oscillations observed in $B_d \to D^* \mu\nu$
- with $D^{*-} \to D^0 \pi^-$ and $D^0 \to K^+ \pi^-$
- using $\mathcal{L} \approx 2\ pb^{-1}$
- tagging not yet optimized, proper time not yet calibrated

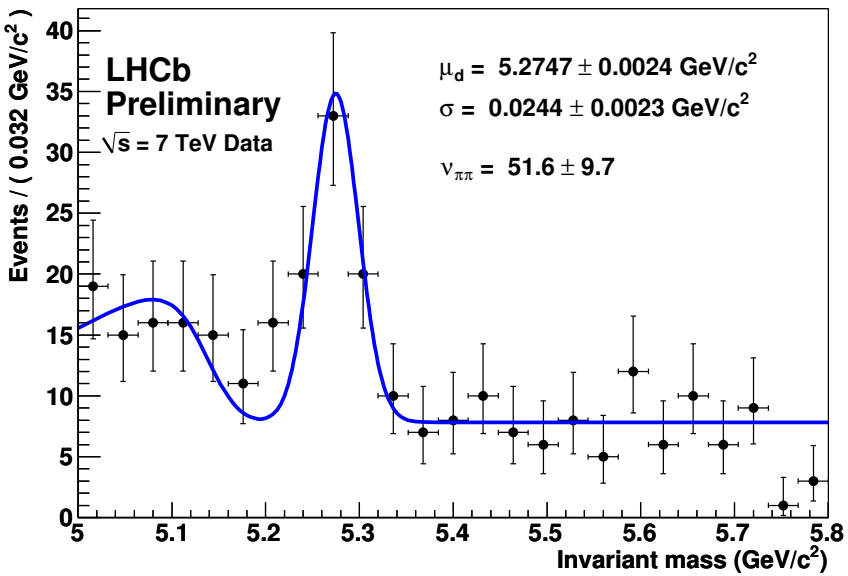


Current status of $B_s \to h^+h'^-$

With $\mathcal{L} = 3\ \mathrm{pb}^{-1}$
Clear $B_s \to K^+K^-$ signal

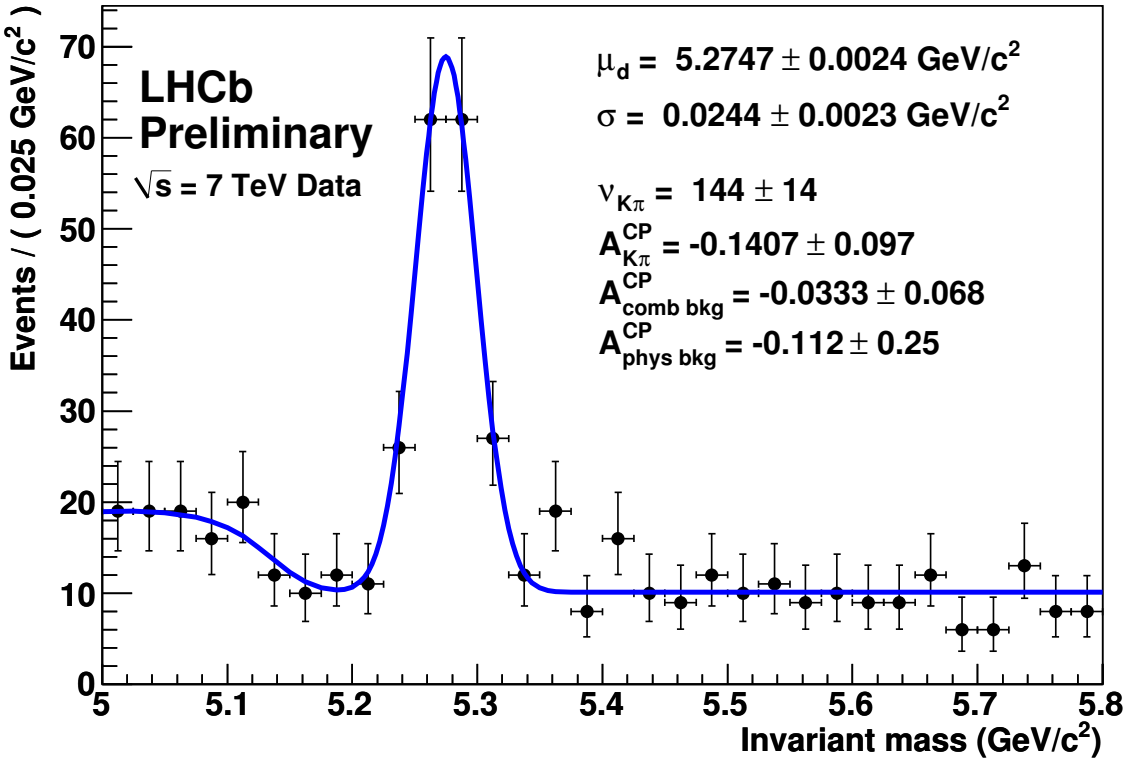


and $B_d \to \pi^+\pi^-$ signal:



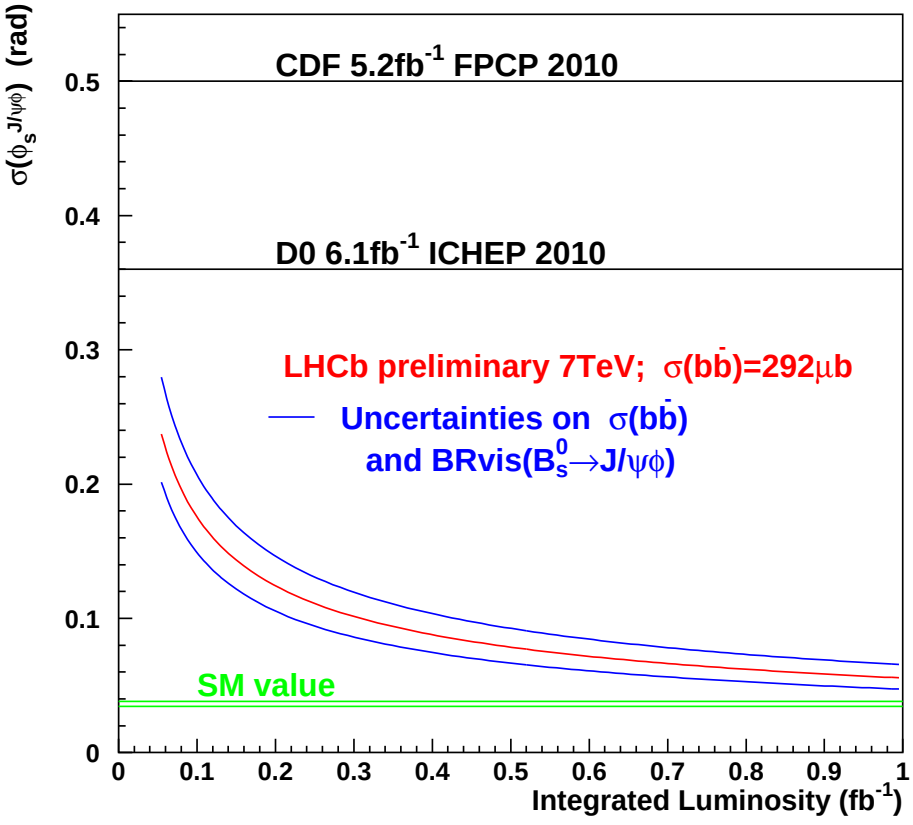
Current status of $B_s \to h^+ h'^-$

Glimpse of CPV in $B_d \to K\pi$:



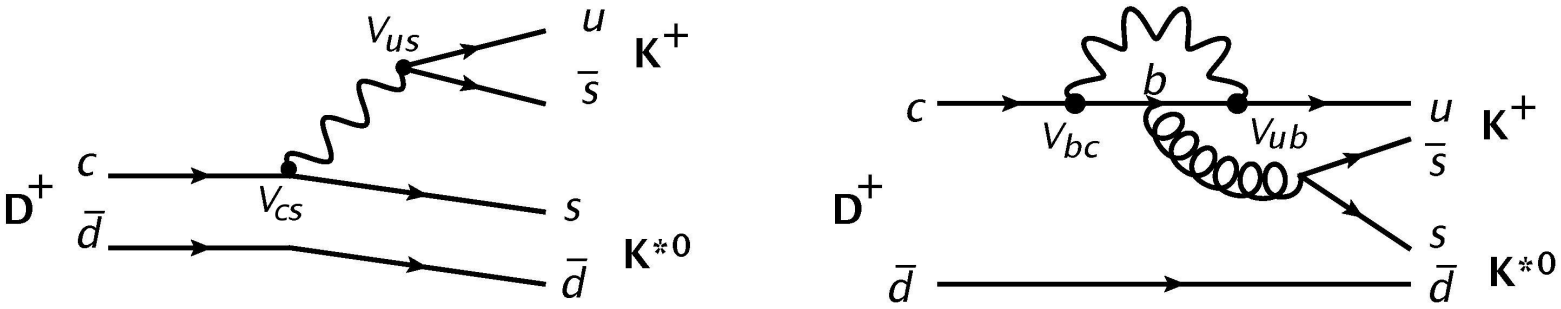
Projections until end of 2010

MC prediction:



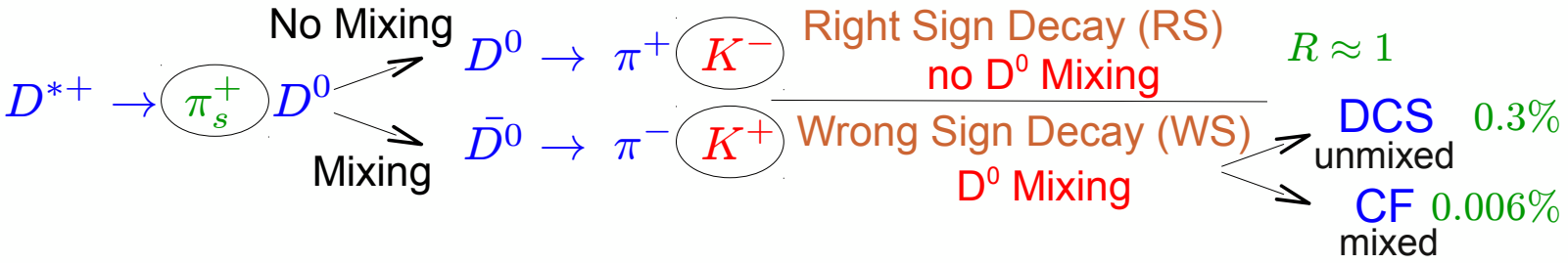
Based on 50 pb^{-1}...

- $\mathrm{B}_s \to J/\Psi\ \phi$ yield: $N = 1\text{-}2 \times 10^3$ events
- proper time resolution: $\sigma(t) \approx 50\text{-}63\ \mathrm{fs}$
- $\Rightarrow \sigma(\phi_s) \approx [0.30; 0.85]$ rad
- expect $\mathcal{O}(10^3)\ \mathrm{B}_d \to \mathrm{K}\pi$ events
- $\Rightarrow \sigma(\phi_d) \approx \mathcal{O}(0.03)$ rad
- For a_{fs}: see Talk by R. Lambert



- interference between tree- and penguin-diagrams
- only possible in Cabibbo-suppressed decays
- Standard Model predicts very small CPV in D^0-$\bar{D}^0$ mixing
- NP could enhance CPV $\rightarrow$
- can be 'easily' visible in charm sector!
- CPV in mixing, interference: time-dependent analyses
- Direct CPV: time-integrated, model-independent Dalitz analyses

CP violation in charm sector
Time-dependent analyses



- $x = \frac{\Delta M}{\Gamma}$ and $y = \frac{\Delta \Gamma}{2\Gamma}$
- time evolution of WS decay rate of D^0 in $\mathrm{D}^{*+} \to \pi_s^+ \mathrm{D}^0$

$$\frac{dN_{\mathrm{D}^0 \to \bar{f}}}{dt} \propto \left[R_D + \sqrt{R_D} y' \Gamma t + \frac{x'^2 + y'^2}{4} \Gamma^2 t^2 \right]$$

- δ: strong phase between CF & DCS
- $x' = x \cos\delta + y \sin\delta$
- $y' = y \cos\delta - x \sin\delta$

- measurement of lifetime difference between CP-even and CP-mixed states: 'y_{CP}'

$$y_{CP} = \frac{\tau(K^-\pi^+)}{\tau(K^-K^+)} - 1$$

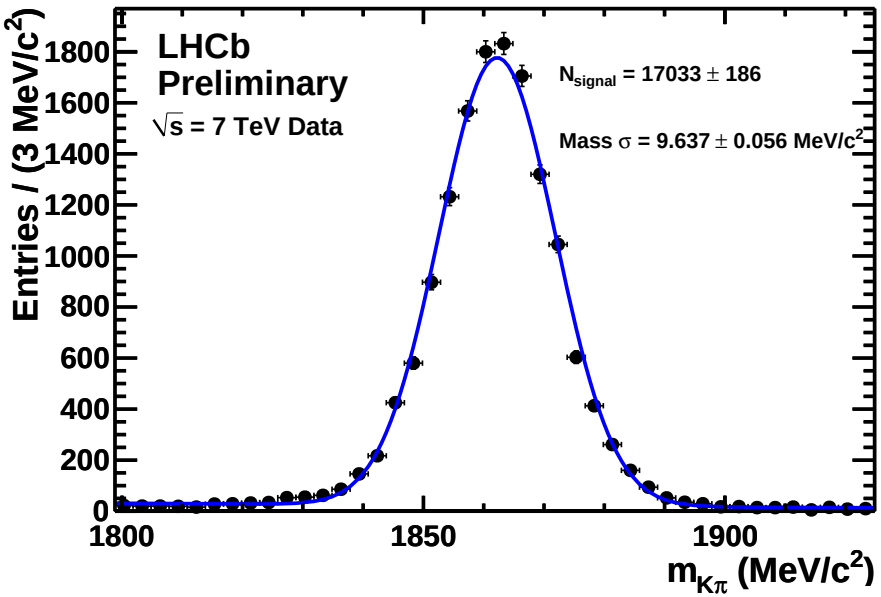
- measurement of lifetime asymmetry between D^0 and $\bar{D}^0$

$$A_\Gamma = \frac{\tau(\bar{D}^0 \to K^-K^+) - \tau(D^0 \to K^+K^-)}{\tau(\bar{D}^0 \to K^-K^+) + \tau(D^0 \to K^+K^-)}$$

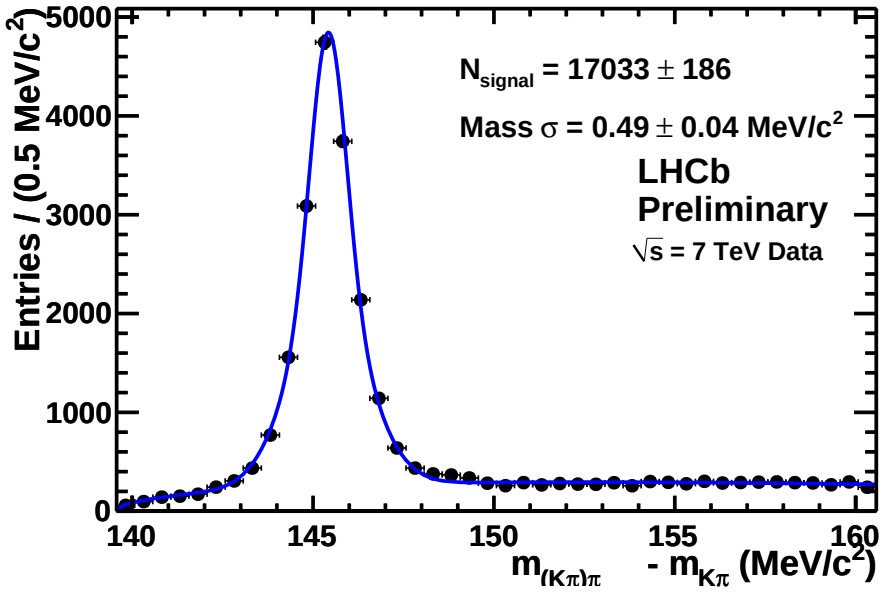
- $A_\Gamma \neq 0$: CP violation in mixing;
- CPV in interference between mixing & decay

$D^{*+} \to \pi_s (D^0 \to K^- \pi^+)$ with $\mathcal{L} = 124\ \mathrm{nb}^{-1}$

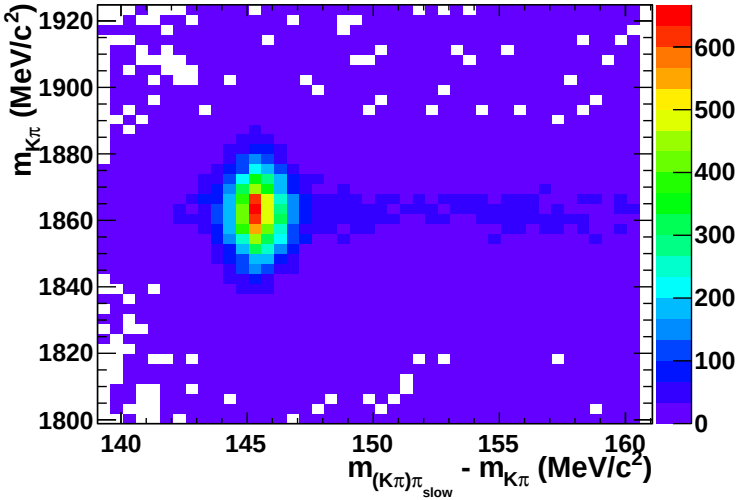
Reconstructed D^0 mass



Mass difference of D^{*+} and D^0



D^0 *vs.* Δm



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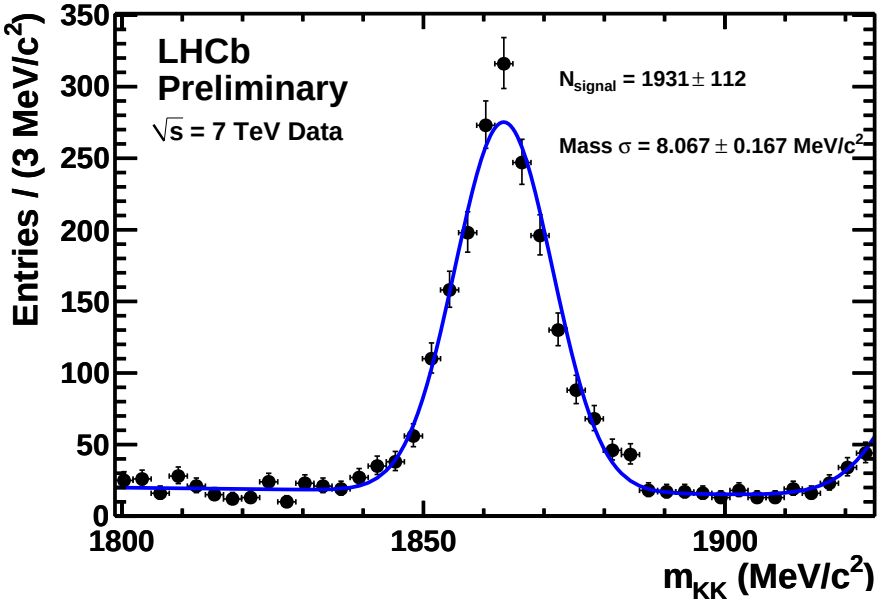

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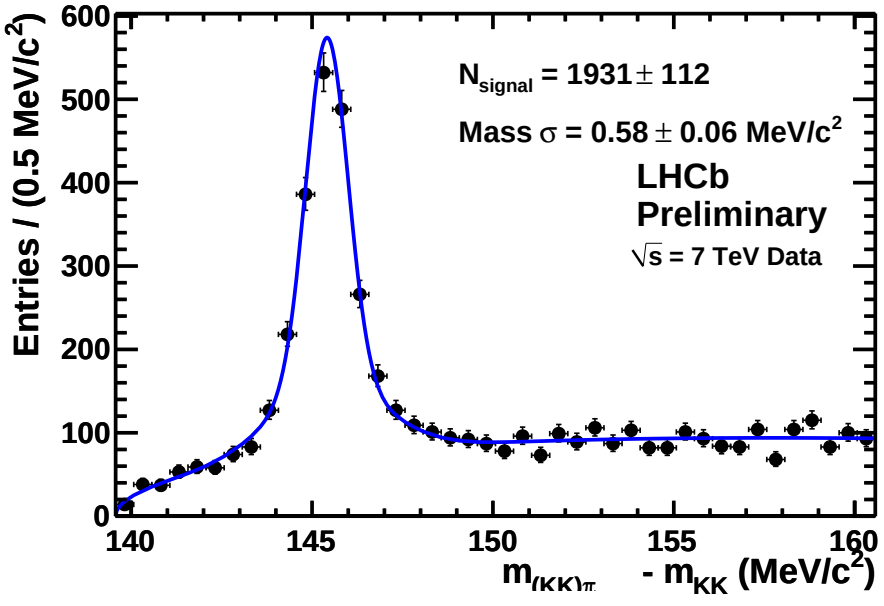
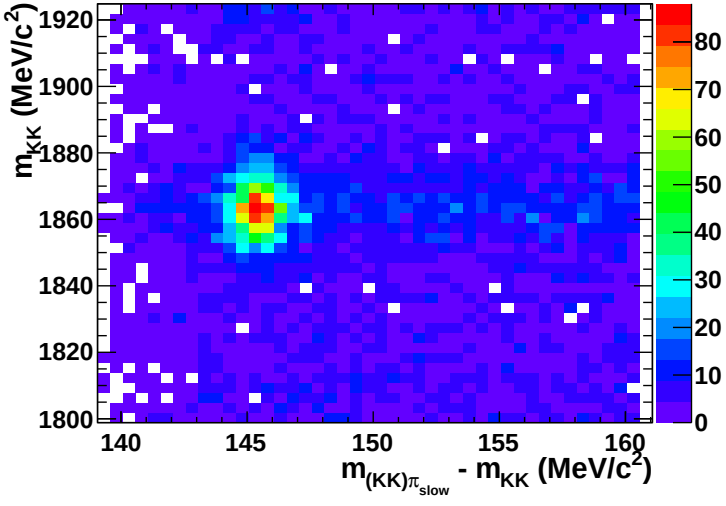
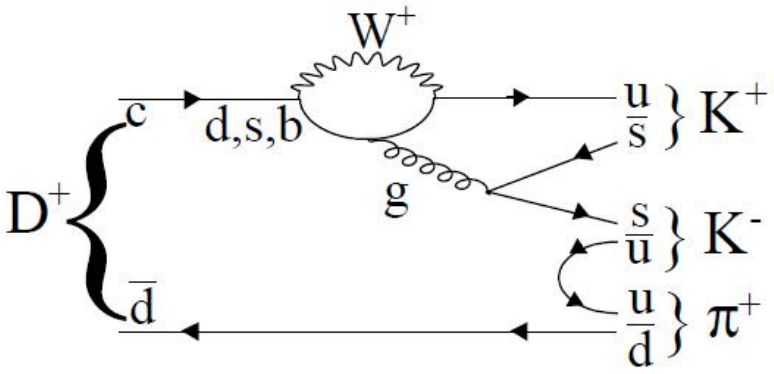


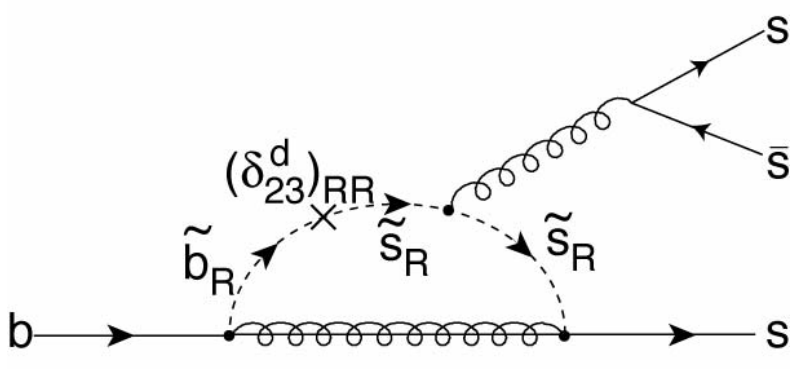
D^0 *vs.* Δm



Dalitz analysis of three-body D decays: ($D^+ \to K^+K^-\pi^+$)



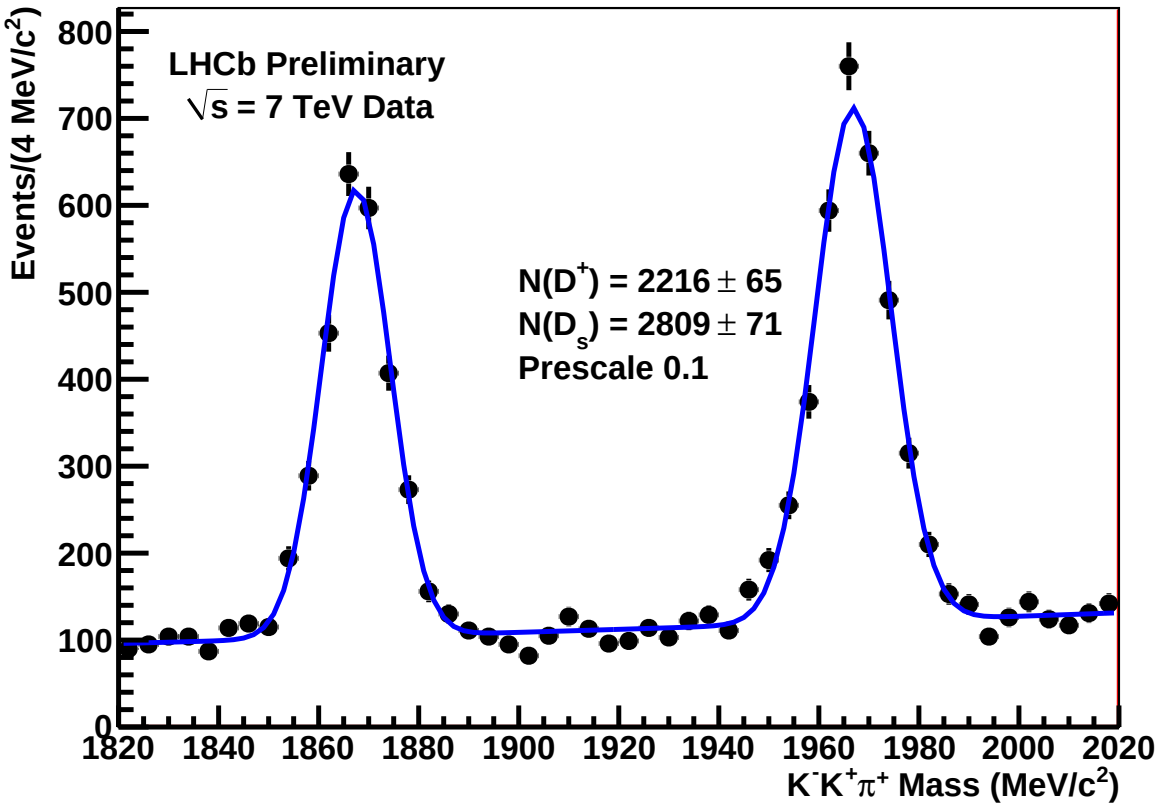
- sensitive to many interference effects
- insensitive to production asymmetries
- differentiate between real asymmetries and statistical fluctuations



- $D_s^+ \to K^+K^-\pi^+$
  $D^+ \to K^+\pi^+\pi^-$ as control channels

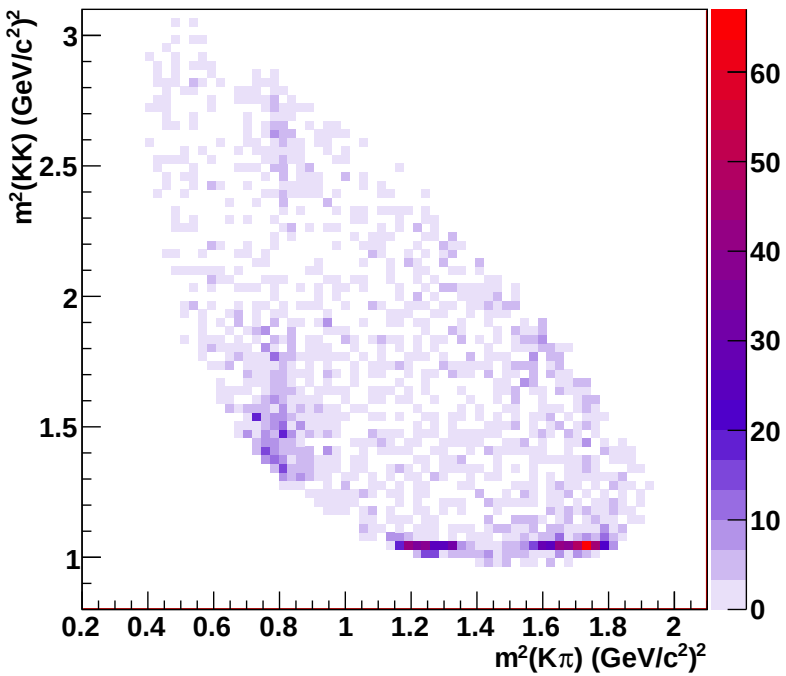
$$D_{p_{S_{CP}}} = \frac{N(i) - \bar{N}(i)}{\sqrt{N(i) + \bar{N}(i)}}$$

Reconstructed three-body charmed decays with $\mathcal{L} = 580\ \mathrm{nb}^{-1}$
$\mathrm{D}^+ \to \mathrm{K}^+\mathrm{K}^-\pi^+$ and $\mathrm{D}_s^+ \to \mathrm{K}^+\mathrm{K}^-\pi^+$

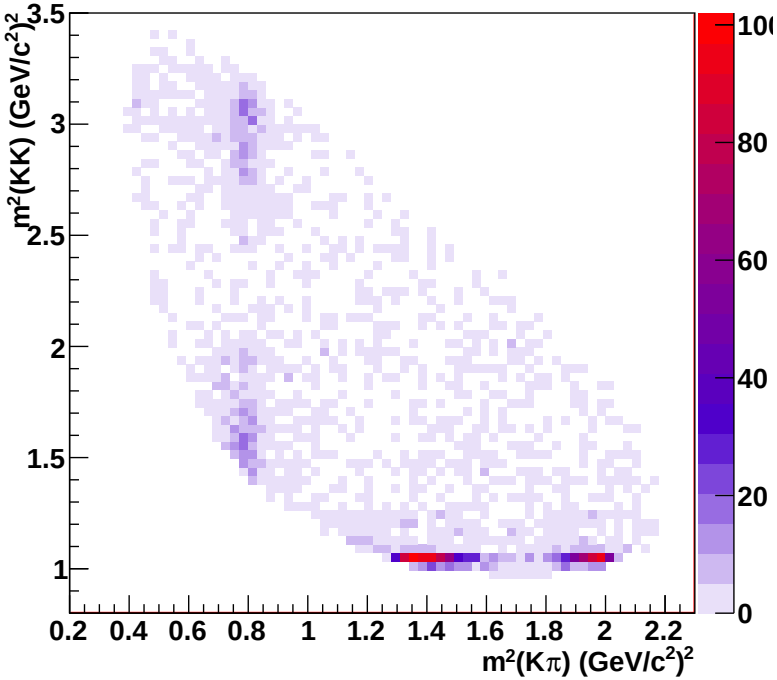


Reconstructed three-body charmed decays with $\mathcal{L} = 580\ \mathrm{nb}^{-1}$

Dalitz plot for $\mathrm{D}^+ \to \mathrm{K}^+\mathrm{K}^-\pi^+$



Dalitz plot for $\mathrm{D}_s^+ \to \mathrm{K}^+\mathrm{K}^-\pi^+$



Conclusions

- Ramp up of LHC very impressive
- LHCb data taking effiency at 90% level
- Hoping for $\mathcal{L} = 50\ \mathrm{pb}^{-1}$ at the end of the year
- With 2010 data already reach high sensitivity:
  - $\mathrm{B}_s \to J/\Psi\ \phi$ yield: $\mathcal{O}(10^3)$ events
  - Propertime resolution: $\sigma(t) \approx$ 50-63 fs
  - sensitivity to $\sigma(\phi_s) = [0.3; 0.9]\ \mathrm{mrad}$
  - Expect sample $\mathcal{O}(10^6)$ events for CPV search in charm sector
- with 2011 data: expect world's best discovery potential!