B→ η' K rediscovery

B->Charmless meeting
04/11/2020

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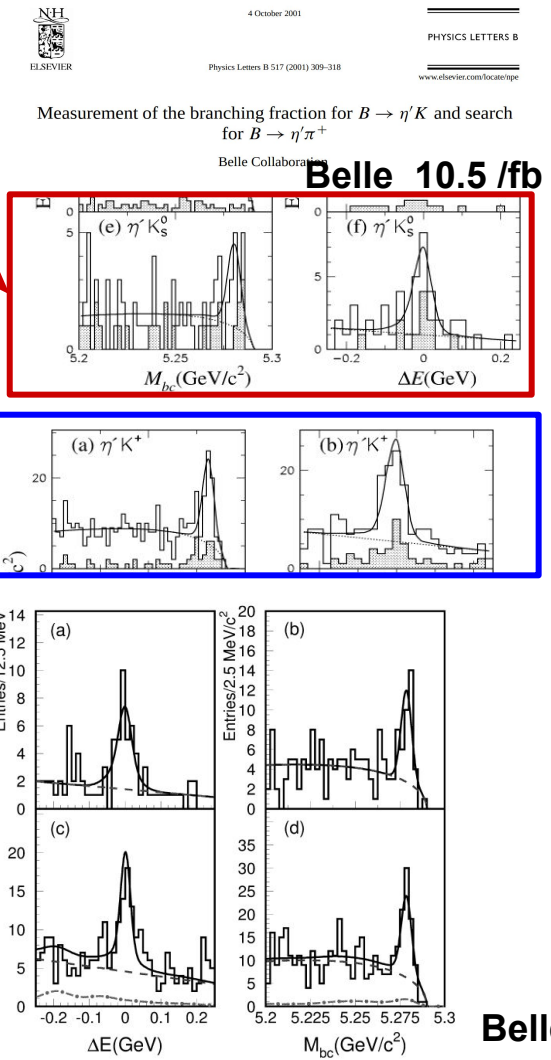
Motivation

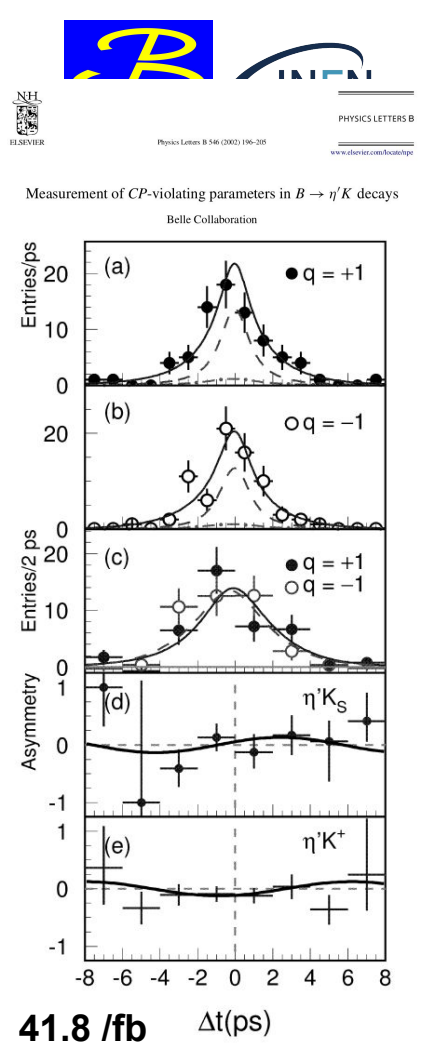
- BR($B^0 \to \eta' K^0_S$) = (6.6 ± 0.4) × 10^{-5}
  - C_{CP} ($B^0 \to \eta' K^0$) = −0.06 ± 0.04
  - $-A_{CP}=S_{CP}$ ($B^0 \to \eta' K^0_S$) = 0.63 ± 0.06
- BR($B^+ \to \eta' K^+$) = (7.06 ± 0.25) × 10^{-5}
- Seen by Belle with 10/fb
  - TDCPV with 41.8 /fb

$$\mathcal{S}_{\eta' K^0_S} = 0.28 \pm 0.55(\text{stat})^{+0.07}_{-0.08}(\text{syst}),$$

$$\mathcal{A}_{\eta' K^0_S} = 0.13 \pm 0.32(\text{stat})^{+0.09}_{-0.06}(\text{syst}).$$

- Hadronic penguin mediated decay
  - Precise measurement a key for NP
- First step is rediscovery





Strategy

- For the time being: focus on rediscovery
  - Setup selection, Continuum suppression, signal extraction
  - Next iteration TDCPV
- Use channels: $\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$ $\eta' \to \rho(\to \pi^+\pi^-)\gamma$
  - BR(η -> $\pi^+\pi^-\pi^0$) ~½ of $\gamma\gamma$ and reco efficiency lower (from η rediscovery BELLE2-NOTE-PH-2018-038)
    - Hanwook Bae (Ushiroda-san's student) is looking into that
    - Maybe in some future also more with more π^0 (η' -> η(->3π^0)$\pi^0\pi^0$ anyone interested)
- Background:
  - Continuum
  - Peaking
  - SxF
- Optimize selection to reduce background and SxF
  - B2TIP studies showed that SxF is significant
  - Continuum suppression: start simple, then complicate
- Signal extraction with UML on Mbc and ΔE plus CS variables
  - Validate UML on Toy MC
- Blind on data for signal region until blessing from RC

Dataset and Technicalities

- Data: proc11 + prompt (**bucket9-15 included**)
  - L=8.86+ 54.0= 62.8 /fb
- Montecarlo **MC13a** (Run independent, BGx1)
  - qqbar+ taus L=500 /fb
  - bbbar (charged and mixed) L=1000 /fb
  - Using **unskimmed** dataset
    - Study on skimming shows ~40% eff loss (pi:loose vs pi:all)
- Signal: MC13a
  - 20K events for channel: L~9-72 /ab (depending on channel)
- Release: **light-2002-janus**
- Analysis stash https://stash.desy.de/users/lacaprar/repos/etaprime/browse
- B2Note BELLE2-NOTE-PH-2020-053 https://docs.belle2.org/record/1976?ln=en
- **Aiming for Moriond2021**

dataset	experiment	$\int Ldt\ [\mathrm{pb}^{-1}]$
proc11	7	425.5 ± 0.3
proc11	8	4597.4 ± 0.9
proc11	10	3741.3 ± 1.1
bucket9	12	2768.7 ± 1.1
bucket10	12	10361.1 ± 2.1
bucket11	12	12687.1 ± 2.3
bucket13	12	5055.1 ± 1.5
bucket14	12	9986.9 ± 2.1
bucket15	12	13171.6 ± 2.4[a]
proc11	7+8+10	8764.2 ± 2.5
prompt	12	54030.5 ± 4.2
total	7-12	62794.7 ± 4.4[b]

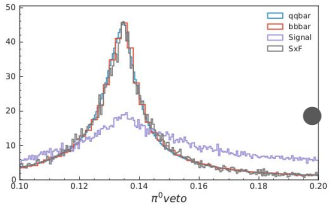
Selection η': two channels

$$\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$$

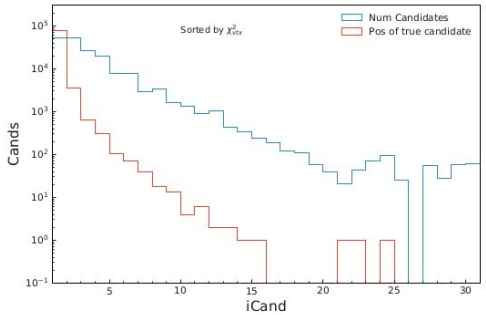
- Gamma:loose
  - E_γ>150 MeV
  - 0.5 < $M_{\gamma\gamma}$ < 0.57 GeV/c ^{2}
- Pi:all
  - opposite charge

$$\eta' \to \rho(\to \pi^+\pi^-)\gamma$$

- Gamma:loose
  - E_γ>150 MeV
  - cos θ_γ > −0.64
  - No pi0 veto: losing too much signal
- Pi:loose
  - 0.47 < $M_{\pi^+\pi^-}$ < 1.07 GeV/c^2
- 0.92 < $M_{\eta'}$ < 1.0 GeV/c ^{2}



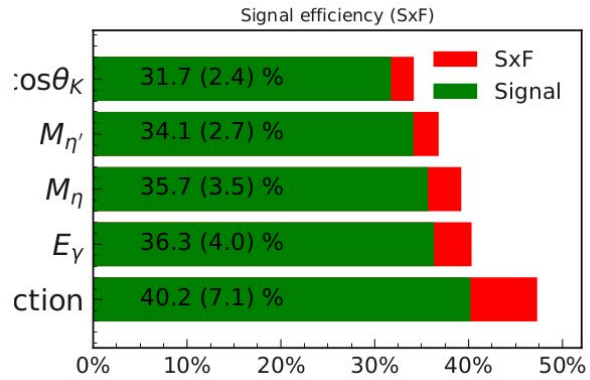
- K:loose
  - Global PID(K) >0.1
  - cos θ_K > −0.5
- K_S0:merged (V0+hh)
  - 0.49 < $M_{\pi^+\pi^-}$ < 0.51 GeV/c ^{2}
  - Vertex fit not failing
  - cos $\theta_{p,v}$ > 0.99
    - (angle between momentum and vertex vector)
- **B_0** and **B^+** decay chain fitted with treeFit algo
  - Mass constraint on η, η‘,
  - NO IP vertex constraint
- Keep only one candidate per event sortex by vtx pValue

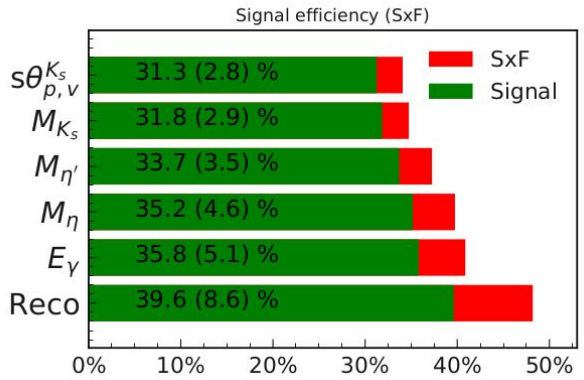


Signal Efficiency (w/o CS selection)

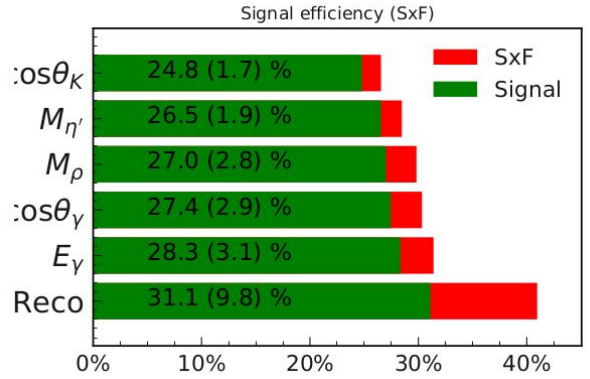
$B^{\pm}$ B^{0}

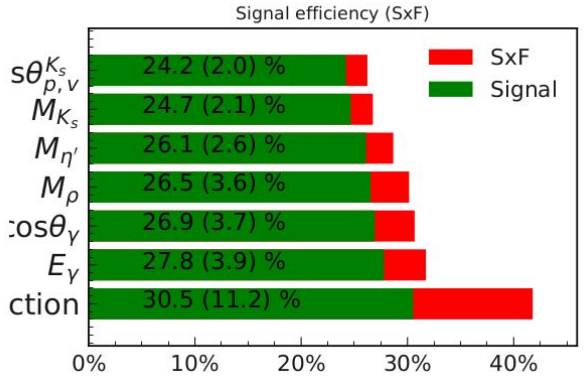
$\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$





$\eta' \to \rho(\to \pi^+\pi^-)\gamma$





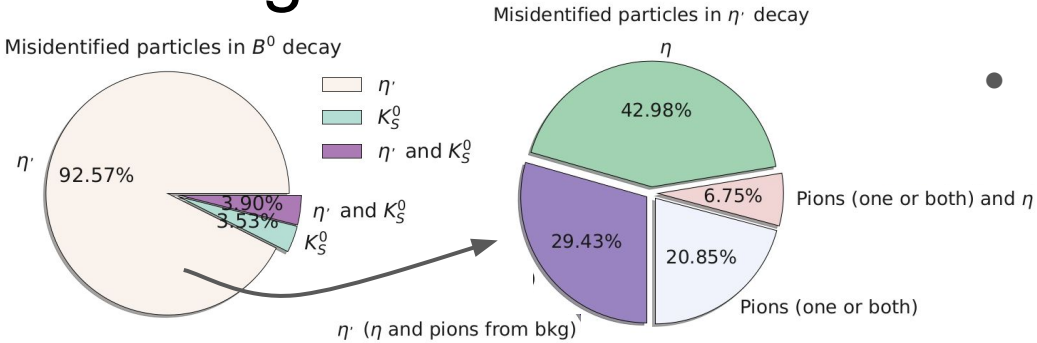
- Efficiency:

~30% for **η'->ηππ**

~25% for **η'->ργ**

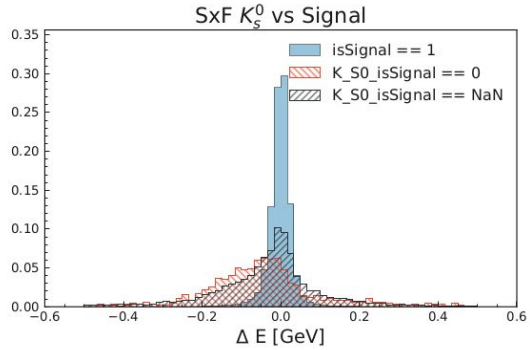
- SxF from 10% (just reconstruction) to ~2% (after selection)

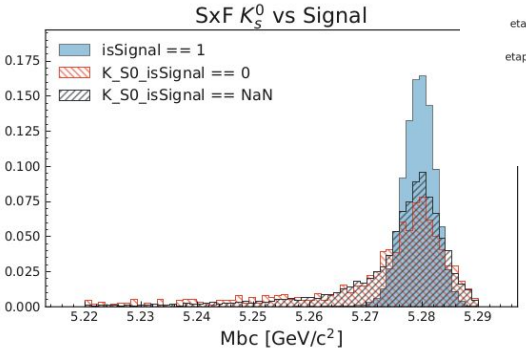
SxF origin



- Most of SxF from η' due to random daughter
- Non negligible amount of NaN (no MC association)
  - Partially SxF + some signal

- Developing fBDT to separate signal and SxF: not included yet, preliminary
  - To be included in the final UML fit (see later)
  - Vtx+Track fit prob, helicity, InvM + other variables





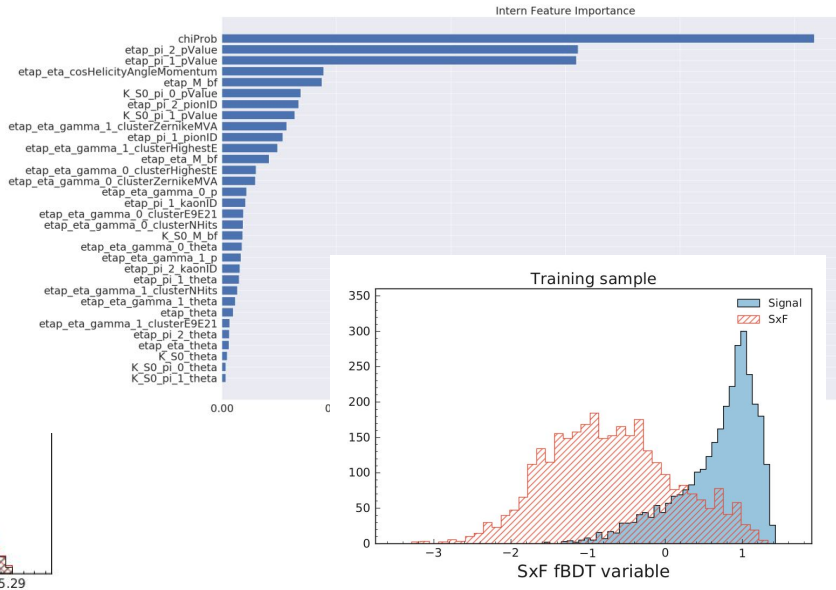
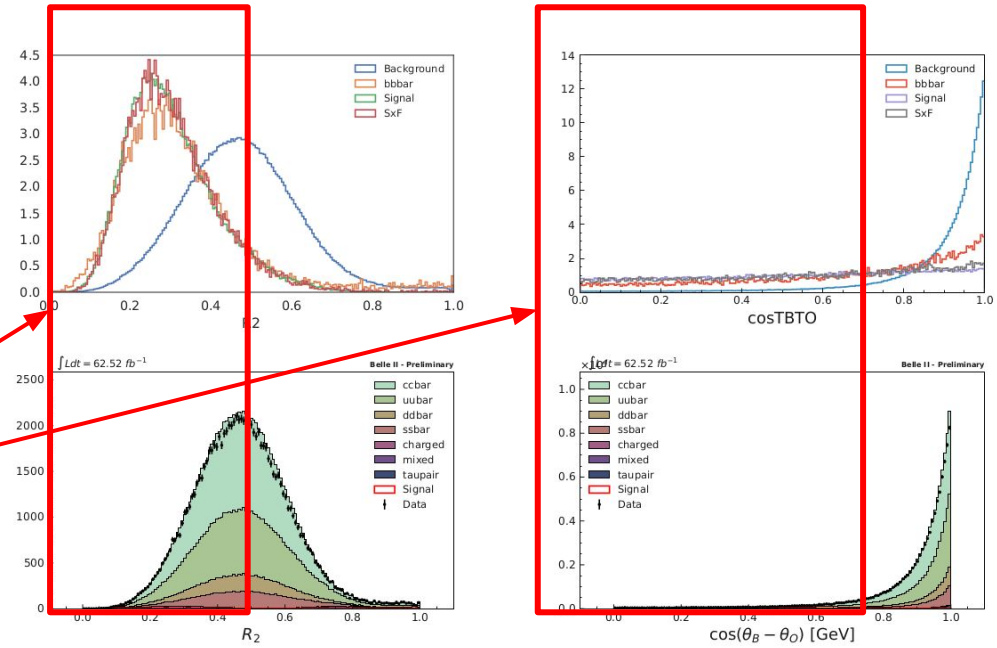


FIG. 2. fBDT Variable for training sample

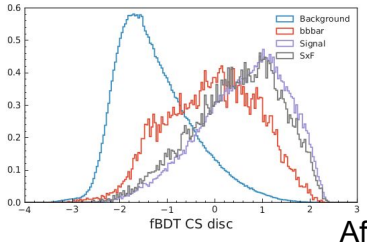
Continuum suppression

- Two strategies:
  - cut on cosTBT0 and R2
  - fastBDT on many (27) variables
- In both case selection defined by maximizing FoM = S/√(S+B) in signal region
- **SR**:
  - M_{bc}>5.27 GeV/c^2
  - -0.07 < ΔE <0.05 GeV
- Eff ~63%Signal



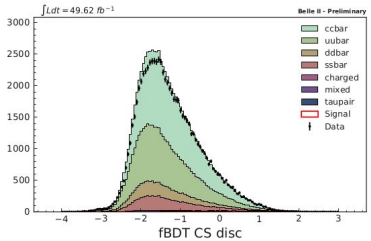
Continuum suppression fBDT

- FastBDT
  - Excluding all variables correlated with M_{bc} or ΔE
  - Most discriminating cosTBT0 and KSFW-hso12/02/hoo2
  - Not so discriminating against Peaking and SxF (expected)
- Selection max FoM: eff ~80%
  - (~60% for **$B^+ \to \eta'(\to \rho\gamma) K^+$**: larger background)

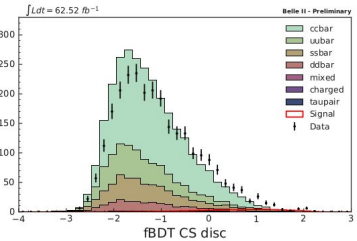


Signal vs Backgroun
(MC - unit normalized)

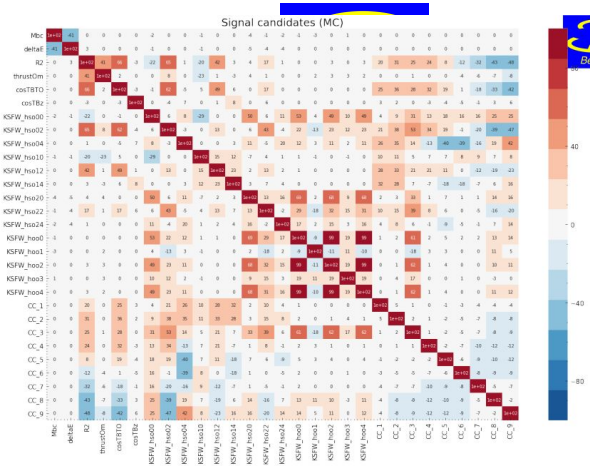
Before signal selection

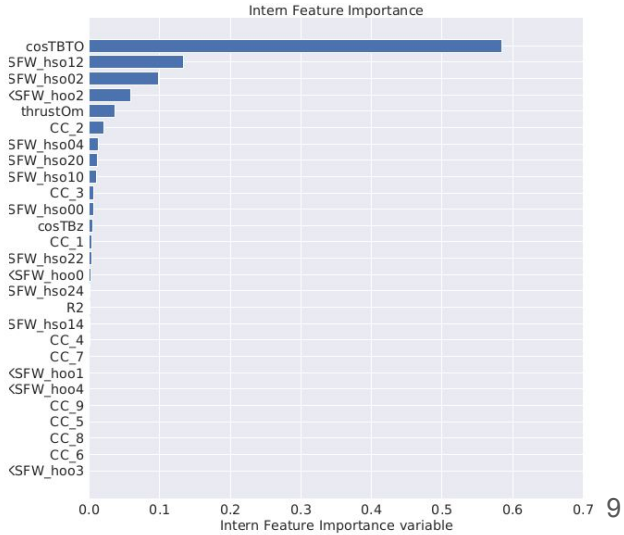


After signal selection



- Or no selection and use it directly on UML fit





Signal efficiency (including CS)

- CS selection based on FoM on signal region
  - Two CS plus none (no cut but use CS directly in UML)
  - For fBDT best FoM different for each channel
    - Hard cut for **$B^+ \to \eta'(\to \rho\gamma) K^+$** due to large background
  - Not so for cosTBTO/R2 CS
- Belle used a Likelihood based CS with selection based on FoM
  - BelleII efficiency better for $\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$ similar or much better for $\eta' \to \rho(\to \pi^+\pi^-)\gamma$
  - Much better if no CS selection is applied

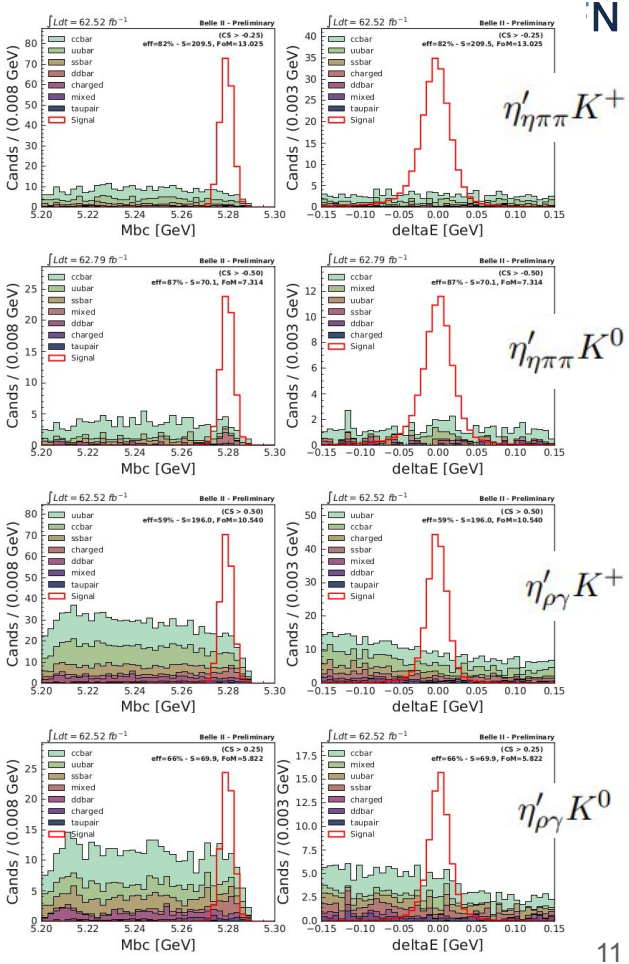
Channel	CS type	$B^\pm \to \eta' K^\pm \mid B^0 \to \eta' K^0_S$, $\eta' \to \eta\pi^+\pi^-$		$B^\pm \to \eta' K^\pm \mid B^0 \to \eta' K^0_S$, $\eta' \to \rho\gamma$	
		ε %	ε %	ε %	ε %
Selection		31.7 ± 0.1	31.3 ± 0.1	24.8 ± 0.1	25.2 ± 0.1
CS	R2+cosTBTO	63.4 ± 0.2	63.0 ± 0.2	62.6 ± 0.2	61.7 ± 0.2
Total	R2+cosTBTO	20.1 ± 0.2	19.7 ± 0.2	15.5 ± 0.2	15.6 ± 0.2
$CS_{fBDT} >$		-0.25	-0.5	0.5	0.25
CS	fBDT	82.2 ± 0.2	87.5 ± 0.1	58.7 ± 0.2	81.0 ± 0.2
Total	fBDT	26.1 ± 0.2	27.7 ± 0.2	14.8 ± 0.2	20.4 ± 0.2
BELLE			21.7	20.8	14.2	11.5

CS w/ R2+ cosTBTO selection

- Cut optimising FoM S/sqrt(S+B) on signal region
  - R2<0.5
  - cosTBTO<0.7
- Expected (MC) signal and background for four channels
  - Normalized to data L

an integrated luminosity of 62 fb^{-1}

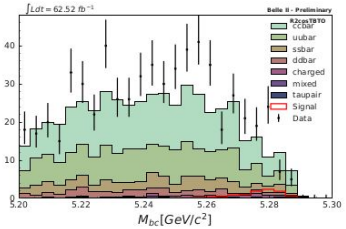
Channel	Region	$B^{\pm} \to \eta' K^{\pm}$, $\eta' \to \eta\pi^+\pi^-$	$B^0 \to \eta' K^0_S$, $\eta' \to \eta\pi^+\pi^-$	$B^{\pm} \to \eta' K^{\pm}$, $\eta' \to \rho\gamma$	$B^0 \to \eta' K^0_S$, $\eta' \to \rho\gamma$
Continuum	SB	628.0 ± 9.0	180.0 ± 5.0	5921.0 ± 27.0	24880.0 ± 60.0
	SR	22.0 ± 1.7	6.8 ± 0.9	256.0 ± 6.0	1129.0 ± 12.0
Peaking	SB	14.3 ± 0.9	5.6 ± 0.6	342.0 ± 5.0	194.0 ± 3.0
	SR	1.5 ± 0.31	3.4 ± 0.5	29.9 ± 1.4	22.2 ± 1.2
Signal	SB	10.67 ± 0.21	3.38 ± 0.07	12.12 ± 0.29	7.69 ± 0.13
	SR	161.5 ± 0.8	50.45 ± 0.25	208.4 ± 1.2	105.5 ± 0.5
Data	SB	758 ± 28.0	202 ± 14.0	6440 ± 80.0	21040 ± 150.0
	SR	blind			

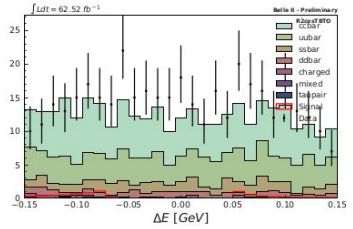


Side band distribution

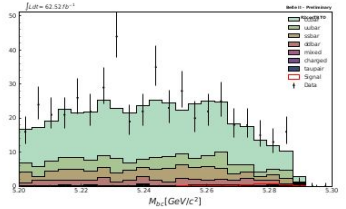
- Data MC comparison in side bands
  - M_{bc}<5.27 GeV/c^2
  - ΔE>-0.07 GeV or ΔE>0.05 GeV
- MC normalized to data integrated luminosity
  - Signal present (in red)
- Agreement is generally good
  - Some issue in absolute normalization for $\eta'_{\rho\gamma}K^0$
  - Background will be extracted from data, so ok
- **η'**(->**ργ**) has significantly more background than $\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$

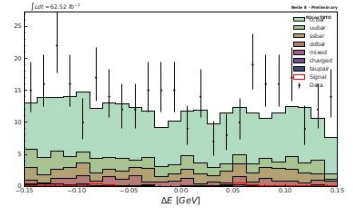
$\eta'_{\eta\pi\pi}K^+$



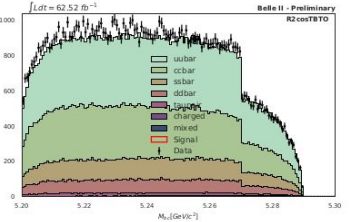


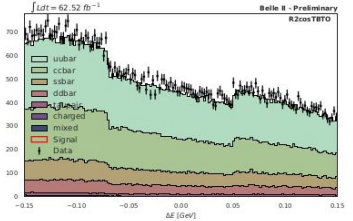
$\eta'_{\eta\pi\pi}K^0$



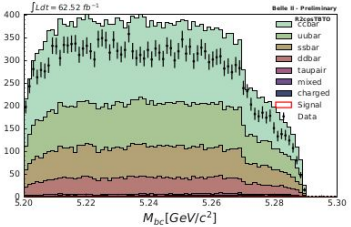


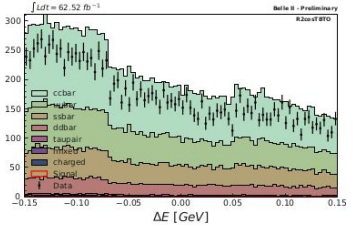
$\eta'_{\rho\gamma}K^+$





$\eta'_{\rho\gamma}K^0$



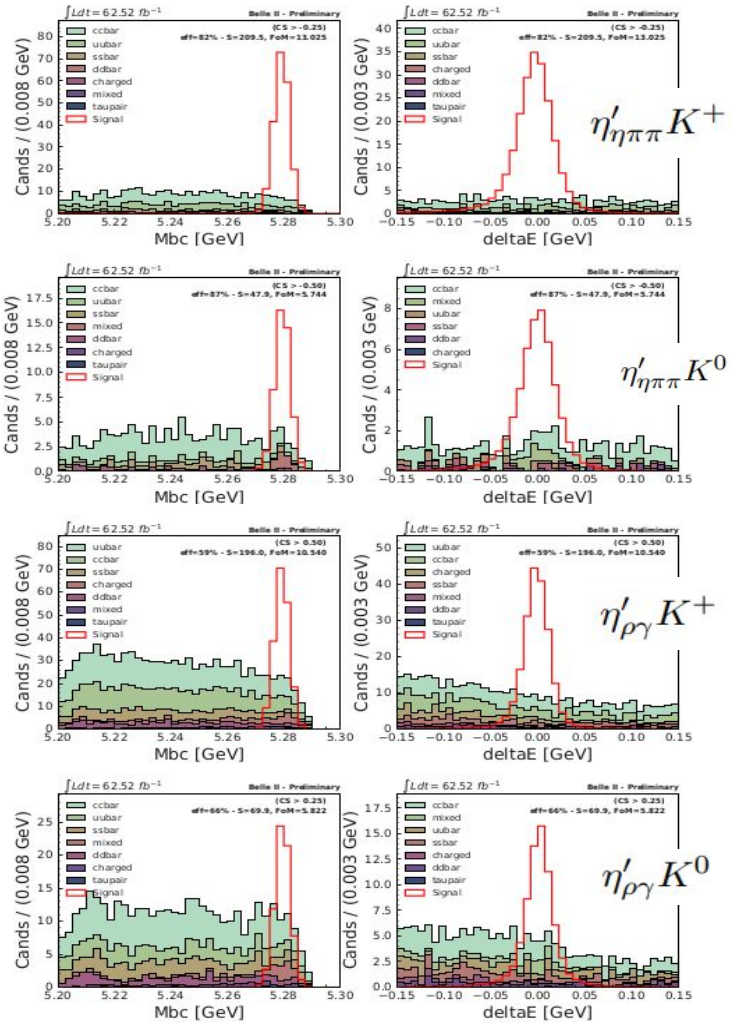


CS w/ fBDT

- Cut optimised with FoM=S/sqrt(S+B) on signal region
  - Higher efficiency wrt cosTBTO/R2 but also higher background
    - Especially for **η'(->ργ)**
- Expected signal and background
  - Normalized to data L

responding to an integrated luminosity of $62\,\mathrm{fb}^{-1}$

Channel	Region	$B^\pm \to \eta' K^\pm$, $\eta' \to \eta\pi^+\pi^-$	$B^0 \to \eta' K^0_S$, $\eta' \to \eta\pi^+\pi^-$	$B^\pm \to \eta' K^\pm$, $\eta' \to \rho\gamma$	$B^0 \to \eta' K^0_S$, $\eta' \to \rho\gamma$
Continuum	SB	1182.0 ± 12.0	471.0 ± 8.0	3179.0 ± 20.0	1232.0 ± 12.0
	SR	47.0 ± 2.4	16.5 ± 1.4	124.0 ± 4.0	60.3 ± 2.7
Peaking	SB	21.8 ± 1.2	8.9 ± 0.7	298.0 ± 4.0	103.9 ± 2.5
	SR	2.1 ± 0.4	5.1 ± 0.6	25.9 ± 1.3	13.8 ± 0.9
Signal	SB	13.89 ± 0.24	4.83 ± 0.08	10.67 ± 0.27	4.29 ± 0.1
	SR	209.5 ± 0.9	70.08 ± 0.3	196.0 ± 1.1	69.9 ± 0.4
Data	SB	1450 ± 40.0	535 ± 23.0	3760 ± 60.0	1220 ± 30.0
	SR	blind			



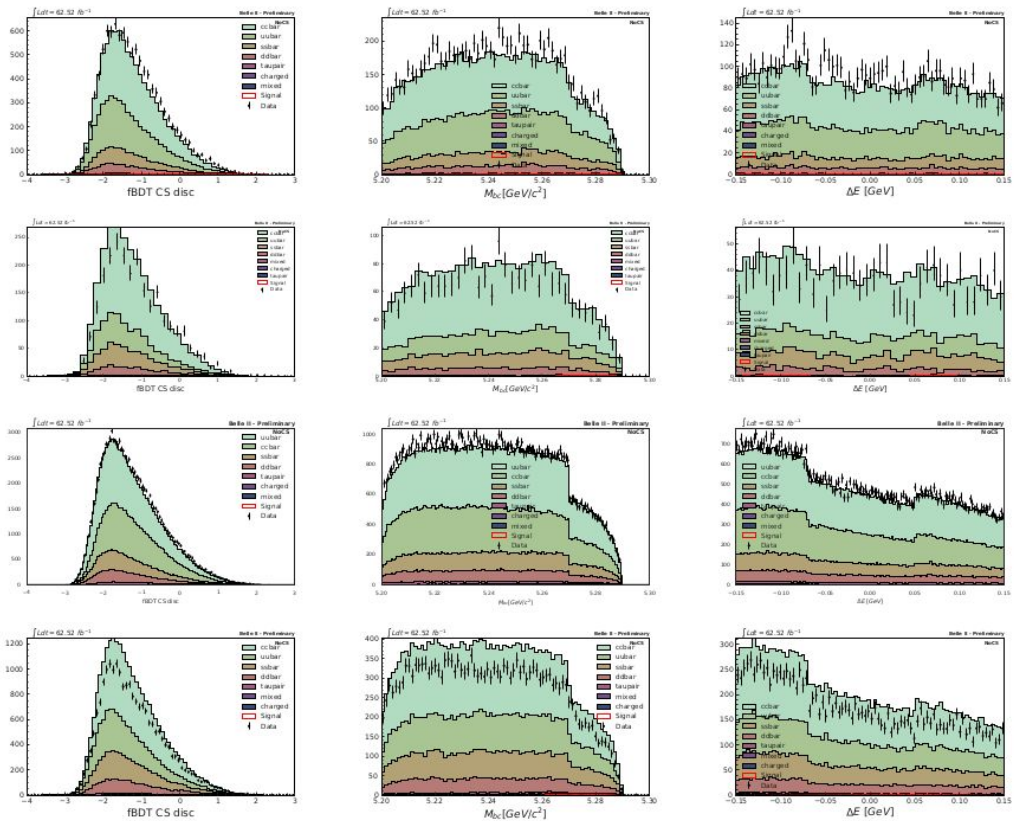
CS w/ fBDT no cut

- Expected yield

Montecarlo and data without CS selection, corresponding to an integrated luminosity of 62 fb^{-1}

Channel	Region	$B^{\pm} \to \eta' K^{\pm}$, $\eta' \to \eta\pi^+\pi^-$	$B^0 \to \eta' K^0_S$, $\eta' \to \eta\pi^+\pi^-$	$B^{\pm} \to \eta' K^{\pm}$, $\eta' \to \rho\gamma$	$B^0 \to \eta' K^0_S$, $\eta' \to \rho\gamma$
Continuum	SB	9690.0 ± 30.0	2699.0 ± 18.0	99270.0 ± 110.0	24880.0 ± 60.0
	SR	386.0 ± 7.0	105.0 ± 4.0	4614.0 ± 24.0	1129.0 ± 12.0
Peaking	SB	36.4 ± 1.5	12.6 ± 0.9	666.0 ± 6.0	194.0 ± 3.0
	SR	3.1 ± 0.4	6.1 ± 0.6	52.3 ± 1.8	22.2 ± 1.2
Signal	SB	17.79 ± 0.27	3.98 ± 0.06	22.8 ± 0.4	7.69 ± 0.13
	SR	254.8 ± 1.0	54.75 ± 0.22	334.1 ± 1.5	105.5 ± 0.5
Data	SB	10520 ± 100.0	2450 ± 50.0	103500 ± 300.0	21040 ± 150.0
	SR	blind			

- Signal extraction via 3 variables UML fit



CS Mbc DeltaE

Control region only

Mbc<5.27 GeV/c^2

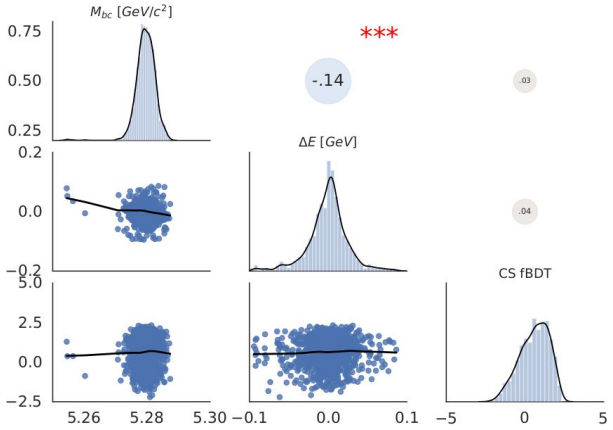
ΔE<-0.07 OR >0.05 GeV

UML fit

$$\mathcal{L} = \frac{e^{-\sum n_j)}}{N!} \prod_{i=1}^{N} \mathcal{L}_i$$

$$\mathcal{L}_i = \sum_{j=1}^{m} n_j \mathcal{P}_j(\vec{x}_i)$$

- x_i = M_{bc}, ΔE, and CS_{fBDT}
  - No correlation included
- Three components (m=3):
  - Signal+SxF
    - Ratio fixed from MC
      - Will add also SxF in future, now #SxF is anyhow low
  - Peaking
  - Continuum
- Get **pdf** for three components on MC
- Extract yield from Data UML
  - Still using `RooRarFit` interface (from BaBar, thanks to Ale) to `RooFit`
    - Very powerful, not so friendly at times, no real control on the code.
      - Would like to move to a BelleII tool at some point
- Validate tool on Toys to check linearity



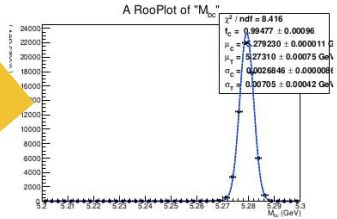
Signal	SxF	$q\ \bar{q}$	$B\ \bar{B}$
$B \to \eta' K, \eta' \to \eta\pi^+\pi^-$			
M_{bc}	Gauss(2)	Gauss(3)	Argus	Argus+Gauss(1)
ΔE	Gauss(2)	Gauss(2)	Pol(2)	Pol(2)/Gauss(2)
CS	Bifurcated Gauss			
$B \to \eta' K, \eta' \to \rho\gamma$				
M_{bc}	Gauss(2)	Gauss(3)	Argus	Argus+Gauss(1)
ΔE	Gauss(2)	Gauss(2)	Pol(2)	Pol(2)
CS	Bifurcated Gauss			

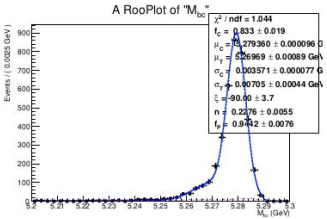
PDF

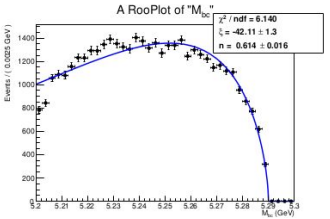
$B^{\pm} \to \eta' K$ with $\eta' \to \eta\pi^{+}\pi^{-}$.

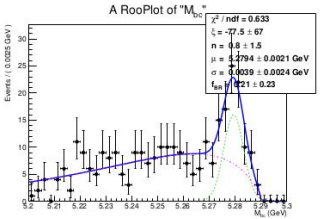
Signal | **SxF** | **Cont** | **Peak**

Mbc

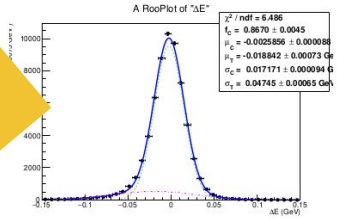


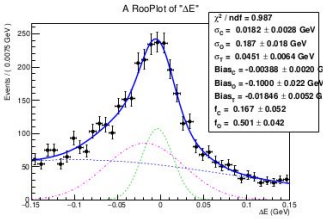


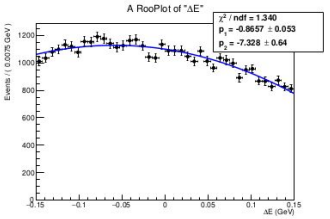


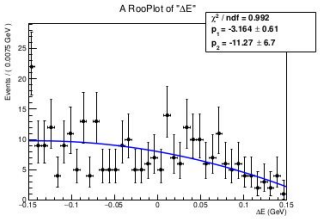


ΔE

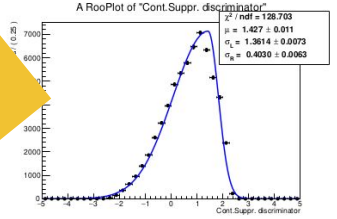


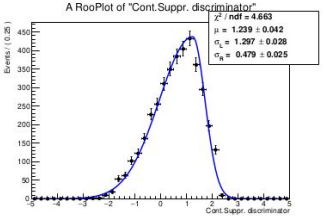


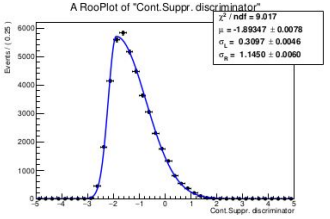


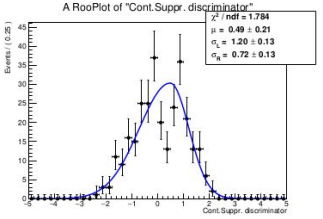


CS







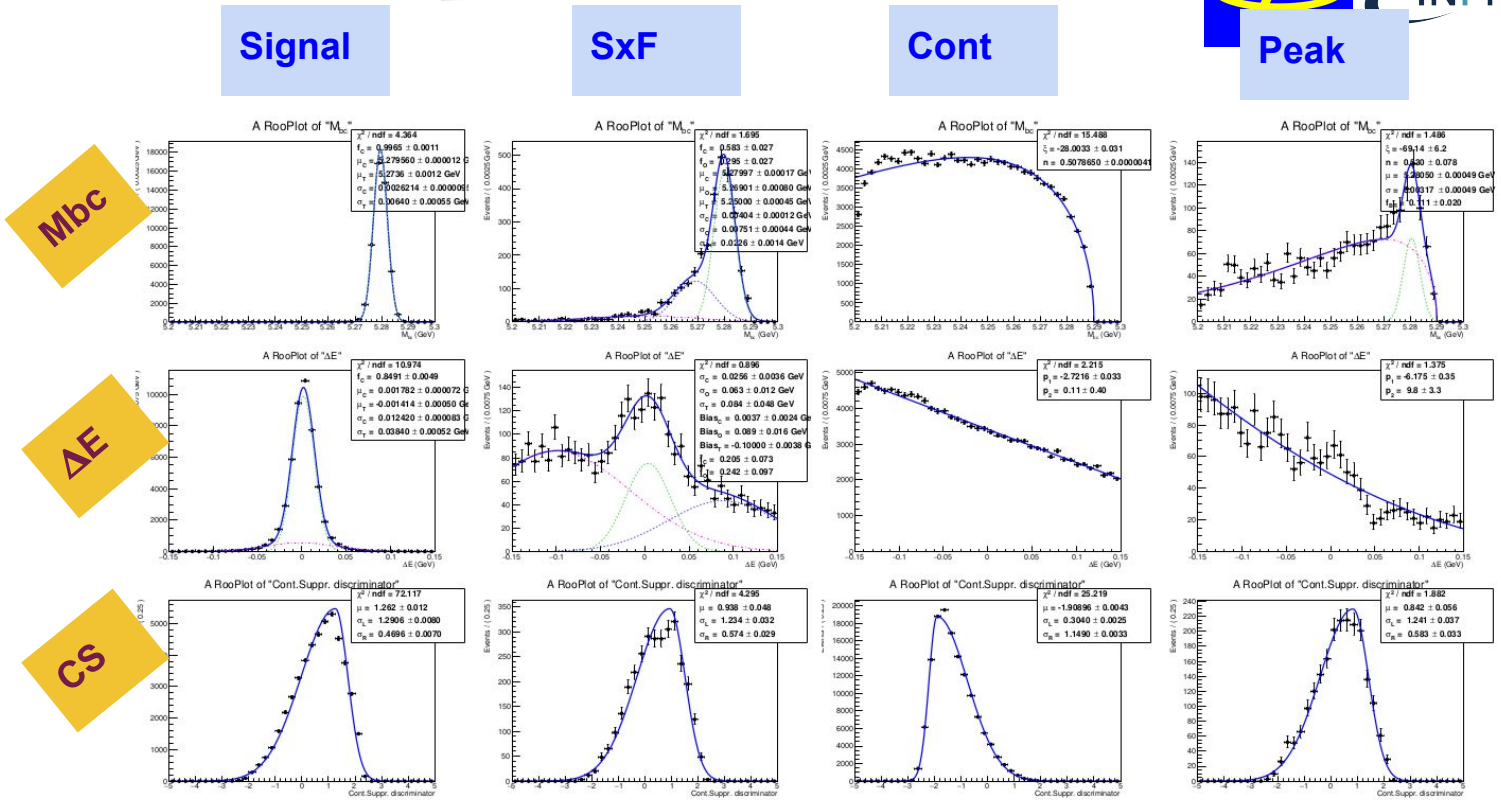


Pdf defined for all four channels
CS pdf ~identical, as expected

Fit with Sgn+SxF together, ratio fixed from MS

PDF

$B^0 \to \eta' K_S^0$ with $\eta' \to \rho\gamma$

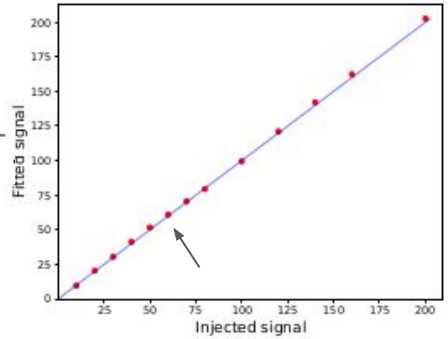


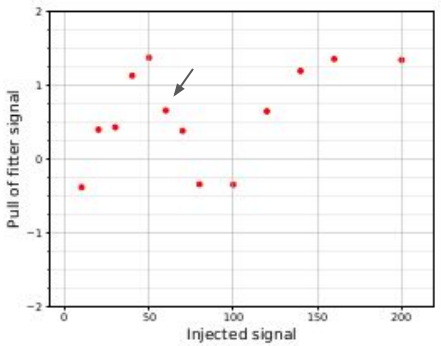
Pdf defined for all four channels
CS pdf ~identical, as expected

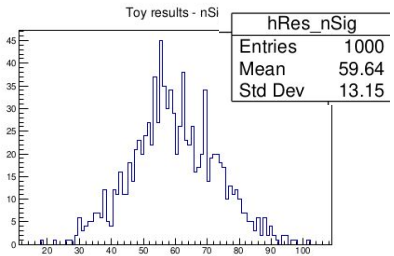
Fit with Sgn+SxF together, ratio fixed from MS

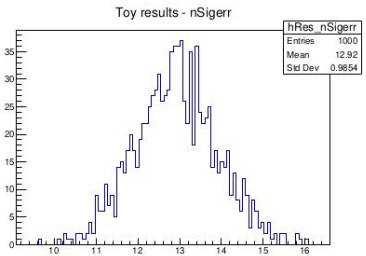
Toy MC for linearity

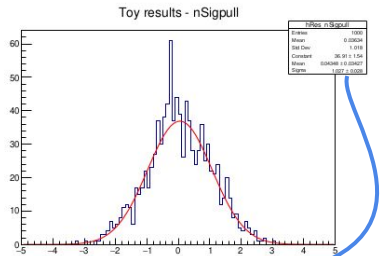
- Tested for $B^0 \to \eta' K_S^0$ with $\eta' \to \eta\pi^+\pi^-$
  - Linearity
  - Fitted vs injected signal yield within ~1 sigma
- 1000 Toys for expected signal and background
  - N_{sig}=58.7
    - Includes also SxF
  - Good pulls
- Ok also for other channels
  - In spite of large background



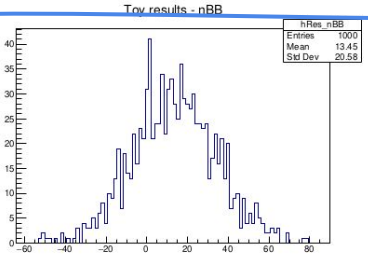


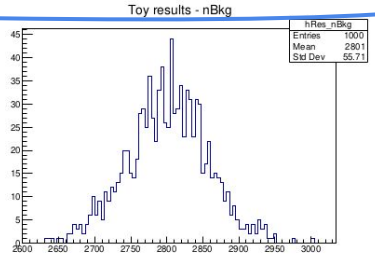






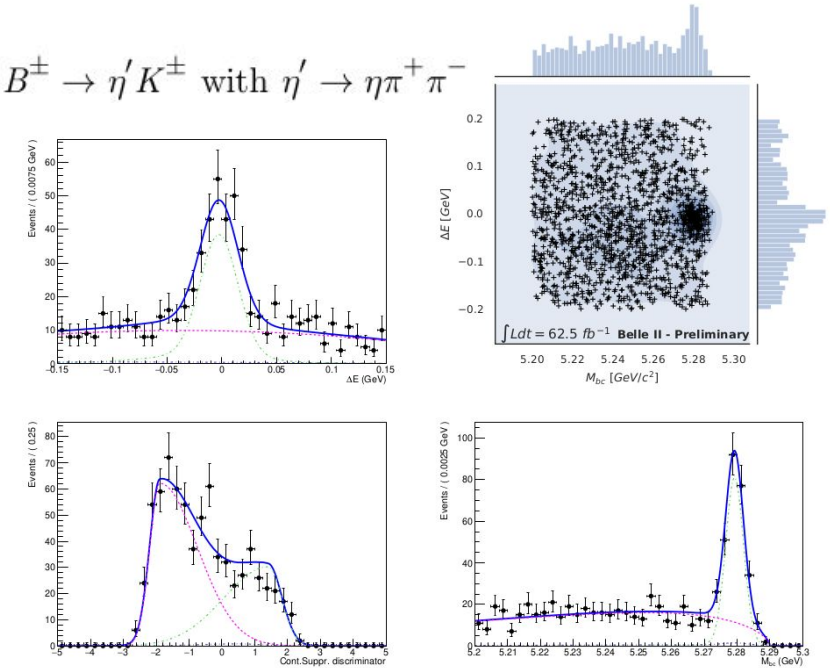
hRes_nSigpull	
Entries	1000
Mean	0.03634
Std Dev	1.018
Constant	36.91 ± 1.54
Mean	0.04348 ± 0.03427
Sigma	1.027 ± 0.028



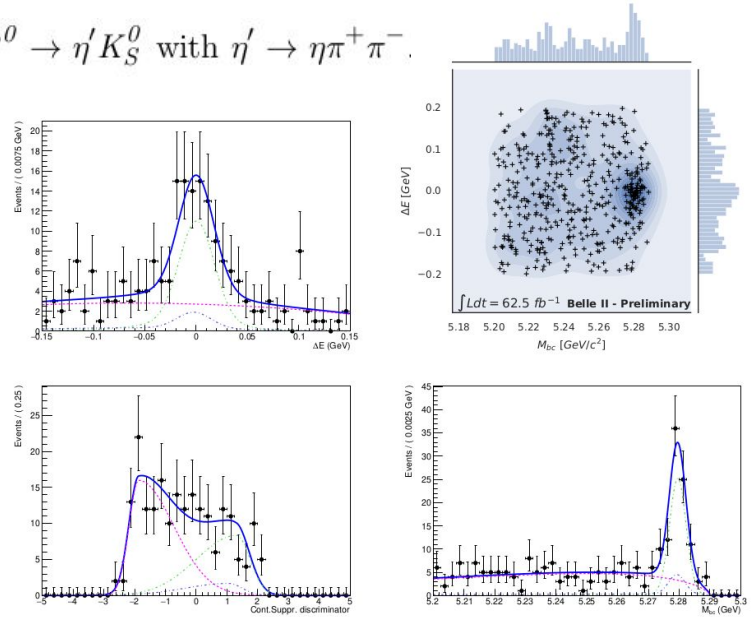


Results (still MC)

$B^{\pm} \to \eta' K^{\pm}$ with $\eta' \to \eta\pi^{+}\pi^{-}$



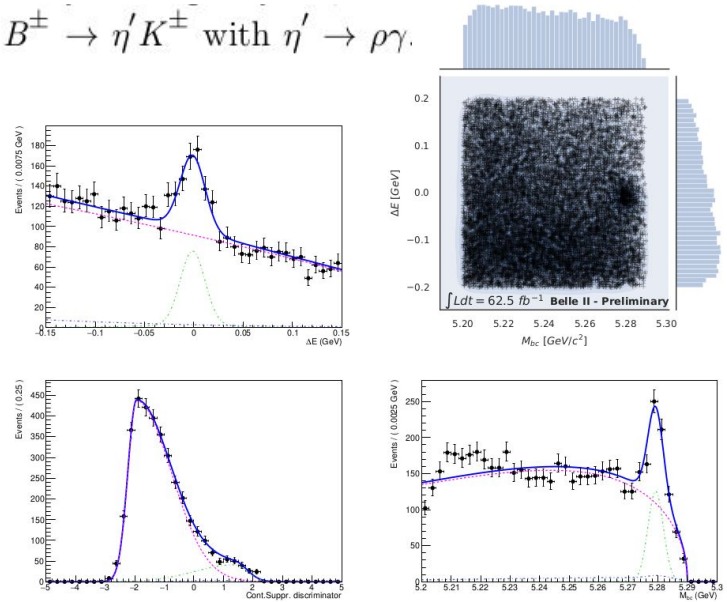
$B^{0} \to \eta' K^{0}_{S}$ with $\eta' \to \eta\pi^{+}\pi^{-}$



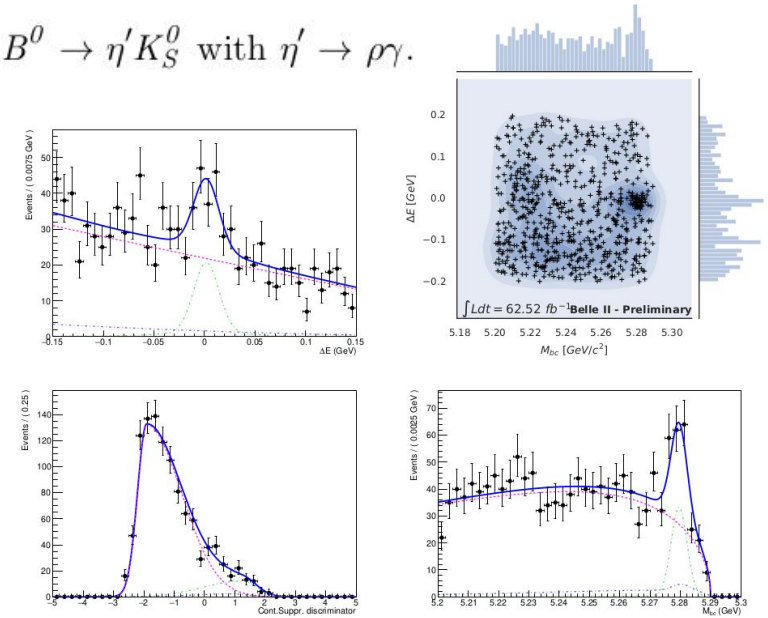
- M_{bc}, ΔE, and CS_{fBDT} for signal enriched region ($\mathscr{L}_R > 0.7$)
  - M_{bc} vs ΔE appling CS_{fBDT} selection which optimize FoM

Results (still MC)

$B^{\pm} \to \eta' K^{\pm}$ with $\eta' \to \rho\gamma$.



$B^0 \to \eta' K^0_S$ with $\eta' \to \rho\gamma$.



- M_{bc}, ΔE, and CS_{fBDT} for signal enriched region ($\mathscr{L}_R > 0.7$)
  - M_{bc} vs ΔE appling CS_{fBDT} selection which optimize FoM
  - Charged state with large background, but still well visible.

Conclusion and outlook

- B→ **η**’ K rediscovery analysis in good shape
  - Efficiency similar or better than Belle
  - UML tested and working
  - waiting for WG conveener green light for RC
- Documentation ready and available
- Feedback is welcome!

TABLE 12. Summary of results for the four channels, with an integrate luminosity of $\mathcal{L} = 65.8\,\mathrm{fb}^{-1}$. Measured signal yield (n_{sig}), statistical significance (sig), efficency (ε), total efficiency including the seconrady BR (εB), and the measured B. Uncertainty are statistical only. Warning: the current results are from MC, as the data is blind in the signal region.

Mode	n_{sig}	sig	$\varepsilon(\%)$	$\varepsilon B(\%)$	$B\ (10^{-6})$
$B^{\pm} \to \eta'(\to \eta(\to \gamma\gamma)\pi^+\pi^-)K^{\pm}$	254 ± 19	23.0	31.3 ± 0.1	5.45	70.7 ± 5.1
$B^{\pm} \to \eta'(\rho(\to \pi^+\pi^-)\gamma)K^{\pm}$	369 ± 26	23.7	24.8 ± 0.1	7.19	77.8 ± 5.5
$B^{0} \to \eta'(\to \eta(\to \gamma\gamma)\pi^+\pi^-)K^{0}_S$	7341 ± 13.5	6.1	31.3 ± 0.1	1.81	61.9 ± 11.4
$B^{0} \to \eta'(\rho(\to \pi^+\pi^-)\gamma)K^{0}_S$	100.3 ± 14.5	11.0	24.8 ± 0.1	2.47	62.2 ± 8.5

Outlook

- Add more channel η' -> η (-> $\pi^+\pi^-\pi^0$) $\pi^+\pi^-$
- SxF from UML using fBDT (in progress)
  - Neither needed for Moriond
- Add also K_L modes!
- Start with TDCPV analysis
  - Re-use from Δt resolution from J/ψ K_s analysis
  - Re-use also CP fitting tools
  - Flavour tagger already included and validated
- Belle/BaBar results done with 772E6 / 476E6 BB so the measurment will not be competitive
  - However, will demonstrate the capability of BelleII to perform TDCPV on a b->qqs transition

Backup

Selections

$\eta' \to \eta\pi^+\pi^-$

- $E_\gamma > 150$ MeV
- $0.5 < M_\eta < 0.57 \ \frac{GeV}{c^2}$
- $0.92 < M_{\eta'} < 1.0 \ \frac{GeV}{c^2}$

$\eta' \to \rho\gamma$

- $E_\gamma > 150$ MeV
- $\cos\theta_\gamma > -0.64$
- $0.51 < M_\rho < 1.0 \ \frac{GeV}{c^2}$
- $0.92 < M_{\eta'} < 1.0 \ \frac{GeV}{c^2}$

K

- $\cos\theta_K > -0.5$

K_s^0

- $\cos\theta_{p,v} > -0.64$
- $0.49 < M_{K_s^0} < 0.51 \ \frac{GeV}{c^2}$

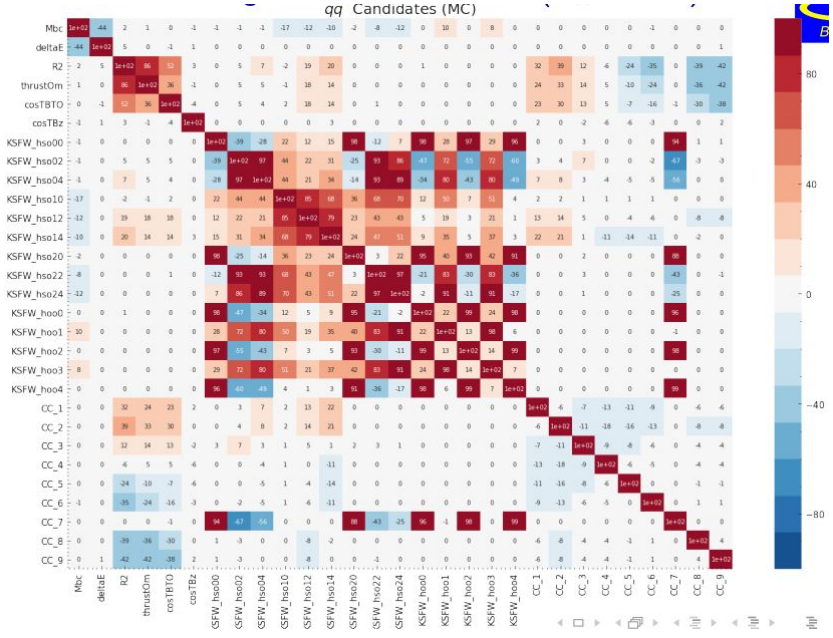
CS fBDT

- So far, used only R2 and cos(TB-TO) as Continuum Suppression variables
  - Hard cut on both
- Move to fBDT
  - Variables considered
  - No TagV variables

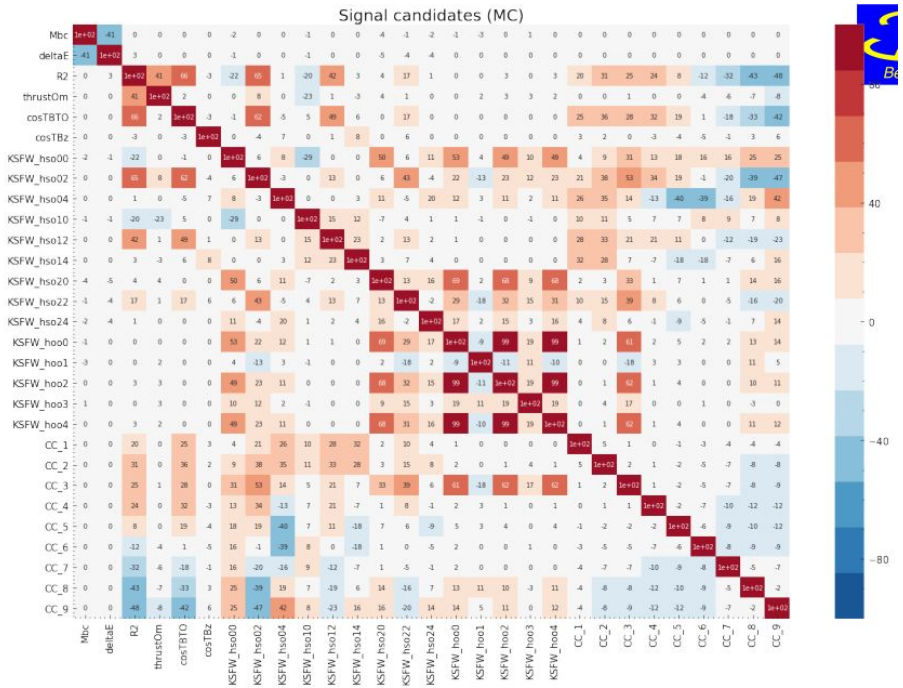
Variable name		
KSFW_hso00	KSFW_hoo0	CC_1
KSFW_hso02	KSFW_hoo1	CC_2
KSFW_hso04	KSFW_hoo2	CC_3
KSFW_hso10	KSFW_hoo3	CC_4
KSFW_hso12	KSFW_hoo4	CC_5
KSFW_hso14	R2	CC_6
KSFW_hso20	thrustOm	CC_7
KSFW_hso22	cosTBTO	CC_8
KSFW_hso24	cosTBz	CC_9

Correlations

- Large correlation w/ Mbc and DeltaE for mme and et (excluded)
- For continuum also for some KSFW moments, not for signal (kept)



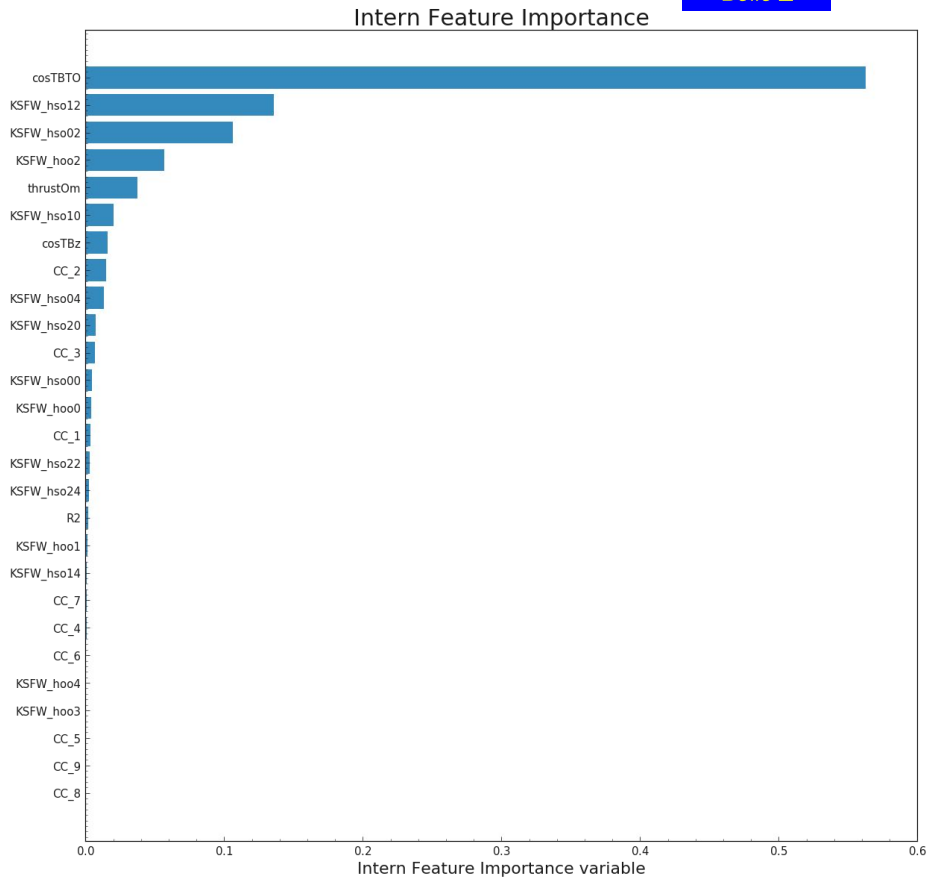
Continuum



Signal

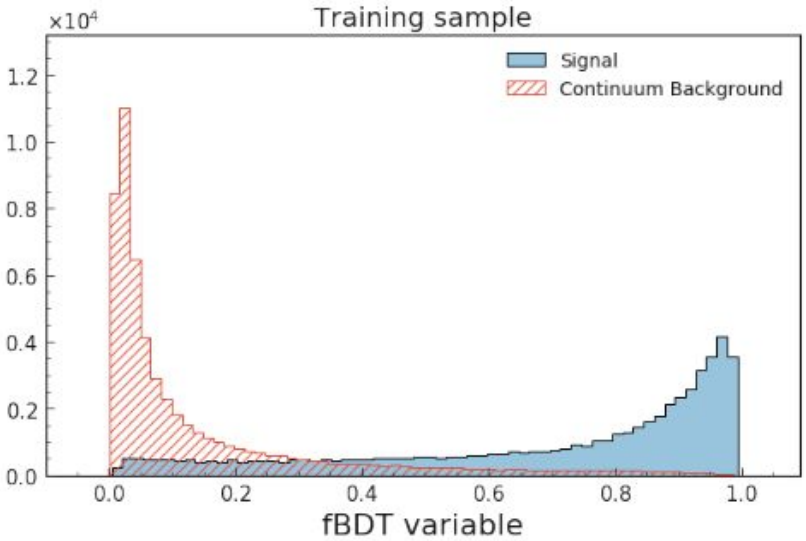
Intern feature importance

- cos(TB-TB) by far the most discriminating variables
- Most of correlated variables not very important
- Tried with less variables, basically same performances
- Could remove many w/o any significant change



Training (and Validation)

- Dataset divided in training (50%) - Validation (30%) - Test (20%)



Confusion matrix:

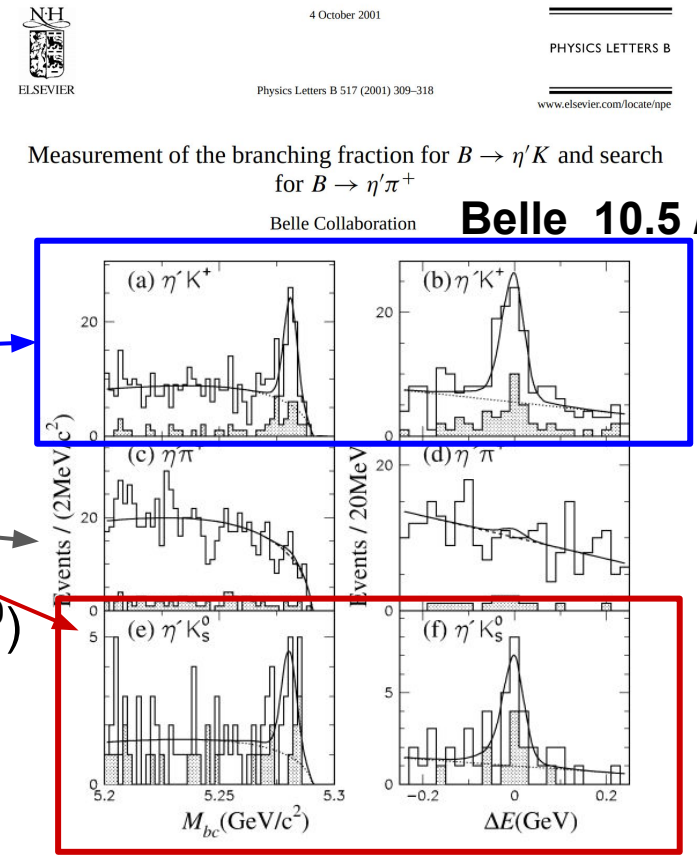
	pred bkg	pred sgn
true bkg	0.92	0.08
true sgn	0.25	0.75

Score (fBDT<>0.5) 0.8666

Same performances for validation sample

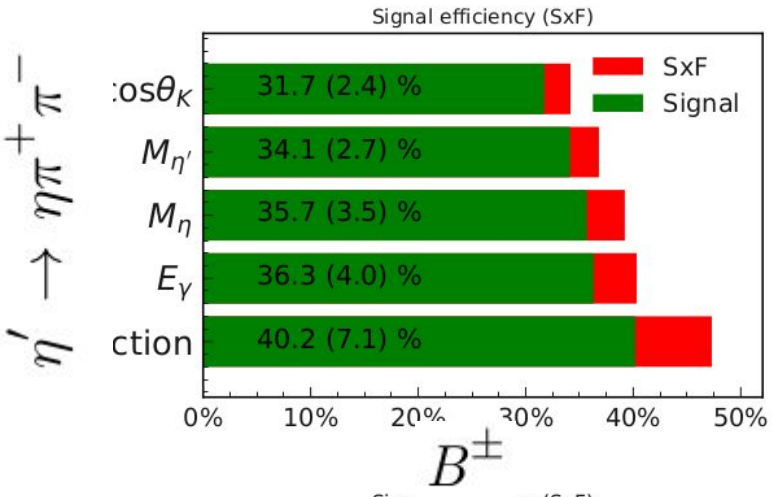
Motivation

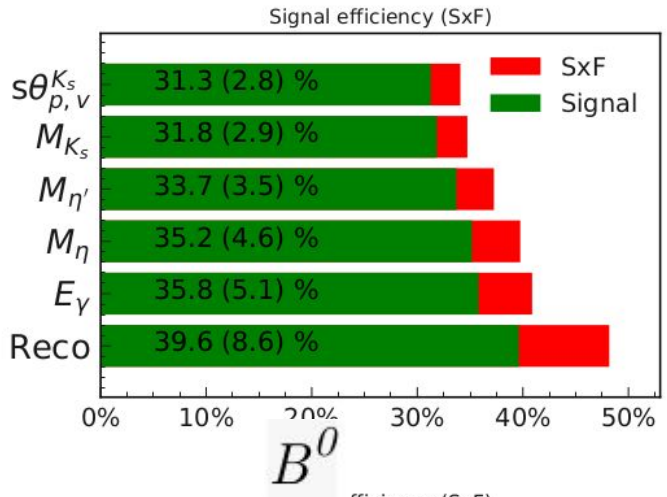
- BR($B^0 \to \eta' K^0_S$) = (6.6 ± 0.4) × 10^{-5}
  - C_{CP} ($B^0 \to \eta' K^0$) = −0.06 ± 0.04
  - $-A_{CP}=S_{CP}$ ($B^0 \to \eta' K^0_S$) = 0.63 ± 0.06
- BR($B^+ \to \eta' K^+$) = (7.06 ± 0.25) × 10^{-5}
- Seen by Belle with 10/fb?
  - B^+: BR=$(79^{+12}_{-11} \pm 8) \times 10^{-6}$
  - B^0 : BR=$(55^{+19}_{-16} \pm 9) \times 10^{-6}$
  - Limit for $B^0 \to \eta' \pi^+$
- Final states used at Belle
  - $\eta' \to \rho(\to \pi^+\pi^-)\,\gamma$ (42/10 ev B^+/B^0)
  - $\eta' \to \eta(\to \gamma\gamma)\,\pi^+\pi^-$ (29/6 ev)
  - $\eta' \to \eta(\to \pi^+\pi^-\pi^0)\,\pi^+\pi^-$ not used

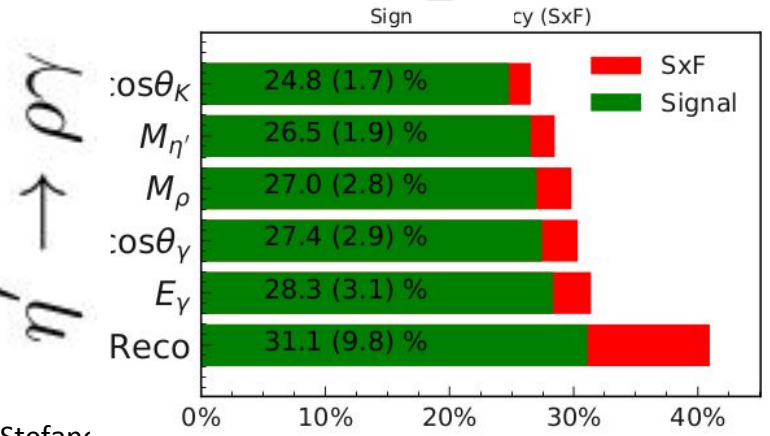


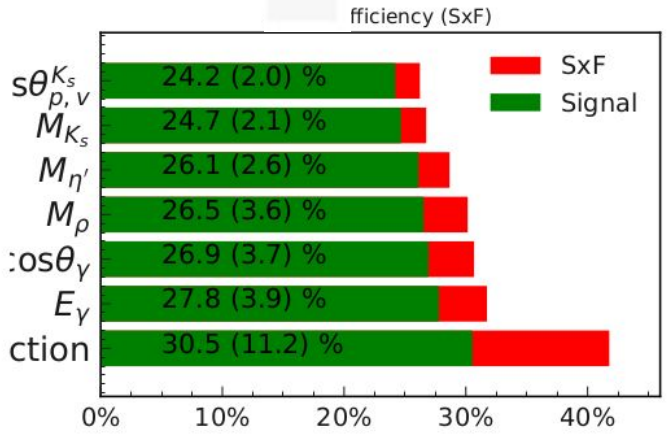
Shaded $\eta' \to \eta\pi\pi$, white all (including $\eta' \to \rho\gamma$)

Selection efficiency







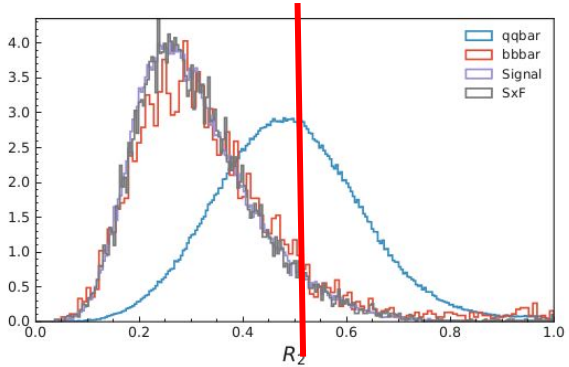


- High selection efficiency **24-30%**
- SxF **10->2%**
- **no CS cut (next slides)**

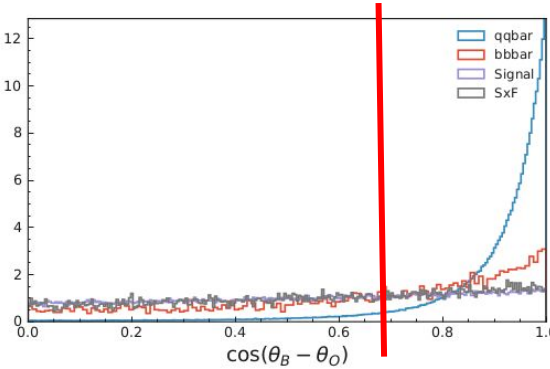
Stefanc

Continuum suppression

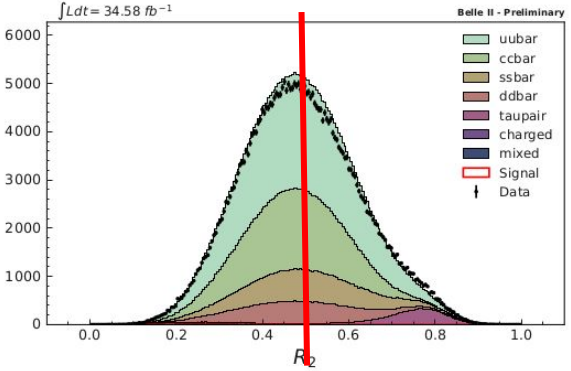
- Using only **R2** and **CosTBTO**
- Started MVA but still some correlation with data not understood
  - For next iteration
- Optimization of cut based on
- FoM=S/sqrt(S + B)
  - S and B in signal region from MC
  - Mbc>5.27
  - -70<De<50 MeV
- **R2<0.5**
- **CosTBTO<0.7**
  - Probably too hard

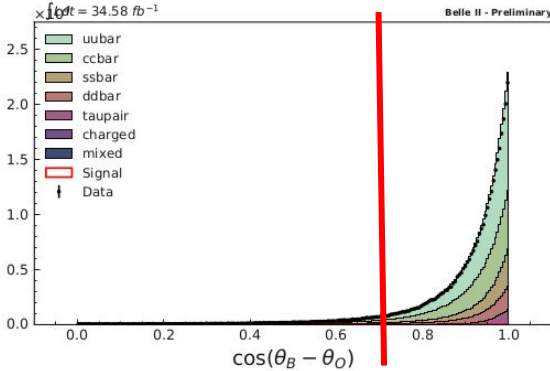


R2



cosTBTO



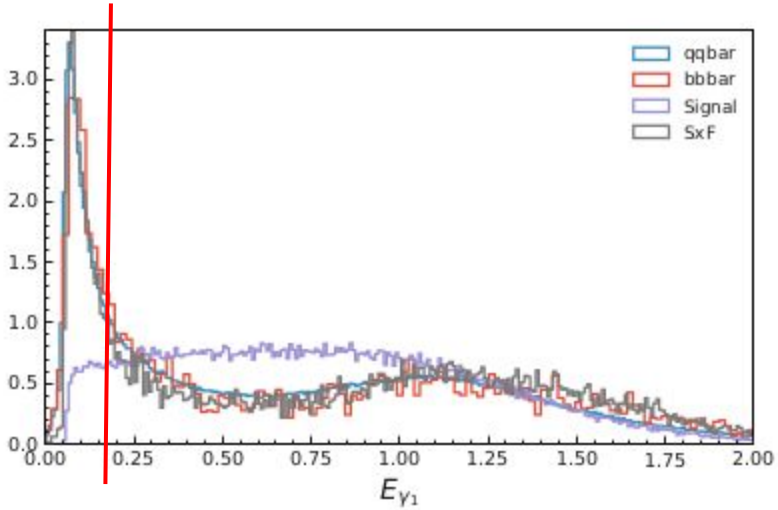


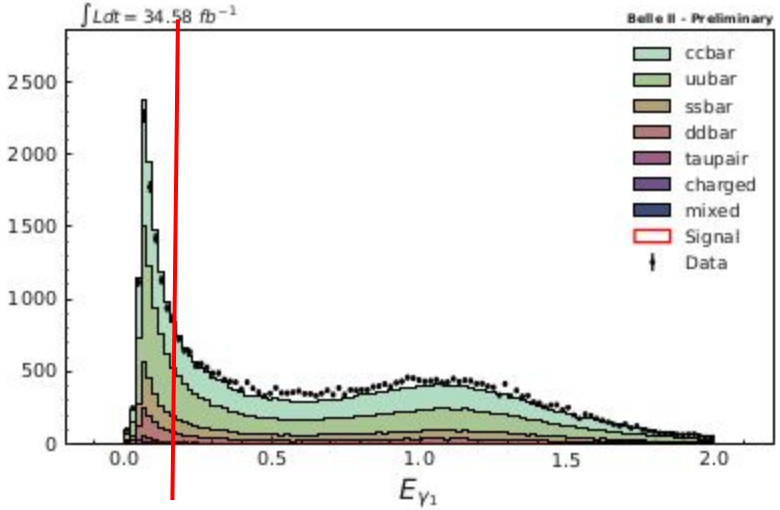
Branching fractions

Mode	Decay channel	Branching fraction
$B^+ \to \eta' K^+$	inclusive	7.06×10^{-5}
	$\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$	1.19×10^{-5}
	$\eta' \to \rho(\to \pi^+\pi^-)\gamma$	2.04×10^{-5}
	total	3.23×10^{-5}
$B^0 \to \eta' K$	includive	6.6×10^{-5}
	$\eta' \to \eta(\to \gamma\gamma)\pi^+\pi^-$	5.54×10^{-6}
	$\eta' \to \rho(\to \pi^+\pi^-)\gamma$	9.54×10^{-6}
	total	1.51×10^{-5}

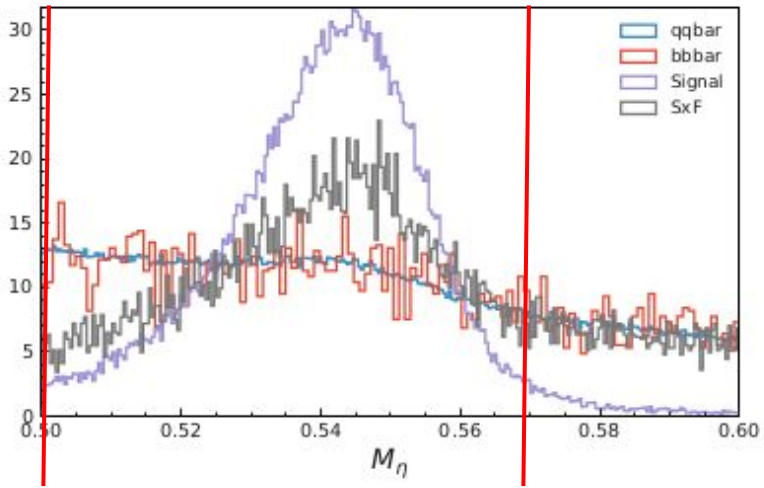
- Effective BR twice for charged state due to K+ vs Ks

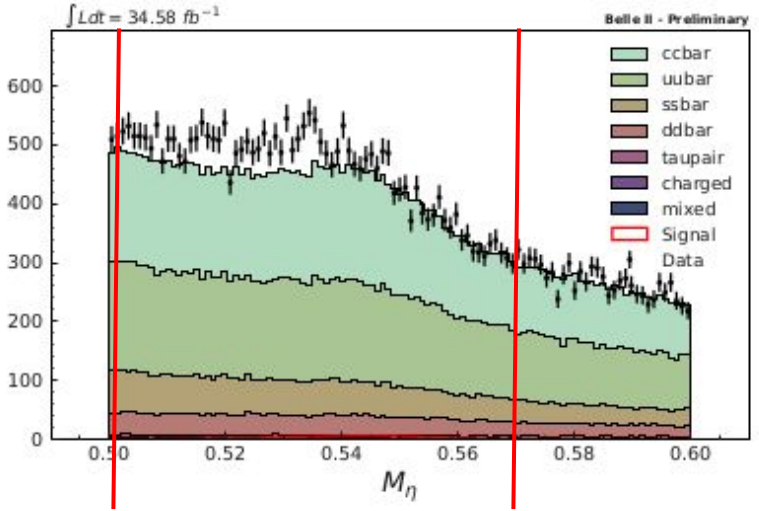
E gamma (eta->gamma gamma)





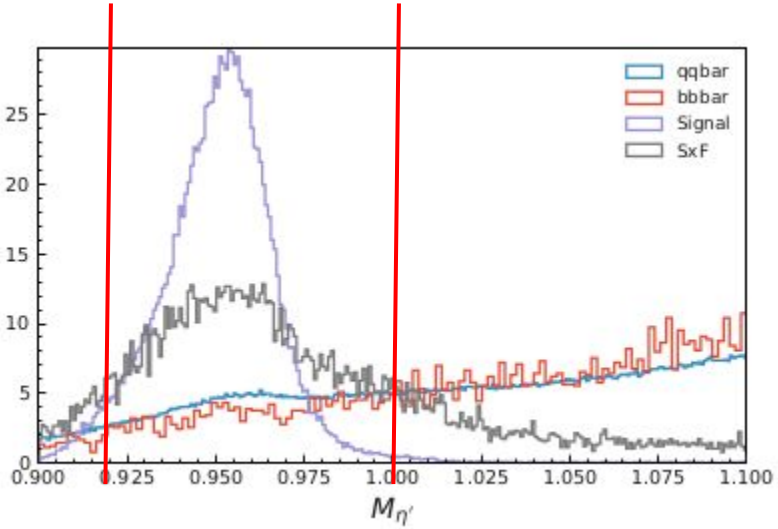
M(eta)

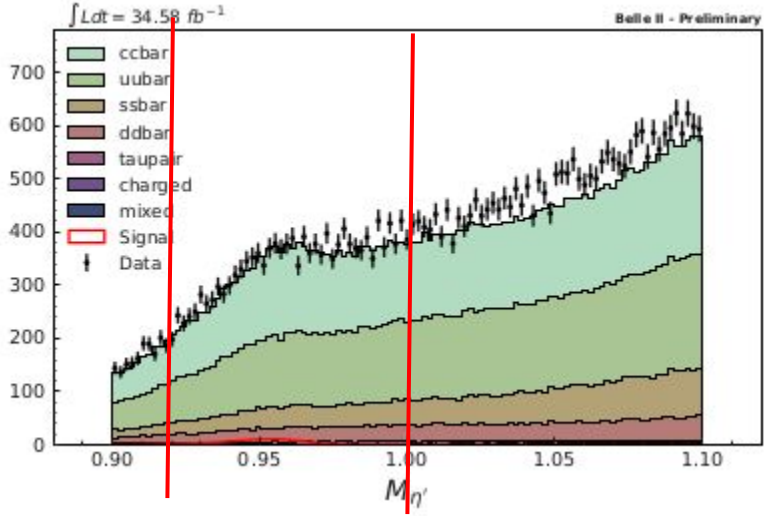




eta->gg peak not well visible due to low gamma threshold (60 MeV)

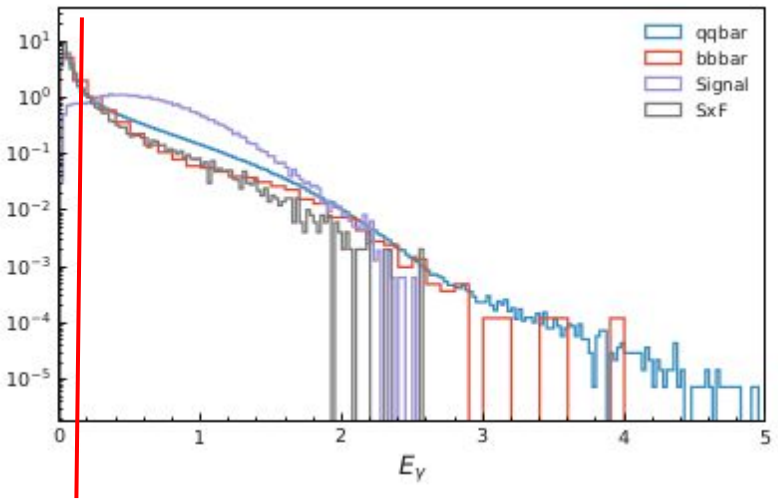
M(etaprime)

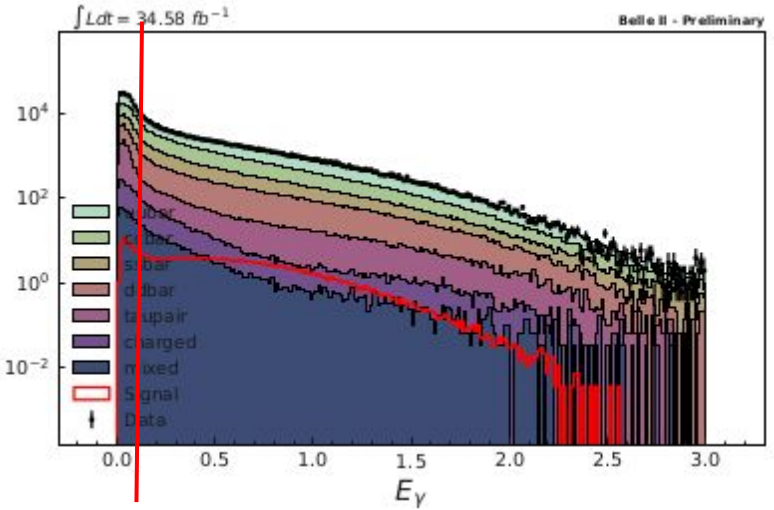




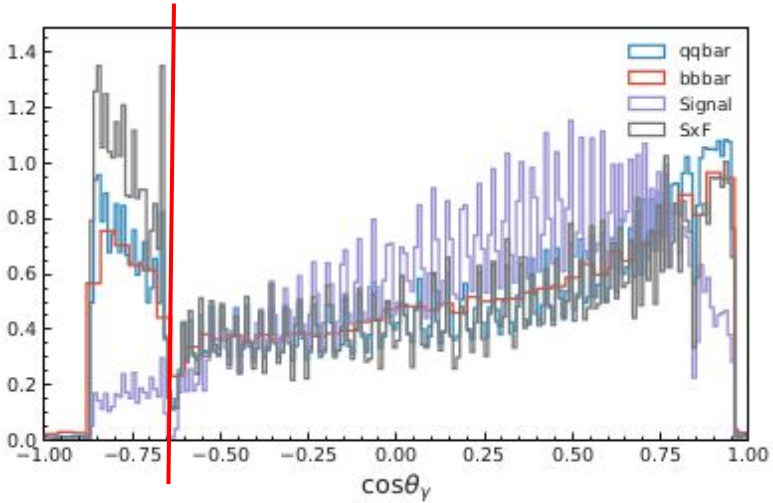
eta'->eta(gg)pipi peak not well visible due to low gamma threshold (60 MeV) and pion ones

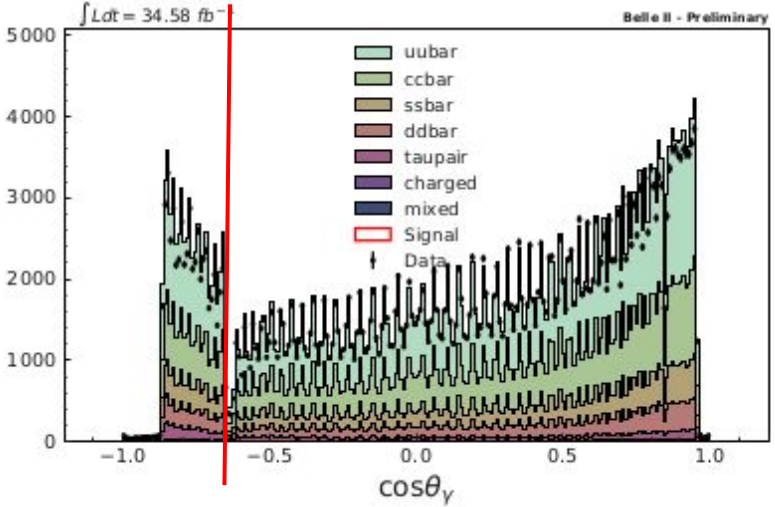
E(gamma) from eta'->rho gamma



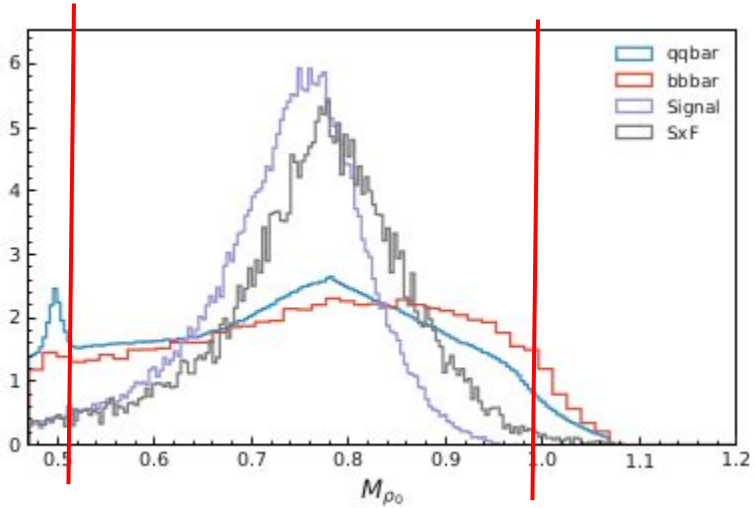


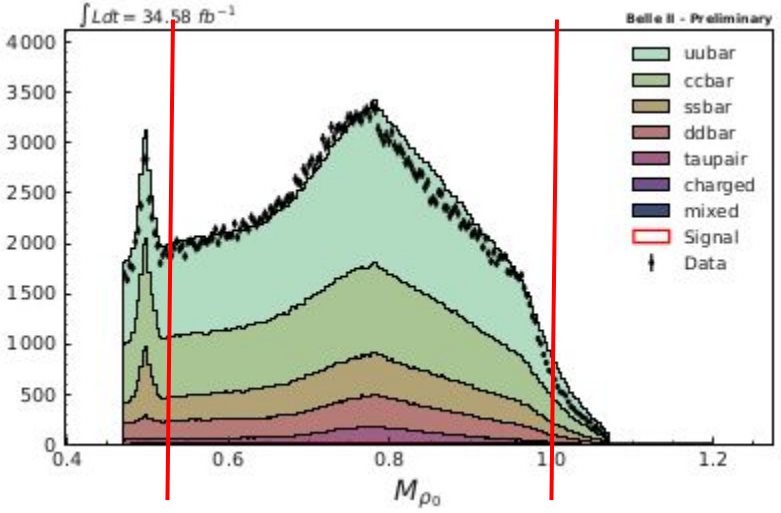
cos(theta gamma)





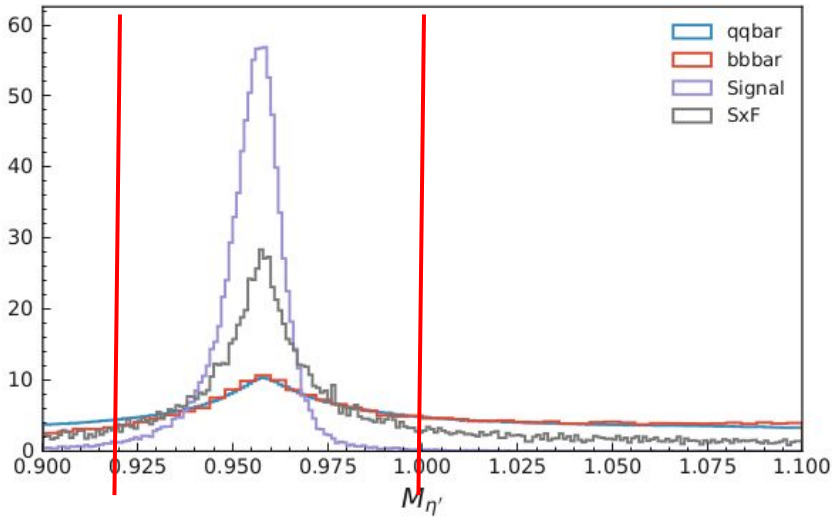
M(pi+ pi-)

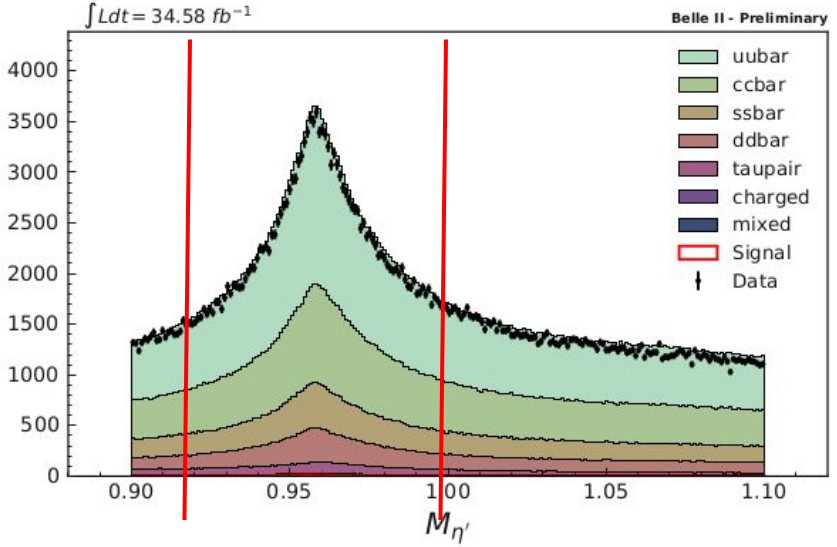




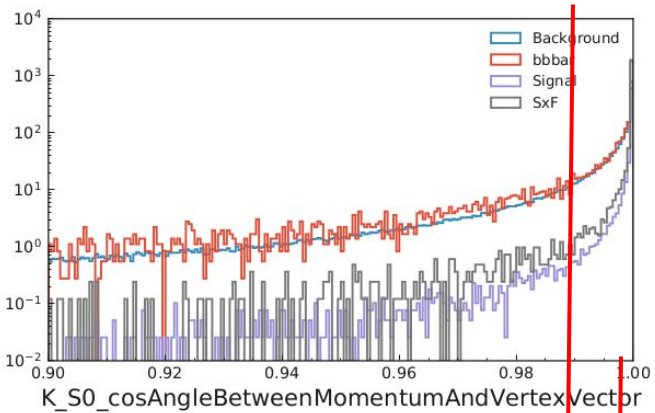
- Clear Ks peak
- Shift between rho peak for signal and SxF

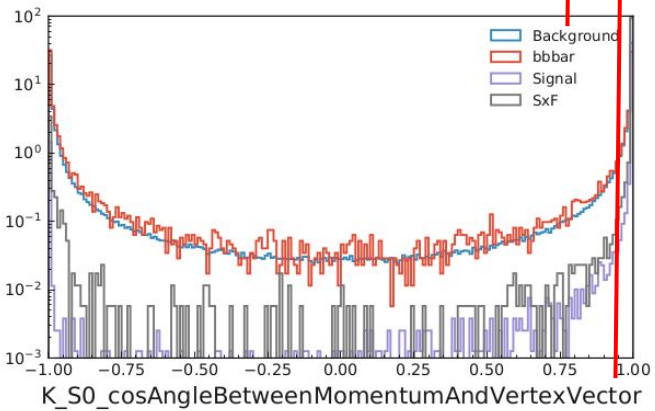
M(etaprime)

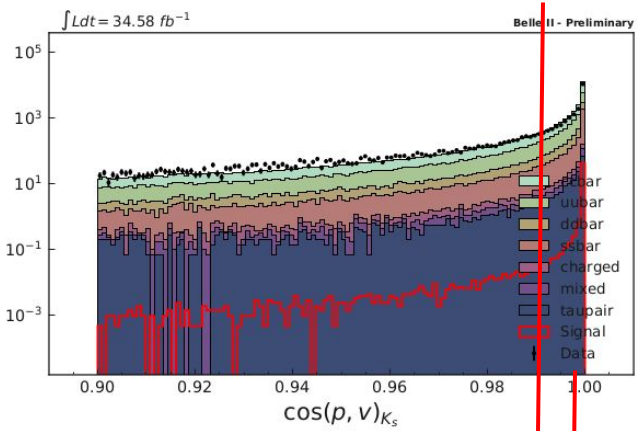

qqbar
bbbar
Signal
SxF
$M_{\eta'}$

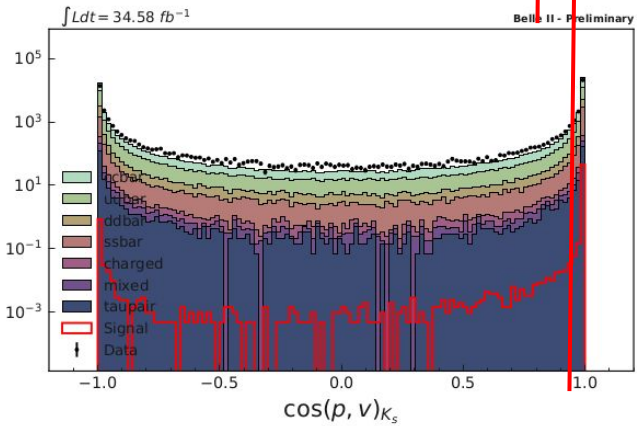

$\int Ldt = 34.58\ fb^{-1}$
Belle II - Preliminary
uubar
ccbar
ssbar
ddbar
taupair
charged
mixed
Signal
Data
$M_{\eta'}$

cos(alpha) (momentum vs vertex)

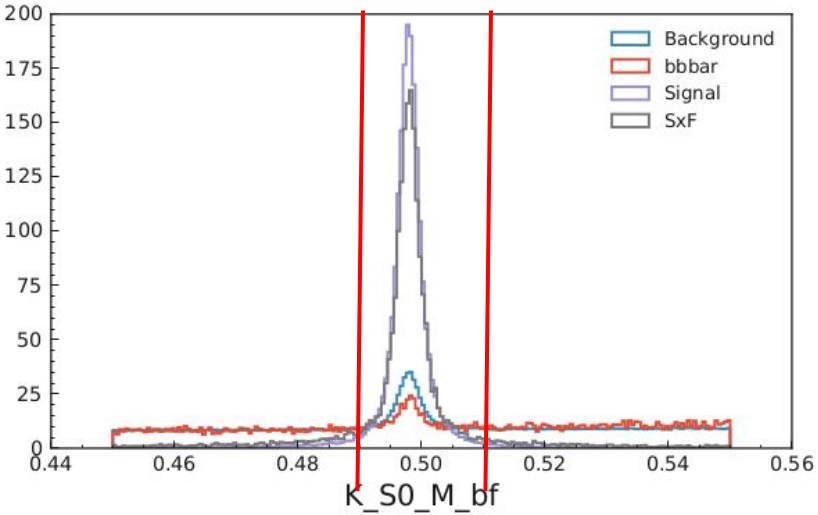


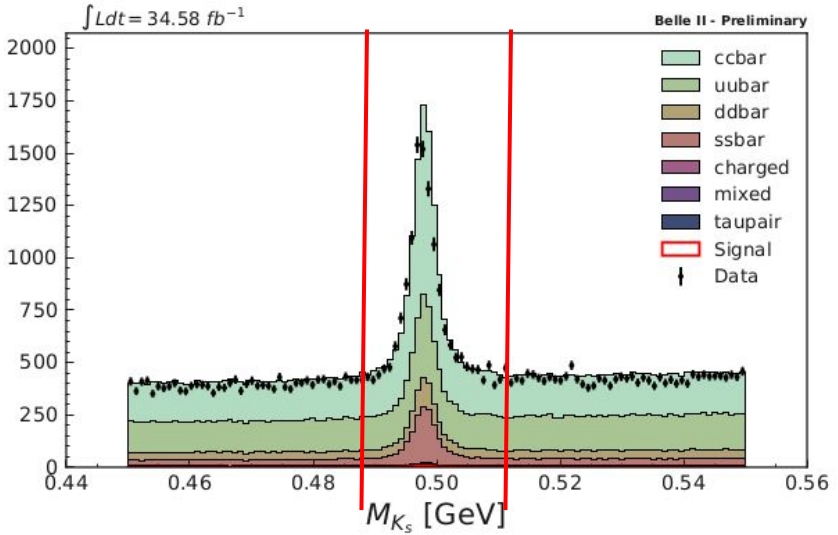






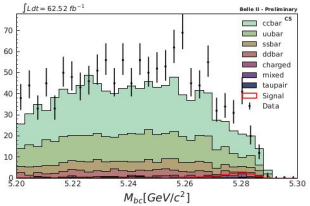
M(Ks)

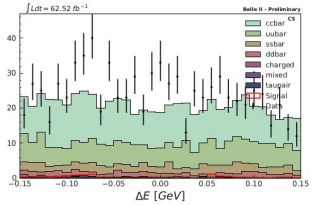

Background
bbbar
Signal
SxF
K_S0_M_bf


$\int Ldt = 34.58\ fb^{-1}$
Belle II - Preliminary
ccbar
uubar
ddbar
ssbar
charged
mixed
taupair
Signal
Data
M_{K_S} [GeV]

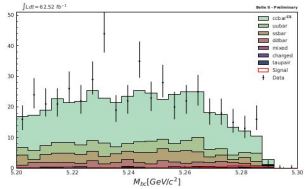
Control region with CS fBDT cut

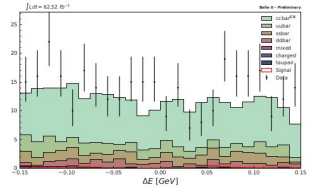
$\eta'_{\eta\pi\pi}K^+$



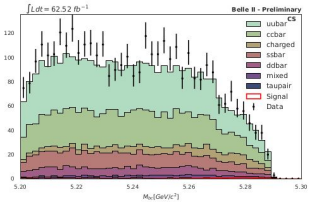


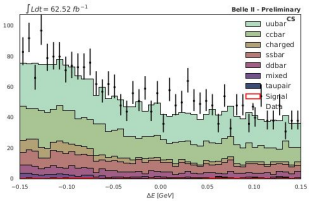
$\eta'_{\eta\pi\pi}K^0$



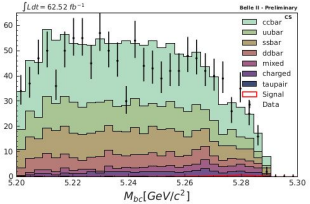


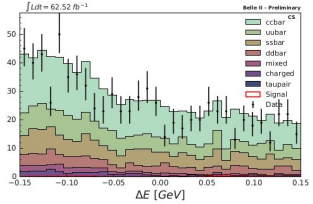
$\eta'_{\rho\gamma}K^+$



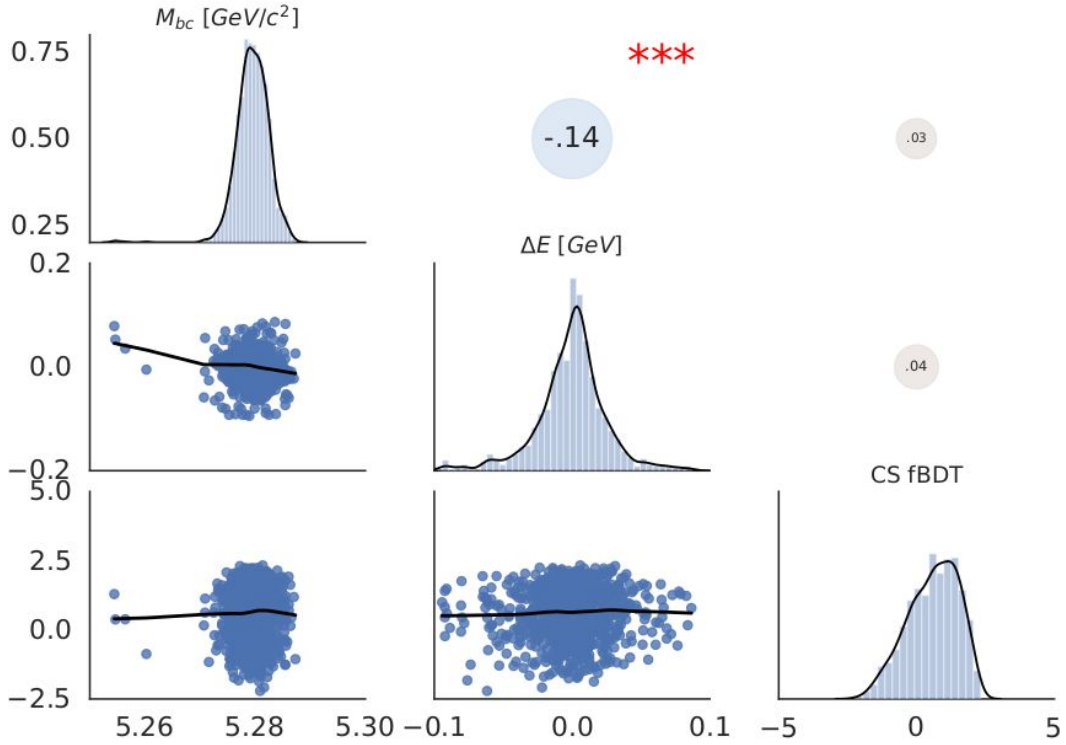


$\eta'_{\rho\gamma}K^0$





UML variable correlation



AnaSkim cuts

- Main difference between Skim and Reco is list of pions
  - Skim uses pi:loose
  - Reco uses pi:all

The additional cuts implemented in pi:loose are:

- $dr < 0.5\ cm$ } Distance between the B decay vertex
- $|dz| < 2\ cm$ } and the interaction one.
- $nCDCHits > 20$
- $pionID > 0.1$,

but the relevant ones are the last two.

pi:all	pi:all+ nCDCHits	pi:all+ pionID	pi:all+pionID+ nCDCHits	pi:loose
43.8%	36.8%	33.8%	28.3%	28.4%

Reconstruction efficiency changing the pion list used.

- nCDC hits and PID responsible for 40% loss

AnaSkim with pi:all

- Relative eff increase
  - 62->74%
  - But not ~100% yet
  - Probably need to work on R2/cosTBT0 cut
- Impact on retention rate negligible
  - NB pi:all only in eta' skim!

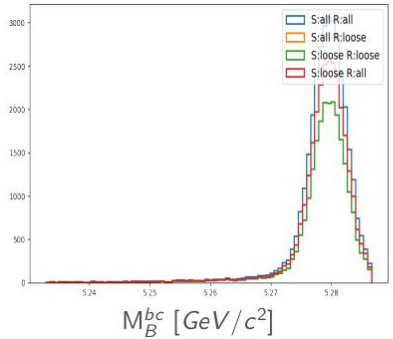
- $\epsilon_{Skim\_pi:all,Reco\_pi:all} = 29.4 \pm 0.1\ \%$
  $\rightarrow r_{Skim\_pi:all,Reco\_pi:all} = 74.4^{+0.2}_{-0.2}\ \%$
- $\epsilon_{Skim\_pi:loose,Reco\_pi:all} = 24.7 \pm 0.1\ \%$
  $\rightarrow r_{Skim\_pi:loose,Reco\_pi:all} = 62.5^{+0.2}_{-0.2}\ \%$

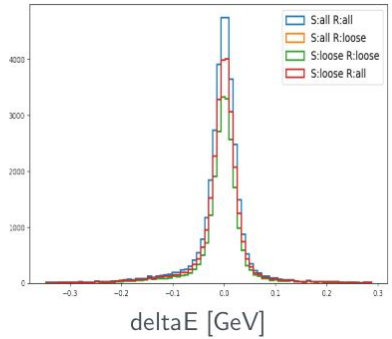
using pi:loose for the skim

$$\epsilon^{bkg}_{c\bar{c}} = 5.7^{+0.2}_{-0.2}\,\% \qquad \epsilon^{bkg}_{u\bar{u}} = 5.2^{+0.2}_{-0.2}\,\%.$$

using pi:all for the skim

$$\epsilon^{bkg}_{c\bar{c}} = 5.8^{+0.2}_{-0.2}\,\% \qquad \epsilon^{bkg}_{u\bar{u}} = 5.3^{+0.2}_{-0.2}\,\%.$$





Preliminary conclusion: it is safe and good to use pi:all for skimming, but not enough.

fBDT for CS background overlap (Valeria)

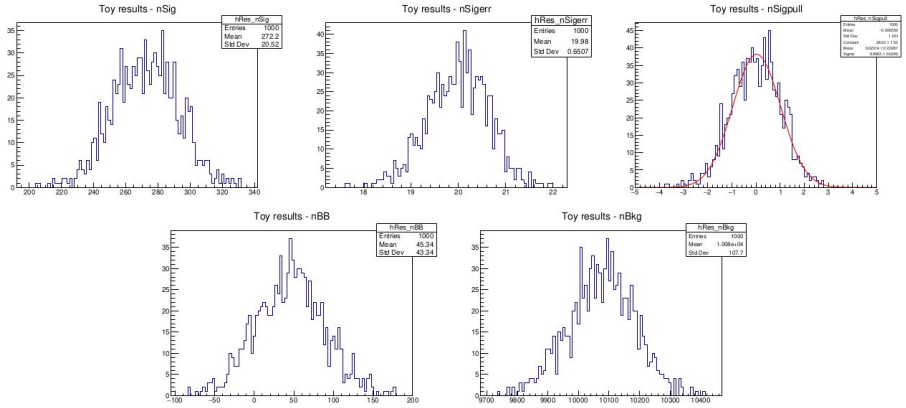
- CS using fBDT - presented on 9/9/2020
- Use signal and Continuum after signal selection
  - Train together all four channels (charged/neutral, eta'->rho gamma, eta'->eta pipi)
    - Investigating possible overlap of background for different channels
      - Same background event for B0->eta' Ks and B+->eta' K+
      - Unlikely for different eta' decay modes
        - Possible for neutral/charged state

AND	**B0ch1**	**B0ch3**	**Bpch1**	**Bpch3**
B0ch1	22428 (100%)	254 ($\sim$ 1%)	225 ($\sim$ 1%)	128 ($\sim$ 0.5%)
B0ch3	254 ($\sim$ 0.1%)	(207997) 100%	150 ($\sim$ 0.07%)	3090 ($\sim$ 1.5%)
Bpch1	225 ($\sim$ 0.3%)	149 ($\sim$ 0.2%)	80594(100%)	1548 ($\sim$ 2%)
Bpch3	128 ($\sim$ 0.015%)	3100 ($\sim$ 0.3%)	1552 ($\sim$ 0.2%)	830758 (100%)

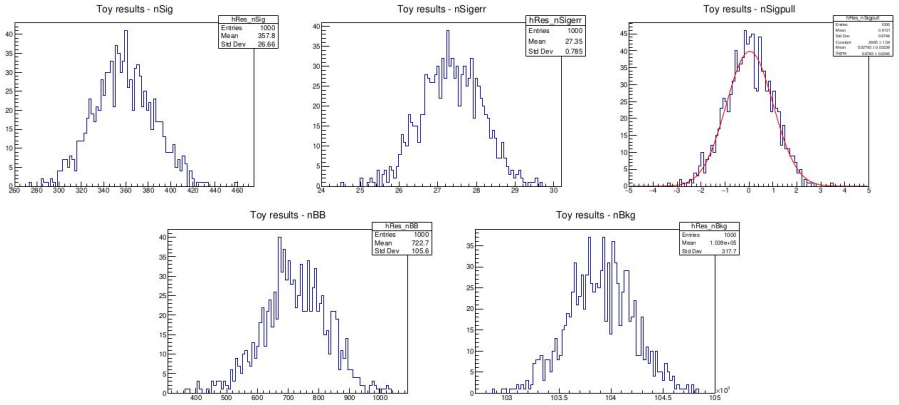
Conclusion: overlap small/negligible.
Will exclude duplicates candidates anyhow, no difference for fBDT training

MC toys for other channels

$B^{\pm} \to \eta' K$ with $\eta' \to \eta\pi^{+}\pi^{-}$



$B^{\pm} \to \eta' K^{\pm}$ with $\eta' \to \rho\gamma$.



- UML working fine on MC for all channels
- Including **η'(->ργ)**
  - In spite of very large background
-

$B^{0} \to \eta' K^{0}_{S}$ with $\eta' \to \rho\gamma$.