Status of $B_0 \to \eta' K_0$

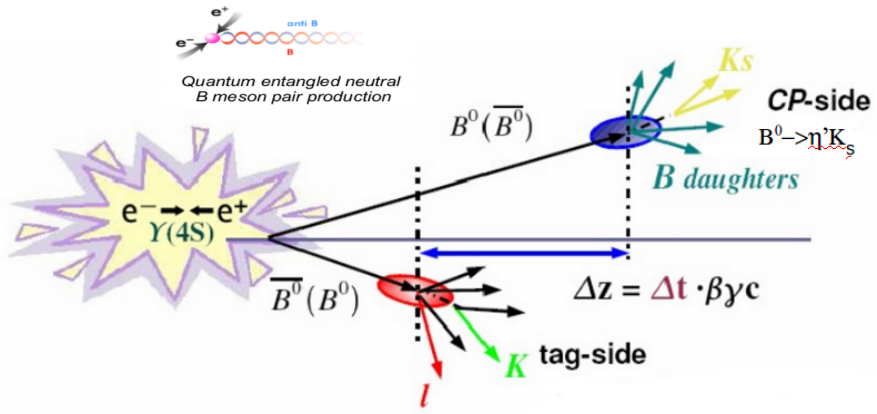
Stefano Lacaprara, Alessandro Mordà

stefano.lacaprara@pd.infn.it

INFN Padova

6^{th} Belle II Italian collaboration meeting,
Roma, 14 december 2016

Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state

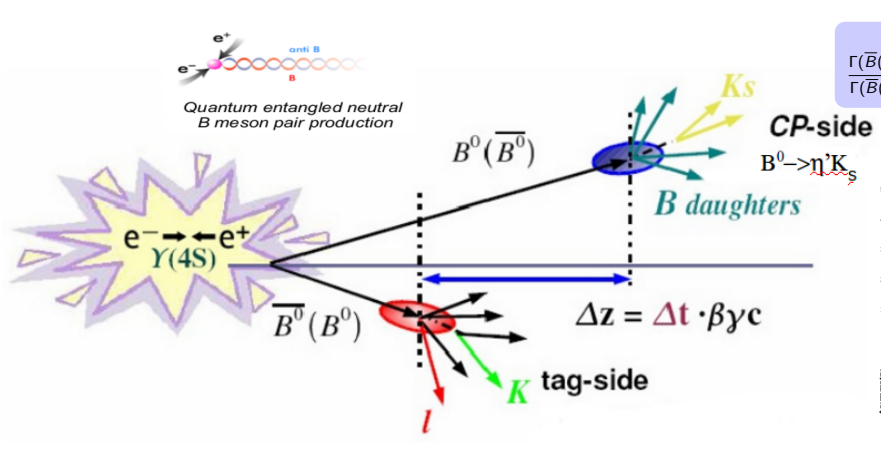


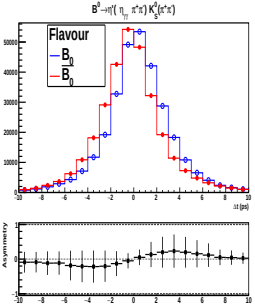
Time Dep. $\not{CP}$:
a powerful tool to both perform

- precise measurement of the UT
- look for new physics BSM
- here with charmless hadronic mode

Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state

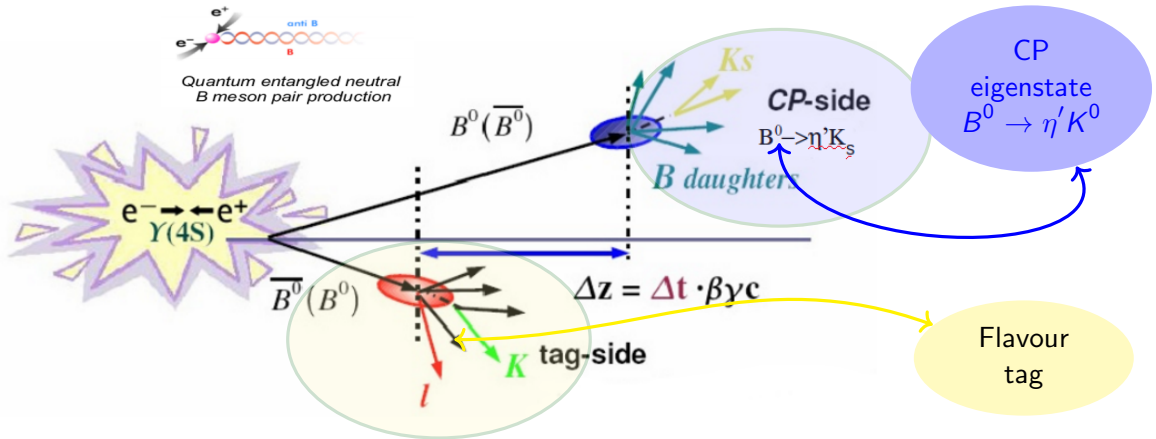
$$Asym_{CP}(t) = \frac{\Gamma(\overline{B}(t) \to f_{CP};t) - \Gamma(B(t) \to f_{CP};t)}{\Gamma(\overline{B}(t) \to f_{CP};t) + \Gamma(B(t) \to f_{CP};t)}$$





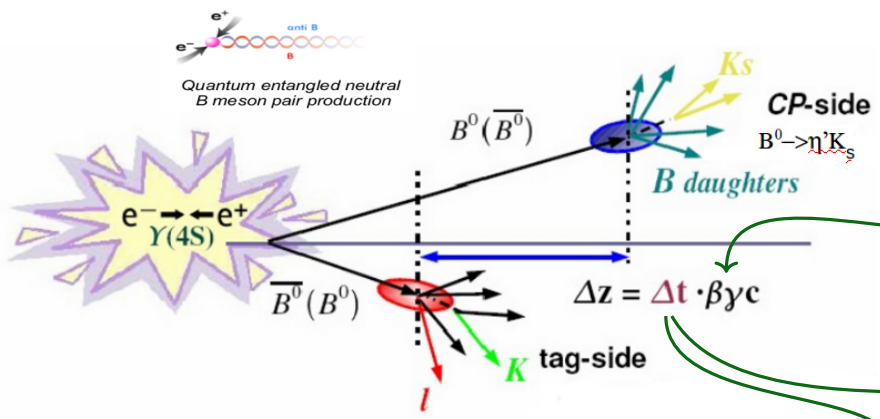
Δt probabilty parametrization: $\mathcal{P}(\Delta t, q) = \frac{e^{-\Delta t/\tau_{B^0}}}{4\tau_{B^0}} [1 + q\,(\mathcal{A}_{CP} \cos \Delta m_d \Delta t + \mathcal{S}_{CP} \sin \Delta m_d \Delta t)]$

Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state



Δt probabilty parametrization: $\mathcal{P}(\Delta t, q) = \frac{e^{-\Delta t/\tau_{B^0}}}{4\tau_{B^0}} [1 + q\,(\mathcal{A}_{CP} \cos \Delta m_d \Delta t + \mathcal{S}_{CP} \sin \Delta m_d \Delta t)]$

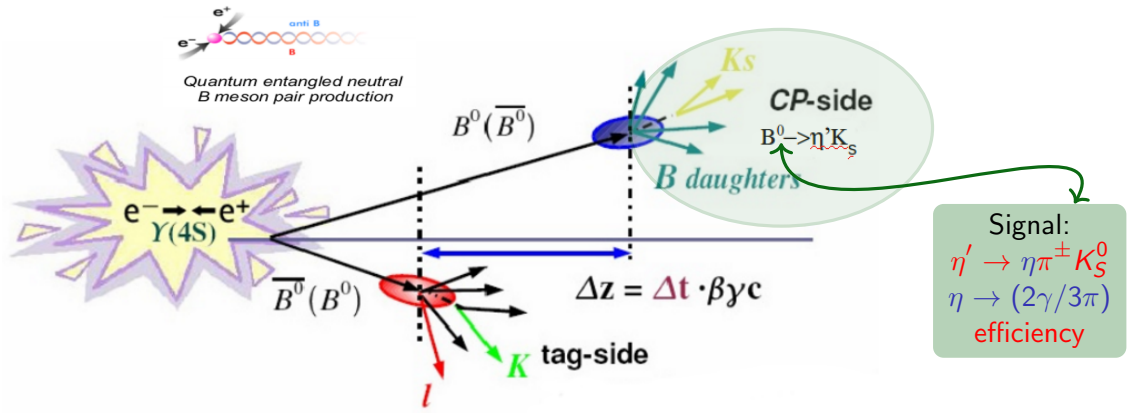
Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state



$\beta\gamma$ = 0.28(0.45) Belle2(Belle)

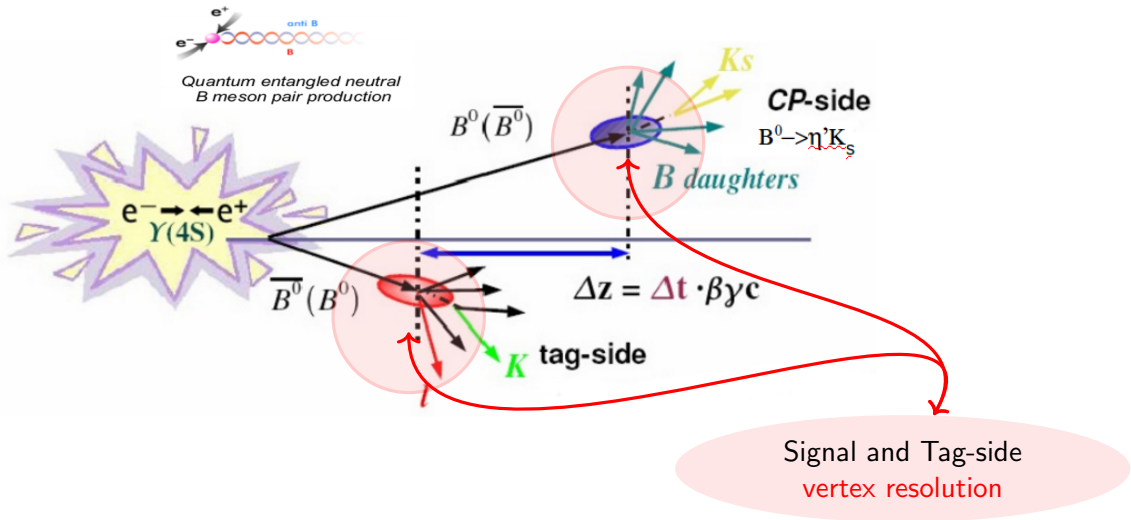
Δt probabilty parametrization: $\mathcal{P}(\Delta t, q) = \frac{e^{-\Delta t/\tau_{B^0}}}{4\tau_{B^0}} [1 + q\,(\mathcal{A}_{CP} \cos \Delta m_d \Delta t + \mathcal{S}_{CP} \sin \Delta m_d \Delta t)]$

Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state

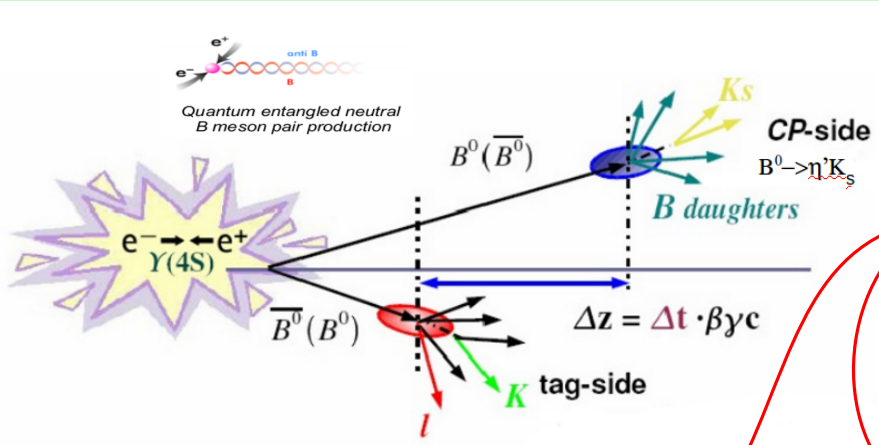


Signal:
$\eta' \to \eta\pi^{\pm} K_S^0$
$\eta \to (2\gamma/3\pi)$
efficiency

Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state



Time Dependent $\not{CP}$ Violation using $\eta' K_0$ final state



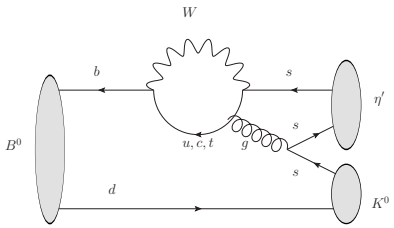
- signal x feed
- Background
  - Continuum
  - Peaking
- ML fit to extract the phys params
- Toys to project sensitivity to 1 and 5 ab^{-1}
- ...

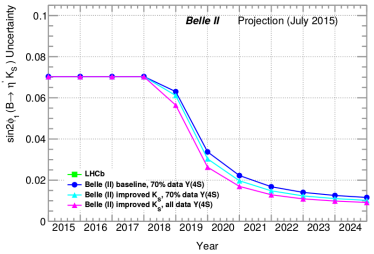
Δt probabilty parametrization: $\mathcal{P}(\Delta t, q) = \frac{e^{-\Delta t/\tau_{B^0}}}{4\tau_{B^0}} [1 + q\,(\mathcal{A}_{CP} \cos \Delta m_d \Delta t + \mathcal{S}_{CP} \sin \Delta m_d \Delta t)]$

Charmless decay

TDCPV in charmless $b \to s$ decay

- the BR is much lower than the $b \to c$ $B \to J/\psi K_s$
- also, vertex resolution is generally worse due to lower q of B^0 decay
- $S_{\eta' K^0} = \sin 2\phi_1^{eff}$ tightly related to $\sin 2\phi_1$ measured in $b \to c s \bar{s}$ decay
- identical if only penguin diagram were present. Not so: $\Delta S_{\eta' K^0} \approx \pm 0.03, 0.05$
- new physics can enter in the loop, shifting $\Delta S_{\eta' K^0}$ more than SM expectation
- errors are statistically dominated, so far: fast improvement with first data;
- no competition from LHCb for η', due to the presence of neutrals.





What's new wrt last B2GM

- Move to MC6 dataset
  - Full BGx1 analysis
- Efficiency of the signal w/ and w/o machine background understood;
  - Signal detector acceptance;
  - tracking efficiency drop from BGx0 to BGx1;
- BDT for signal cross feed (SxF) included in the ML fit;
  - separate well true from cross feed signal
- Accept multiple candidates per event;
  - particularly useful for $\eta_{3\pi}$, where cands multiplicity is high;
  - increase of efficiency for true signal yield, at the cost of more SxF;
  - the SxF BDT allows for separation of signal and SxF on a statistical basis on the ML fit;
- study sensitivity obtained using different number of candidates per event $\eta_{3\pi}$
  - not so relevant for $\eta_{\gamma\gamma}$ final state: low multiplicity;
  - $\mathcal{S}_{CP}$ sensitivity with toys.
- Documented in B2TIP report

Decay channels

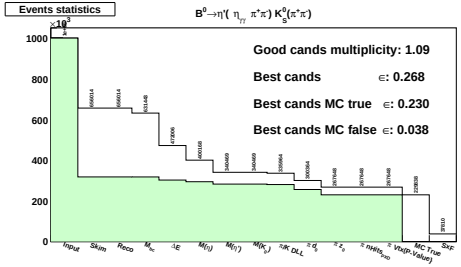
many decay channels available $B^0 \to \eta' K^0$

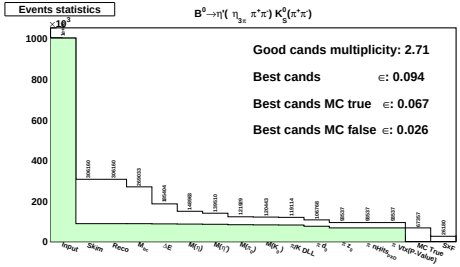
decay channel		
$\eta' \to \rho^0(\to \pi^+\pi^-)\gamma$	BR=29%	not yet
$\eta' \to \eta\pi^+\pi^-$	43%	today
$\searrow \eta \to \gamma\gamma$	40%	$\eta_{\gamma\gamma}$
$\searrow \eta \to \pi^+\pi^-\pi^0$	23%	$\eta_{3\pi}$
$K^0_S \to \pi^+\pi^-$	69%	today
$K^0_S \to \pi^0\pi^0$	31%	just started
K^0_L		not yet
$B_0 \to \eta'(\to \eta_{\gamma\gamma}/\eta_{3\pi}\pi^+\pi^-)K^0_S(\to \pi^+\pi^-)$	BR=19%	

- Not all final state studied in time for B2TIP report
- final states considered so far in red
- not yet $(\rho^0, K^0_S \to \pi^0\pi^0, K^0_L)$
  - π^0 reconstruction eff still quite low
  - K^0_L reconstruction not yet available
  - $\rho^0\gamma$ not yet
- educated guess in final sensitivity for the missing channels

Impact of machine background on signal efficiency

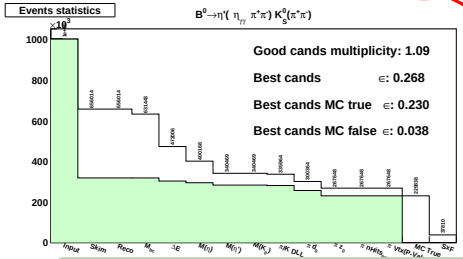
channel	BGx0 ϵ %	BGx0 SxF%	BGx0 cands/ev	BGx1 ϵ %	BGx1 SxF %	BGx1 cands/ev
$B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S\ (\to \pi^+\pi^-)$	30.1	2.3	1.06	23.0	3.8	1.09
$B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S(\to \pi^+\pi^-)$	15.1	3.0	1.45	6.7	2.6	2.71

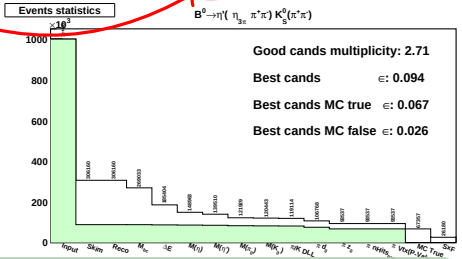




Impact of machine background on signal efficiency

channel	BGx0 ϵ %	BGx0 SxF%	BGx0 cands/ev	BGx1 ϵ %	BGx1 SxF %	BGx1 cands/ev
$B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S\ (\to \pi^+\pi^-)$	30.1	2.3	1.06	23.0	3.8	1.09
$B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S(\to \pi^+\pi^-)$	15.1	3.0	1.45	6.7	2.6	2.71

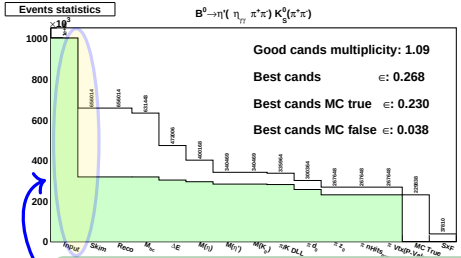


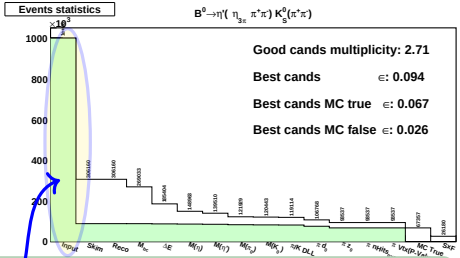


Important drop of efficiency passing from BGx0 to BGx1

Impact of machine background on signal efficiency

channel	BGx0 ϵ %	BGx0 SxF%	BGx0 cands/ev	BGx1 ϵ %	BGx1 SxF %	BGx1 cands/ev
$B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S\ (\to \pi^+\pi^-)$	30.1	2.3	1.06	23.0	3.8	1.09
$B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S(\to \pi^+\pi^-)$	15.1	3.0	1.45	6.7	2.6	2.71



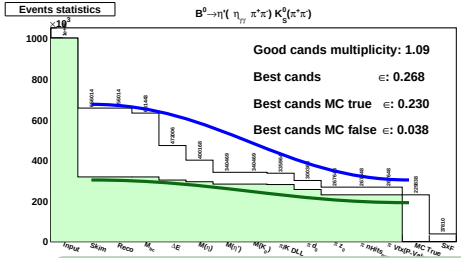


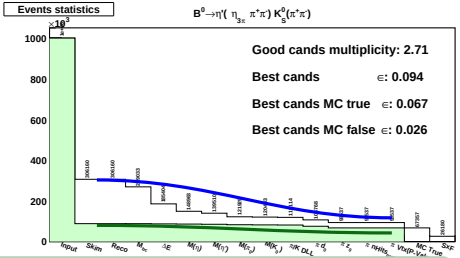
Important drop of efficiency passing from BGx0 to BGx1

- Reconstruction efficiency accounts for almost all eff drop
- Acceptance for signal is about: $\sim 50\%$

Impact of machine background on signal efficiency

channel	BGx0 ϵ %	BGx0 SxF%	BGx0 cands/ev	BGx1 ϵ %	BGx1 SxF %	BGx1 cands/ev
$B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S\ (\to \pi^+\pi^-)$	30.1	2.3	1.06	23.0	3.8	1.09
$B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S(\to \pi^+\pi^-)$	15.1	3.0	1.45	6.7	2.6	2.71



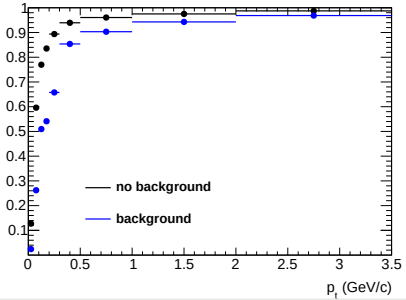


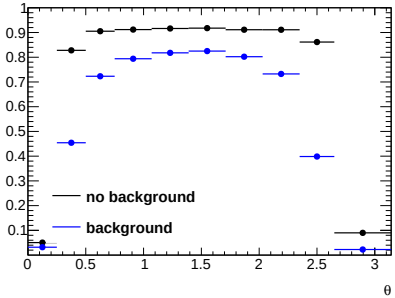
Important drop of efficiency passing from BGx0 to BGx1

- Reconstruction efficiency accounts for almost all eff drop
- Acceptance for signal is about: $\sim 50\%$
- Signal selections mostly reduce SxF (and background)
- optimization for signal efficiency at the cost of SxF increase.

Tracking efficiency without and with machine background

From B2TIP report (draft): Belle2 Performances





- About 8% loss for track
- $B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S$ ($\to \pi^+\pi^-$) has 4 charged tracks: $\sim$ 30% drop, 30 $\to$ 23.0
- $B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S(\to \pi^+\pi^-)$ has 6 charged tracks: $\sim$ 50% drop, 15.1 $\to$ 6.7
  - Some gain possible with fine tuning selections, but mostly is reconstuction;
- likely to improve with better reconstruction algorithms
  - Efficiency for $K^0 \to 2\pi^0$ channels approx 1/2;

Signal cross feed

Issue

- an other problem from machine background for signal is the increase of signal cross feed
- Signal is selected but a wrong set of tracks or photons are used to build the decay chain
  - BGx0→BGx1

$\eta_{\gamma\gamma}$: SxF/Signal=2.3% → 16.5%
$\eta_{3\pi}$: SxF/Signal=5.8% → 27%

Origin

mis−Reco ⇒	$\frac{wrong\ \eta'}{tot\ SXF}$	$\frac{wrong\ \eta}{wrong\ \eta'}$	$\frac{wrong\ \pi^0}{wrong\ \eta}$
$\eta_{\gamma\gamma} K_S^{\pm}$	99.0 %	78.1 %	− − −
$\eta_{3\pi} K^{\pm}$	99.9 %	98.7 %	82.03%

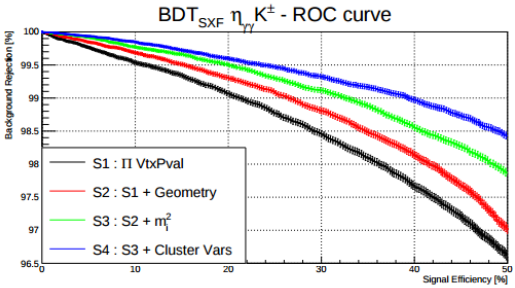
As expected, in most of the cases the problem is in the neutrals $\eta, \pi^0 \to \gamma\gamma$
In addition, loosening signal selection to try and inprove signal efficiency worsen the problem

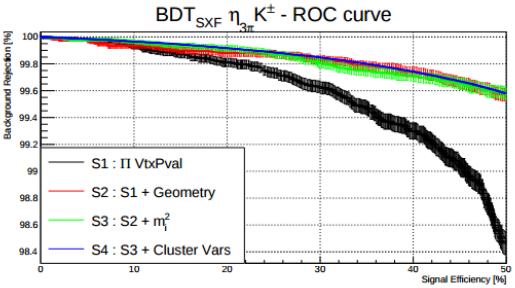
Possible solution

- improve the choice of best candidate in events with multiple ones
- inizial choice based on best $\Pi(P_{vertex})$ or χ^2 of invariant masses in the decay chain
- try a multivariate approach

Signal cross Feed: BDT

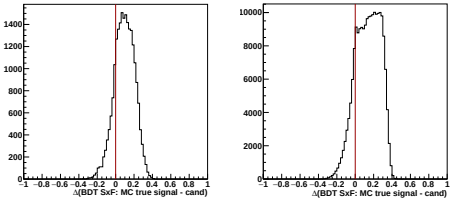
- Refine the selection of the best candidate after the selection through a BDT
- trained before selection on true (sig) & wrongly reconstructed (bkg) signals
- topological and cluster-related input variables
- apparently room for improvement

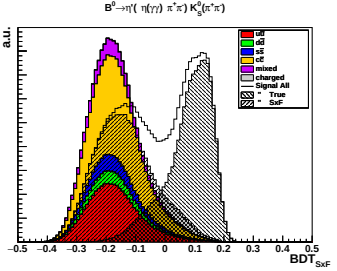




SxF BDT (II)

- The behaviour is good, true signal has the best BDT in most of the cases
- Separation between signal and SxF is good
- Background (continuum and peaking) is well separated as well
- Choose the candidate with the highest BDT





But . . .

In spite of all this, the actual improvement in Sxf contamination is marginal: few % at most!

$\eta_{\gamma\gamma}$: SxF/Signal=16.5% $\rightarrow$ 15%

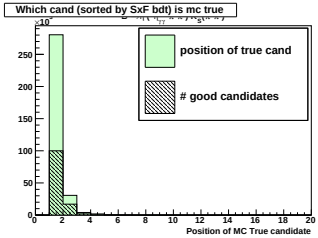
$\eta_{3\pi}$: SxF/Signal=27% $\rightarrow$ 25%

true signal vs SxF separation possible

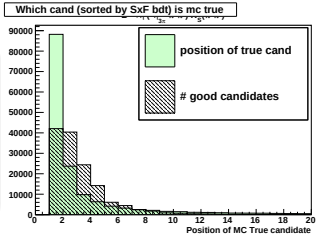
Improve efficiency by multiple candidates

- The SxF BDT not able to select the *one* best candidate;
- but, allow to understand if a selected candidate is true or not;
- since we have problem with efficiency, we can select more than one candidate per event
  - $\eta_{\gamma\gamma}$ can take all candidates, low multiplicity per event
  - $\eta_{3\pi}$ many true candidates are the next to best BDT
- this will significantly increase SxF as well
- include SxF BDT in the ML to separate the two sources

$B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S$



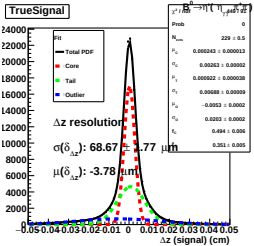
$B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S$



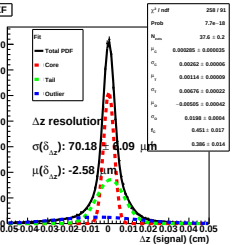
$\eta_{3\pi}$: efficiencies and SxF

candidates	1	2	all
True signal efficiency	6.7	8.1	9.6
SxF efficiency	2.3	6.0	28.6

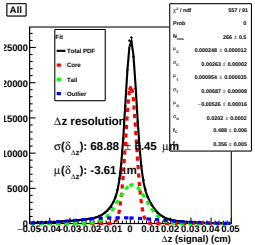
Vertex resolution: True signal, SxF, all. $B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S$



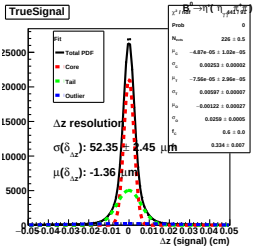
True Signal

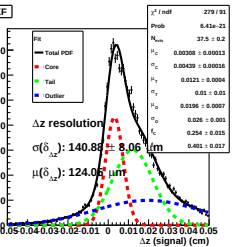


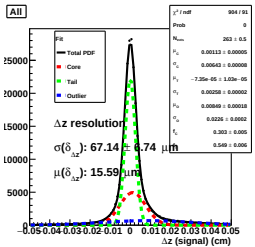
SxF



All







Signal side

True $\sigma = 69\ \mu m$

SxF $\sigma = 70\ \mu m$

All $\sigma = 69\ \mu m$

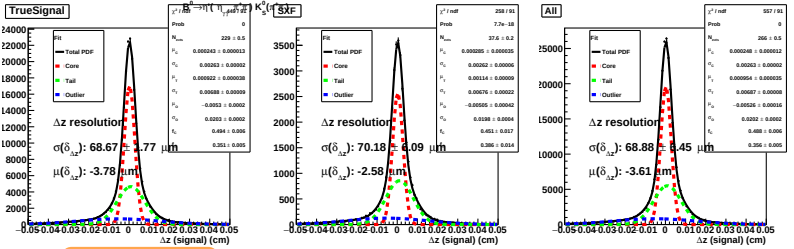
Tag side

True $\sigma = 52\ \mu m$

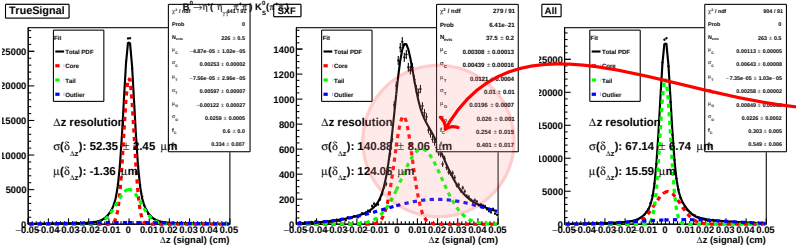
SxF $\sigma = 141\ \mu m$

All $\sigma = 67\ \mu m$

Vertex resolution: True signal, SxF, all. $B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S$



True Signal SxF All



Signal side

True $\sigma = 69\ \mu m$

SxF $\sigma = 70\ \mu m$

All $\sigma = 69\ \mu m$

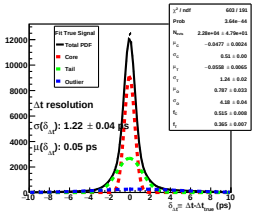
Tag side

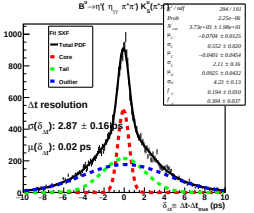
True $\sigma = 52\ \mu m$

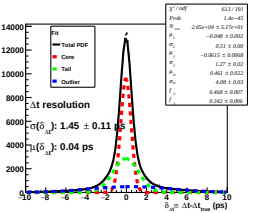
SxF $\sigma = 141\ \mu m$

All $\sigma = 67\ \mu m$

Δt resolution



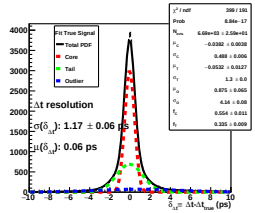


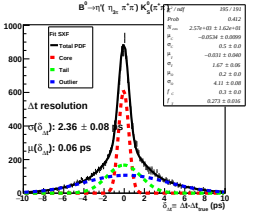


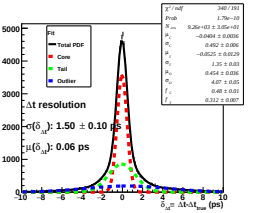
True Signal

SxF

All







Non negligible impact of BGx1 on Δt resolution

$\eta_{\gamma\gamma}$(BGx1)

True $\sigma = 1.22$ *ps*

SxF $\sigma = 2.87$ *ps*

All $\sigma = 1.45$ *ps*

True (BGx0) $\sigma = 0.91$ *ps*

$\eta_{3\pi}$(BGx1)

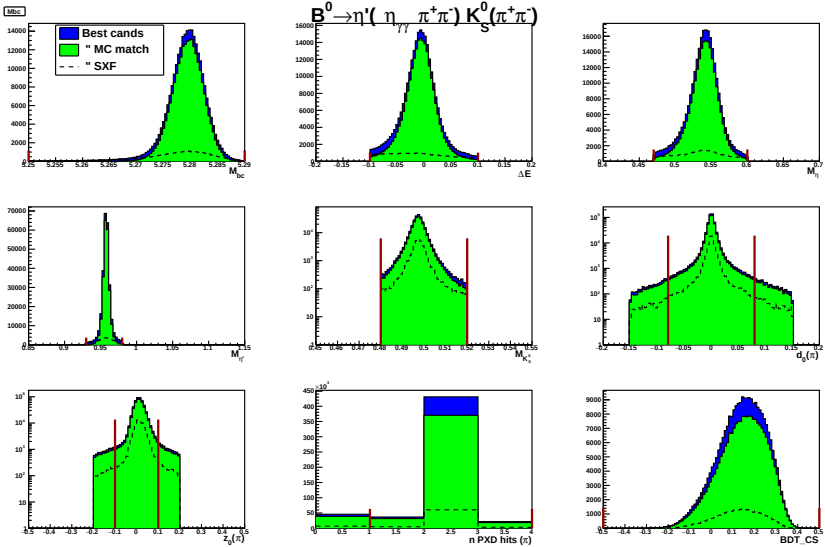
True $\sigma = 1.17$ *ps*

SxF $\sigma = 2.36$ *ps*

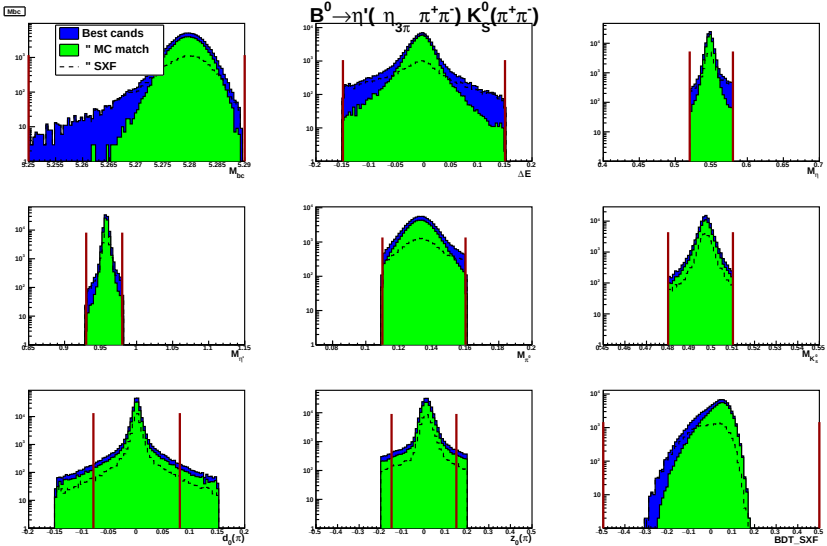
All $\sigma = 1.50$ *ps*

True (BGx0) $\sigma = 0.88$ *ps*

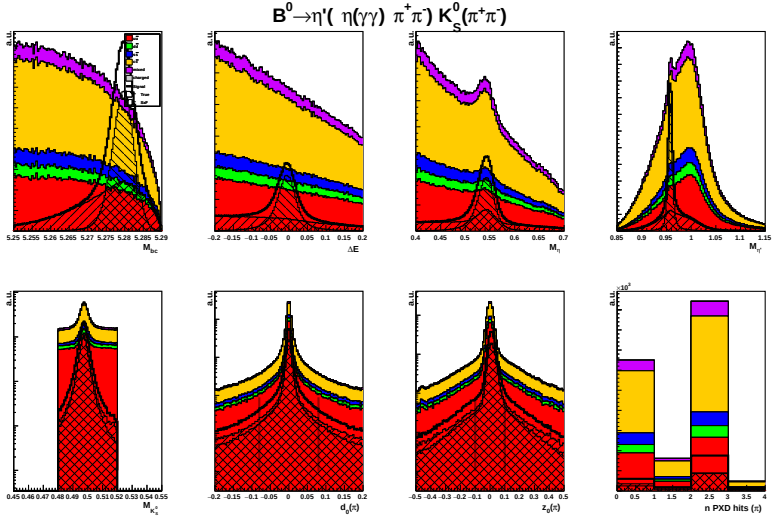
Distribution for Signal



Distribution for Signal

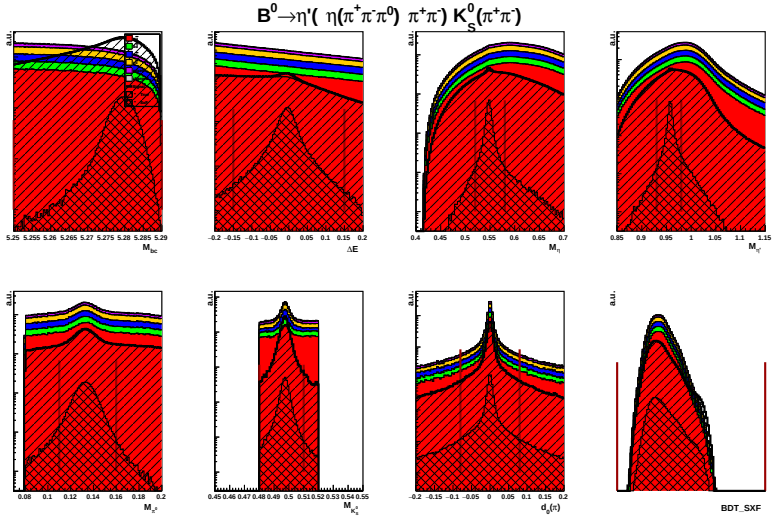


Distribution for Signal and Background



- Black: signal
  - True \\
  - SxF //
  - All candidates!
- Colors: background
- No major differences for Signal and Background distribution from BGx0 to BGx1

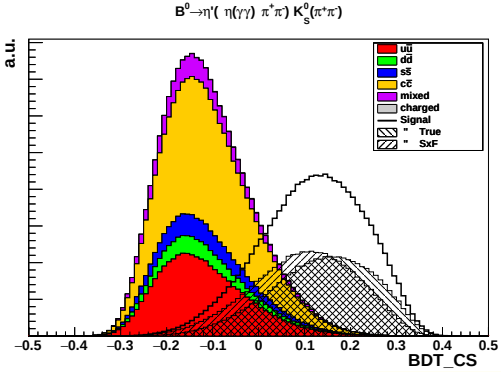
Distribution for Signal and Background

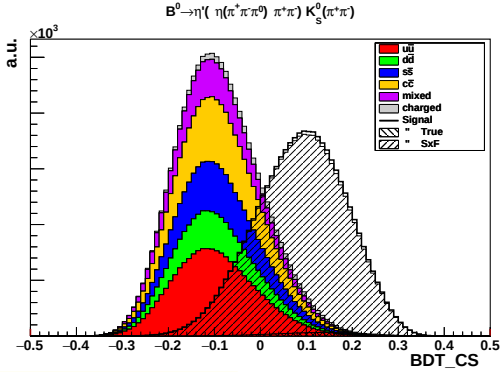


- Black: signal
  - True \\
  - SxF //
  - All candidates!
- Colors: background
- Signal shown with all good candidates
  - multiplicity 2.7 cand/ev

Background: continuum suppression

Plot with all candidates





Channel	Continuum	$B\bar{B}$	B^+B^-
$\eta(2\gamma)K^0_S(\pi^\pm)$	16413	1834	57
$\eta(3\pi)K^0_S(\pi^\pm)$	4508	304	13

Likelihood fit

Multi dim. extended maximum likelihood fit to extract S and A.

Pdf is of the form: $\mathcal{P}_j^i = \underbrace{\mathcal{T}_j\left(\Delta t^i, \sigma_{\Delta t}^i, \eta_{CP}^i\right)}_{\text{time-dep part}} \prod_k \underbrace{\mathcal{Q}_{k,j}(x_k^i)}_{\text{time integrated}}$

time-dependent part, taking into account mistag rate ($\eta_f = \pm 1$ is CP state):

$$f(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}\left\{1 \mp \Delta w \pm (1-2w) \times \left[-\eta_f S_f \sin(\Delta m \Delta t) - A_f \cos(\Delta m \Delta t)\right]\right\}$$

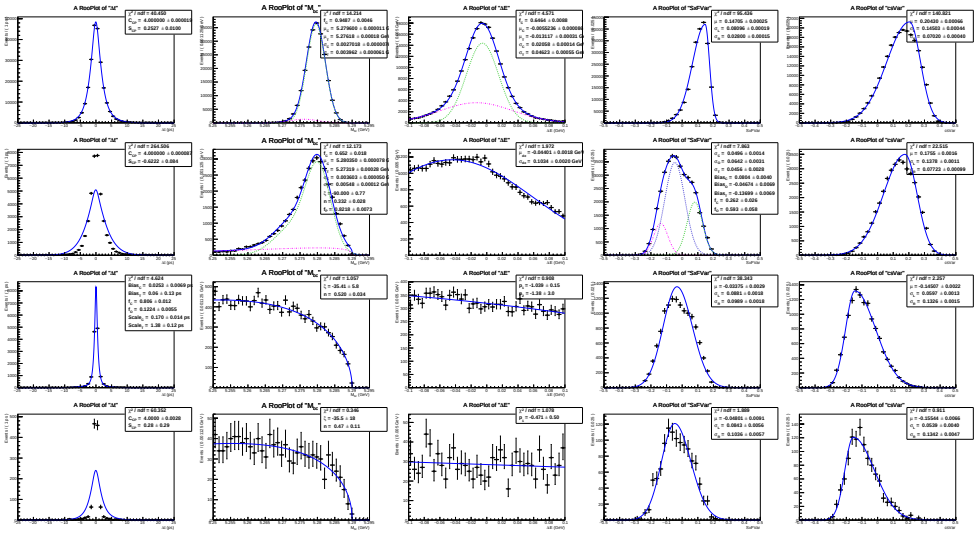
variables (x_k) used, in addition to Δt

- M_{bc}
- ΔE
- Cont. Suppr.
- SxF BDT new

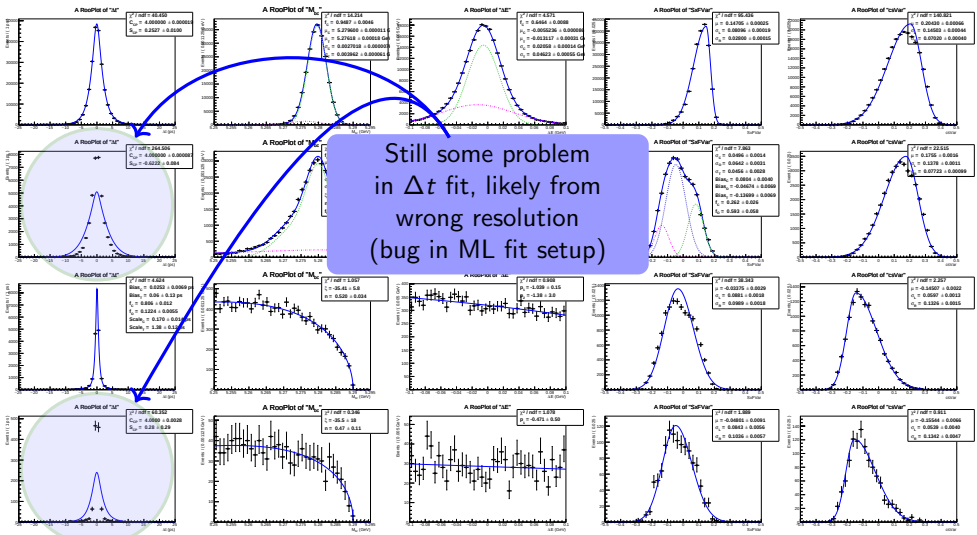
Parameters:

- effective tagging efficiency: $Q = \epsilon(1-2w)^2 = 0.33$
  - $w = 0.21$, $\Delta w = 0.02$
- Δt resolution as shown previously (convoluted)
- τ, Δm from PDG

ML fit $B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S$



ML fit $B^0 \to \eta'(\eta_{\gamma\gamma}\pi^{\pm})K^0_S$



Signal

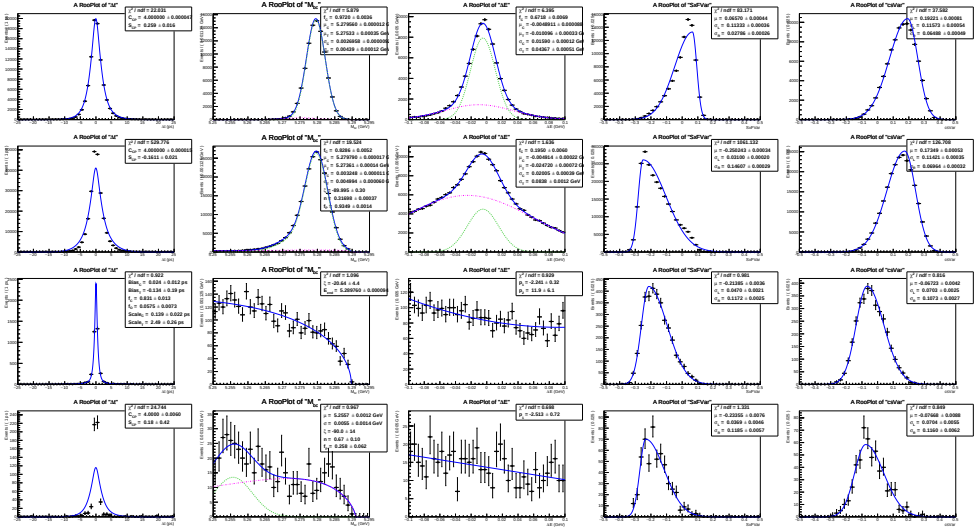
SxF

Continuum

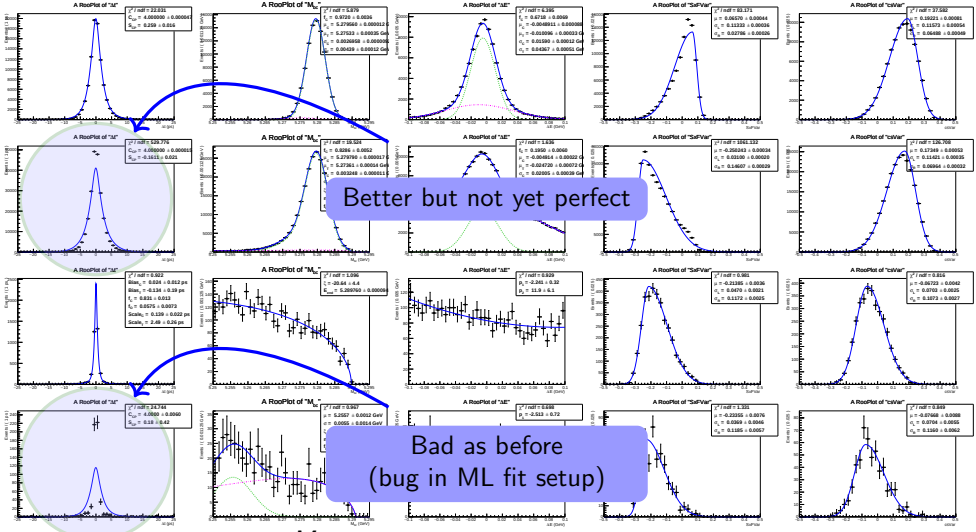
Peaking

Δt M_{bc} ΔE SxF CS

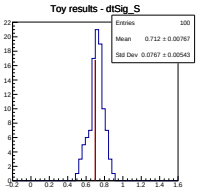
ML fit $B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S$

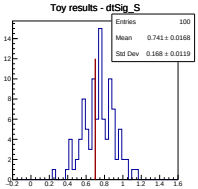


ML fit $B^0 \to \eta'(\eta_{3\pi}\pi^{\pm})K^0_S$



Toys and projection





Channel	yield	$\sigma(S)$	$\sigma(C)$
	1 ab^{-1}		
$\eta(2\gamma)K^0_S(\pi^\pm)$	1915	0.07	0.06
$\eta(2\gamma)K^0_S(2\pi^0)$	423	0.15	0.13
$\eta(3\pi)K^0_S(\pi^\pm)$	390	0.17	0.10
K_S modes		0.04	0.03
$K_S + K_L$ modes		0.038	0.028
	5 ab^{-1}		
$\eta(2\gamma)K^0_S(\pi^\pm)$	9600	0.04	0.03
$\eta(2\gamma)K^0_S(2\pi^0)$	2100	0.09	0.07
$\eta(3\pi)K^0_S(\pi^\pm)$	1900	0.07	0.04
K_S modes		0.03	0.022
$K_S + K_L$ modes		0.028	0.02

Missing channel

- $K^0_S \to 2\pi^0$ and K^0_L
- Use educated extrapolation;
- start from fully analyzed channels;
- use Belle published ratio wrt those;
- TODO for $\eta' \to \rho\gamma$
- Bias on $\mathcal{A}(C)_{CP}$: non negligible bias, under investigation

Published results:

Belle ($772 \cdot 10^6$ $B\overline{B}$): $N_{sig} = 648$, $\sigma_S = 0.15$, $\sigma_C = 0.10$

BaBar ($467 \cdot 10^6$ $B\overline{B}$): $N_{sig} = 472$, $\sigma_S = 0.17$, $\sigma_C = 0.11$

Summary and outlook

- K_S^{00} as well as K_L final states, but educated extrapolation included
- $\eta' \to \rho\gamma$ not touched at all; educated extrapolation TODO
- ML fit tuning;
  - Still some remaining issues:
  - migration between continuum and peaking background
  - still failing to properly fit Δt distribution for peaking (possibly related);
  - Bias seen for A in toys ($\mathcal{A}_{CP} = -0.1$), S is fine
- Included in B2TIP report (draft)
  - Working Group 3 (WG3), chapter 9: "Time Dependent CP Violation of B mesons and the determination of ϕ_1" ,
  - chapter mostly completed (missing introduction, summary, ...)
  - waiting for reviewer comments
- not clear if a more detailed study based on MC is really worth;
- I'd like to have a B2 note with more complete documentation for future reference;

Additional stuff

Additional or backup slides

Selection

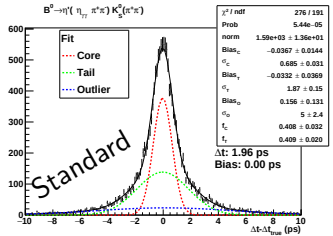
candidate selection: main cuts

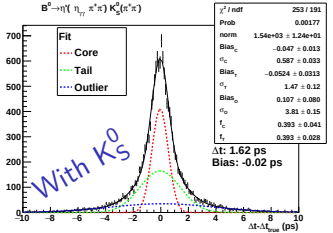
- Reconstruct decay chain with mass constrains for π^0, η, η', K^0_S,
  - vertex only (w/o mass) for B^0 (more later)
    - π^0, $\eta_{\gamma\gamma}$:
    - $0.06 < E_\gamma < 6\,\text{GeV}$, $E_9/E_{25} > 0.75$
    - $M(\pi^0) \in [100, 150]\,\text{MeV}$
    - $M(\eta_{\gamma\gamma}) \in [0.52, 0.57]\,\text{GeV}$;
    - $\eta' \to \eta_{\gamma\gamma}\pi^+\pi^-$:
    - $d_0(\pi^\pm) < 0.08\text{mm}$; $z_0(\pi^\pm) < 0.1\text{mm}$;
    - N hits$_{PXD}(\pi^\pm) > 1$, PID
    - $M(\eta') \in [0.93, 0.98]\,\text{GeV}$;
    - $\eta' \to \eta_{3\pi}\pi^+\pi^-$:
    - $M(\eta') \in [0.93, 0.98]\,\text{GeV}$;
    - $K^0 \to \pi^+\pi^-$:
    - $M(K^0_S \to \pi^+\pi^-) \in [0.48, 0.52]\,\text{GeV}$;
    - $B^0 \to \eta'(\to \eta_{\gamma\gamma}\pi^+\,\pi^-)K^{0+-}_S$
    - $M_{bc} > 5.25\,\text{GeV}$;
    - $|\Delta E| < 0.1\,\text{GeV}$;
    - $B^0 \to \eta'(\to \eta_{3\pi}\pi^+\pi^-)K^{0+-}_S$
    - $|\Delta E| < 0.15\,\text{GeV}$;

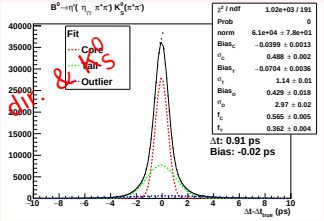
if $N_{cands} > 1$, select that with best reduced χ^2 for η, η', K^0_S inv. masses

Vtx reco and Δt resolution: $\eta_{\gamma\gamma}$ channel

1. Fit the B_0 vertex from charged tracks; ($\pi^{\pm}$ from $\eta' \to \eta\pi^{\pm}$)
2. add also constraint from reconstructed K^0_S direction; ($K^0_S \to \pi^+\pi^-$)
3. add also constraint from B^0 boost direction, transverse plane only.







With beamspot (x, y) & K^0_S:

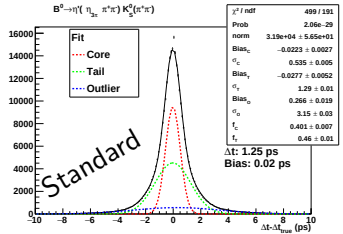
No efficiency loss

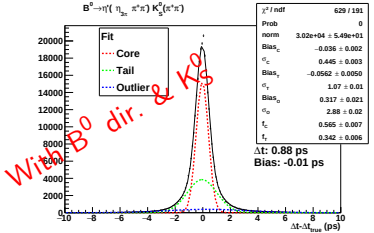
important improvement in Δt resolution

$1.89 \to 1.62 \to 0.91$ *ps*

Vtx reconstruction for $B^0 \to \eta'(\to \eta_{3\pi}\pi^+\pi^-)K_S^{0+-}$

Standard reconstruction uses four charged tracks:
$\pi^\pm$ from $\eta' \to \eta\pi^\pm$ and $\eta \to \pi^\pm\pi^0$





With B^0 dir. & K_S^0:

No efficiency loss

$1.25 \to 0.88$ *ps*

In both cases, Δt resolution better than in Belle, in spite of lower boost

Backgrounds

- **Combinatorial**: from continuum background $e^+e^- \to u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}$
  - evaluated from M_{bc} side bands on real data
  - now from MC production: **NB: still w/o machine background!**
  - use Continuum Suppression variable
    - ⋆ multivariate variables sensitive to event topology
    - ⋆ central (signal) vs jet-like (continuum)
    - ⋆ past issues w/ variables "fixed"
- **Peaking**: any other B decays possibly with real η' and/or K^0_S
  - evaluated from MC of generic $B^0\overline{B}^0$, B^+B^-
    - ⋆ actual $B^0 \to \eta' K^0$ removed.
- Current results based on BGx0 production, namely w/o machine background
  - impact of machine background under study
  - signal w/ machine background already produced
- Next table numbers before Continuum Suppression cut

Background reduction (before CS cut)

Sample	$u\bar{u}$	$d\bar{d}$	$s\bar{s}$	$c\bar{c}$	contiuum	$B^0\overline{B}^0$	B^+B^-
Input ev (M)	1284	321	306	1063	2974	2160	2070
$B^0 \to \eta'(\to \eta_{\gamma\gamma}\pi^+\pi^-)K_S^{0+-}$							
ϵ_{sel} $(\cdot 10^{-6})$	2.69	3.06	2.40	3.62	3.0	0.11	0.038
ev for 300 fb^{-1}	1247	369	275	1445	3335	13	6
$B^0 \to \eta'(\to \eta_{3\pi}\pi^+\pi^-)K_S^{0+-}$							
ϵ_{sel} $(\cdot 10^{-6})$	0.34	0.54	0.17	1.50	0.76	0.14	0.02
ev for 300 fb^{-1}	166	65	20	597	847	24	3

- Background reduction better for $\eta_{3\pi}$ than for $\eta_{\gamma\gamma}$

  $\eta_{\gamma\gamma}$ mostly $u\bar{u}$ and $c\bar{c}$

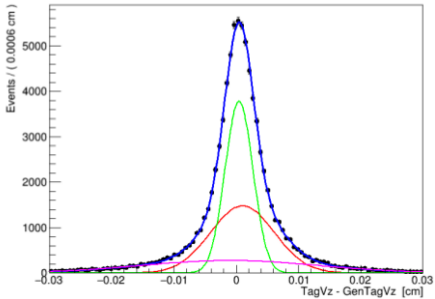
  $\eta_{3\pi}$ mostly $c\bar{c}$
- peaking background is small
  - analyzed whole 5 ab^{-1} dataset from MC5
- preliminary study on w/ machine background shows similar rates

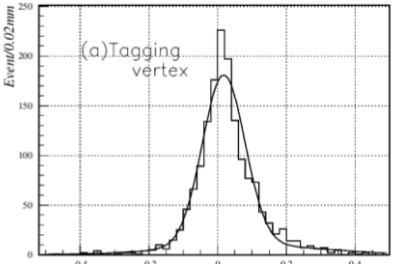
Golden Mode Proposal

Golden modes proposal

- Time dependent CP asymmetry in $B_d \to J/\psi K_S$
- Time dependent CP asymmetry in $B_d \to \phi K_S$, $B_d \to \eta' K_S$, $B_d \to \pi^0 K_S$, $B_d \to K_S K_S K_S$
- Time dependent CP asymmetry in $B_d \to K_S \pi^0 \gamma$
- Time dependent CP asymmetry in $B_d \to \pi\pi$, $B_d \to \pi\rho$, $B_d \to \rho\rho$

Δz resolution Tag Side

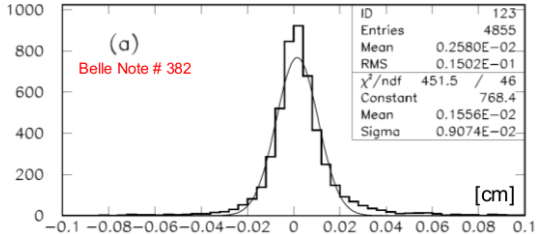




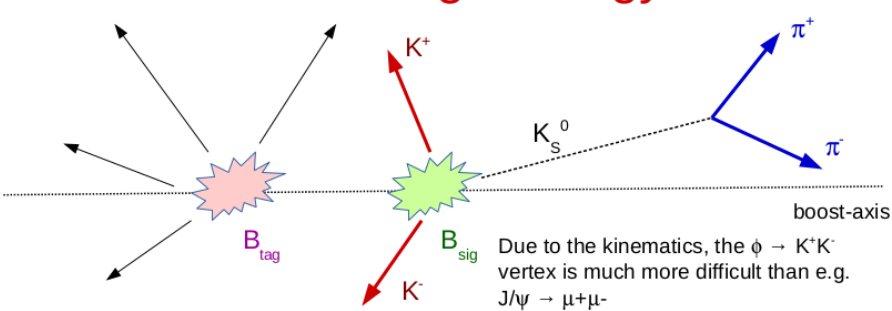
T.Kawasaki, PhD Thesis

Belle II
- Shift = 3.8 μm
- Resolution = 56 μm

Belle
- Shift = 29 μm
- Resolution = 89 μm



Vertexing strategy



Due to the kinematics, the $\phi \rightarrow K^+K^-$ vertex is much more difficult than e.g. $J/\psi \rightarrow \mu+\mu-$

Different strategies to determine the B_{sig} decay vertex:

- Simply use the tracks from “prompt decays”;
- Add also a kinematical constraint:
  - `ipprofile`: beamspot constraint (all three axes);
  - `iptube`: constraint just on the plane transverse to boost, useful for B-physics;
- Can use also the K^0_S flight direction.

Bibliography I