Decay Properties: New Possible Analyses in CMS

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A couple of measurements still not pursued at CMS

- CPV in interference between Mixing and Decay:
  - $B_s \rightarrow J/\psi\pi\pi$: Φ_s
  - $B^0 \rightarrow J/\psi K_s$: β

Other ideas for the future:

- B Physics in $t\bar{t}$ events
  - Ongoing: b mixing (see Paolo talk)
  - Challenge: reconstruct B states in b-jets from top?

Time dependent CPV Measurements

- Reconstruct B/$\overline{\mathrm{B}}$ decays in the same CP eigenvalue:

$$\mathcal{A}_{f_{CP}}(t) \equiv \frac{d\Gamma/dt[\overline{M}^0_{\rm phys}(t) \to f_{CP}] - d\Gamma/dt[M^0_{\rm phys}(t) \to f_{CP}]}{d\Gamma/dt[\overline{M}^0_{\rm phys}(t) \to f_{CP}] + d\Gamma/dt[M^0_{\rm phys}(t) \to f_{CP}]}$$

$$\mathcal{A}_f(t) = \frac{S_f \sin(\Delta m t) - C_f \cos(\Delta m t)}{\cosh(\Delta\Gamma t/2) - A_f^{\Delta\Gamma} \sinh(\Delta\Gamma t/2)}$$

$$S = -\eta \sin 2\beta\,(\Phi_s), \quad C = 0$$

- Ingredients of the Measurement:
  - Flavor Tagging, FOM: $P_{TAG} = \varepsilon(1-2\omega)^2$
    - LHCb > 3%; CMS (only OS) ~ 1.3%
  - Time resolution, σ_t
    - LHCb: ~ 40 fs; CMS ~ 75 fs
  - Integrated Statistics… next slide…

"Very difficult" to be competitive with LHCb, but useful excercise to look for possible improvements

Run 2 Projections & Challenges

- Back of envelope Run2 projection at CMS:

  σ_{bb}(Run2) = 2 σ_{bb}(Run1); [σ_{tt}(Run2) = 4 σ_{tt}(Run1)]

  L(Run2) = 100/120 fb^{-1} = 5 L(Run1)
- Total sample (Run1 + Run2) = 11 x Run1 (5 x Run1 for LHCb)
  - ➔ Expect factor ~3 improvement in statistical errors wrt Run1 & systematic uncertainties scaling with statistics

But:

- Increased Pile-up: ~ 40 PU @ 13 TeV with L=1.4 10^{34} $cm^{-2}s^{-1}$
- Trigger: stay within the Run1 bandwidth (L1=10 kHz ~ 10% of the total Bandwidth, HLT= 100 Hz) despite the increase of a factor 4 in rate.
  - ➔ Trigger selection defined to reduce the rate without affecting too much the signal, path driven by specific analysis

$B^0 \to J/\psi K_s$

LHCb (Phys. Rev. D 115, 031601) L=3 fb^{-1}

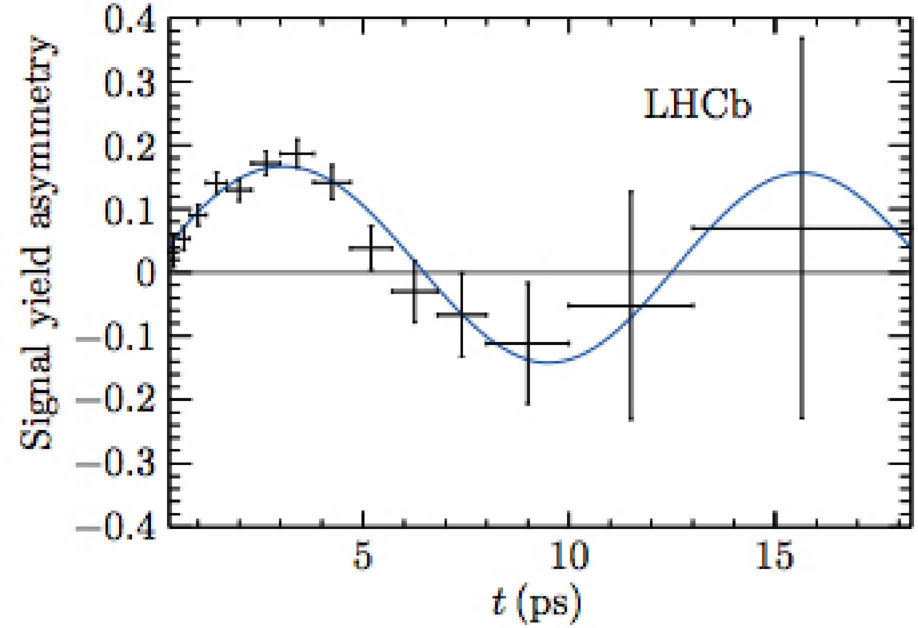
S= 0.731 ± 0.035 ± 0.020

C=-0.038 ± 0.032 ± 0.005

N_{sig} = 114000 (All) → 41500 (Tagged)

P_{TAG}=3.02% (OS+SSπ)

Origin	σ_S	σ_C
Background tagging asymmetry	0.0179 (2.5%)	0.0015 (4.5%)
Tagging calibration	0.0062 (0.9%)	0.0024 (7.2%)
$\Delta\Gamma$	0.0047 (0.6%)	—
Fraction of wrong PV component	0.0021 (0.3%)	0.0011 (3.3%)
z-scale	0.0012 (0.2%)	0.0023 (7.0%)
Δm	—	0.0034 (10.3%)
Upper decay time acceptance	—	0.0012 (3.6%)
Correlation between mass and decay time	—	—
Decay time resolution calibration	—	—
Decay time resolution offset	—	—
Low decay time acceptance	—	—
Production asymmetry	—	—
Sum	0.020 (2.7%)	0.005 (15.2%)



Extrapolation for Run2:

N_{sig} = 570000

δS_{stat} ~ 0.016; δC_{stat} ~ 0.014

Systematic error not significantly reducible with statistics

$B_s \to J/\psi\pi\pi$

LHCb (Phys. Lett. B 736, 186-195) $L=3\ fb^{-1}$

$\Phi_s = 70 \pm 68 \pm 8$ mrad

$N_{sig} = 27100$ (All) → 14800 (Tagged)

$P_{TAG}=3.89\%$ (OS+SSK)

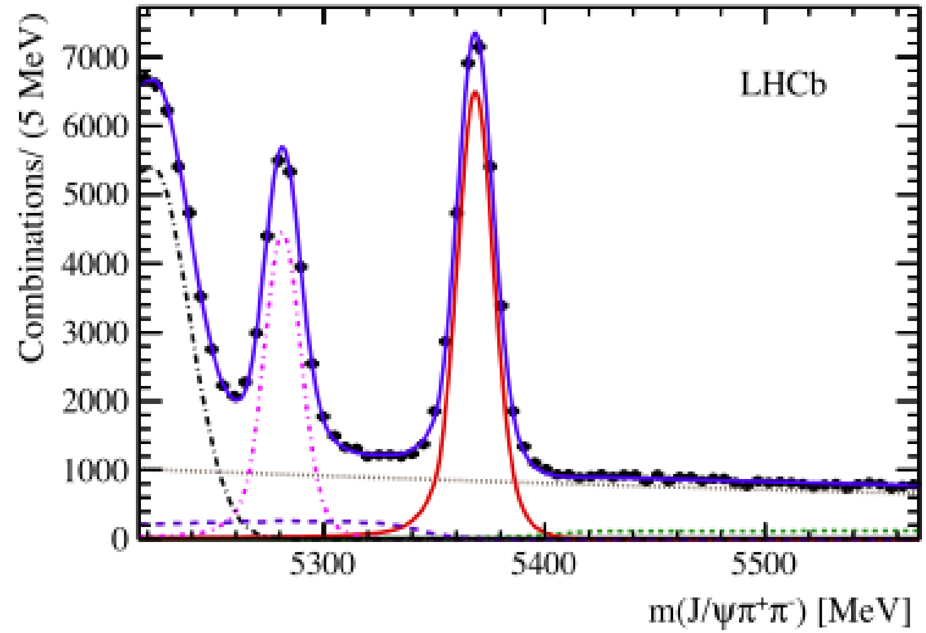


Table 2
Systematic uncertainties. The total is the sum in quadrature of each entry.

Sources	ϕ_s (mrad)
Decay time acceptance	±0.6
Mass acceptance	±0.3
Background time PDF	±0.2
Background mass distribution PDF	±0.6
Resonance model	±6.0
Resonance parameters	±0.7
Other fixed parameters	±0.4
Production asymmetry	±5.8
Total	±8.4

Extrapolation for Run2:

$N_{sig} = 135500$

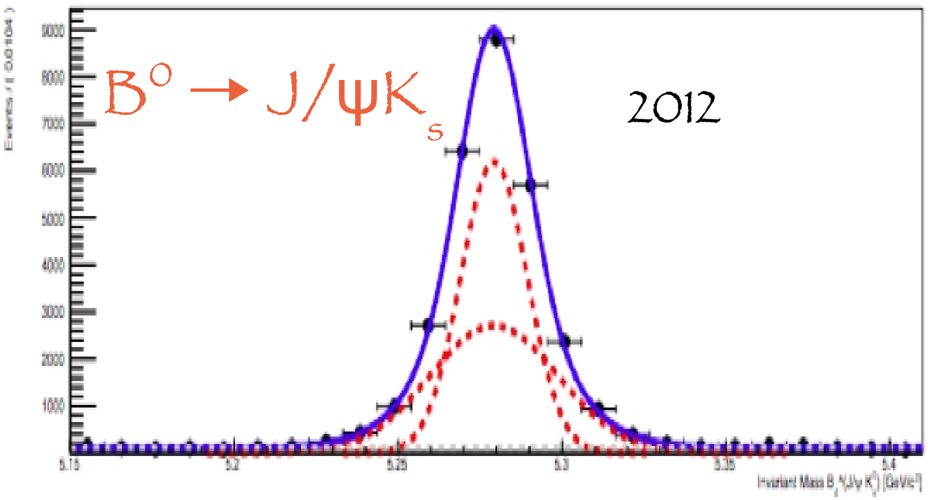
$\delta_{stat} \sim 30$ mrad

Precision still dominated by statistical error

CMS Perspectives

Thanks to
Jhovanny & Sara

Run1 Reconstructed Yields in CINVESTAV Lifetime analyses:



N_{sig} (No Tag) = 35188

Run1 HLT used Paths:

HLT_Dimuon7_Jpsi_Displaced

HLT_DoubleMu4_Jpsi_Displaced

Run2 HLT available Paths:

7e33 HLT prescale	1e34 HLT prescales	Path	Modified L1 seed	1e34 L1 prescales	Total (7e33 column)		
2	5	HLT_DoubleMu4_3_Jpsi_Displaced_v2	Prescaled: control channel for $B \to \mu\mu$ Not needs full statistics	120|1|1	26.9	±	1.92
1	1	HLT_DoubleMu4_JpsiTrk_Displaced_v2	L1_DoubleMu0_Eta1p6_WdEta18 OR L1_DoubleMu0_Eta1p6_WdEta18_OS OR L1_DoubleMu_10_0_WdEta18	120|1|1	41.48	±	2.71
1	0	HLT_Dimuon16_Jpsi_v2	L1_DoubleMu_10_0_WdEta18	1	17.33	±	1.03

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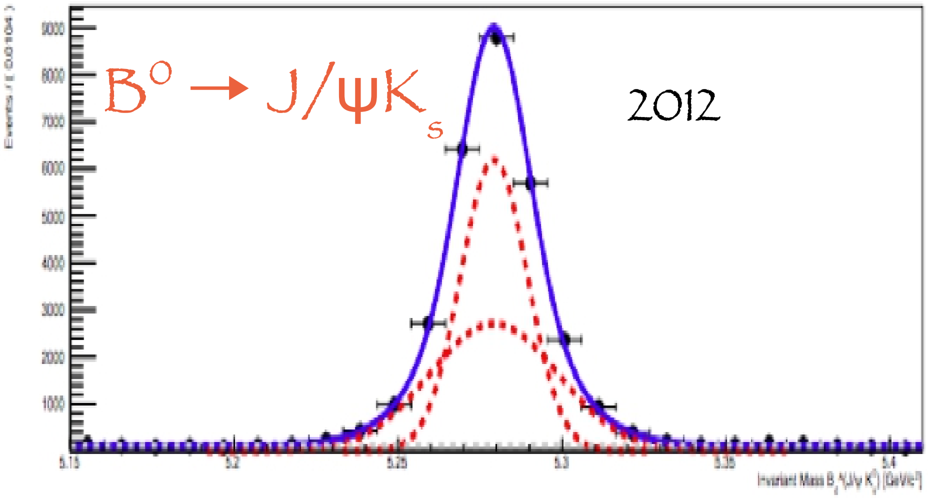

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- Run2 Extrapolation:

  N_{sig} (No Tag) = 330000

  (assuming 15% ε reduction)

L1 seed (2015) was **L1_DOubleMu0er1p6_dEta_Max1p8 or L1_DOubleMu_10_0dEta_Max1p8** (prescaled by factor 10) probably will move to **L1_DoubleMu_10_3p5** → Endcap Efficiency reduction

δ_{stat}(CMS)/δ_{stat}(LHCb) = Statistics × Tagging × Resolution = Total

1.2 × 1.5 (1.4) × 1.4 = 2.5 (2.3)

Very naive evaluation → $\delta_{stat} S \sim 0.037$; $\delta_{stat} C \sim 0.032$

CMS Perspectives

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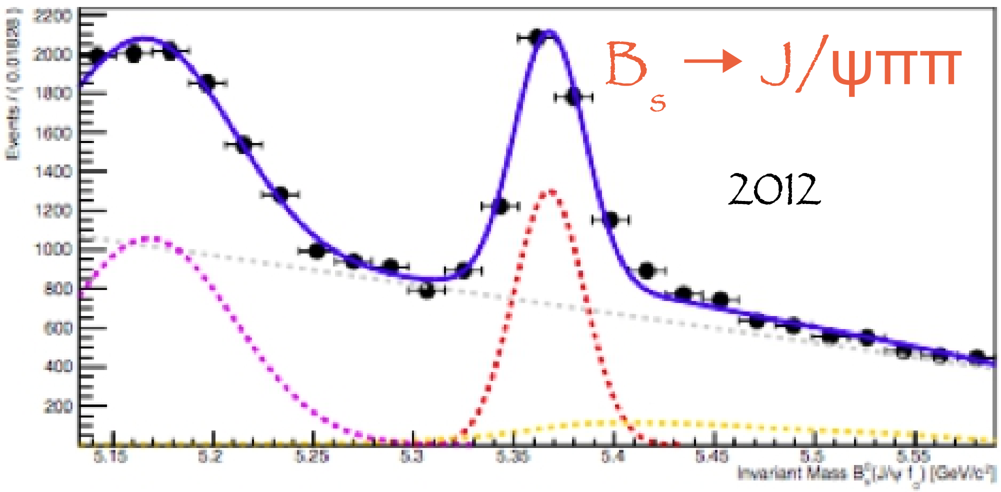
Run1 Reconstructed Yields in CINVESTAV Lifetime analyses:



N_{sig} (No Tag) = 4010

- Run2 Extrapolation

  N_{sig} (No Tag)=37500

  (assuming 15% ε reduction)

δ_{stat}(CMS) / δ_{stat}(LHCb) = Statistics x Tagging x Resolution = Total

1.9 x 1.7 (1.5) x 1.4 = 4.5 (4.0)

Very naive evaluation: → $\delta_{stat}\Phi s$ ~ 120 mrad

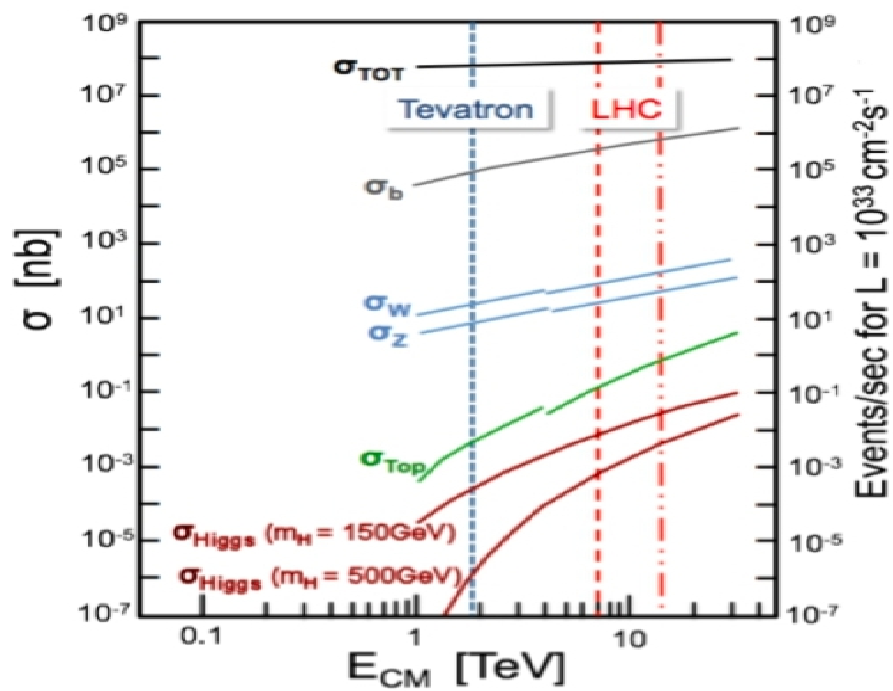
B Physics in tt events?

- Pros:
  - High P_T Physics will not be penalized by trigger paths
  - σ_{tt} increases by a factor 4 from 8 TeV to 13 TeV
  - Expertise in the group on Flavor Tagging both at low P_T (Jacopo Pazzini) and high P_T (Alessio Boletti)
  - Leptons from semileptonic $t \rightarrow l\nu b$ decays tag the b flavor at production time

$\sigma_{tt}(Run2) = 4\sigma_{tt}(Run1)$

$L(Run2) = 5L(Run1)$

→ Expect ~$4.5\ 10^6$ tt, $t \rightarrow l\nu b$ evts



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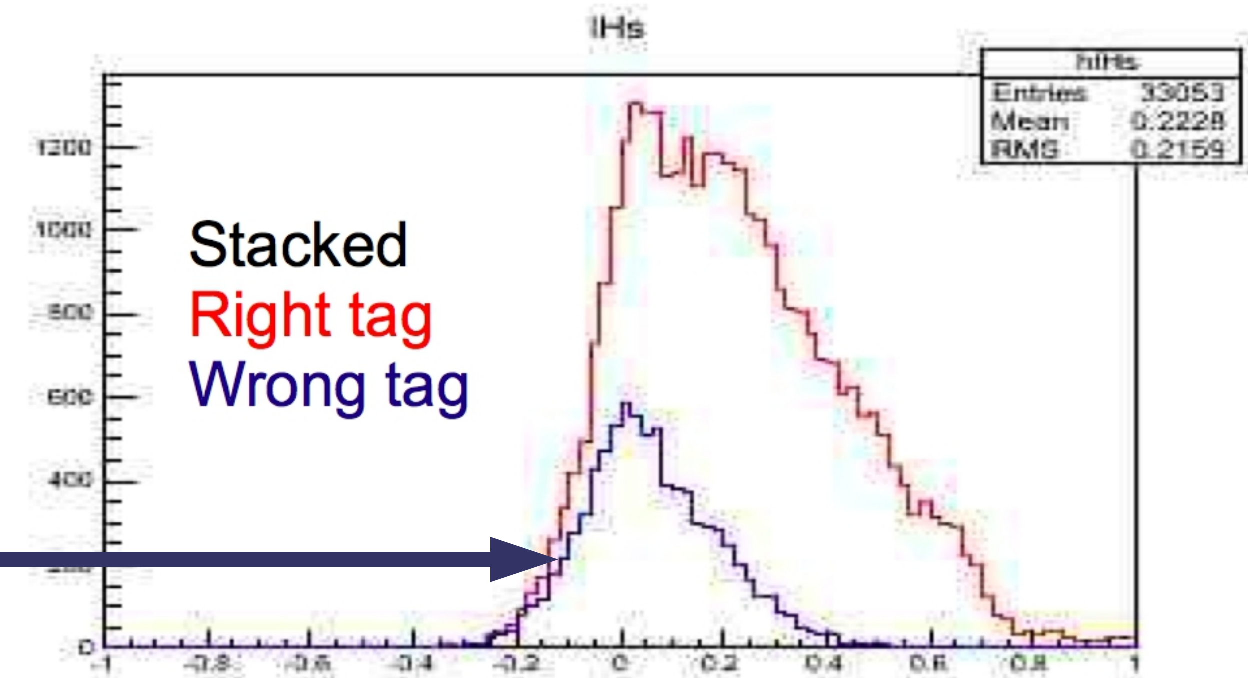
  - Leptons from semileptonic $t \rightarrow l\nu b$ decays tag the b flavor at production time
- B flavor assignment from lepton charge in $t \rightarrow l\nu b$: $\langle\omega\rangle = 25.40 \pm 0.14\%$
- Improvement by fitting BDT output



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- Challenges:
  - What kind of measurements could we do?
    - Inclusive: use additional lepton from $b \rightarrow l$ (as for B-mixing, already ongoing) or $b \rightarrow K$
    - Exclusive B reconstruction in boosted environment?

Backup

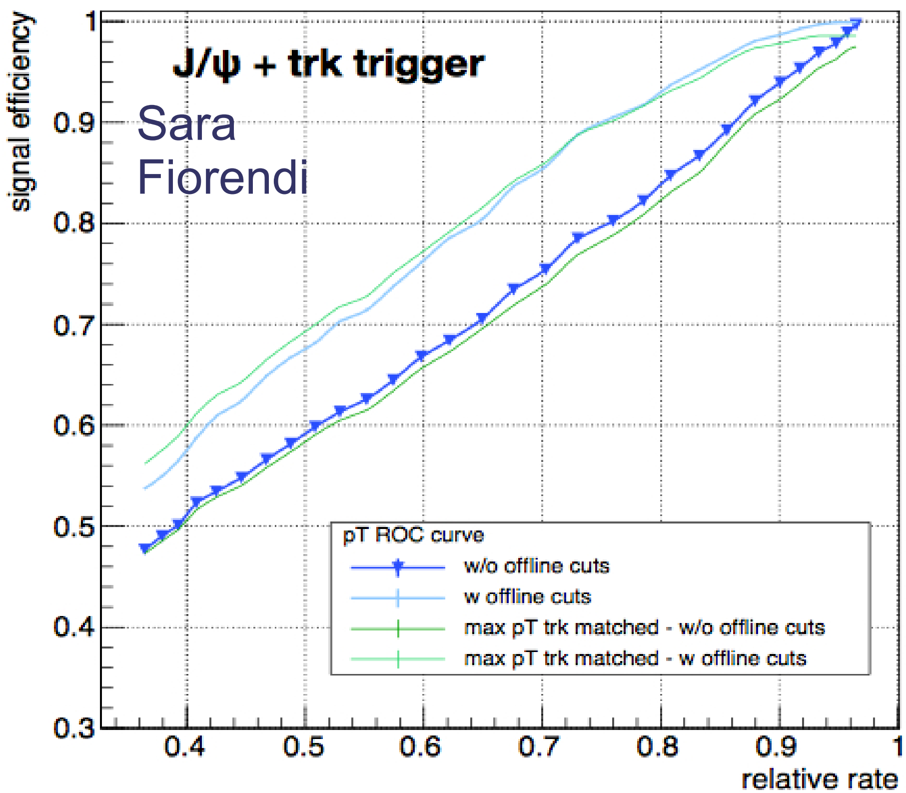
CMS Perspectives

Thanks to Sara

Trigger Efficiency and Rates comparison between "old" HLT_DoubleMu4_Jpsi_DIsplaced and new HLT_DoubleMu4_JpsiTrk_DIsplaced

Signal: $B^0 \rightarrow J/\psi K^*$

Trk P_T > 0.5/3.4 GeV in steps of 0.1 GeV



Trk IP Significance wrt BS d0>0/5.8 in steps of 0.2