B->Eta' K

Padova Belle II meeting
10/04/2020

Stefano Lacaprara, Valeria Fioroni
INFN Padova, Unipd

Introduction

- Technicalities:
  - Release light-1912-icarus
  - Data: proc10 + bucket8 8.86 /fb
  - MC:
    - Signal MC13a
    - Background MC13b run dependent 10 /fb
- Channels: **B -> η' K**
  - **η' (-> η(->γγ)ππ) and η' (-> ρ(->ππ)γ) K**
  - Both for **B⁺-> … K⁺** and **B⁰-> … K⁰ₛ**
- Will mostly concentrate on **B⁺ -> η' (-> η(->γγ)ππ) K⁺**

Stefano Lacaprara, INFN Padova

Rediscovery of η and η' mesons in early phase 3 Belle II data
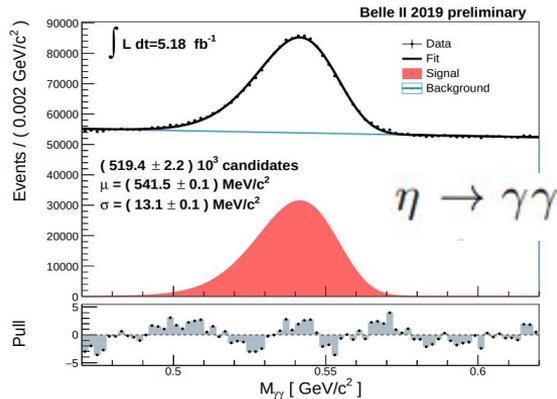
BELLE2-NOTE-PL-2020-003 SL - Padova

$\eta \to \gamma\gamma$

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

$\eta(\to \pi^+\pi^-\pi^0)\pi^+\pi^-$

$\eta \to \pi^+\pi^-\pi^-$
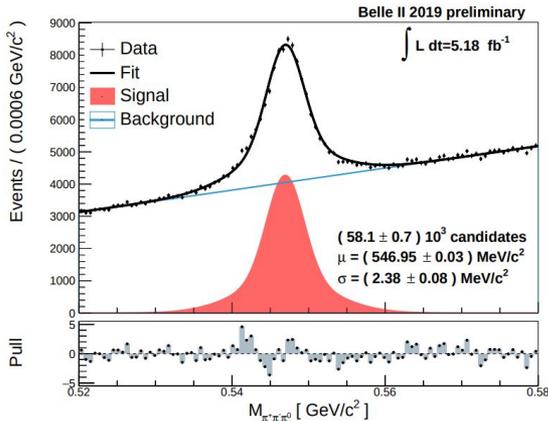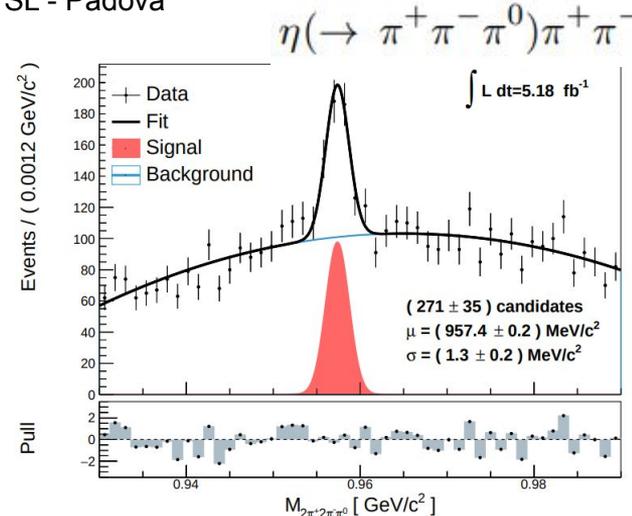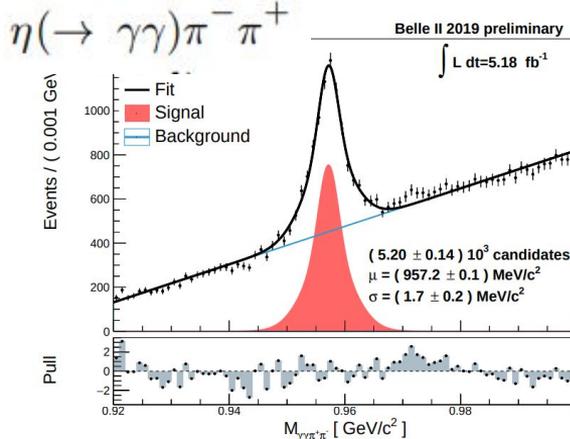
Lesson learned from η' rediscovery:

- $\eta(\to \gamma\gamma)\pi^-\pi^+$ clean
- $\eta(\to \pi^+\pi^-\pi^0)\pi^+\pi^-$ low eff
- $\rho(\to \pi^+\pi^-)\gamma$ High bkg, need pi0 veto

$\rho(\to \pi^+\pi^-)\gamma$
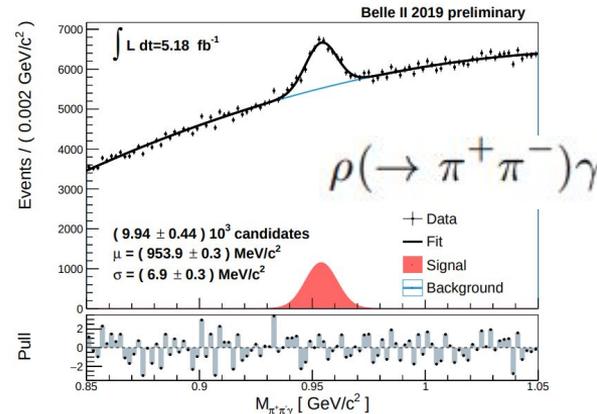
Reconstruction efficiency

- **Reconstruction-only** efficiency for $B^+ \to \eta' K^+$, $\eta' \to \eta (\gamma\gamma) \pi^+\pi^-$
  - About 40%
  - +7% SxF
- No further selection to reduce background!
- Average cand/ev ~2
- First cand (best χ^2_{vtx}) is the correct one

Only first candidate

Sorted by χ^2_{vtx} — True / All

$<N_{cands/ev}> = 2.18$
$RMS_{cands/ev} = 1.86$

Stefano Lacaprara, INFN Padova

4
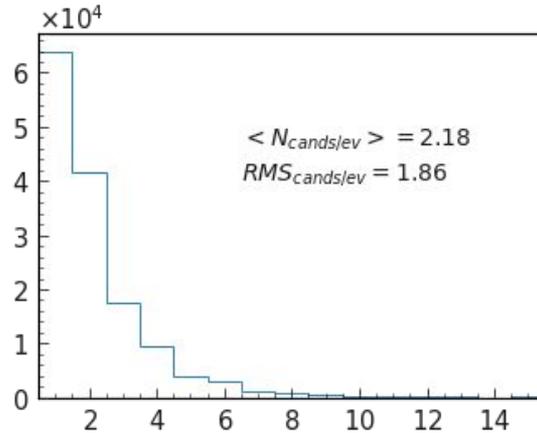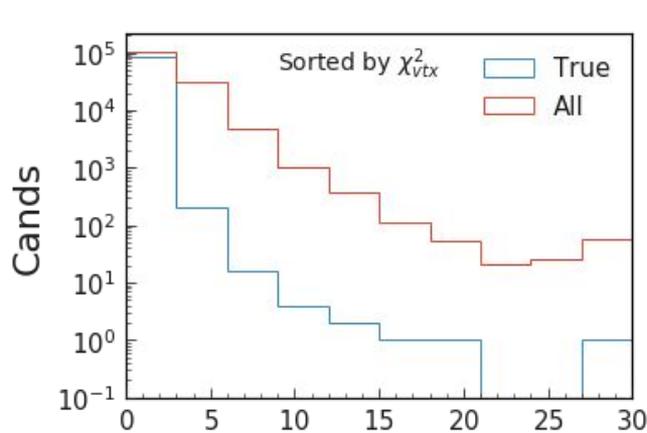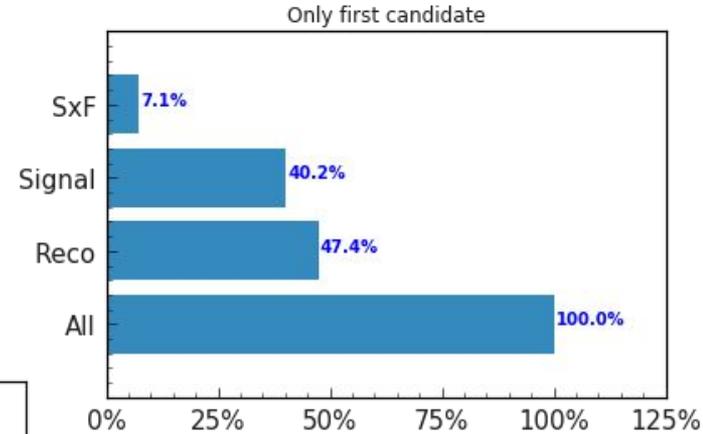
Reco efficiency: neutral channel

Only first candidate

- **$B^0 \to \eta' K^0$, $\eta' \to \eta (\gamma\gamma) \pi^+ \pi^-$**
  - $\epsilon \sim 39.7\%$
    - Strange that K_s eff is similar to that of K^+
  - SxF 9.6%
    - Higher
  - ncad/ev~3
    - True candidate is that with best χ^2_{vtx}
- B2TIP full reco was 23%

Stefano Lacaprara, INFN Padova

Efficiency η'->ρ (π⁺π⁻) ɣ
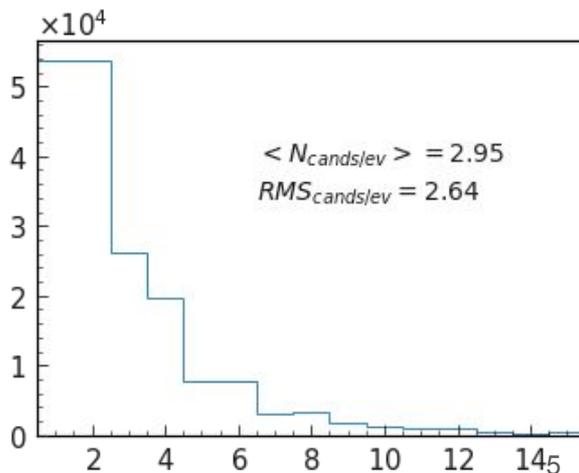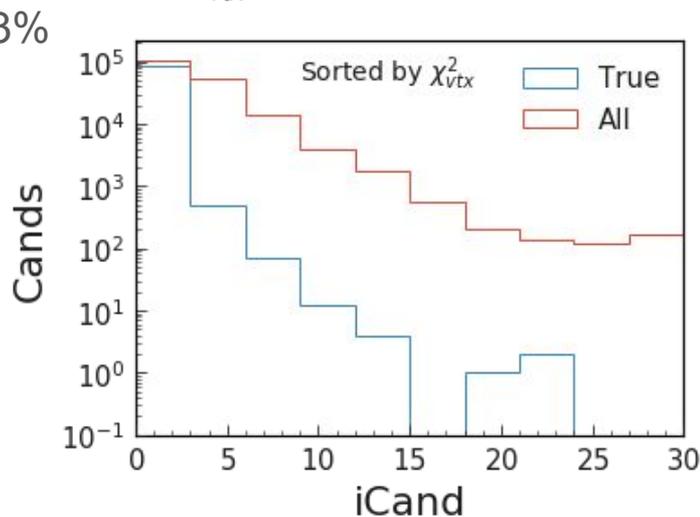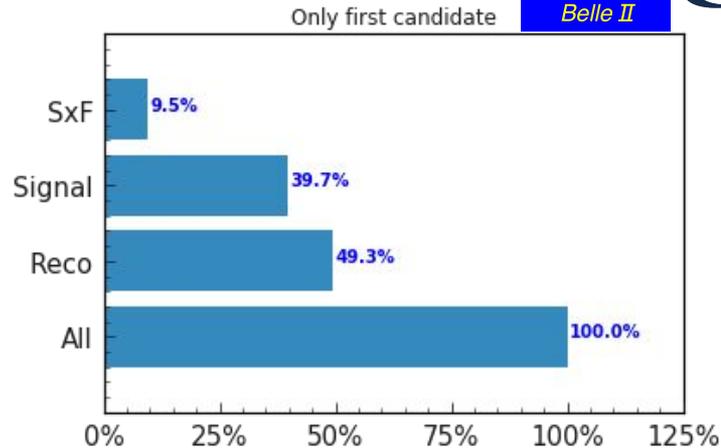
- η'->ρ (π⁺π⁻) ɣ
  - Very first time reconstructing this final state
  - From Belle, expected similar efficiency

Mode	N_S	Σ	$\epsilon(\%)$	$\epsilon B_S(\%)$	$BF(10^{-6})$
$\eta'_{\eta\pi\pi} K^+$	$28.9^{+6.5}_{-5.7}$	9.4	21.7	3.78	69^{+15}_{-14}
$\eta'_{\rho\gamma} K^+$	$42.5^{+9.1}_{-8.3}$	7.5	14.2	4.18	92^{+20}_{-18}
$\eta'_{\eta\pi\pi} \pi^+$	$0.0^{+1.2}_{-0.0}$	0.0	23.7	4.11	–
$\eta'_{\rho\gamma} \pi^+$	$0.0^{+5.6}_{-0.0}$	0.0	15.4	4.55	–
$\eta'_{\eta\pi\pi} K^0$	$6.4^{+3.4}_{-2.7}$	3.5	20.8	1.25	46^{+25}_{-20}
$\eta'_{\rho\gamma} K^0$	$10.1^{+4.4}_{-3.6}$	4.0	11.5	1.16	79^{+34}_{-28}

- Reconstruction with loose cut and pi0 veto
- B⁺ ϵ ~13.4% SxF 8.2%
- B⁰ ϵ ~12.9% SxF 8.1%
- To be understood.

Only first candidate

SxF	8.2%
Signal	13.4%
Reco	21.6%
All	100.0%

0%   25%   50%   75%   100%   125%

6
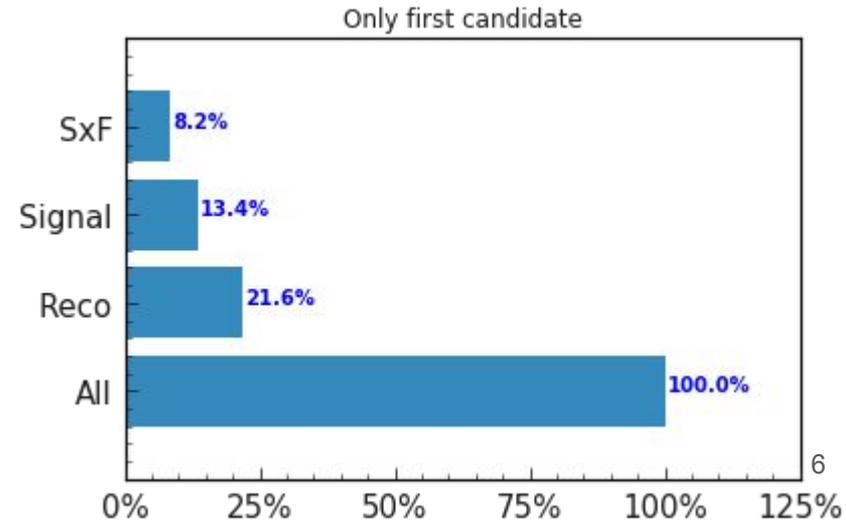
B->eta' K expected yield

- Expected signal 8.8 /fb (Run2019).
  - Total - **total*eff** (SxF)
  - Only reconstruction, no selection (eg no CS cuts, see later)

Belle with 10.4 /fb

	η'->η (ɣɣ) π⁺π⁻	η'->ρ (π⁺π⁻) ɣ	**Total**
B⁺->η' K⁺	113 - **45** (10)	190 - **25** (15)	300 - **60** (25)
B⁰->η' K_s	36.4 - **14** (3)	61.4 - **8** (5)	100 - **22** (8)

Mode	N_S	Σ	$\epsilon(\%)$	$\epsilon B_s(\%)$
$\eta'_{\eta\pi\pi}K^+$	$28.9^{+6.5}_{-5.7}$	9.4	21.7	3.78
$\eta'_{\rho\gamma}K^+$	$42.5^{+9.1}_{-8.3}$	7.5	14.2	4.18
$\eta'_{\eta\pi\pi}\pi^+$	$0.0^{+1.2}_{-0.0}$	0.0	23.7	4.11
$\eta'_{\rho\gamma}\pi^+$	$0.0^{+5.6}_{-0.0}$	0.0	15.4	4.55
$\eta'_{\eta\pi\pi}K^0$	$6.4^{+3.4}_{-2.7}$	3.5	20.8	1.25
$\eta'_{\rho\gamma}K^0$	$10.1^{+4.4}_{-3.6}$	4.0	11.5	1.16

- Belle had more events with η'->ρ (π⁺π⁻) ɣ than with η'->η(ɣɣ) π⁺π⁻
  - Definitely something to be understood on η'->ρ (π⁺π⁻) ɣ

Stefano Lacaprara, INFN Padova

Data - MC comparison

- Start comparing reconstructed quantities for Data and MC
- General idea is to apply selection only on variables that are well modelled by MC
- Start with rectangular cuts, MVA selection will follow later
  - MC: using qq-bar (udsc)
  - bb-bar generic (mixed and charged)
    - For background only study exclude signal from charged (or mixed)
    - Using `reconstructMCdecay(...)`
    - Count #signal events to use MC13b as "data-(not-so-)challenge"
  - Use larger signal MC to model signal and SxF
- All normalized to data integrated luminosity

Stefano Lacaprara, INFN Padova

K$^+$
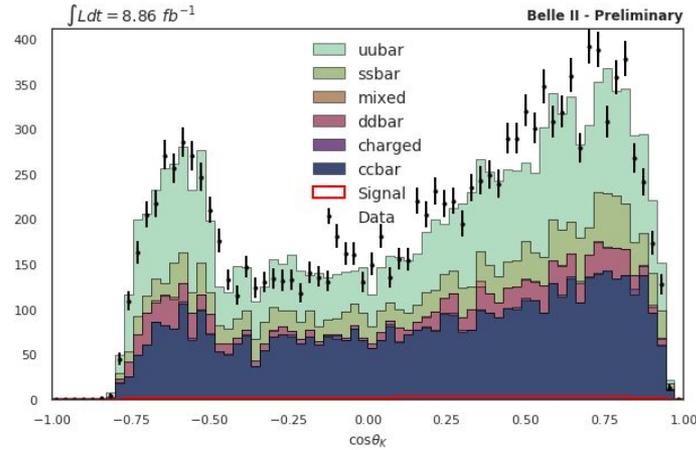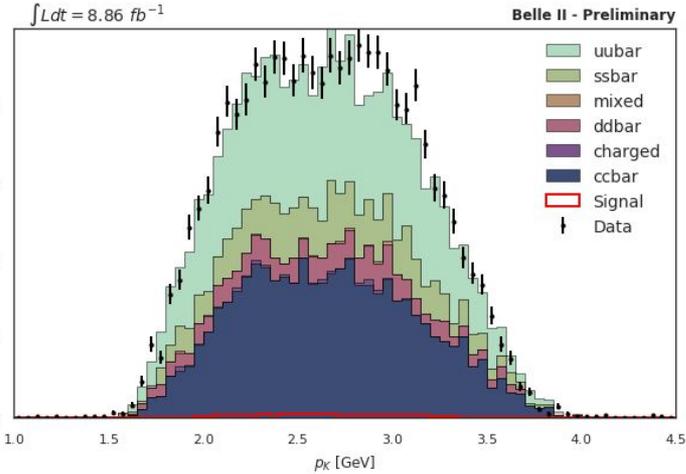
- Overall very nice agreement in shape **and** normalization
- Using only Loose PID>0.1 cut

Stefano Lacaprara, INFN Padova
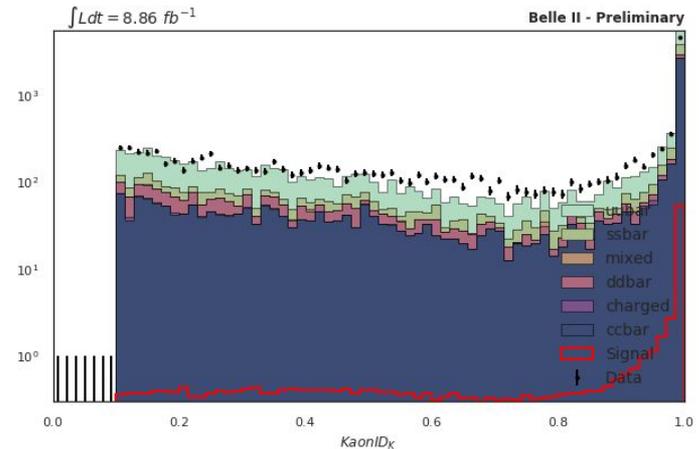
K⁺

- Vertex variables also ~nice
  - Not so much for z<0
- Also N cdc hits not well modelled
  - N PXD is better (not shown)
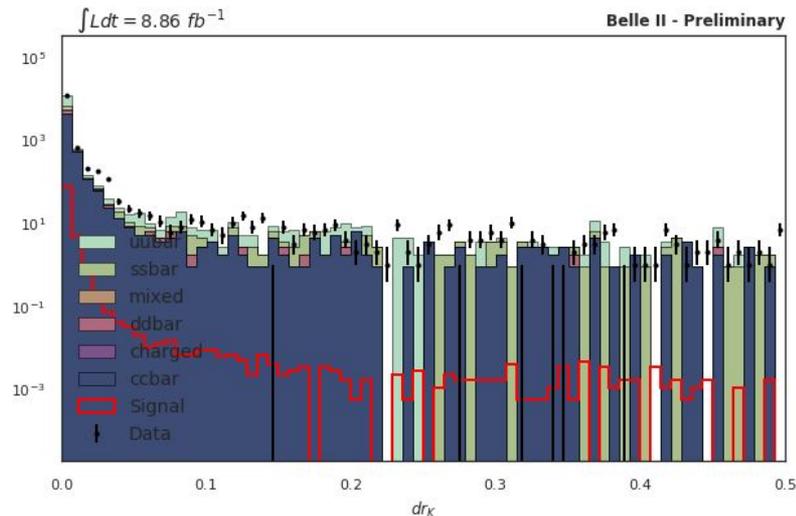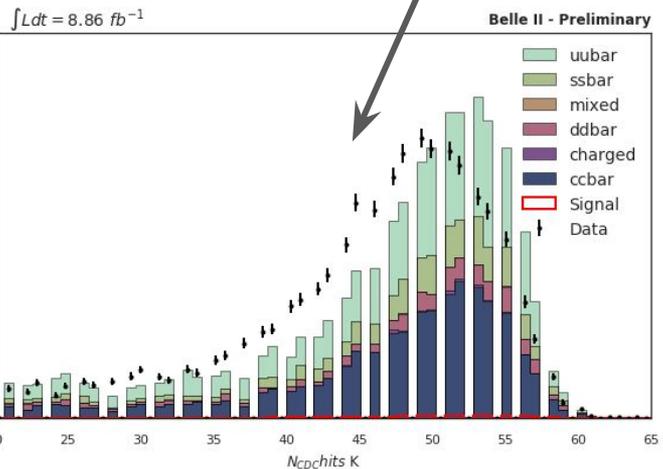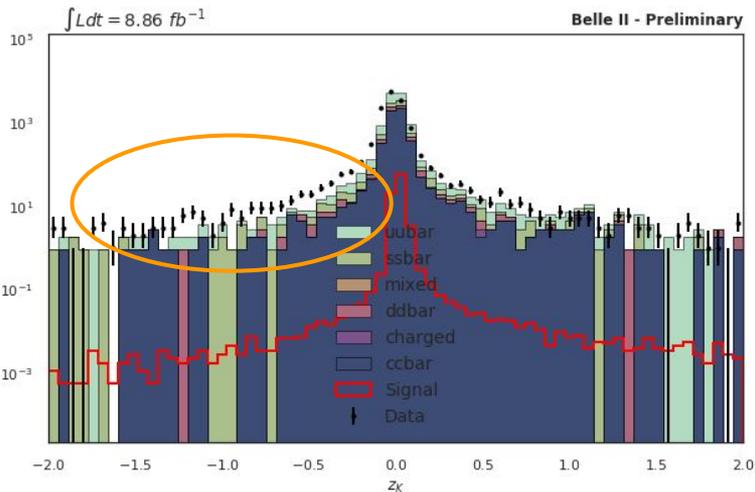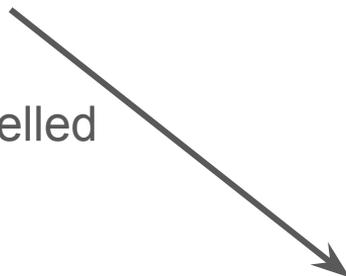
Eta, eta', pi momentum

- Unfortunately, saved only post-fit invariant mass in ntuple.
 - Will fix next iteration
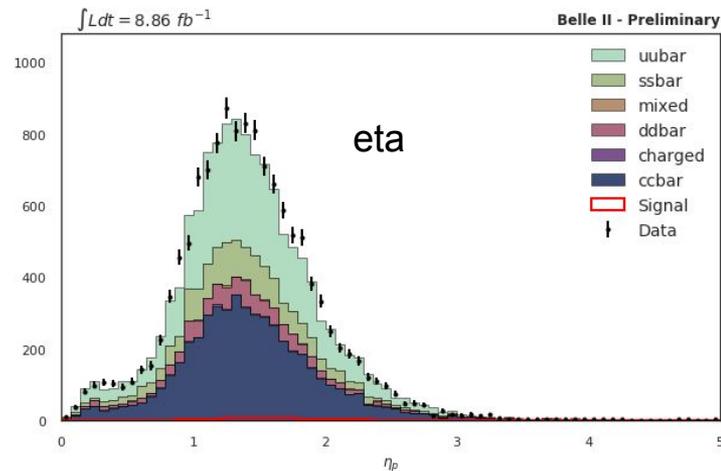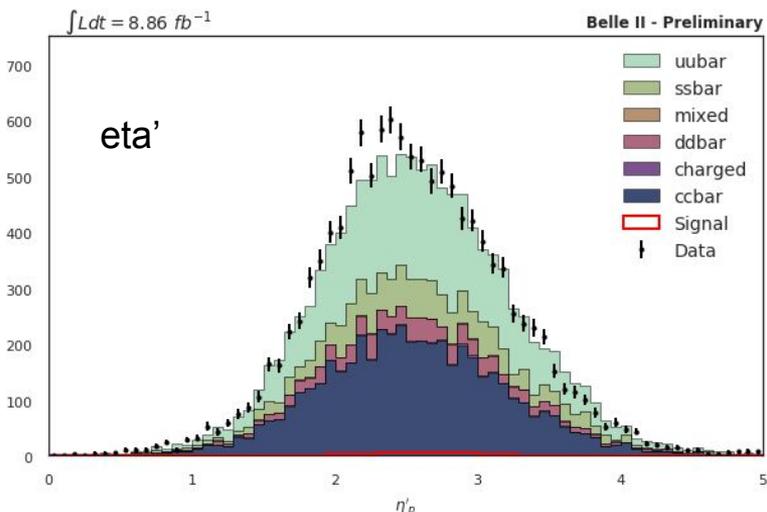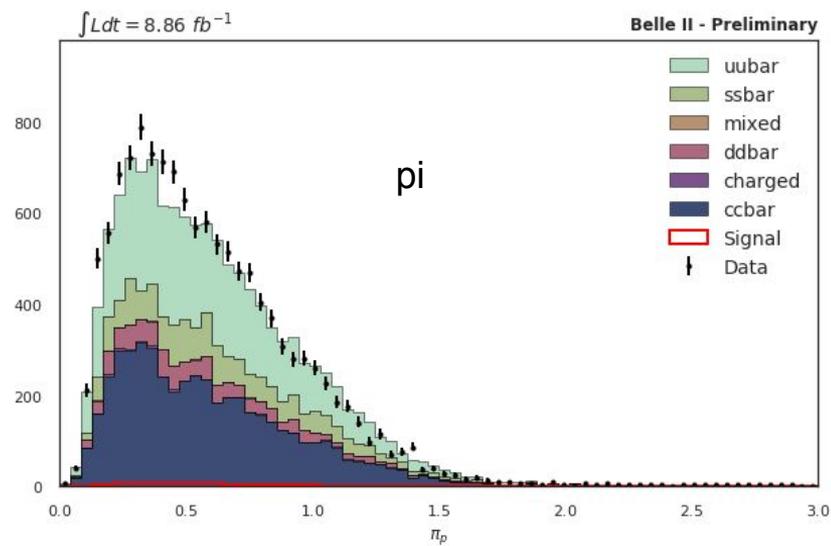
Cont Suppression variables
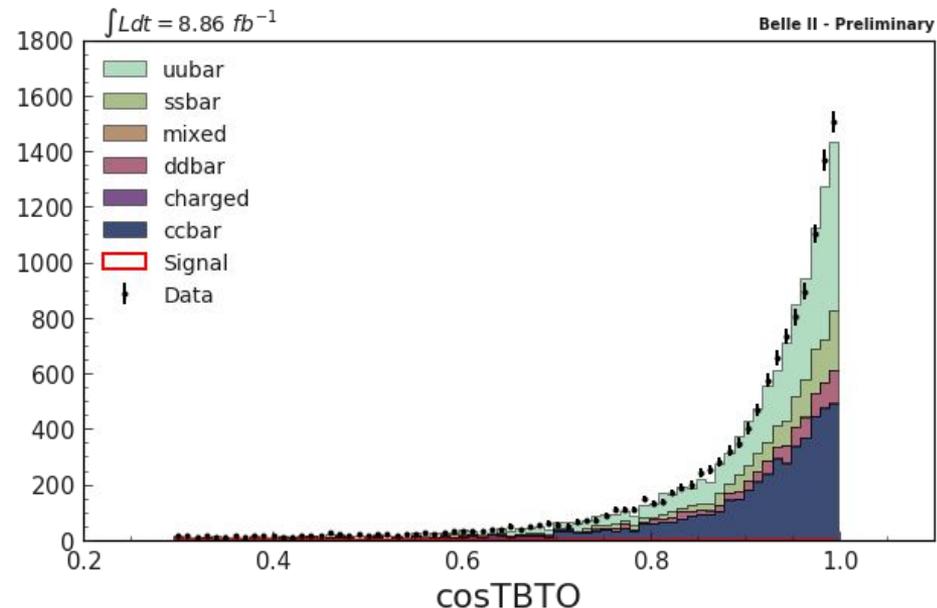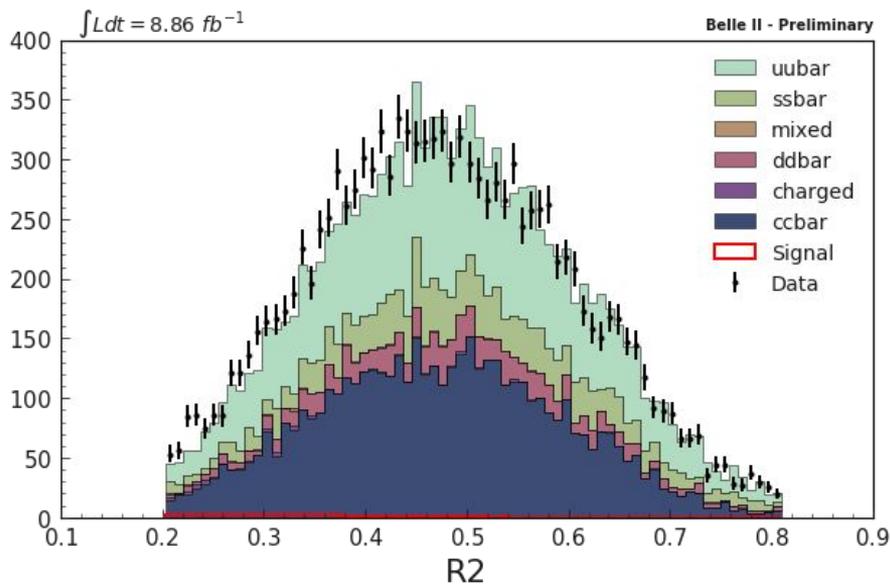
Nice agreement MC - Data, can be used for Continuum Suppression

Stefano Lacaprara, INFN Padova

B⁺->η' K⁺, η'->η (γγ) π⁺π⁻ Data vs MC

- Mbc and DeltaE

Stefano Lacaprara, INFN Padova
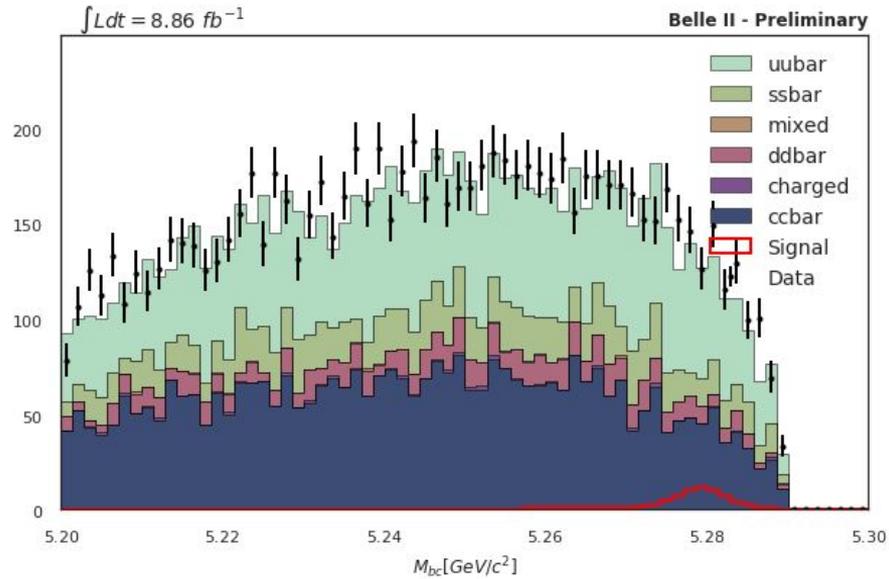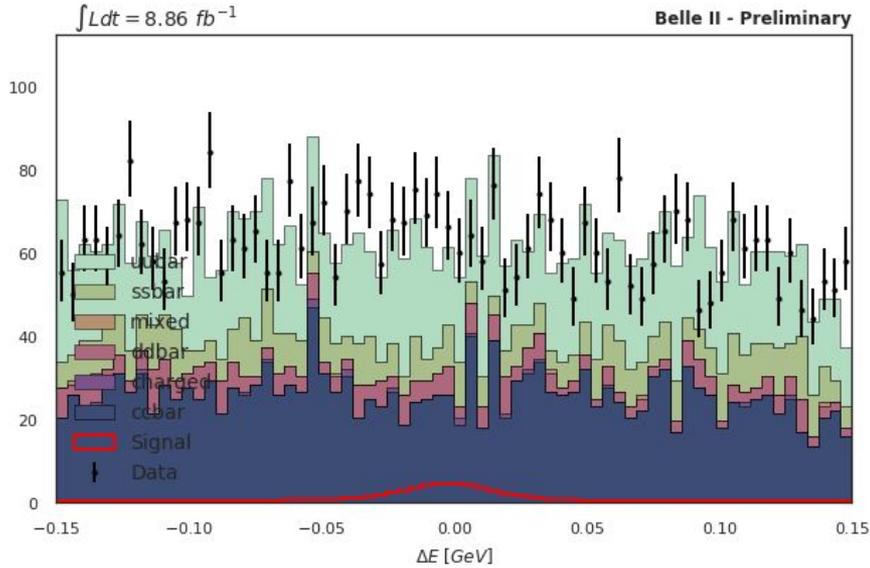
Event shape (BB vs qq vs signal)
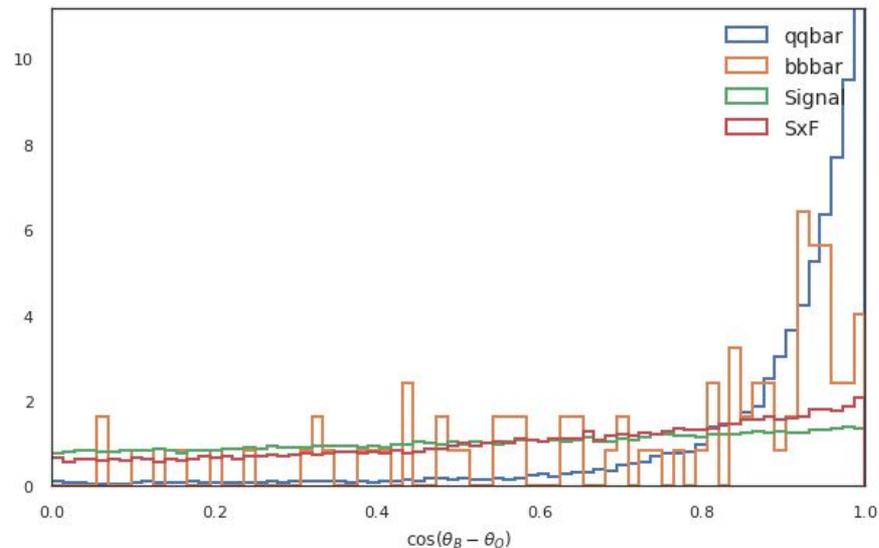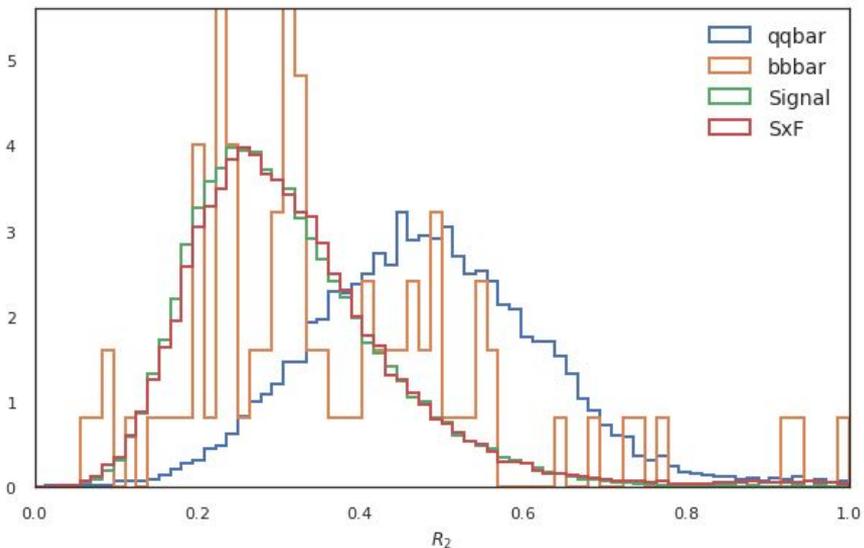
- Do not use (yet) MVA continuum suppression
- Use just these two variables
  - Need more MC from bb-bar
  - SxF behaves as signal for R2 and cosTBTO

Stefano Lacaprara, INFN Padova

Data - MC in signal region

- Simple optimization of S/sqrt(S+B) **in signal region**
- to define a preliminary **CS selection**
- **R2<0.5, cosTBTO<0.8**

S/sqrt(S+B)~4.2

Stefano Lacaprara, INFN Padova
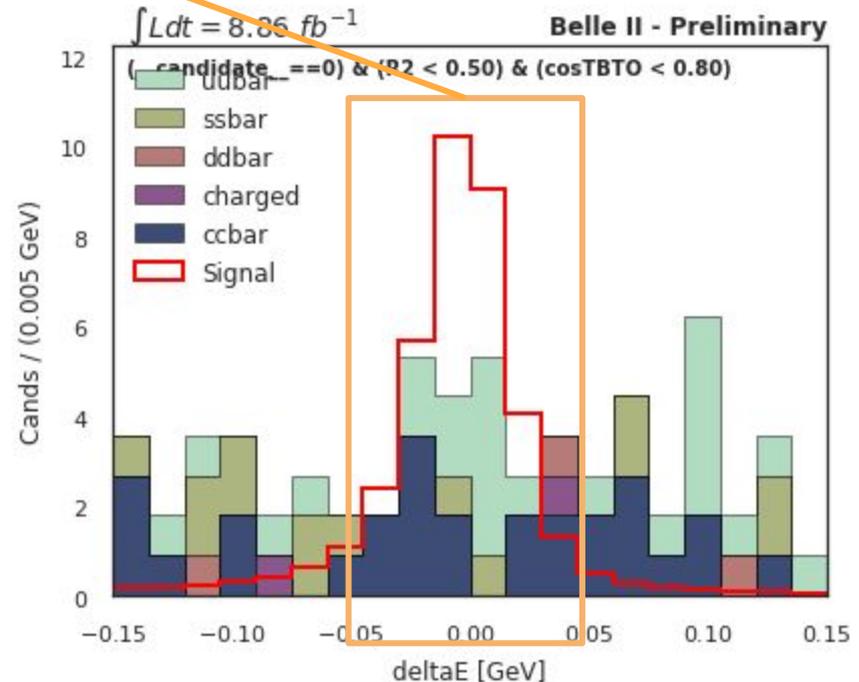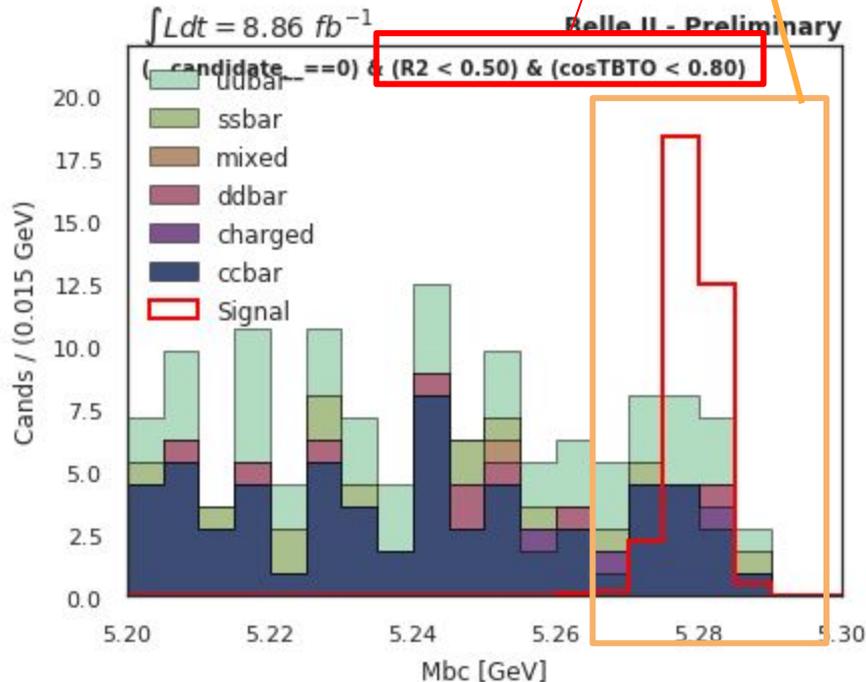
Try to fit signal: only MC + signal injection
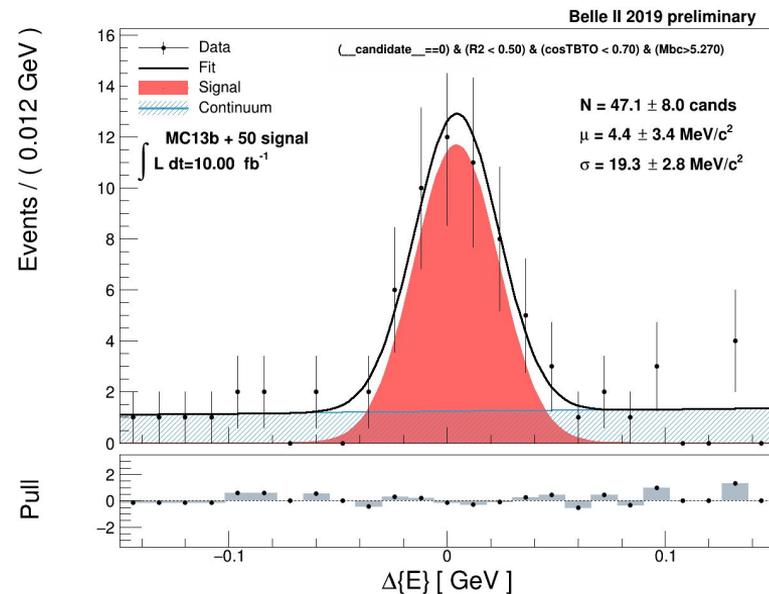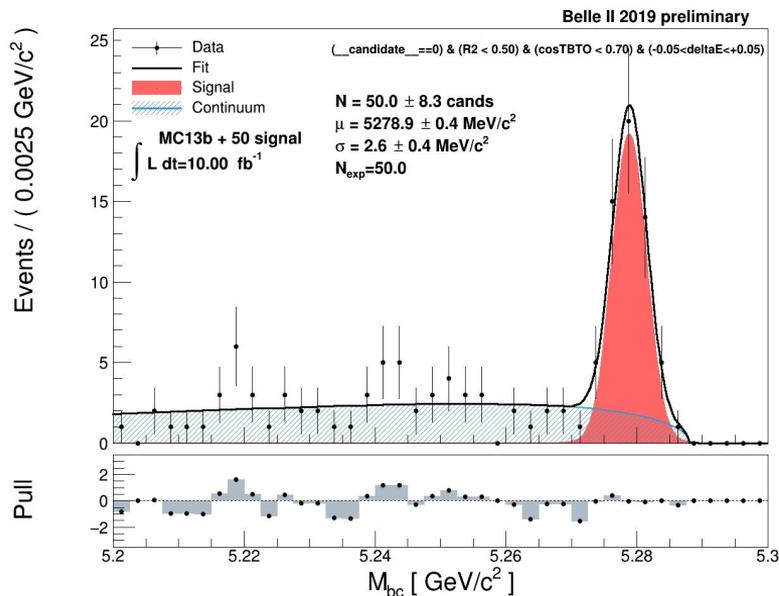
- Cut Mbc>5.27 GeV and |De|<0.05 in the other plot.
- No 2D fit (yet): working on it
- Injected 50 events, seen 50+/-8 (Mbc) and 47+/-8 (De

Try to fit signal: only MC (with its bb signal)
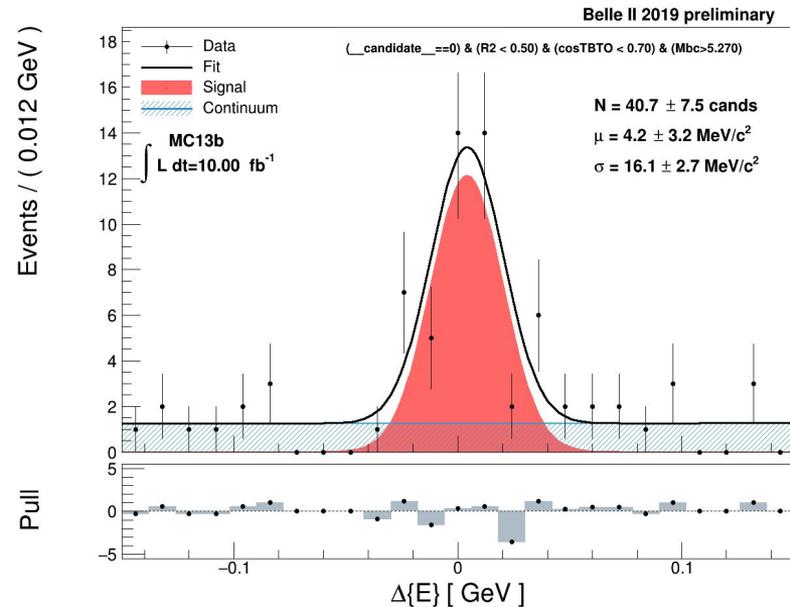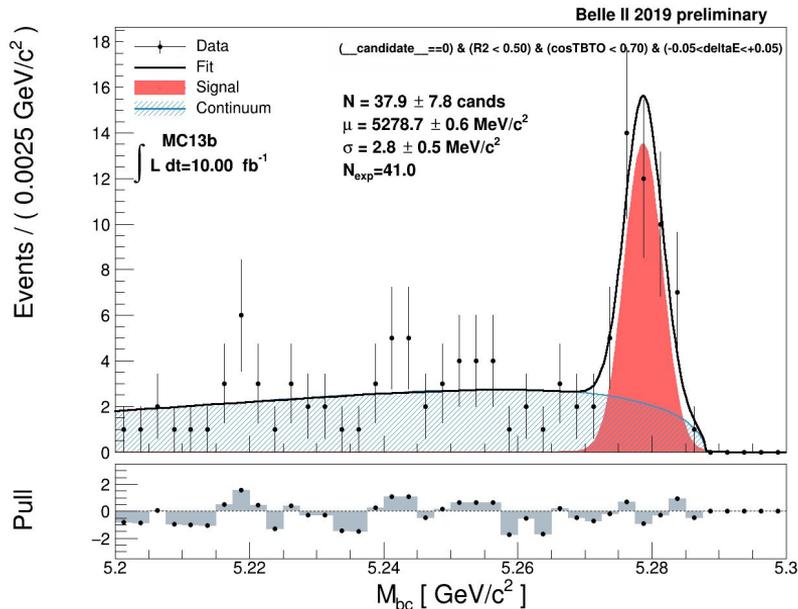
- Previously removed signal from generic BB
  - **Now use MC as data: do not remove signal**
- There are 42 candidates in 10/fb
- Seen 38+/-8 (Mbc) and 41+/-8 (De)

Stefano Lacaprara, INFN Padova

Mbc and DeltaE: **Data** vs MC (w/ signal)
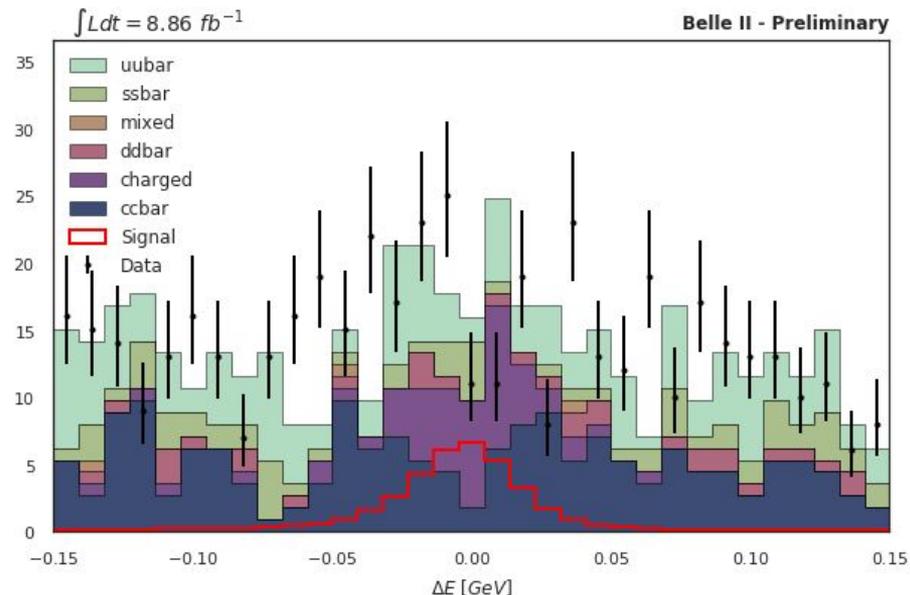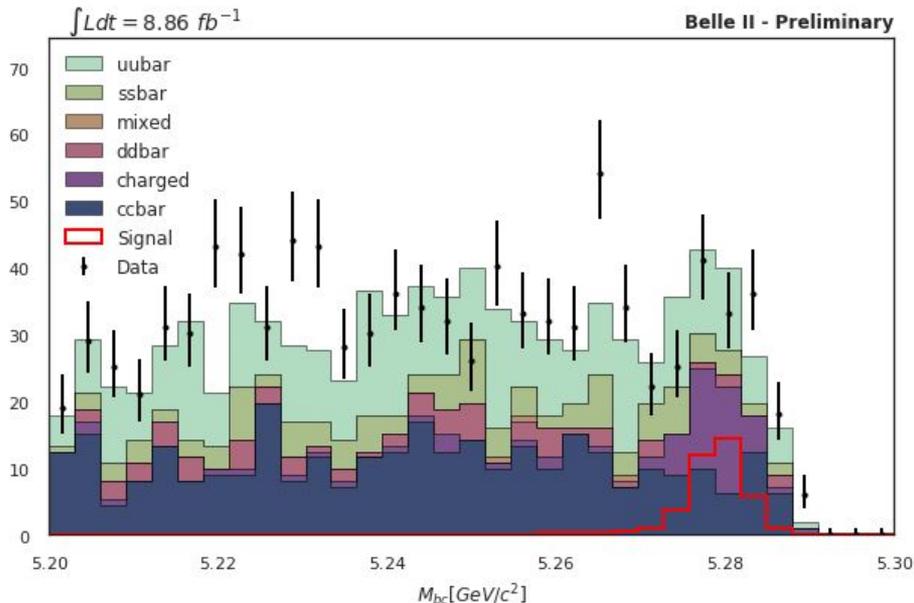
- **R2<0.5 cosTBTO<0.8**
- Signal is not removed from generic bb-bar MC (charged)
- High stat signal MC ovelaid for visualization purpose
- Within statistics, agreement is good

Stefano Lacaprara, INFN Padova

DeltaE vs Mbc

Data

MC13b

Stefano Lacaprara, INFN Padova
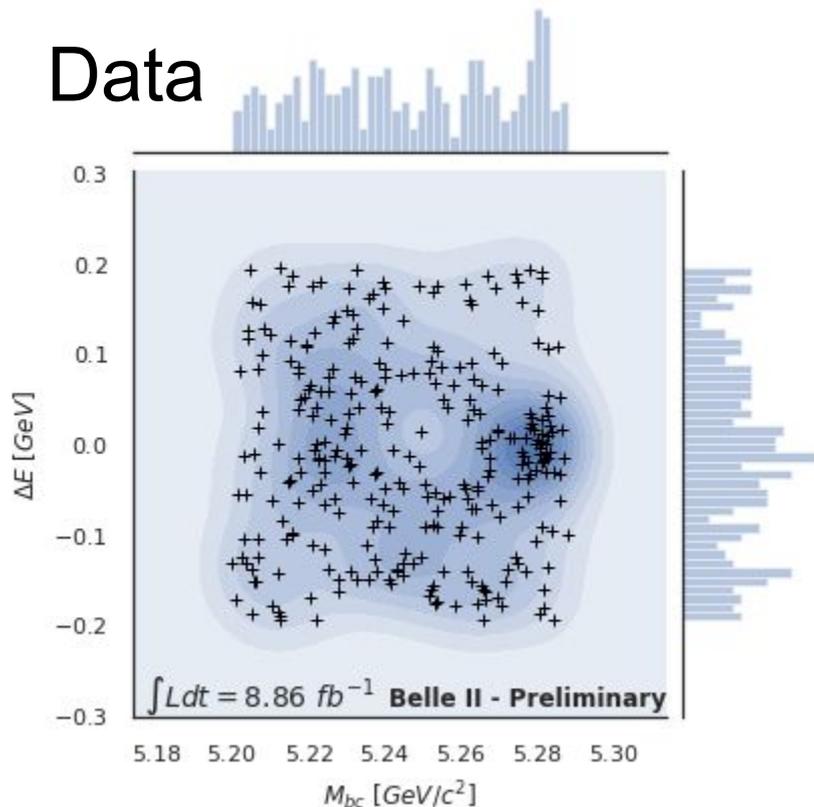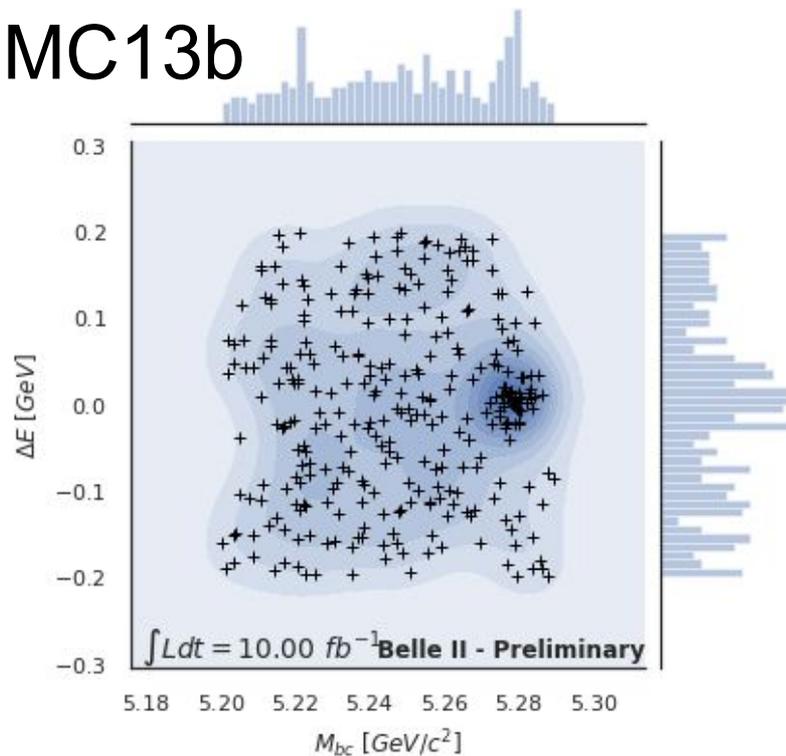
Try to fit signal: Data
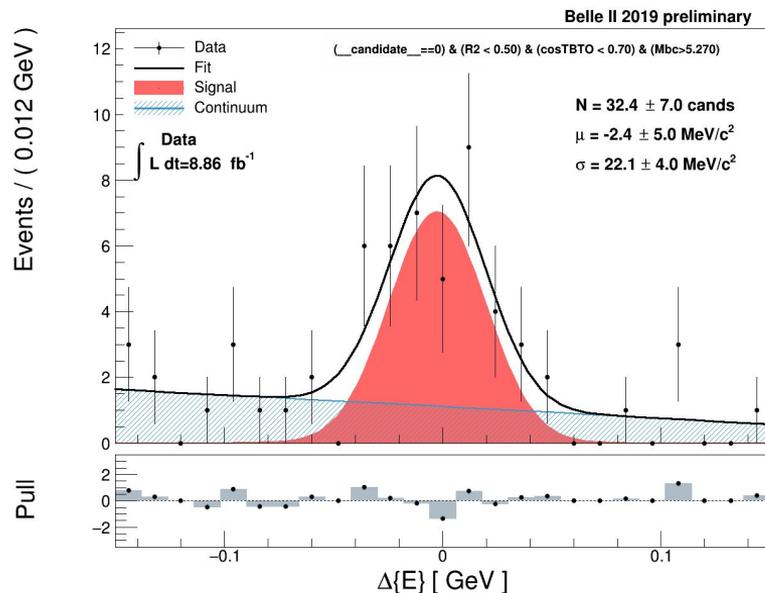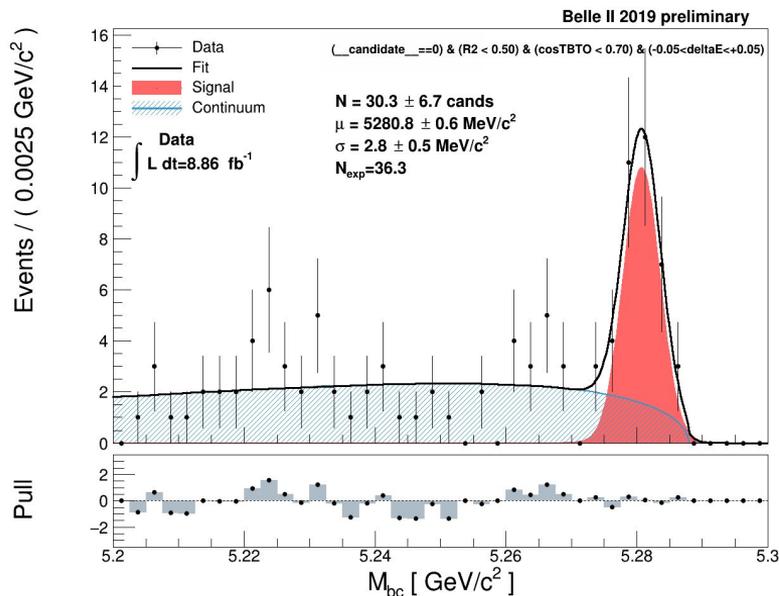
- **Clear signal visible!**
- seen 30.3+/-7 (Mbc) and 32.4+/-7 (De)
  - Expected: 42 * 0.886= 36
  - Very preliminary!

Stefano Lacaprara, INFN Padova

B⁺ -> η' (->ρ (π⁺π⁻) ɣ) K⁺

- Similar work started
- Need to understand the reco efficiency
- Some normalization issue with MC
  - related?
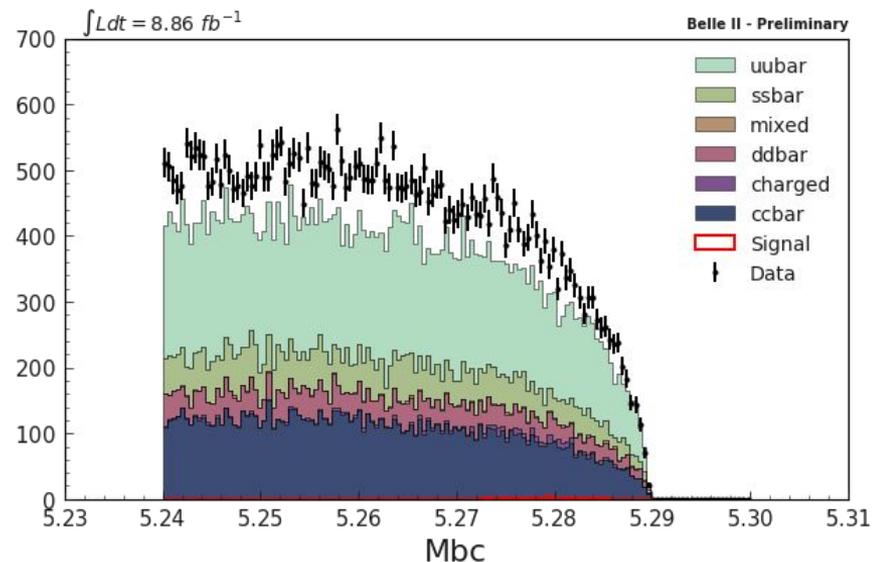
- Signal visible
- Expected 25 events
- Seen 33.7+/- 9

Stefano Lacaprara, INFN Padova
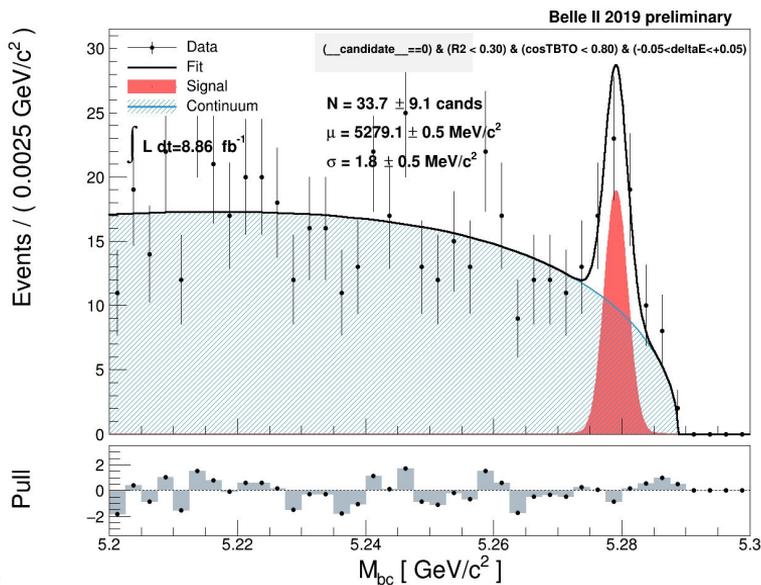
$B^0 \to \eta' K_s$, $\eta' \to \eta$ $(\gamma\gamma)$ $\pi^+\pi^-$

MC w/ signal injection

Belle II 2019 preliminary
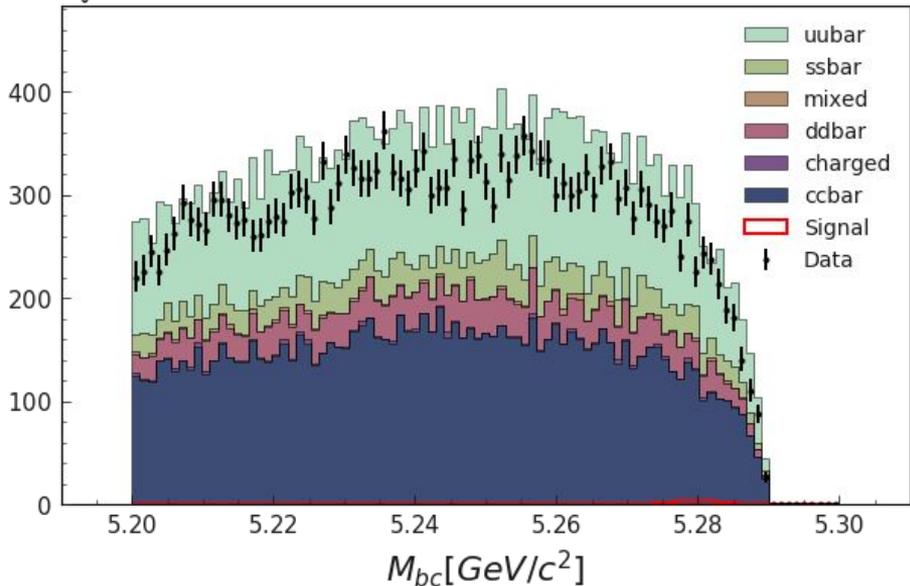
- Data vs MC
  - normalization?
- S/sqrt{S+B}~1.2
  - (was 4 for B+)
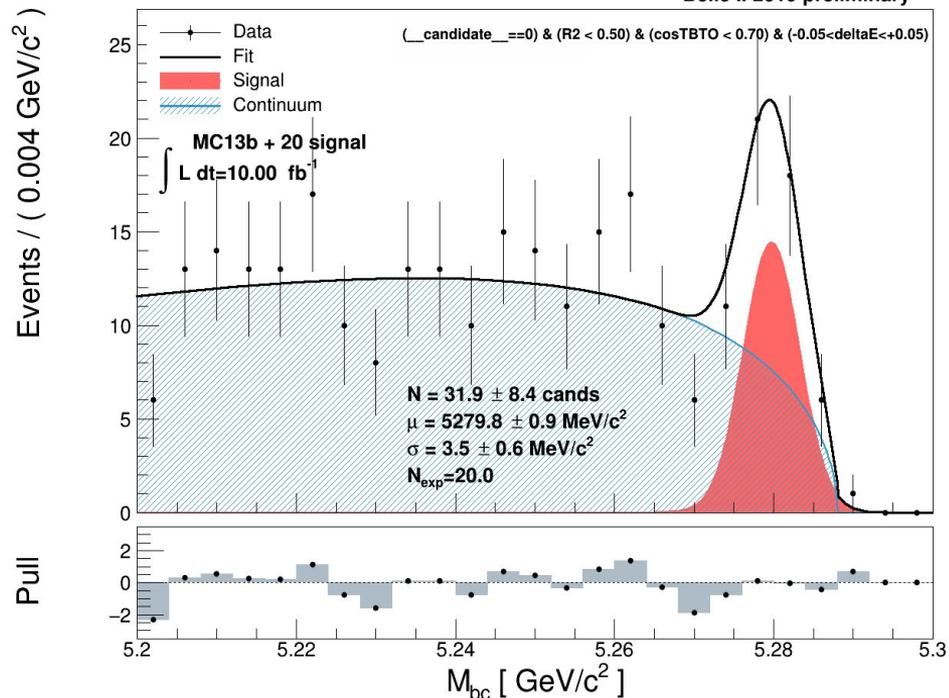
- **NOT Data!**
- Background MC w/ signal injection
  - Even more preliminary

22

Outlook

- First full scale test with Data and MC13 for **B$^+$->η' K$^+$**
  - Concentrated mostly on **B$^+$->η' K$^+$, η'->η (ɣɣ) π$^+$π$^-$**
- **Preliminary results are encouraging,**
  - **Nice agreement between Data and MC**
  - **First signal fit are good**
- Also start working on η'->ρ (π$^+$π$^-$) ɣ
  - More work to do, starting from reconstruction efficiency
- Todo:
  - Study signal selection
  - Continue data/MC comparison
  - Include missing Variables on ntuple
  - Run on more MC
  - Study Belle selections

Stefano Lacaprara, INFN Padova