Measurement of CPT Invariance in $\phi \rightarrow K_s K_s$

A comparison of two approaches

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August 17, 2015

Introduction & Terminology

- Want to measure CPT invariance
- System of choice: $\phi \to K_S K_L$
  - CPTV $\Rightarrow$ loss of coherence
- Two possible approaches:
  - inclusive ϕ production
  - ϕ from decays $D_s \to \phi\pi$
- Comparison of both approaches

Signal: $\phi \to K_S K_S \to \pi^+\pi^-\pi^+\pi^-$
SM background: resulting from CPV, $\phi \to K_L K_S \to \pi^+\pi^-\pi^+\pi^-$
Regeneration background: regeneration $K_L \to K_S$ in material
Combinatoric background Prompt kaons and pions

Selection - inclusive ϕ

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Inclusive ϕ production

- Stripping PhiToKSKS_PhiToKsKsLine
  - π TRGHOSTPROB < 0.35
    - P > 2.GeV
    - MIPCHI2DV(PRIMARY) > 9.
  - K_S ADMASS('KS0') < 35.MeV
    - VFASPF(VCHI2) < 25.
  - ϕ LL or LD combinations *)
    - APT > 400 MeV
    - VFASPF(VCHI2/VDOF) < 6
    - MIPCHI2DV(PRIMARY) < 9
    - M < 1100 MeV
- 1010 MeV <phi_M< 1030 MeV

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*) because of regeneration, KLOE follows the same approach

Selection - $D_s \to \phi\pi$

- Selection (inspired by PhiToKSKS_PhiToKsKsLine and other charm lines) on CHARMCOMPLETEEVENT.DST

$\pi(K_S)$ PT > 150 MeV
BPVIPCHI2() > 1.0
TRCHI2DOF < 5
TRGHOSTPROB < 0.3

K_S ADMASS('KS0') < 35 MeV
VFASPF(VCHI2) < 2.
PT > 200 MeV
BPVVD > 10.0 mm
BPVVDCHI2 > 100
VFASPF(VCHI2PDOF) < 10
BPVDIRA > 0.999

ϕ LL or LD combinations
ADMASS('phi(1020)')<70 MeV
VFASPF(VCHI2/VDOF) < 6
APT > 400 MeV

$\pi(D_S)$ TRGHOSTPROB < 0.35
P > 2 GeV
MIPCHI2DV(PRIMARY) > 9

D_S ADMASS('D_s+') < 150MeV
(BPVVDCHI2 > 16.0) or
(BPVLTIME() > 0.150 ps)
VFASPF(VCHI2/VDOF) < 25.0

- 1010 MeV<phi_M<1030 MeV & 1955 MeV<Ds_M<1985 MeV
- IPCHI2 ≥ 15, (possible to tighten cut if more MC statistics available)

Efficiencies
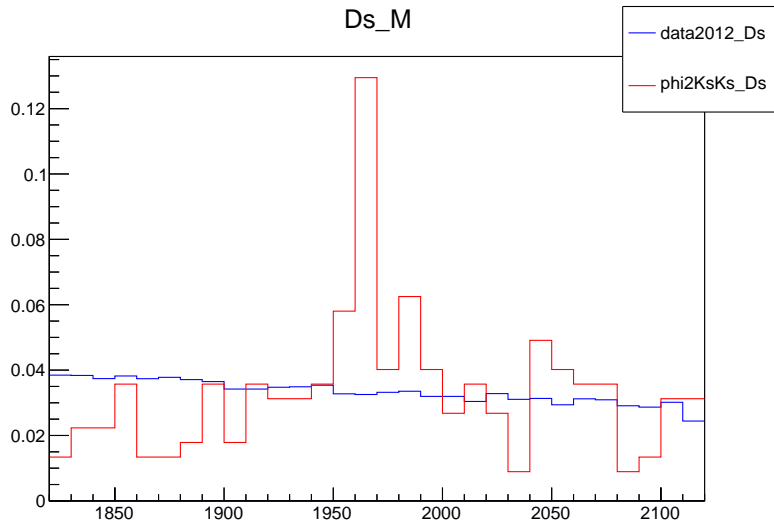
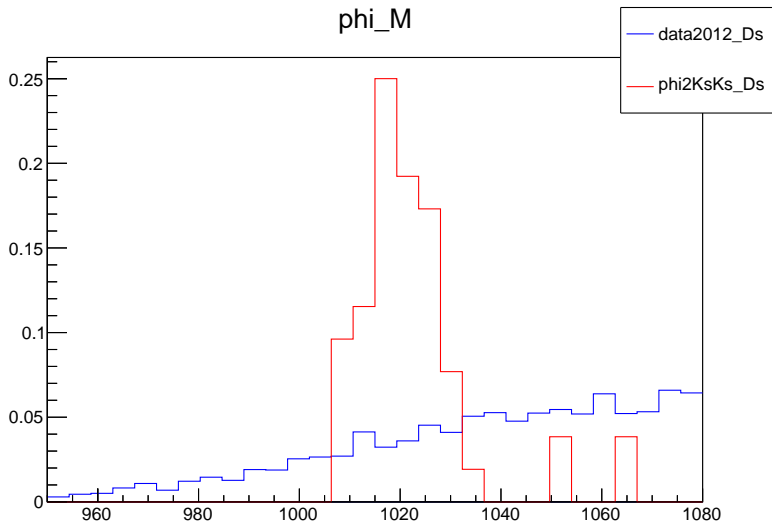|	Inclusive ϕ	$D_s \to \phi\pi$
Cross section (14 TeV)		
LHCb acceptance	3516 µb	388 µb
Branching fractions	34.2 %	4.5 % · 34.2 %
Fiducial cuts efficiency	2.5 %	7.0 %
Prob. $K_s K_s \to 4\pi$,		
exactly 1 (2) decays inside bp	15.1%(2.8%)	
Prob. $K_s K_L \to 4\pi$ (CPV),		
exactly 1 (2) decays inside bp	$3.98 \cdot 10^{-7}(4.99 \cdot 10^{-10})$	
Upper limit KLOE prob. $K_s K_L \to 4\pi$ (CPV		
+ CPTV), exactly 1 (2) decays inside bp	$5.13 \cdot 10^{-7}(1.64 \cdot 10^{-8})$	
Reconstruction & selection efficiency	7.9 %(7.6 %)	1.4 %(4.2 %)
L0 efficiency	16.1 %(18.6 %)	22.4 %(18.2 %)
HLT1 efficiency	13.7 %(16.7 %)	45.5 %(25.0 %)
HLT2 efficiency	65.6 %(100.0 %)	75.0 %(100.0 %)
Total efficiency SM background	$4.39 \cdot 10^{-5}(5.85 \cdot 10^{-5})$	$1.02 \cdot 10^{-4}(1.32 \cdot 10^{-4})$
Expected events SM background / fb^{-1}	$21(3.51 \cdot 10^{-2})$	$2.43 \cdot 10^{-1}(3.94 \cdot 10^{-4})$
Upper limit for signal (KLOE)	27(1.15)	$3.13 \cdot 10^{-1}(1.29 \cdot 10^{-2})$
Background (data 2012) / fb^{-1}	163110 (29120)	1170 (6100)

Mass plots - inclusive ϕ
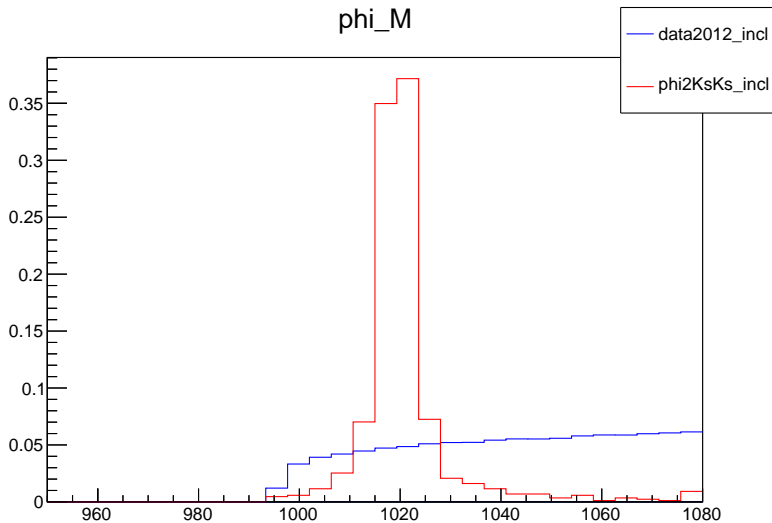
Mass plots - $D_S \to \phi\pi$

Mass plots - $D_S \to \phi\pi$

Comparisons

Good agreement with other studies!

$D_0 \rightarrow K_s K_s$ by Markward Britsch

	M. Britsch	inclusive/D_s approach
Reconstruction & selection	0.2-0.5%	0.2%/ 0.1%
Efficiency L0+Hlt1	3%	10% / 4%
Efficiency L0+Hlt1+Hlt2	1%	7% / 4%

$X \rightarrow K_s K_s$ by Thomas Ruf

|	T. Ruf	inclusive/D_s approach
Acceptance & reconstruction	10%	
Reconstruction & selection		0.2%/ 0.1%
Probability of at least 1 K_s decaying in beampipe	50%	44% / 42%

Backgrounds

Estimates from minimum bias MC (42 M events). Number in brackets is the the number of background events with physical K_s

Background category	inclusive ϕ	$D_s \to \phi\pi$
light flavour	17(17)	0
$b\bar{b}$	1(1)	0
different PV	3(2)	0
physical bkg, partl. reconstructed	1(1)	1(1)
ghosts	0	1(0)
total	21(20)	2(1)

Remaining background for inclusive ϕ mostly irreducible

Time Resolution
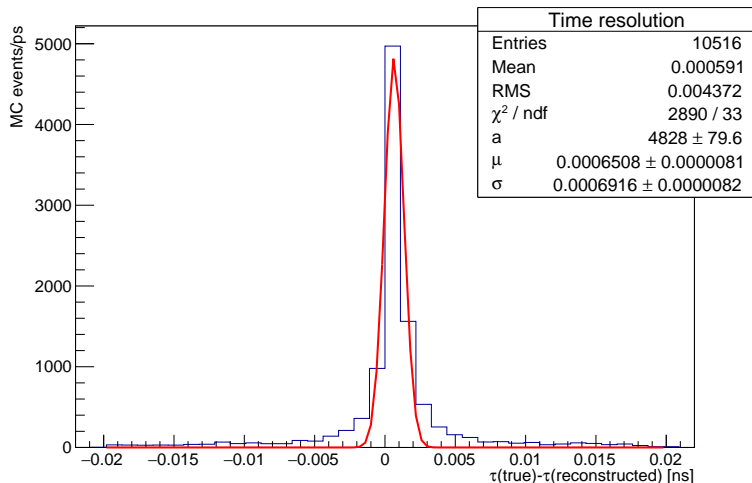
Resolution of a few ps; the core that has a resolution of less than 1 ps

Summary

- Selection for $D_S \rightarrow \phi\pi$ was implemented
- Compared the inclusive and D_S strategies
- For both approaches, the background dominates
- In 2012 data, there is no ϕ peak visible
- The time resolution is about ~ 1 ns