



Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO

$$e^+e^- \rightarrow \eta h_b(1P)$$

*19th Belle II Italia
Padova, May 9th 2023*

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INFN – Sezione di Torino

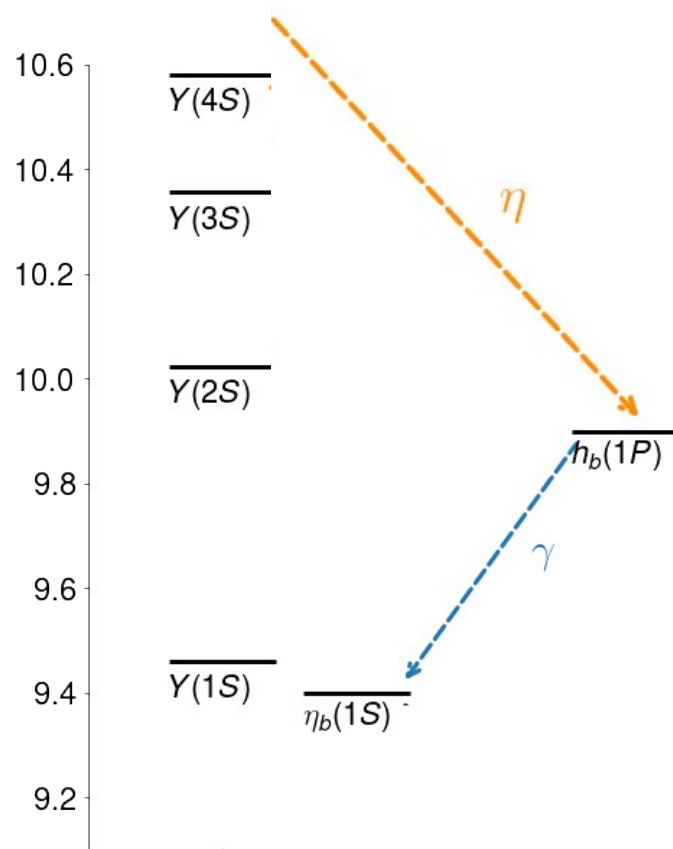
η $h_b(1P)$ transitions: why

$$e^+ e^- \rightarrow \eta + h_b(1P)$$

- $\sigma[\eta h_b(1P)] \sim 1000 \times \sigma[\pi\pi Y(1S)]$

if the $Y(10750)$ is a $b\bar{b}$ -gluon hybrid

[Castella', Passemar PRD 104 (2021) 3, 034019]



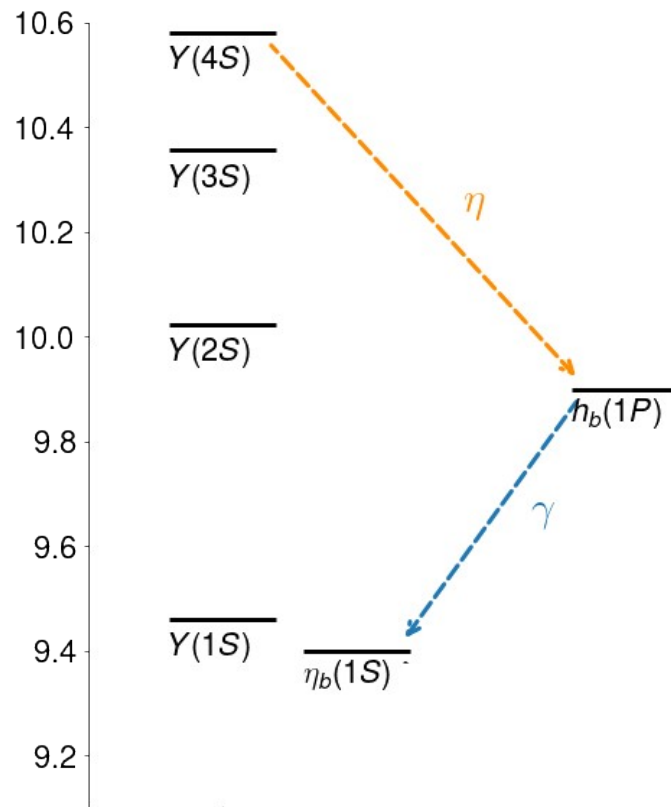
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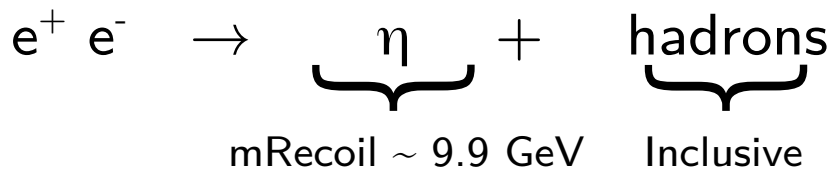
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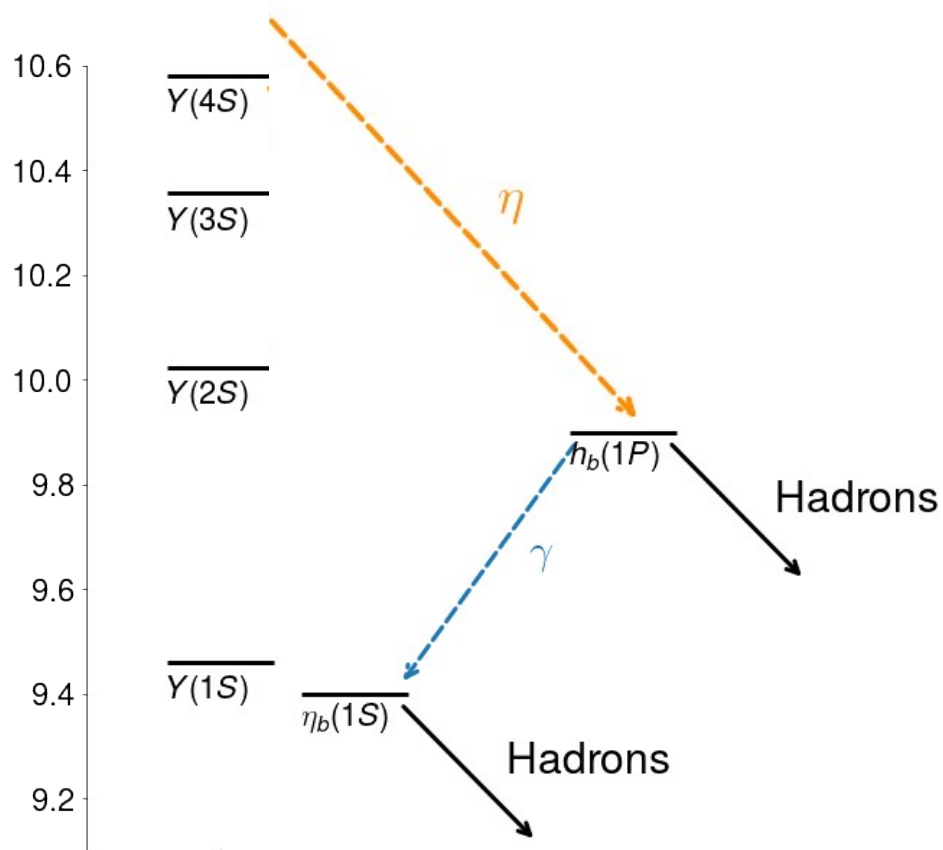
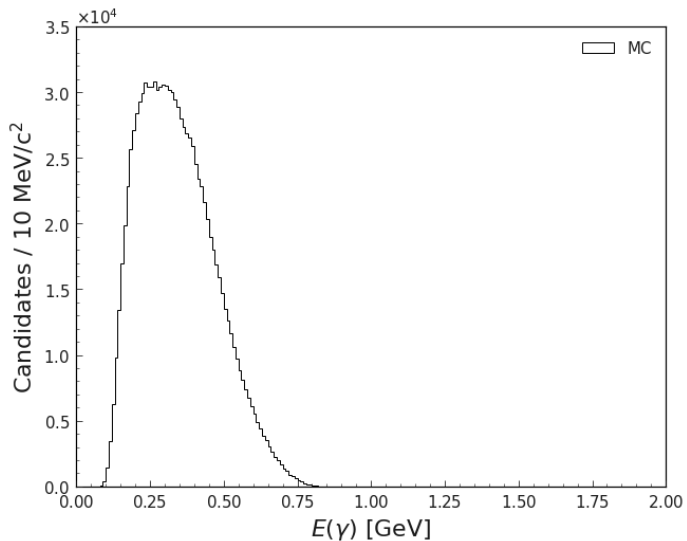
- very large at $Y(4S)$, unclear why
 - Control channel
 - **Observed only once, we want to do a blind analysis on this as well**



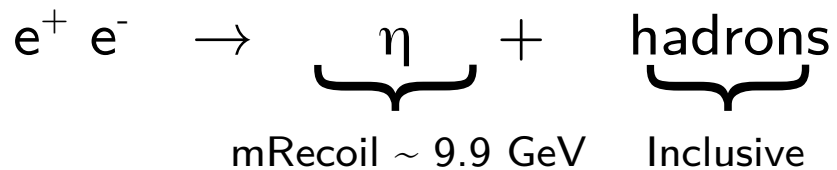
η $h_b(1P)$ transitions: how



$\eta \rightarrow \gamma\gamma$ only (maybe also $\eta \rightarrow 3\pi$?)
 Photons from the signal η have $E < 500 \text{ MeV}$

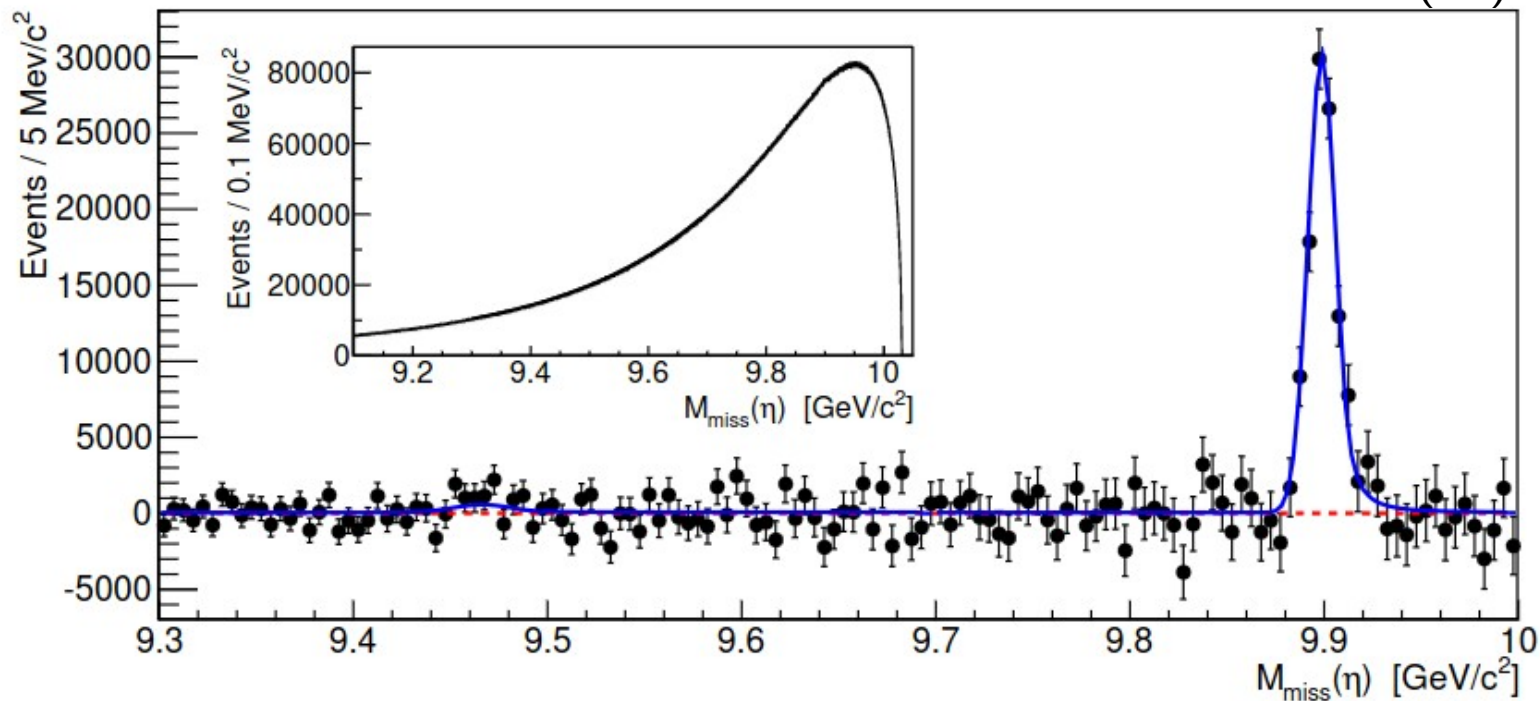


$\eta h_b(1P)$ transitions: how

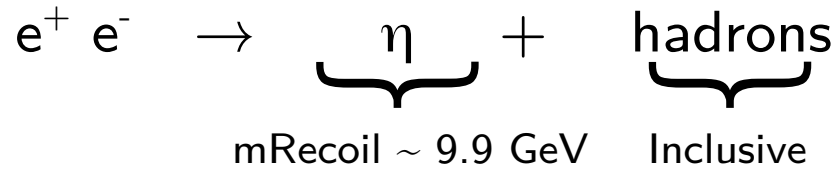


The signal is a small peak over a smooth bkg

Belle at Y(4S)



$\eta h_b(1P)$ transitions: how



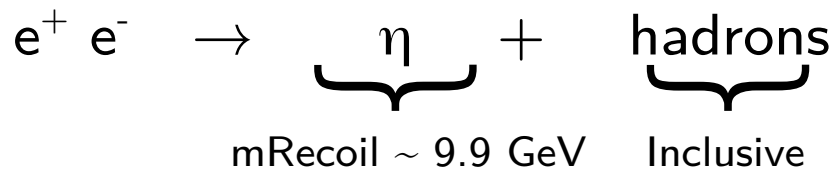
Steps:

- Global event selection
- Continuum suppression ($udsc/b\bar{b} > 10$ @ 10.750 GeV!)
- Photon selection
- π^0 veto
- Systematics
- Fit

Control channel: $Y(4S) \rightarrow \eta h_b(1P)$, $BF \sim 10^{-3}$

→ Use this to estimate most of the systematics (compare yield w/ and w/o cuts)

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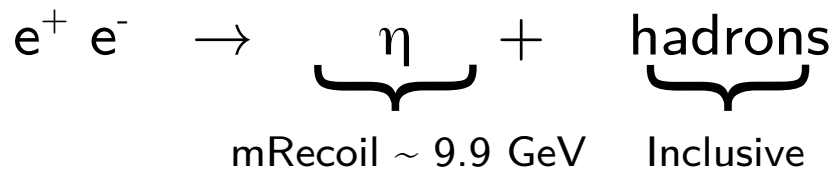
What was done so far

- All steps (full analysis) with MC13/proc11 at Y(4S) **as rediscovery** [BELLE2-NOTE-PH-2021-019]
- Referees asked to move to MC14
- Stopped working for 1 year

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- All steps (full analysis) with MC13/proc11 at Y(4S) **as rediscovery** [BELLE2-NOTE-PH-2021-019]
- Referees asked to move to MC14
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- **Re-started with MC14/proc12 for the control channel, waiting for MC15 run-dependent signal**

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What was done so far

Everything in this talk is about the
re-discovery of the control channel
 with MC14ri/moriond2022

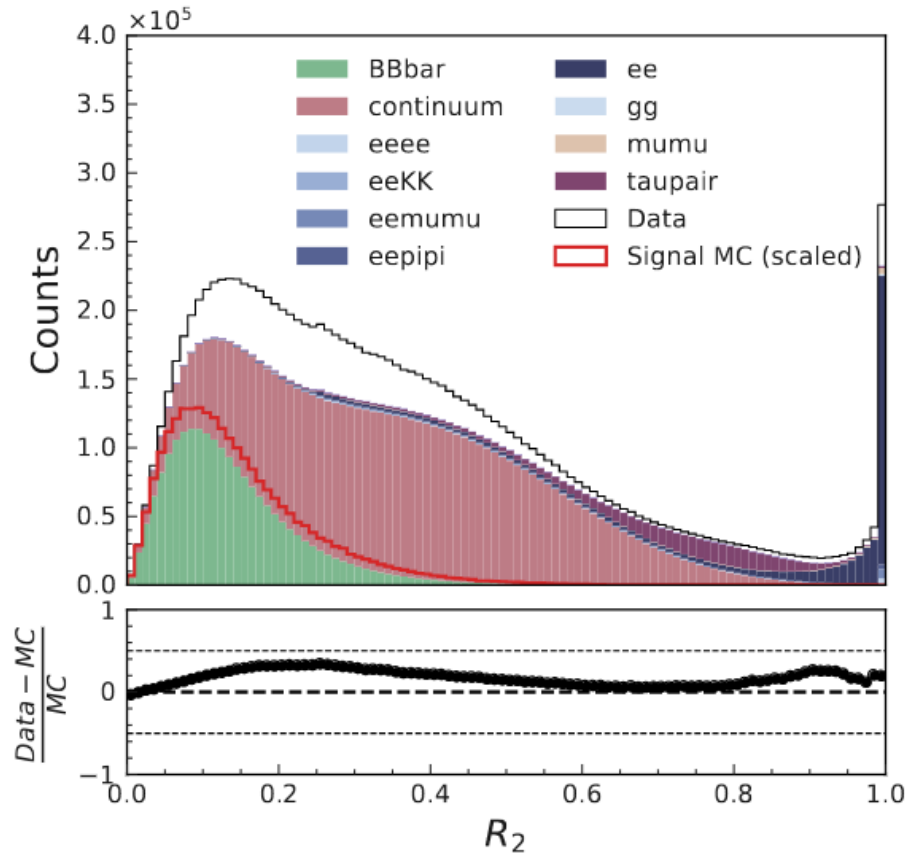
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General event selection

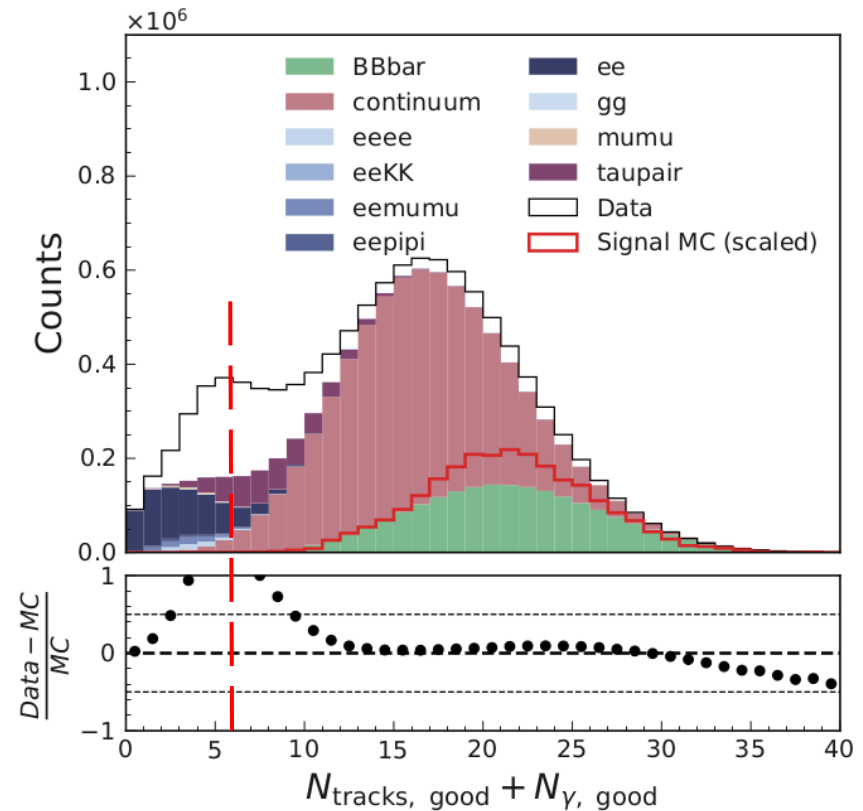
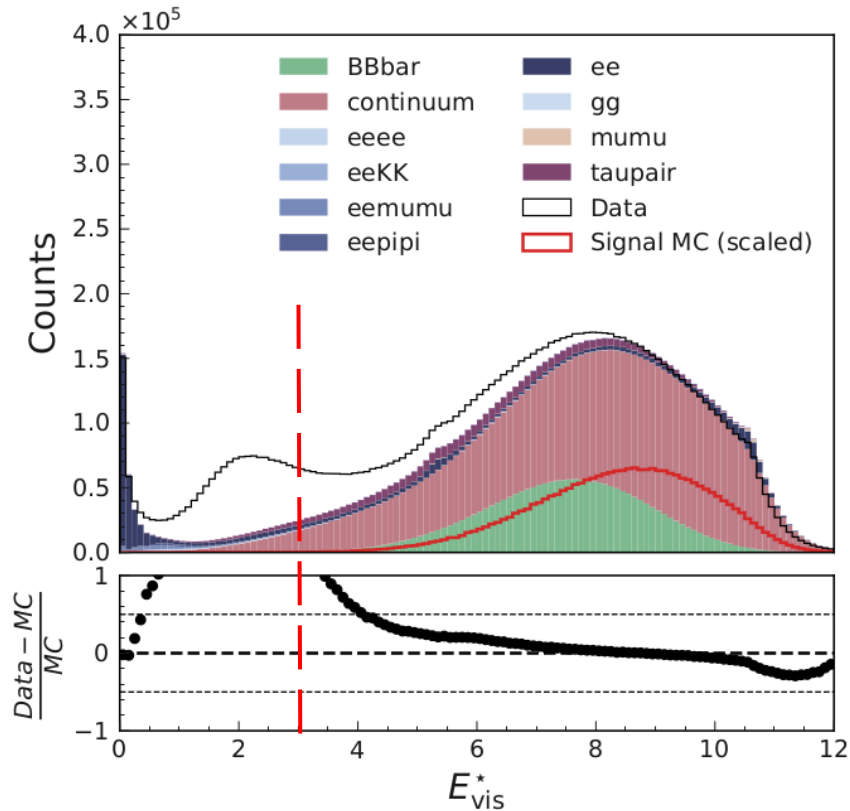
Start from *hlt_hadron*, but this skim is **very loose**

Y(4S), Moriond 2022 + MC14ri



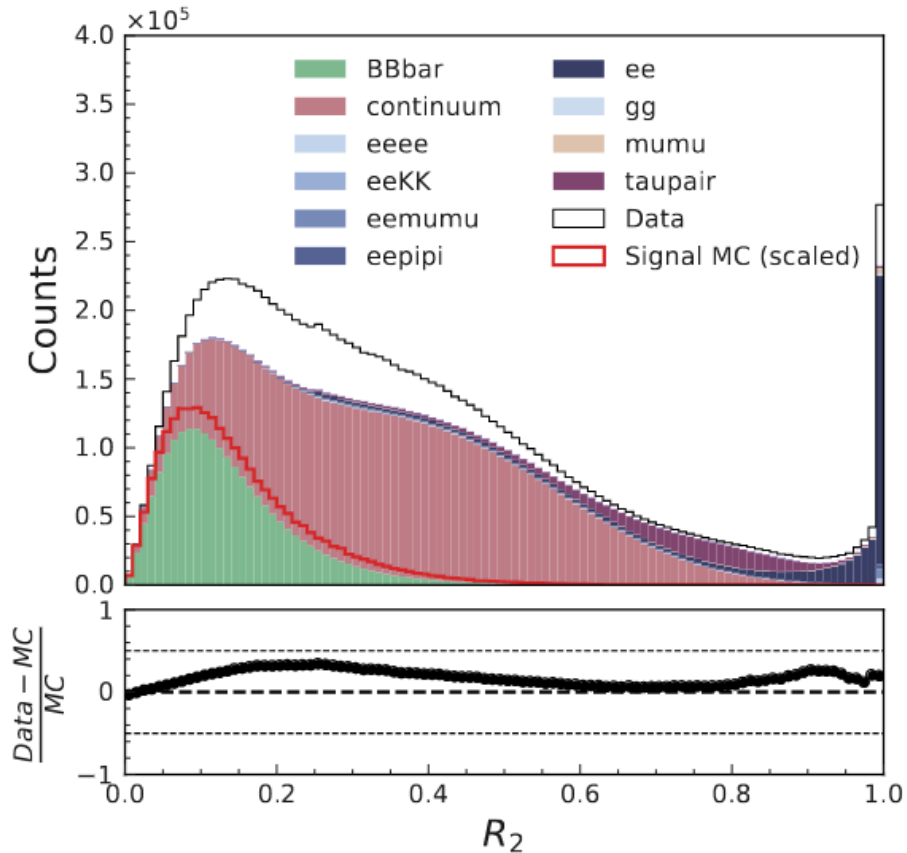
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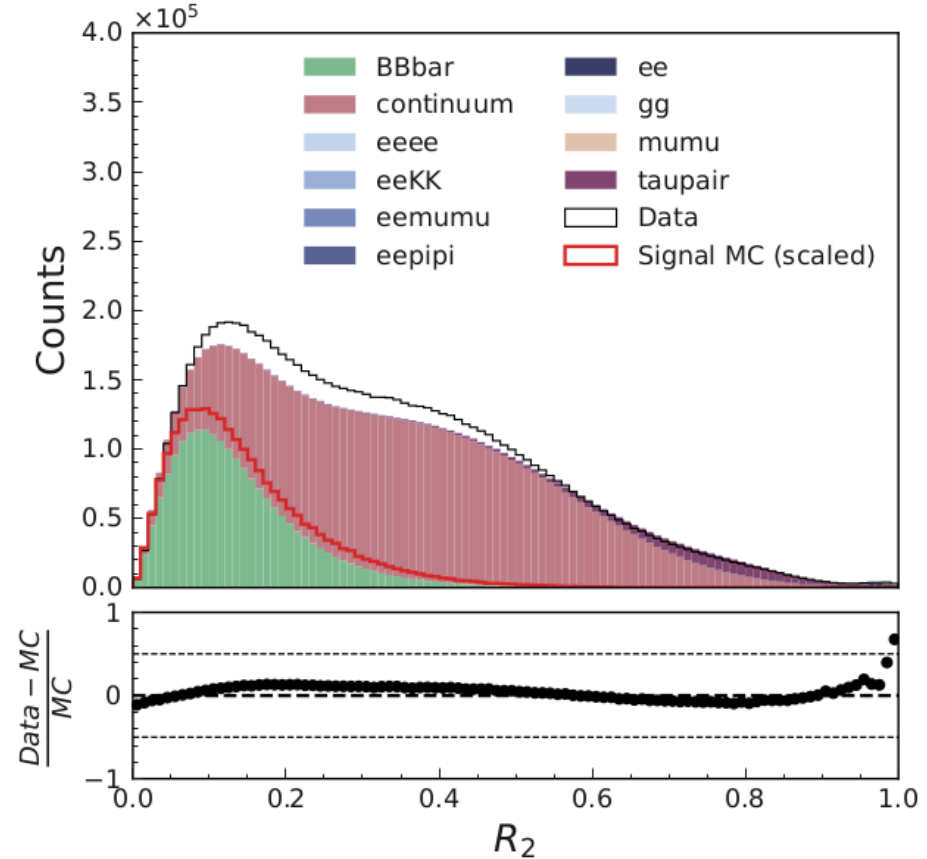


Y(4S), Moriond 2022 + MC14ri

Before selection



After selection



Continuum suppression

In the scan points almost all events are continuum

Y(4S), Moriond 2022 + MC14ri

Build a BDT with:

- Fox-Wolfram moments
- Harmonic moments w/ respect to the thrust axis
- Sphericity, thrust, direction of the thrust axis
- CLEO cones

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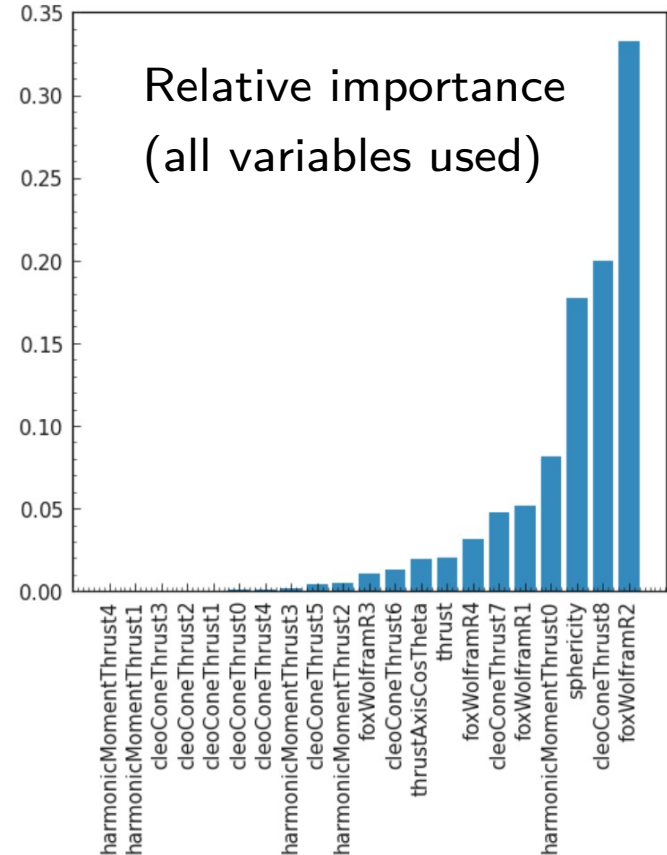
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Adding/removing a variables changes the ranking

→ Try different combination to find the

“minimal” one.

→ Use the ROC area as figure of merit



Continuum suppression

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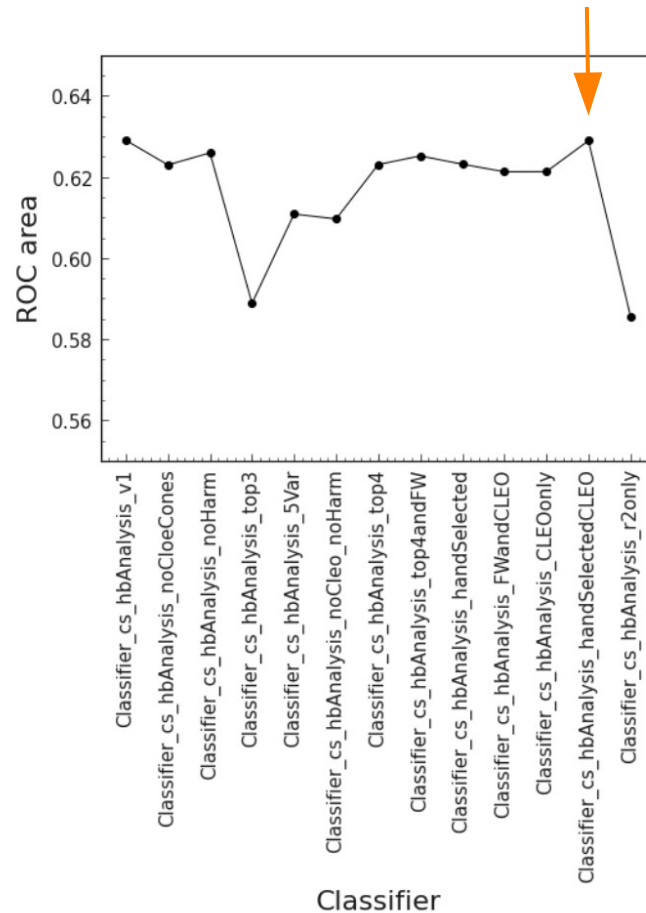
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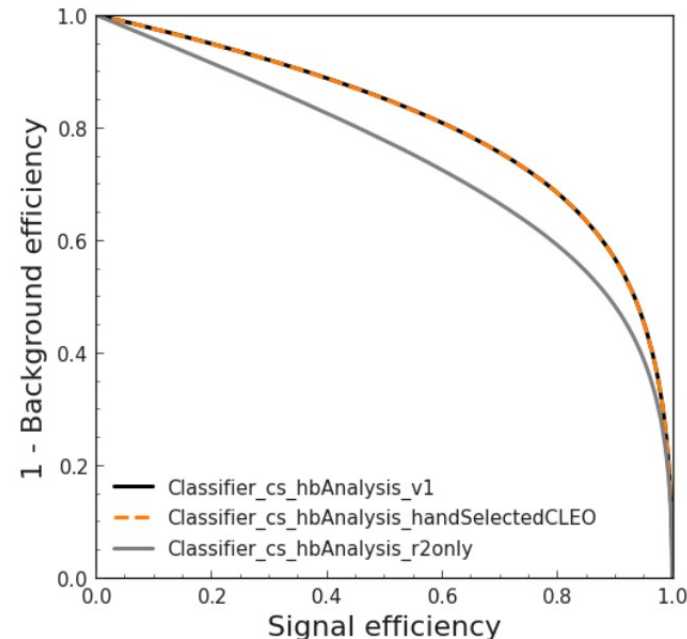
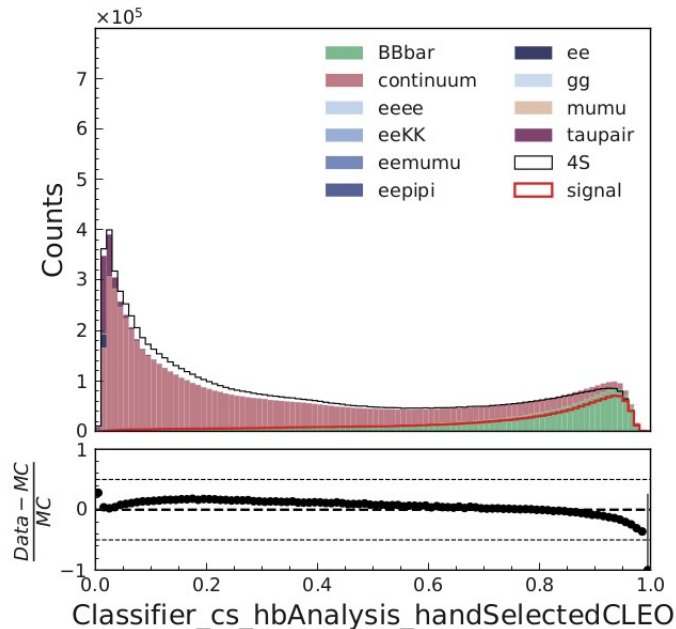


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Y(4S), Moriond 2022 + MC14ri

Best classifier with:

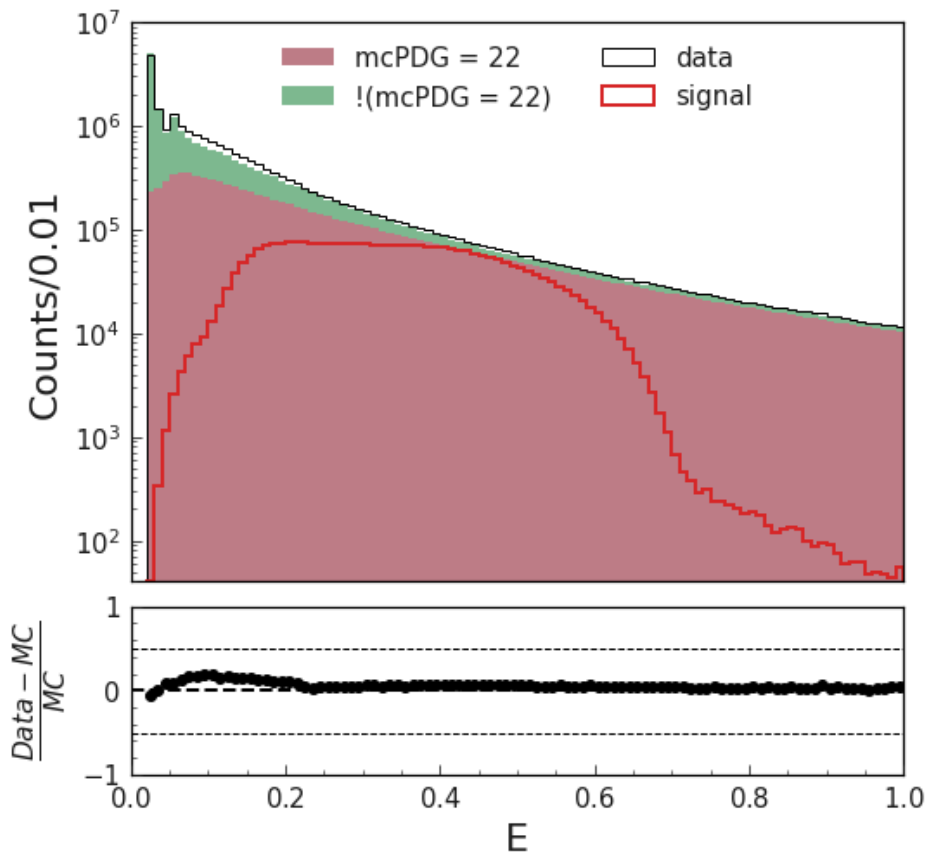
Fox-Wolfram moments, Harmonic moments of order 0, Sphericity, direction of the thrust axis, CLEO cones



Photon selection

Photons from the signal eta have $100 < E < 800$ MeV

Y(4S), Moriond 2022 + MC14ri



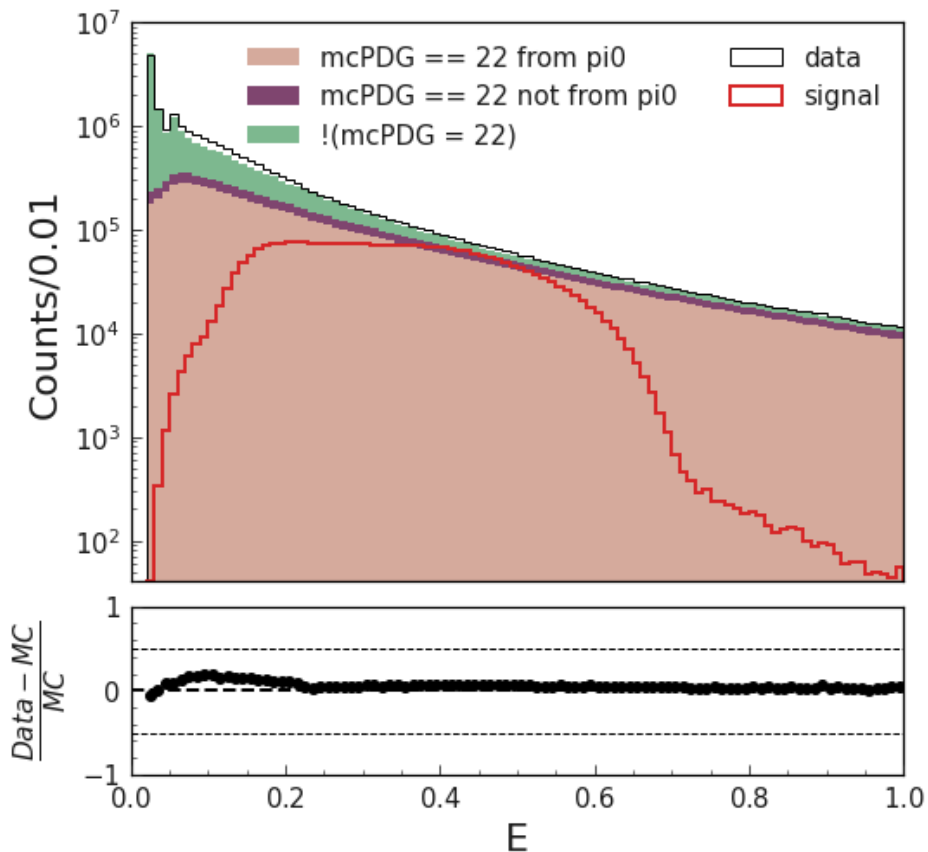
Photon selection strategy:

- Use generic MC14ri
- Compare with 1% of proc12+prompt
- do not optimize using the signal MC but the generic MC

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Y(4S), Moriond 2022 + MC14ri



Photon selection strategy:

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- Compare with 1% of proc12+prompt
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However, π^0 are a large background

- need a π^0 veto
- need a clean π^0 selection too

Photon selection

Three strategies tested:

- Custom BDT
- *clusterZernikeMVA* only
- *beamBackgroundSuppression* + *hadronicSplitOffSuppression*

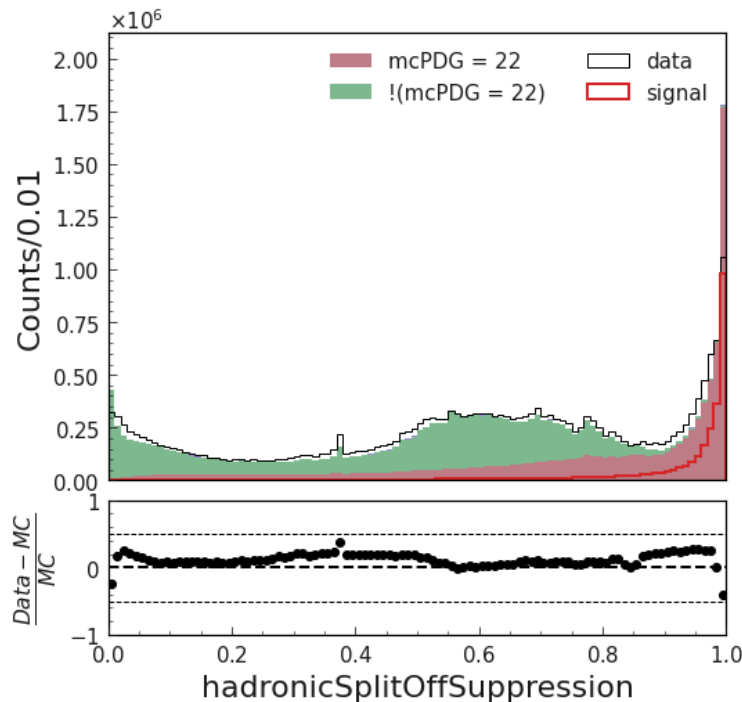
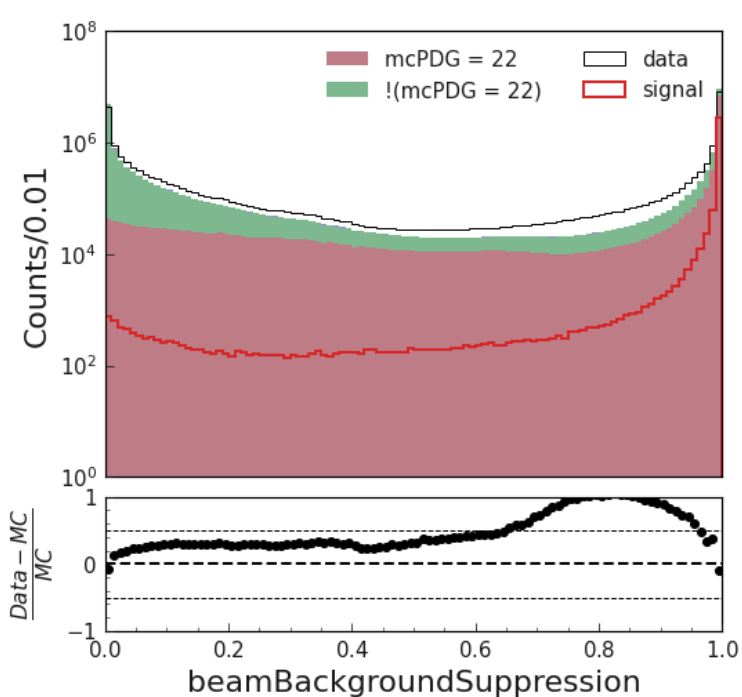
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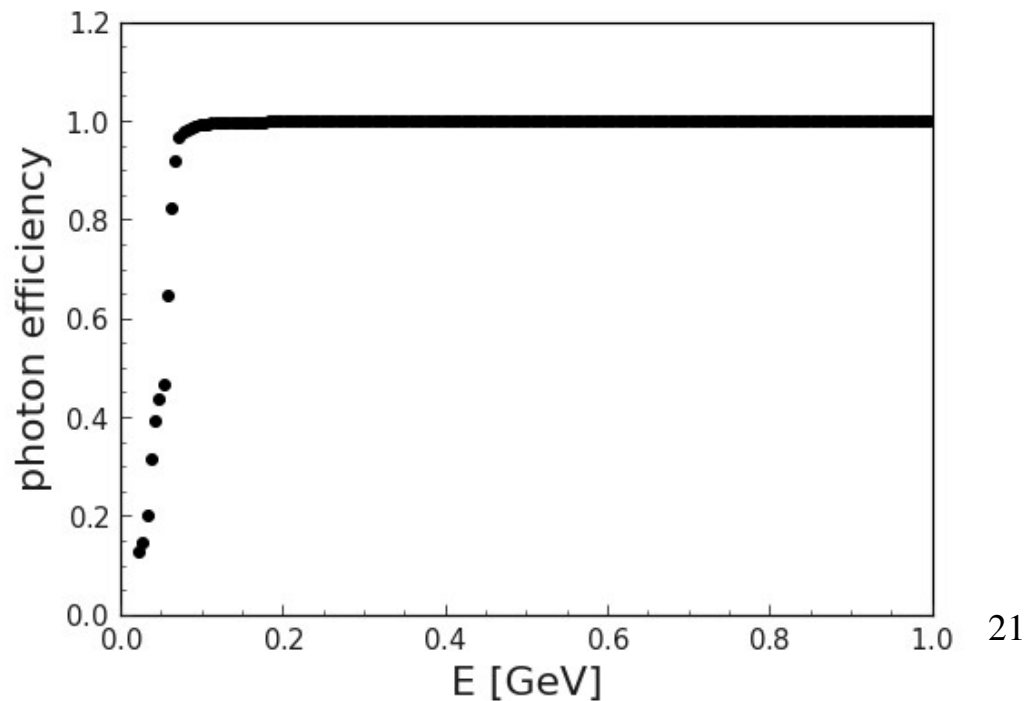
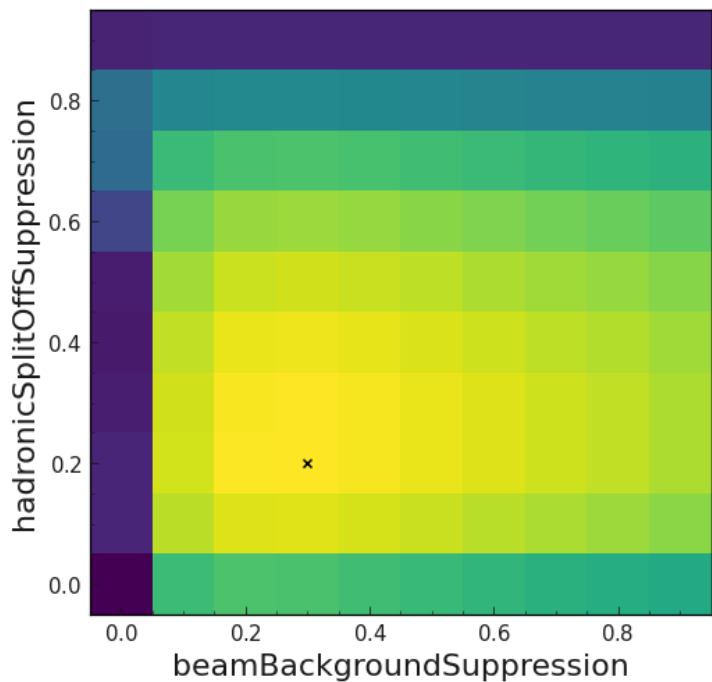


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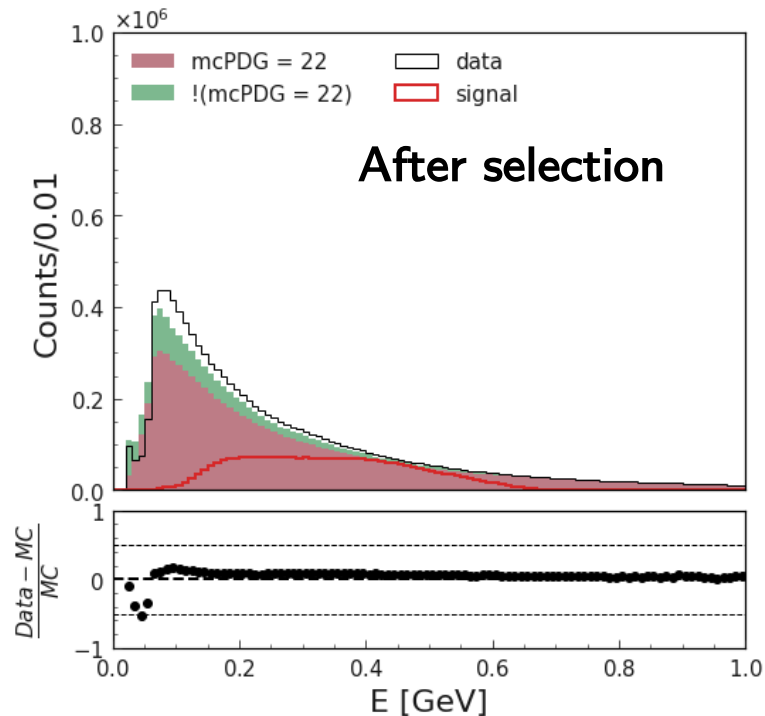
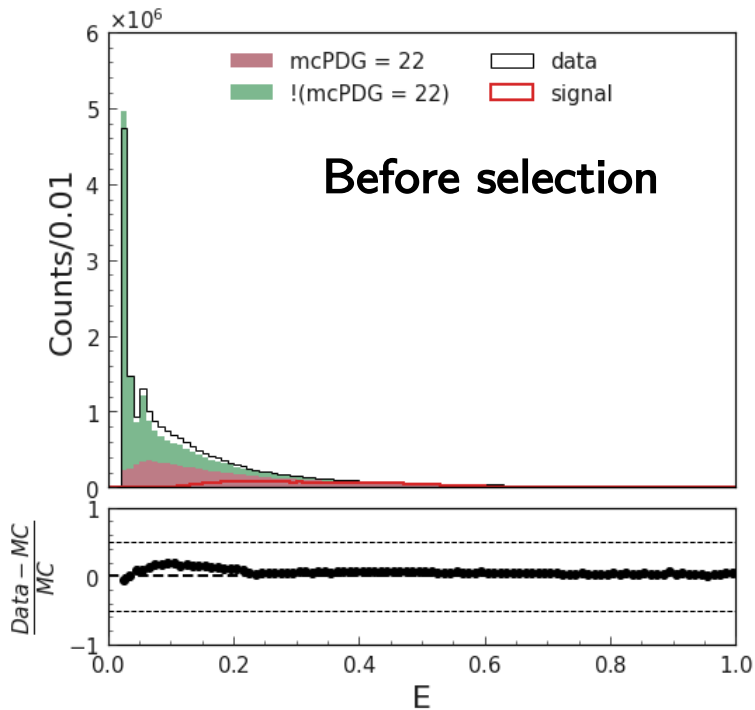


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Y(4S), Moriond 2022 + MC14ri



Next steps

Continue the analysis of the control sample with Moriond 2022 + MC14ri, open the box and then move to the scan points using MC15rd.

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To-do list for the $Y(4S)$ analysis:

- π^0 veto
- Systematics for photon selection: yield of η before and after selection.
- Systematics for cont. suppression: signal yield before and after selection, after box opening
- Fit systematics: signal yield fluctuation changing the fit parameters

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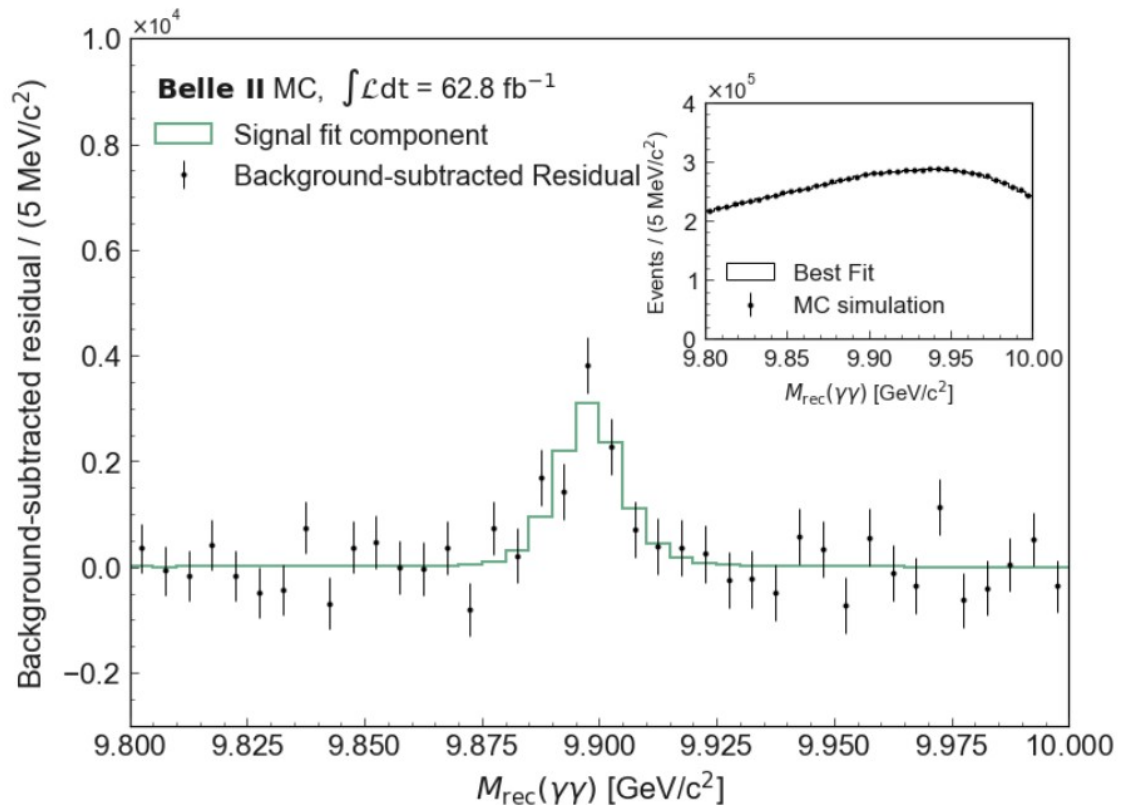
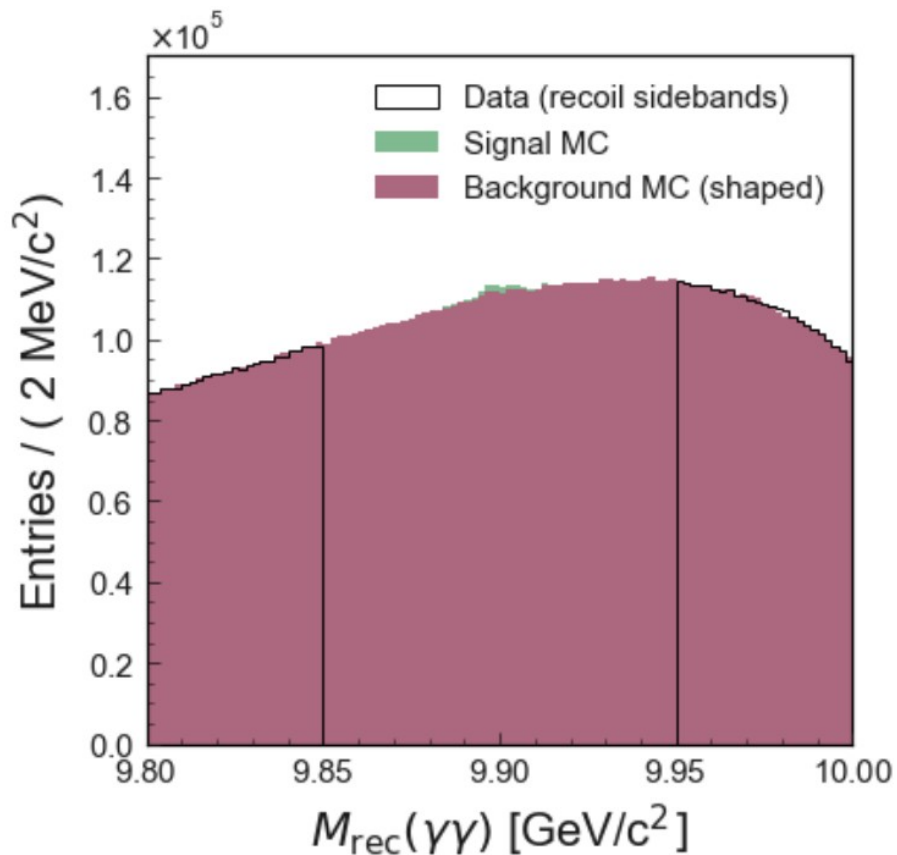
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Then, move everything to MC15/proc13 and analyze both scan and Y(4S).

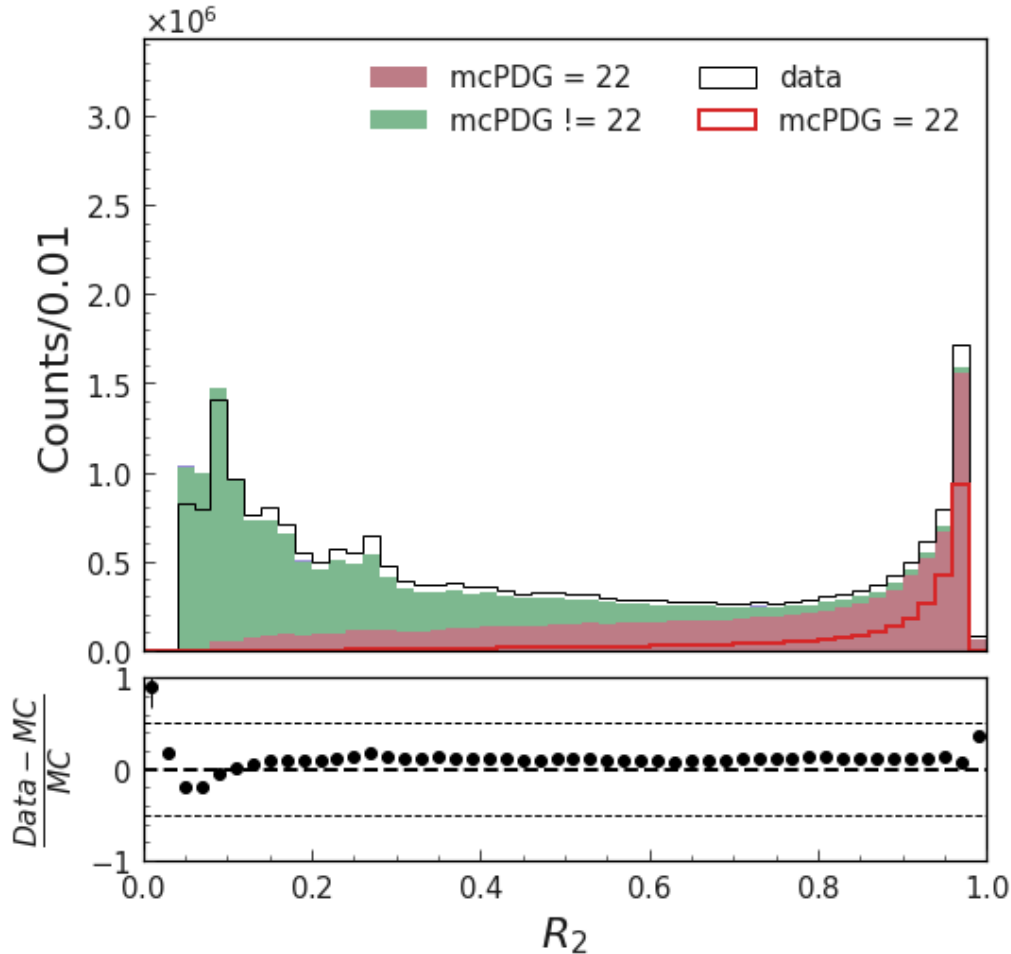
- Global event selection/cont. suppression can be ported without modification
- Re-tune photon selection
- Use the Y(4S) data to estimate all systematics before box opening on the scan data

Backup

Fit, previous version (MC13)



Source	Correction factor	uncertainty
B counting	—	$\sigma_{N_{B\bar{B}}} = 1.3\%$
Clustering efficiency	—	$\sigma_{\text{cluster}} = \text{negligible}$
Cont. suppression	$r_{\text{CS}} = 1.073$	$\sigma_{\text{CS}} = \pm 0.078$
η selection	$r_{\eta} = 1.027$	$\sigma_{\eta} = \pm 0.016$
Fit linearity	$r_{\text{lin}} \approx 1.08$ (TBD)	$\sigma_{\text{lin}} \approx 0.01$ (TBD)
Fit conditions	—	$\sigma_{\text{fit}} = {}^{+8.1}_{-3.2} \%$
Photon energy and resolution	—	$\sigma_{\text{photon}} \approx 2\%$ (TBD)



Variables:

- 'E',
- 'cosTheta',
- 'clusterZernikeMVA',
- 'clusterE1E9',
- 'clusterE9E25',
- 'clusterLAT',
- 'clusterNHits',
- 'minC2TDist'