

Status update on $B^0 \rightarrow \eta' K_S^0$ on DataChallenge

And on η' rediscovery in phase II

Stefano Lacaprara

`stefano.lacaprara@pd.infn.it`

INFN Padova

TDCPV meeting,
SpeakApp, 5 December 2018

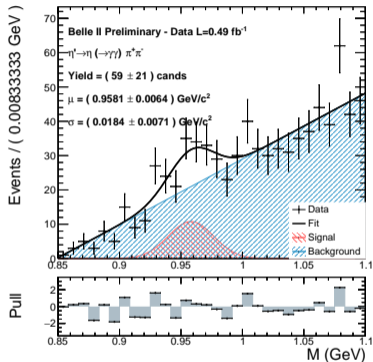
Today: update wrt to 31/10/2018 presentation

- **Update on η' rediscovery on phase2 (a bit Off-Topic, but not completely)**
- Progress on DataChallenge (MC9) and issues found

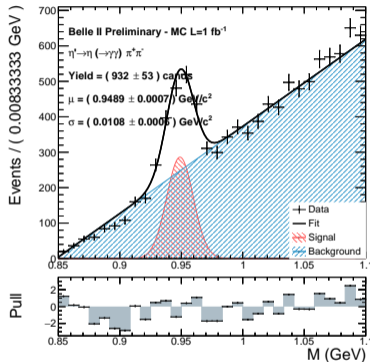
η' rediscovery: what's new

- As promised, note available **BELLE2-NOTE-PH-2018-038**
 - comments welcome! (got many from Phil, will reply asap)
- proper inclusive MC for background ($q\bar{q}$ properly mixed)
- signal properly visible in MC and DC for all three channels
 - was not for $\eta' \rightarrow \eta(\rightarrow \pi^+\pi^-\pi^0)\pi^+\pi^-$
 - Note: for DC I'm using TDCPV skims, which requires a light resonance **and** a K_S^0 so yield cannot be compared
- maybe a signal in data also for $\eta' \rightarrow \rho(\rightarrow \pi^+\pi^-)\gamma$

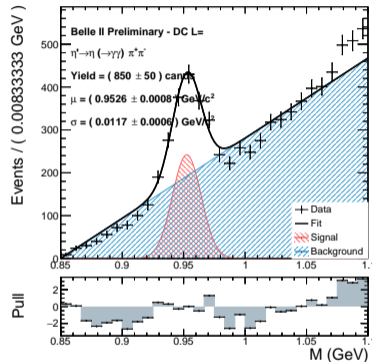
Data - Phase 2



MC - Phase 2 BGx1

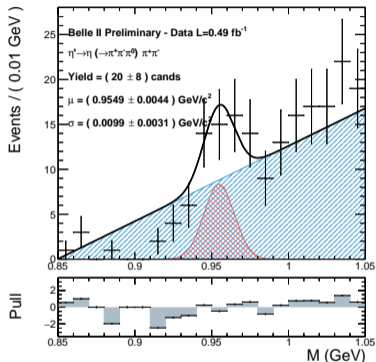


DC - Phase 3 BGx1

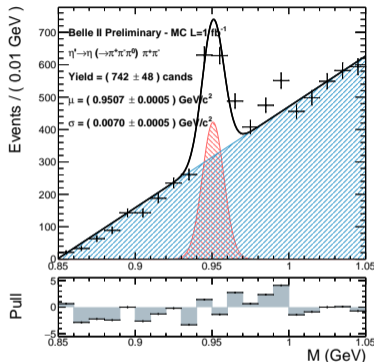


(similar to previous presentation) MC and DC ok, σ wider in DC.
 Small signal on Data, larger σ 18 vs 11 MeV

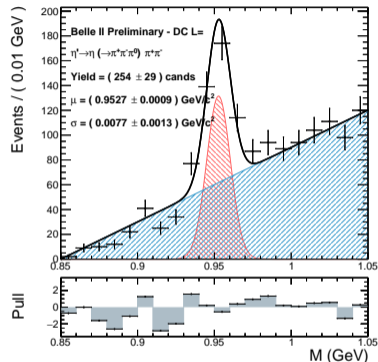
Data - Phase 2



MC - Phase 2 BGx1

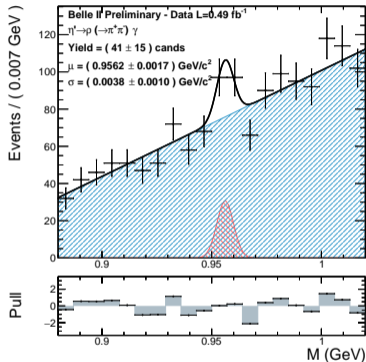


DC - Phase 3 BGx1

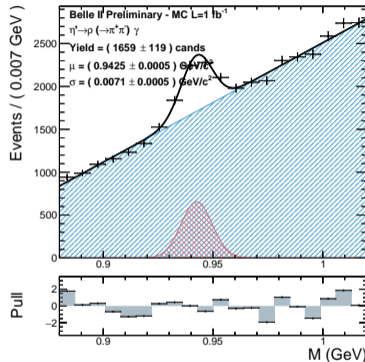


Now MC (new) and DC are as expected.
 Maybe signal on Data, very low significance and background shape not trivial
 (and not well modelled by fit)

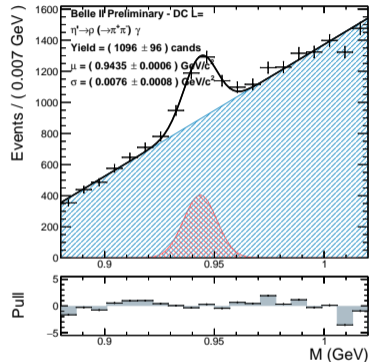
Data - Phase 2



MC - Phase 2 BGx1

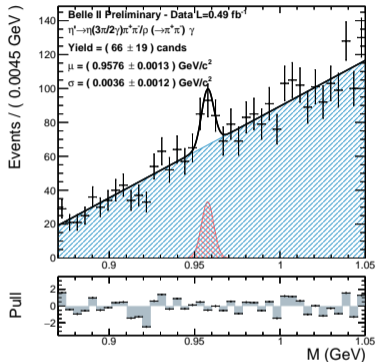


DC - Phase 3 BGx1

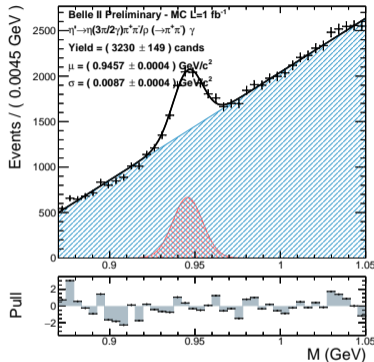


Now MC and DC are as expected (was not). Mass peak $\sim 8 \text{ MeV}$ lower than other channels.
 On Data hard to say (was none), very low significance and very narrow ?

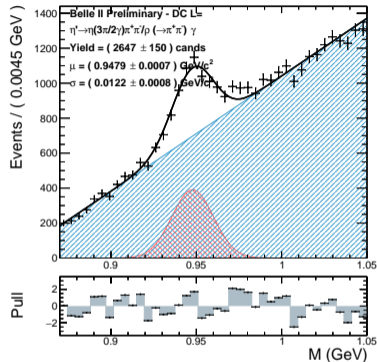
Data - Phase 2



MC - Phase 2 BGx1



DC - Phase 3 BGx1



On Data the peak is good, still very narrow (due to $\rho\gamma$?).

10 MeV bias of Data wrt MC.

In DC (and MC) combined peak width is also due by lower peak position in $\rho\gamma$ channels.

Not so in data.

Today: update wrt to 31/10/2018 presentation

- Update on η' rediscovery on phase2 (a bit, but not completely Off-Topic)
- **Progress on DataChallenge (MC9) and issues found**

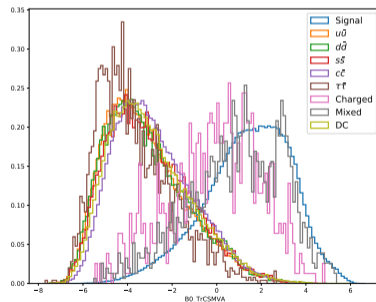
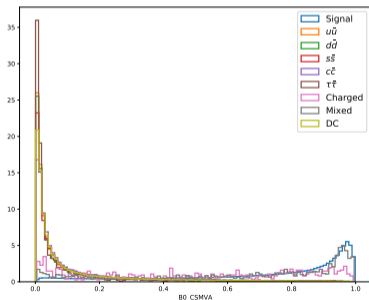
Quick reminder of $B_0 \rightarrow \eta' K_s$ analysis strategy for DataChallenge

- ✓ Signal selection and eff estimation (MC)
- ✓ continuum background suppression
- ✗ Signal cross Feed (SxF) optimization
- 🔧 ML fit to extract signal yield (and compute BR)
- 🔧 Toy study with expected yield to assess resolution and bias
- 🔧 study Δt and Δz resolution in MC, including modelization
- ✗ ML fit to Data challenge to extract TDCPV parameters

What's new

- **Still only $B^0 \rightarrow \eta' (\rightarrow \eta_{\gamma\gamma} \pi^+ \pi^-) K_S^0$**
- Moved back to MC9 (was MC10 only)
 - ▶ DC is based on MC9 release-01-0x-xx
 - ✓ signal (BGx0, BGx1), also MC10 BGx1 for comparison
 - ✓ background ($q\bar{q}$, $B\bar{B}$ generic, τ): BGx1, 0.8 ab^{-1}
- Continuum suppression re-implemented (wrong in previous presentation)
- check also sibling channel $B^+ \rightarrow \eta' K_S$ for cross check;
- First look at DC: search for signal and first yield estimation;
 - ▶ Many issues found, will discuss later.

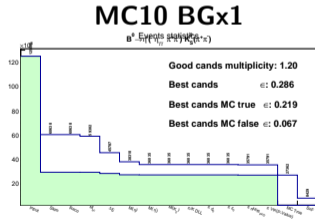
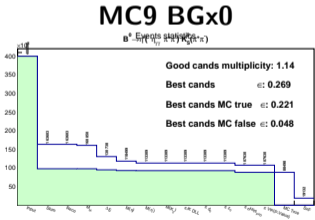
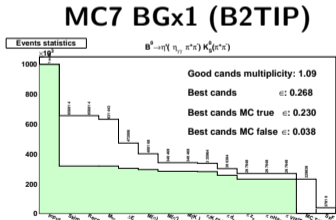
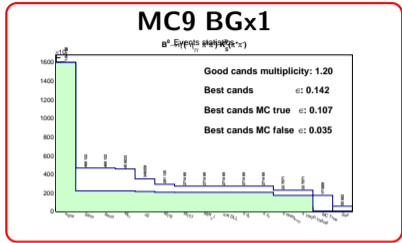
- Was wrong in previous iteration (that's why I got no signal!)
- re-trained using signal events (MC9 BGx1) against continuum $q\bar{q}$ passing preselection;
 - ▶ Still working with `NtupleTools`, will move to `VariableToNtuple` sometime;
- I prefer to use Transformed CS-MVA rather than prob since it is easier to model in ML fit.
- **TODO: use Data (DC) side bands as training sample**



warning: mixed have also signal inside: removed for final selection

Dataset	ϵ %	SxF%	cand/ev
MC9 BGx0	22.1	3.5	1.2
MC9 BGx1	10.7	4.8	1.14
MC10 BGx1	21.7	6.7	1.2
B2TIP BGx0	30.1	2.3	1.06
B2TIP BGx1	23.0	3.8	1.09

Same selections: $\epsilon_{MC9} \ll \epsilon_{MC10}$
DC is based on MC9



Warning: some selection (eg $M_{\eta, \eta'}$) moved to pre-selection wrt B2TIP

- Reporting B2TIP table
- event yield for background looking at 0.8 ab^{-1} of MC9, rescaled to 1 ab^{-1}
 - ▶ continuum a bit higher, but compatible
 - ▶ **peaking lower for neutral (/10) and higher for charged (x4)**
 - ▶ **signal is removed from neutral mixed**
- signal expected given the (low) ε in MC9
 - ▶ Was ~ 970 events, $\varepsilon \sim 23\%$
 - ▶ in MC9 expect ~ 350 events.
 - ▶ from 0.8 ab^{-1} of generic $B^0\bar{B}^0$ I got ~ 316 true signal
 - ★ **~ 400 in 1 ab^{-1}**

$L=1 \text{ ab}^{-1}$

	B2TIP	MC9 N ev.	DC
$q\bar{q}$	16413	18300	-
$B^0\bar{B}^0$	1834	150	-
B^+B^-	57	210	-
Signal	969	400	-
Total	$\sim 20\,000$	$\sim 19\,000$	6150

Even before searching for the signal, I do have roughly 1/3 of the continuum events I do expect
And (in principle) MC9 and DC are the same thing.

- I'm always using the TDCPV skim centrally produced;
- not for the signal, where I run my selection w/o intermediate skim;
- **Check the event yields and retention rate ϵ after the TDCPV skims**
 - ▶ not clear to me if these numbers refer to 1 or 0.8 ab^{-1}

Dataset	MC9			DC		
	all	skim	ϵ	all	skim	ϵ
$q\bar{q}$	$4.6 \cdot 10^9$	$213 \cdot 10^6$	4.6%		-	
$B^0\bar{B}^0$	$0.53 \cdot 10^9$	$3.5 \cdot 10^6$	0.67%		-	
B^+B^-	$0.56 \cdot 10^9$	$4.6 \cdot 10^6$	0.8%		-	
Total	$5.7 \cdot 10^9$	$221 \cdot 10^6$	3.8%	$5.6 \cdot 10^9$	$60 \cdot 10^6$	1%

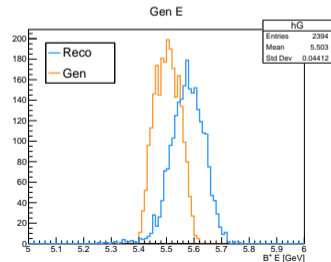
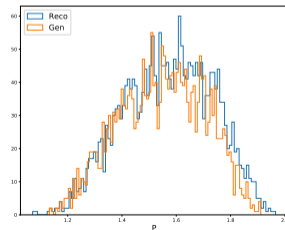
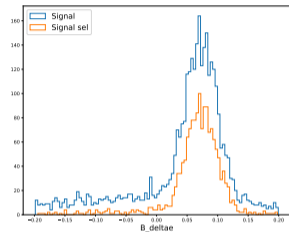
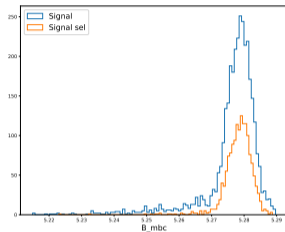
What am I missing?

It seems that the initial number of events is correct, but the TDCPV skims retains about 1/4 of what I would expect.

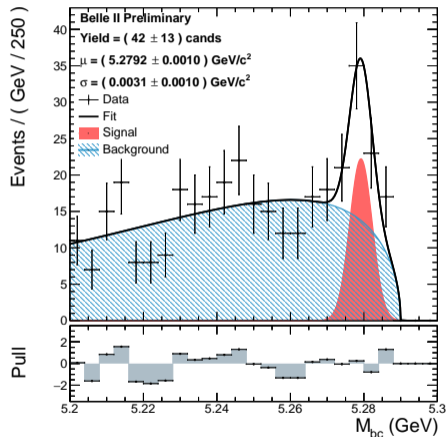
- Why B^+ ?
 - ▶ The idea was to have a control channel with similar final state
 - ▶ (thanks Ale for the suggestion)
- BR is similar: $\mathcal{B}(B^+) = 4.1 \cdot 10^{-6}$ vs $\mathcal{B}(B^0) = 3.86 \cdot 10^{-6}$
- no MC available (not even dec file)
 - ▶ produce and test a dec file
 - ✗ **pro tip:** if you ask EVTGEN to decay $\eta' \rightarrow \eta' \pi^+ \pi^-$, it will do it w/o complaining.
 - ▶ produced privately 10k events (release-02-01-00)
 - ▶ setup a quick and dirty selection:
 - ★ η' as in B^0 channel, plus a K^+
 - ▶ ϵ roughly 33% reconstruction and preselection
 - ▶ $\epsilon \sim 15\%$ with cut on $M_{\eta, \eta'}$ and $CS_{MVA} > 0.5$
 - ▶ rescale by factor 2? for MC10 \rightarrow MC9? $\epsilon \sim 7 - 10\%$
- expected yield in 1 ab^{-1} : $1.1 \cdot 10^9 (B\bar{B})$, $550 \cdot 10^6 (B^+ B^-)$
- Yield = $N_{B^+ B^-} \cdot 2 \cdot \mathcal{B} \cdot \epsilon \approx 300 - 400 \text{ events in } 1 \text{ ab}^{-1}$
 - ▶ side note: almost as hard as the signal channel...

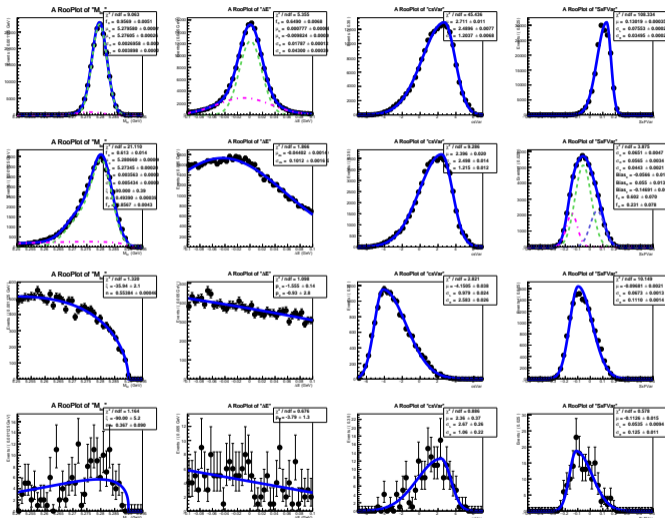
sel is w/ cut on $M_{\eta, \eta'}$ and $CS > 0.5$

- why ΔE is not at 0 ???
- traced back to $M_{B^\pm}^{reco} = 5.35 \text{ GeV}$ and not 5.28 GeV.
 - ▶ MC truth mass is correct $M = 5.28 \text{ GeV}$
 - ▶ decay chain is correct
 - ▶ B^0 reconstructed momentum match well the MC truth one.
 - ▶ B^0 reconstructed energy (P4[3]) does not
- As if the particle reconstruction associate B_s^0 in place of B^\pm to the decay
 - ▶ `reconstructDecay("B+ -> eta' K+:good", "Mbc > 5.2 and abs(deltaE) < 0.2")`



- Pretending that it is fine that ΔE is not centered at zero
- selection $CS > 0.5$ and $M_{\eta, \eta'}$
 - ▶ No cut in ΔE
- found a nice signal in DC in M_{bc} distribution
- event yield ~ 40 . Expected $\sim 300 - 400$
- Ok, only M_{bc} ML fit, not a $M_{bc}, \Delta E$ one, but still ...

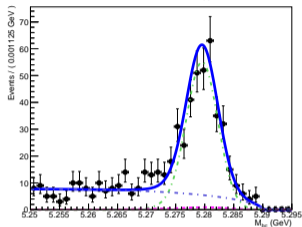




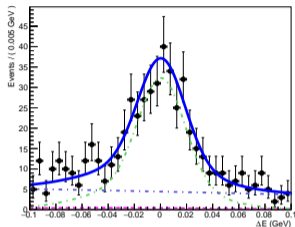
Back to B^0

- Columns:
 - M_{bc}
 - ΔE
 - CS_{MVA}
 - SxF_{MVA} not retrained yet
- Rows:
 - Signal
 - SxF
 - continuum
 - peaking signal removed

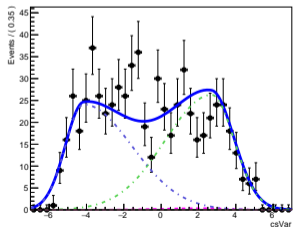
A RooPlot of " M_{bc} "



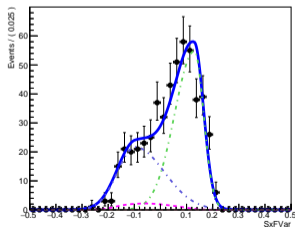
A RooPlot of " ΔE "



A RooPlot of " $csVar$ "



A RooPlot of " $SxFVar$ "

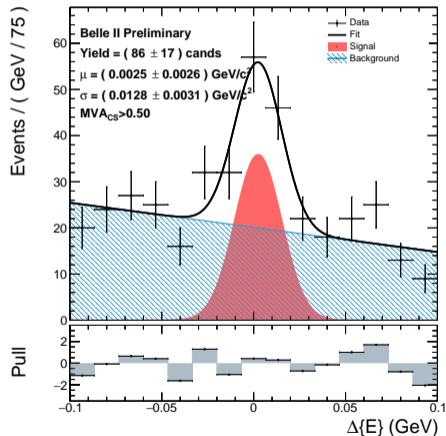
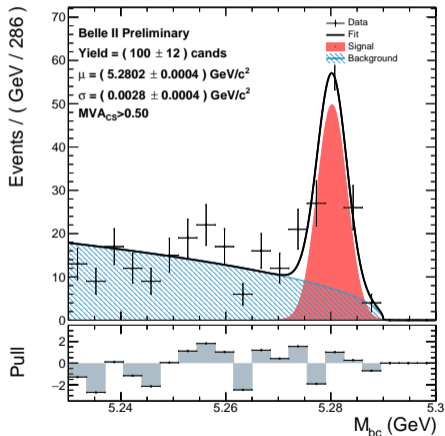


B^0 in MC, not yet DC

- Build my own "DC"^a,
 - ▶ combining 0.8 ab^{-1} of continuum
 - ▶ and $0.8 \text{ ab}^{-1} B \bar{B}$
 - ★ w/o removing my signal
- MC truth tells me that I do have ~ 320 `B0_isSignal`
- ML fit found:
 - ▶ **nSig=407** (30σ)
 - ▶ **nSxF=57.8** (1.2σ)
 - ▶ bias to be investigated, might be related to bad SxF MVA

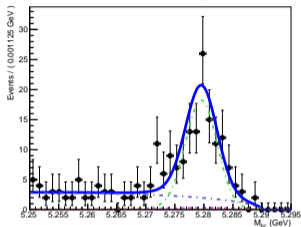
^a with blackjack and h... [Bender Bending Rodríguez, Futurama, ep. 2, s. 1]

First just try to apply all selection plus $CS_{MVA} > 0.5$ and perform a 1D fit on M_{bc} and ΔE

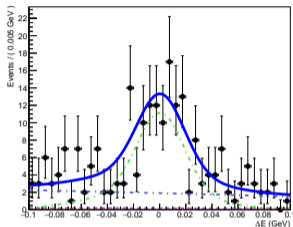


Expected event yield ~ 400 events

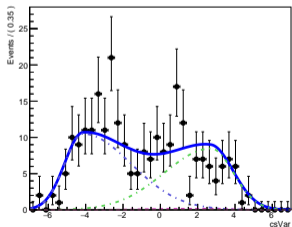
A RooPlot of " M_{bc} "



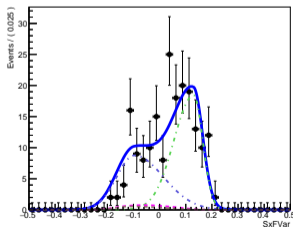
A RooPlot of " ΔE "



A RooPlot of " $csVar$ "



A RooPlot of " $SxFVar$ "



The full 4D ML fit and signal extraction

- ML fit found:
 - ▶ **$n_{\text{Sig}} = 136.6 \pm 14.7 \text{ ev}$** (16σ)
 - ▶ **$n_{\text{SxF}} = 22.2 \pm 33.1 \text{ ev}$** (0.7σ)
- expected ~ 400 events
- A good signal, but significantly lower than expected
 - ▶ signal is roughly 1/4 of expected, as the ratio between TDCPV skimmed events
 - ▶ worth investigating...

Summary

- ✓ Found small signal for $\eta' \rightarrow \eta(3\pi/2\gamma)\pi^\pm/\rho\gamma$ in Phase II Data
- ✓ Found signal for both $B^+ \rightarrow \eta'K^+$ and $B^0 \rightarrow \eta'K_S^0$ in DC
- ✗ both significantly lower than expected
- ✓ hand-made 0.8 ab^{-1} DC mixture has the expected number of signal events

Todo

- 🔧 Understand TDCPV skims retention in DC
- 🔧 Understand why B^+ mass reconstruction is wrong
- 🔧 Do SxF retraining (and/or try if π^0 veto improves SxF)
- 🔧 toys for ML fit for signal yields to check bias
- 🔧 a better control channel?

Additional or backup slides