B->Eta' K

Padova Belle II meeting
29/04/2020

Stefano Lacaprara, Valeria Fioroni
INFN Padova & University

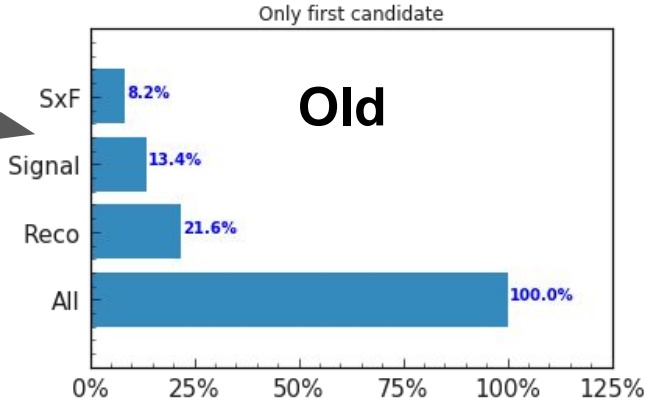
Introduction

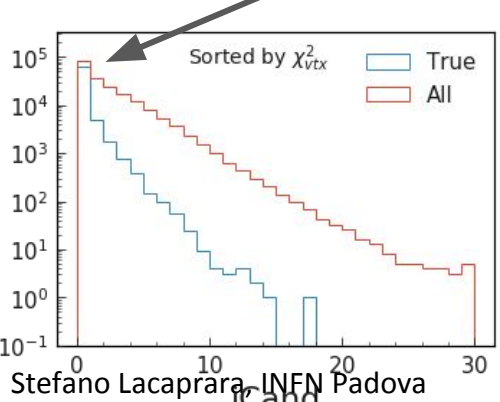
- Technicalities:
  - Release light-1912-icarus
  - Data: proc10 + bucket8 8.86 /fb
  - MC:
    - Signal MC13a
    - Background MC13b run dependent 10 /fb
- Channels: **B -> η' K**
  - **η'** (-> **η**(->**γγ**)**ππ**) and **η'** (-> ***ρ***(->**ππ**)**γ**) **K**
  - Both for $\mathbf{B^+}$**-> … K**$^+$ and $\mathbf{B^0}$**-> … K**^0_s
- Will mostly concentrate on $\mathbf{B^+}$ -> **η'** (-> ***ρ***(->**ππ**)**γ**) K^+

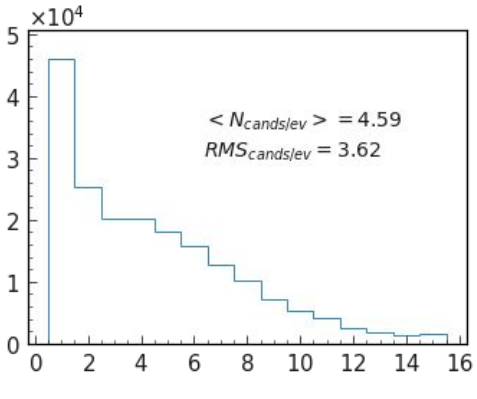
Stefano Lacaprara, INFN Padova

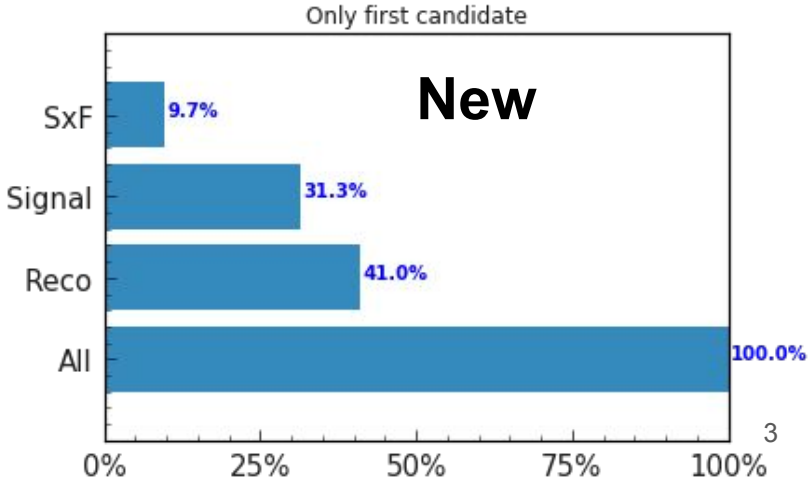
Efficiency: B^+ -> η'->ρ ($\pi^+\pi^-$) ɣ K^+

- Low eff reported two week ago.
- Fixed a bug in pi0 veto
  - I was vetoing all events with an additional ɣ in RoE, regardless to M
- **Eff 31.3 %** (was 13.4 %)
- **SxF 9.7%**
  - Large SxF
  - Also large multiplicity
- True cand had best chi2



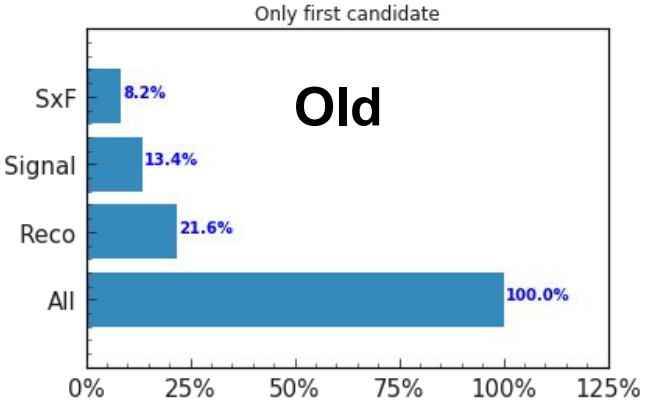


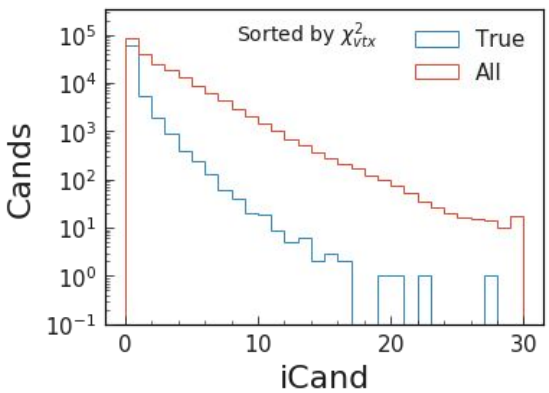


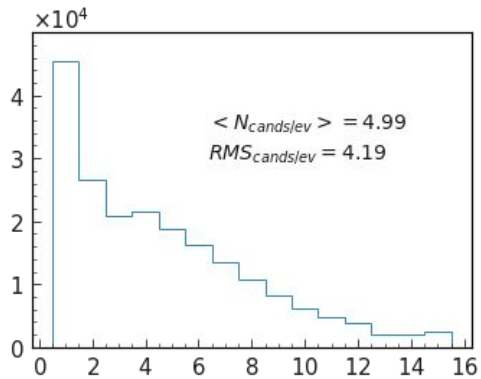


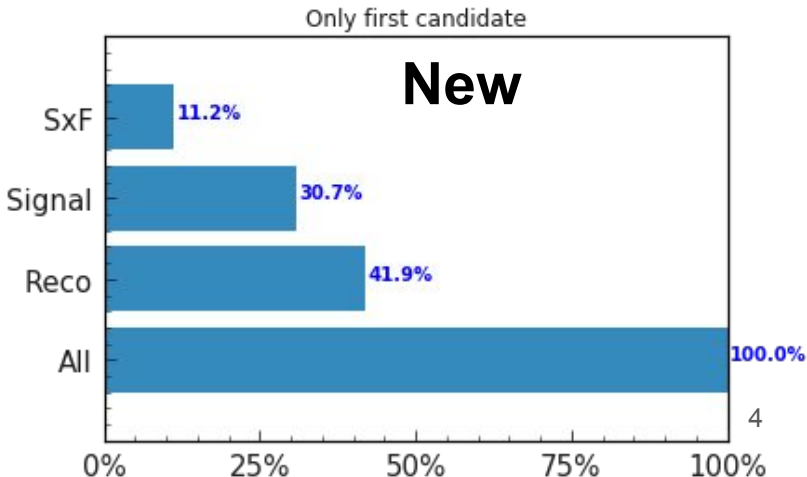
Efficiency: B^0 -> η'->ρ ($\pi^+\pi^-$) ɣ K_S

- **Eff 30.7 %**
- **SxF 11.2%**
  - Was Eff = **12.9% SxF 8.1%**
  - No selection yet, only reco
  - high multiplicity and high SxF
- True cand has best chi2









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)

	η'->η (γγ) $\pi^+\pi^-$	η'->ρ ($\pi^+\pi^-$) γ	**Total**
B^+->η' K^+	113 - **45** (10)	190 - **59** (19)	300 - **105** (30)
B^0->η' K_s	36.4 - **14** (3)	61.4 - **19** (7)	100 - **33** (10)

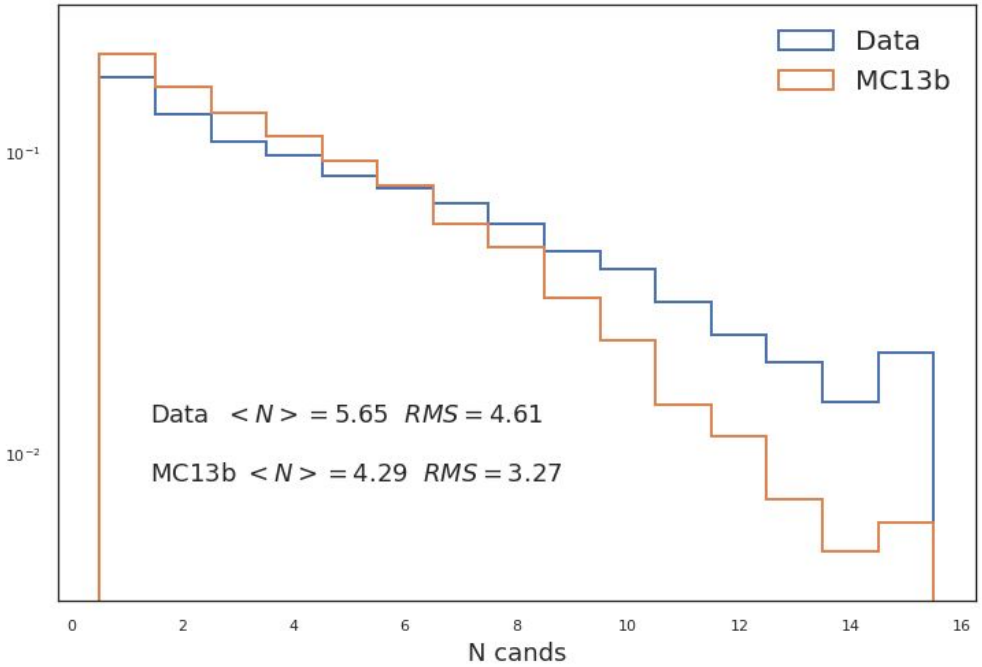
Belle with 10.4 /fb

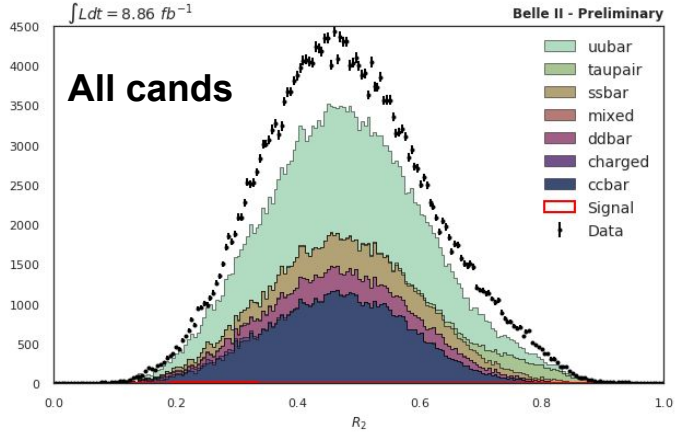
Mode	N_S
$\eta'_{\eta\pi\pi} K^+$	$28.9^{+6.5}_{-5.7}$
$\eta'_{\rho\gamma} K^+$	$42.5^{+9.1}_{-8.3}$
$\eta'_{\eta\pi\pi} \pi^+$	$0.0^{+1.2}_{-0.0}$
$\eta'_{\rho\gamma} \pi^+$	$0.0^{+5.6}_{-0.0}$
$\eta'_{\eta\pi\pi} K^0$	$6.4^{+3.4}_{-2.7}$
$\eta'_{\rho\gamma} K^0$	$10.1^{+4.4}_{-3.6}$

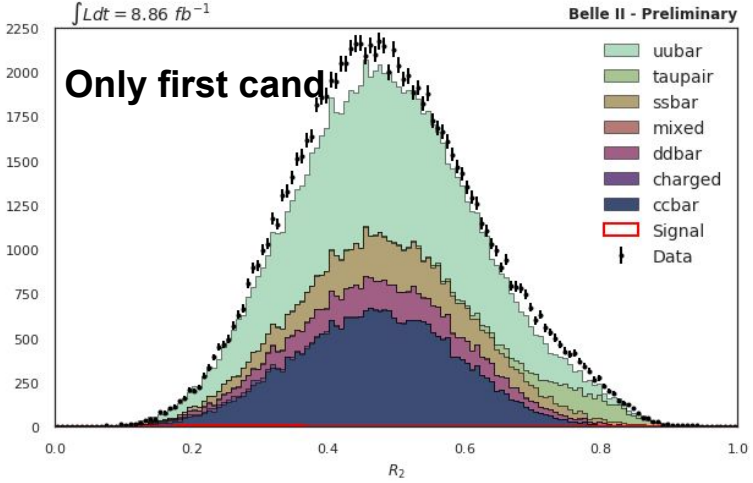
- With new efficiency for η'->ρ ($\pi^+\pi^-$) γ, relative expected yield for Belle II is similar to that of Belle.
  - Reminder: it is only reconstruction, no selection cut. **The actual final yield will be less.**

Data/MC comparison

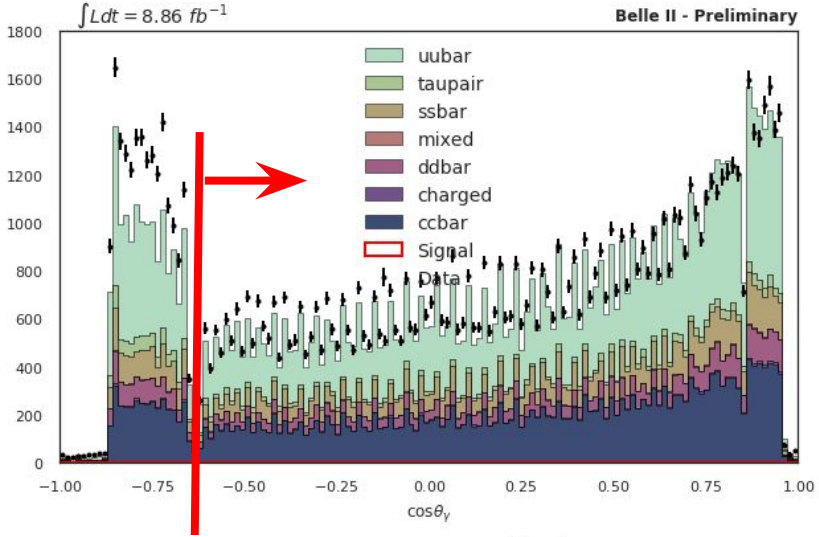
- Normalization problem when using all candidates
- Average cands/ev different in Data/MC
- Using only first candidate better but not yet perfect



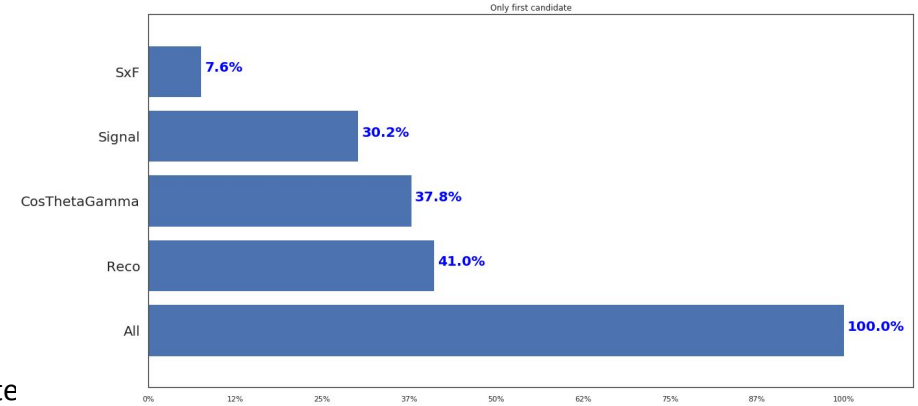


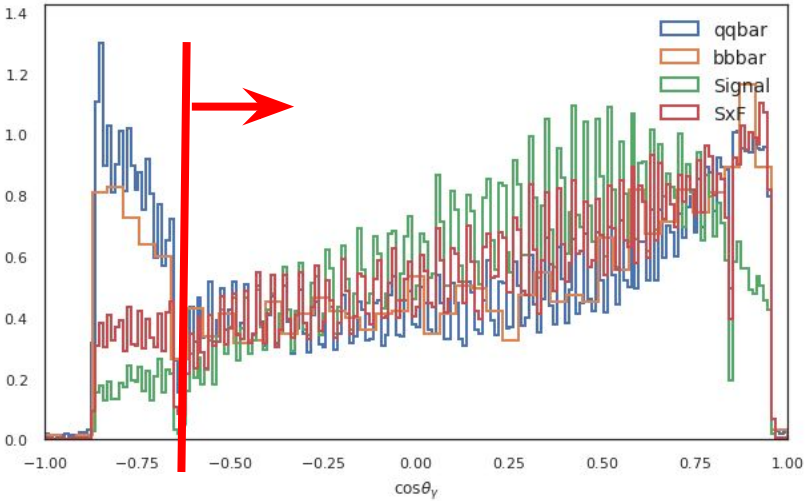


Gamma CosTheta



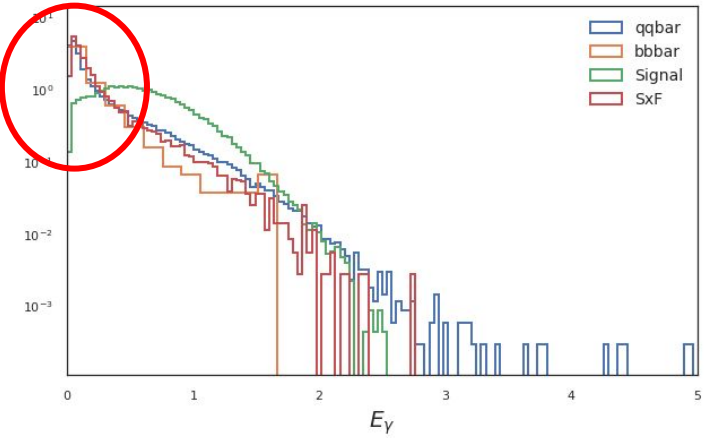
- Most of excess in data is for backward gamma
- Also a place where the background and SxF is large (and signal small)
- Cut **cosThetaGamma>-0.64**
- **Small eff loss (41 -> 37.8%)**



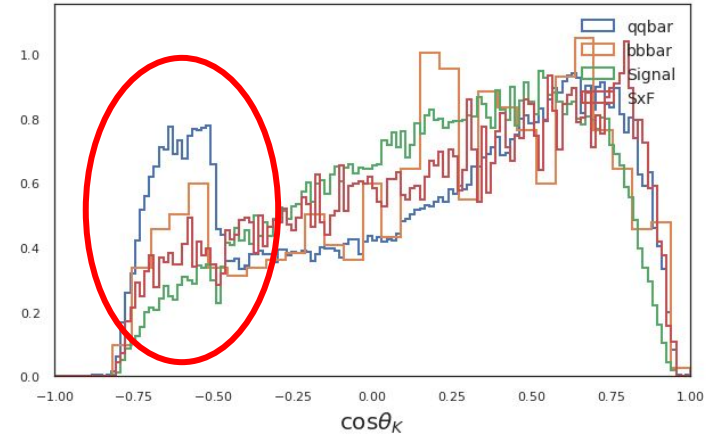


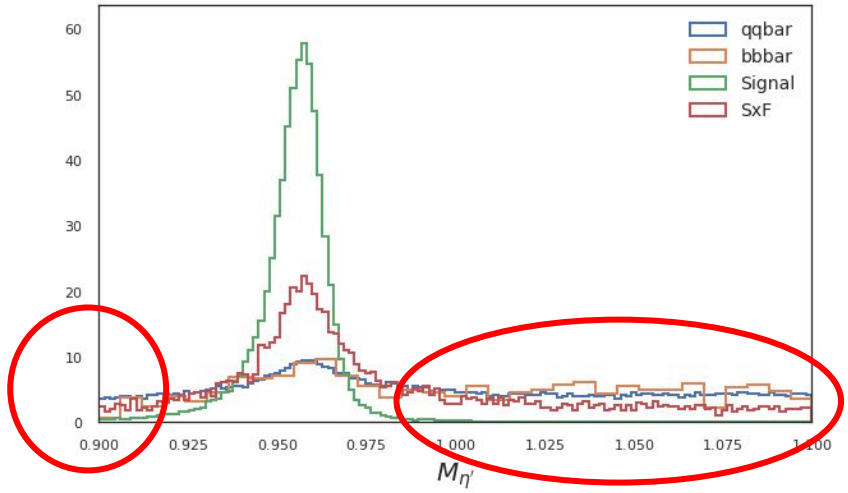
Ste

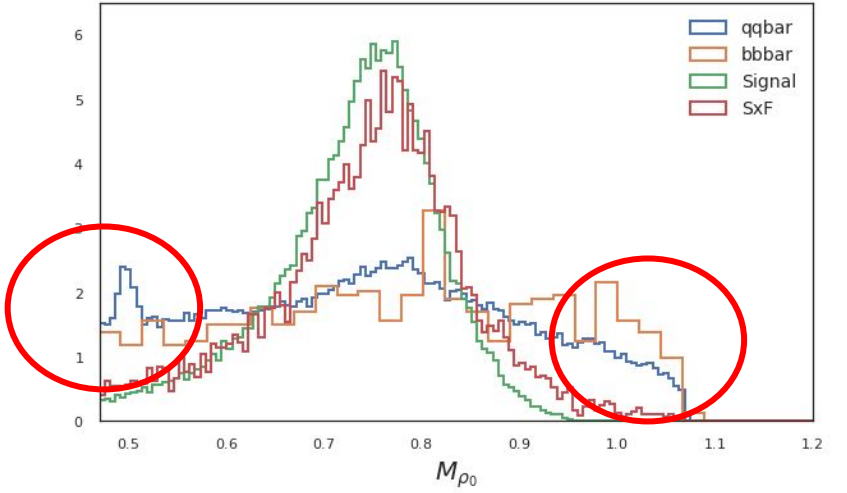
Other possible selection



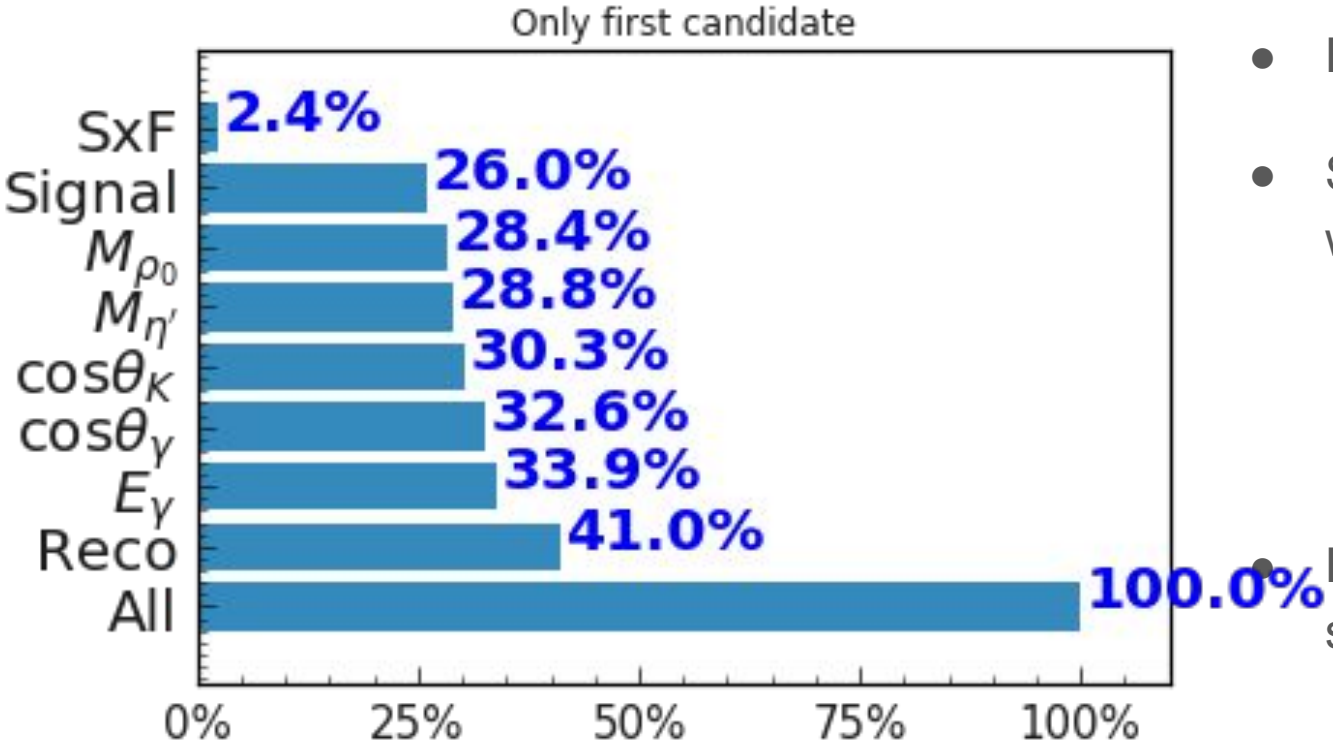
- cos **θ** ɣ > -0.64
- E ɣ>100 MeV
- M η' in [0.92-1] GeV/c^2
- cos **θ** K > -0.5
- M ϱ_0 in [0.51-1]GeV/c^2







Selections efficiency

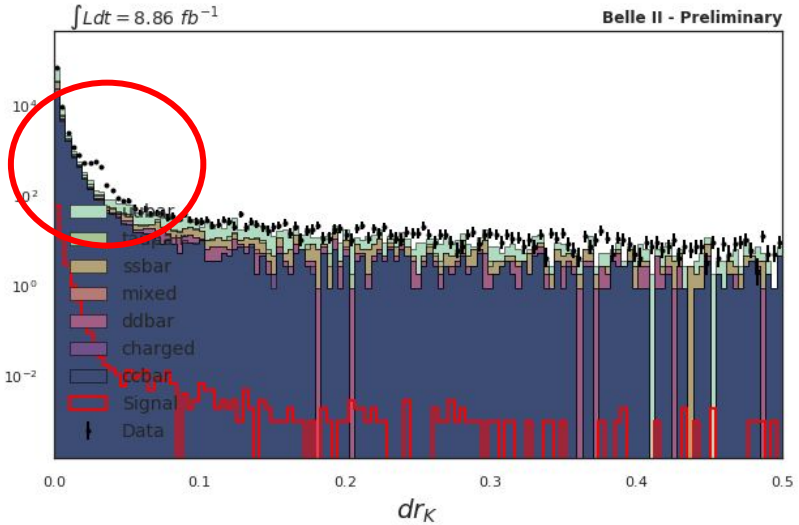


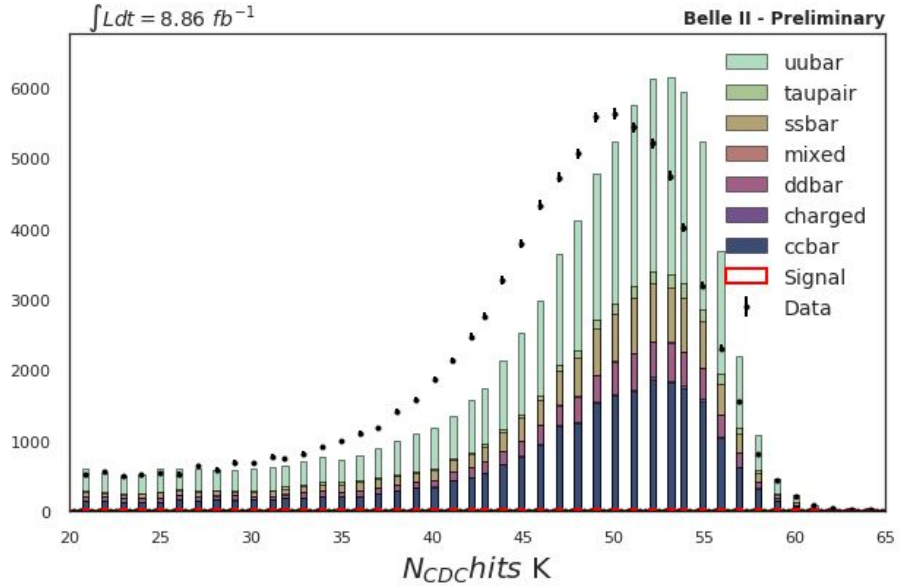
- Efficiency still good
  - **Was 31.3%**
- SxF greatly reduced with simple cuts
  - **Was 9.7%**
  - Further optimization possible: eg MVA,
  - Not sure want to do it at this stage
- Expected yield with selection:
  - **~5.5 ev /fb^{-1}**
  - ~50 ev in 8.86 fb^{-1}
- Belle: **~4.2 ev /fb-1**

WARNING: no continuum suppression cut, yet (see later)

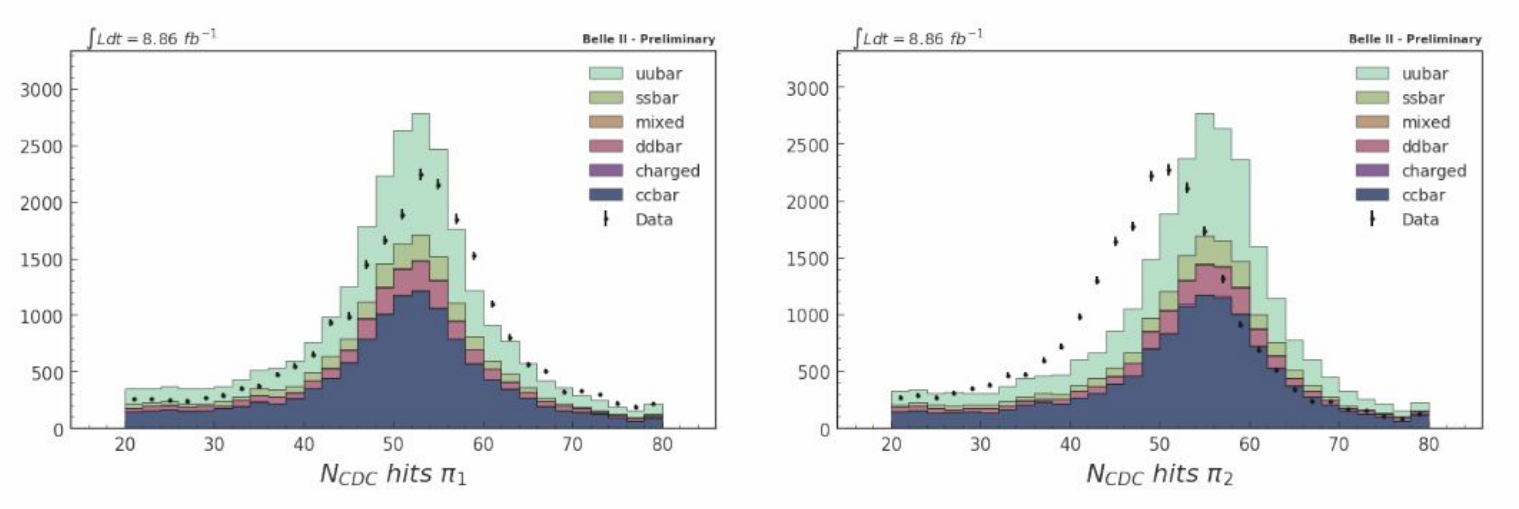
K dr and N CDC hits

- Data has peak at dr~50 um. Seen also for pions from eta'->eta pi pi decay
- Significant difference on N CDC hits
- For pion, also between pi+ and pi- from eta' -> eta pi+ pi- decay



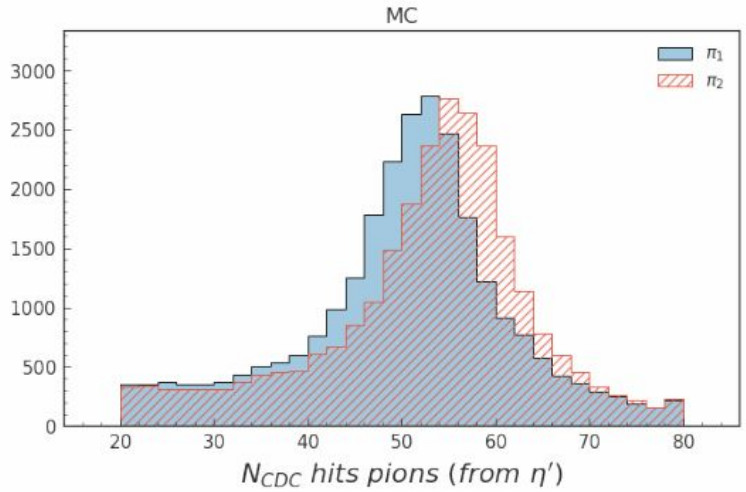


N CDC hits for pion eta'->eta pipi

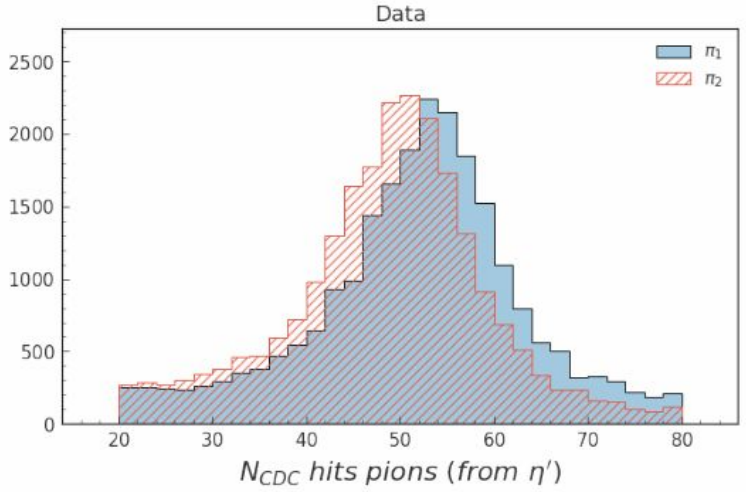


- Disagreement between data and MC
- And also between the two pions pi1=pi+ pi2=pi-
  - Is this a charge related asymmetry? Is it known?

N CDC hits for pion eta'->eta pipi

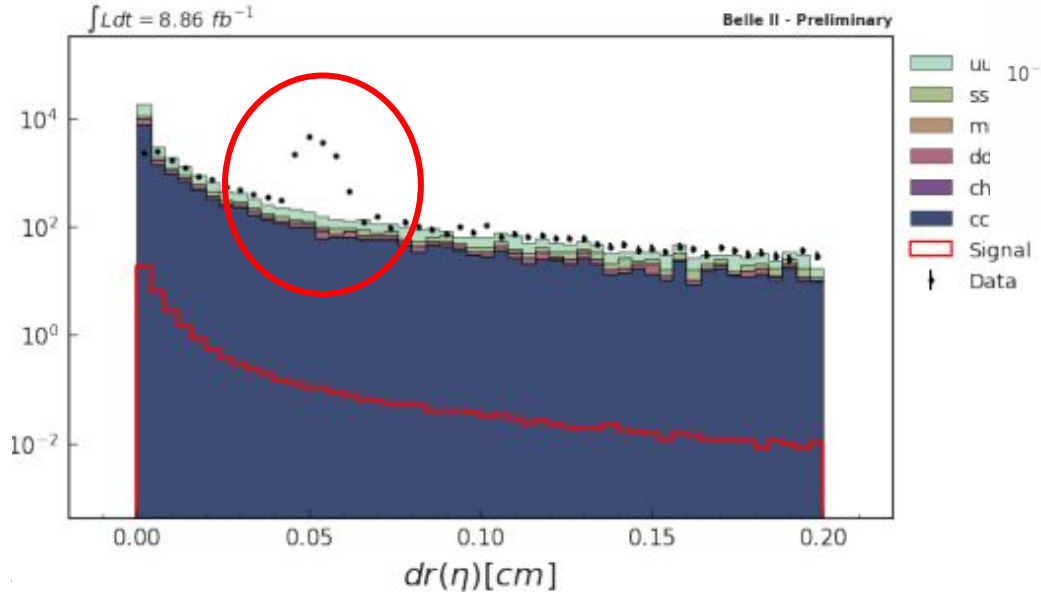


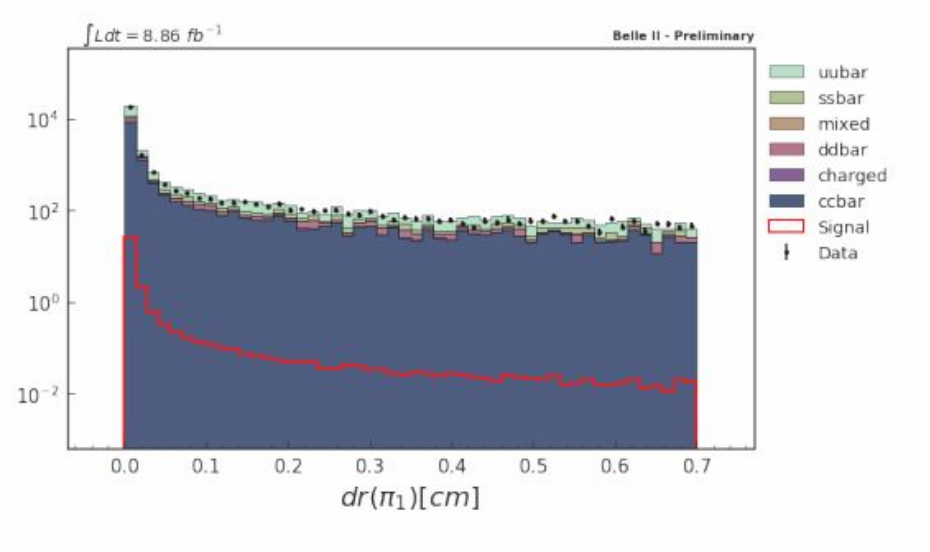
- N_{CDC} different for pi+ and pi-
- But in different way in Data and MC
- Same for pions from K_s



Dr for eta' and pi (in eta'->eta pi+ pi-)

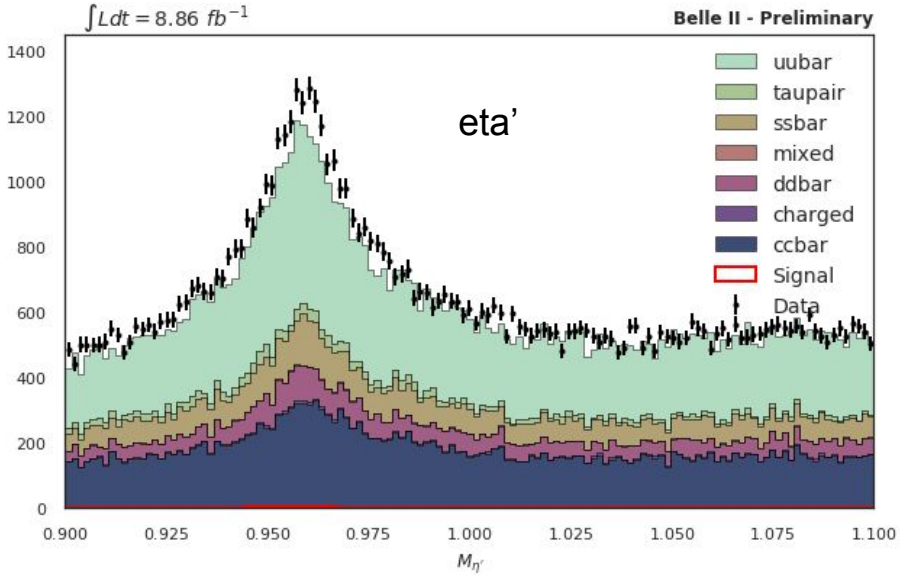
- **dr= transverse distance in respect to IP**
- Do I have a problem with IP in data?
- Should I get dr wrt Beam Spot?
- ipConstraint=True in TreeFit?

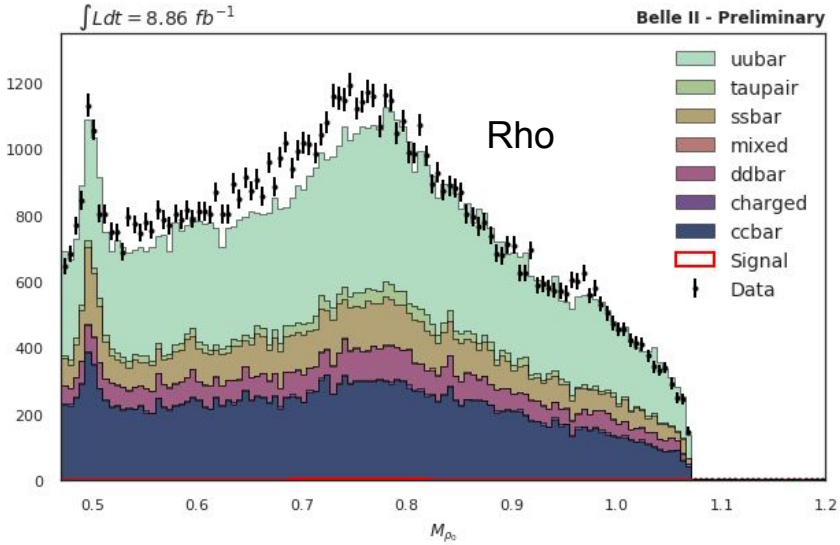





```
vx.treeFit("B+:ch3",
conf_level=-1, ipConstraint=True,
updateAllDaughters=True,
massConstraint=[331],
path=my_path)
```

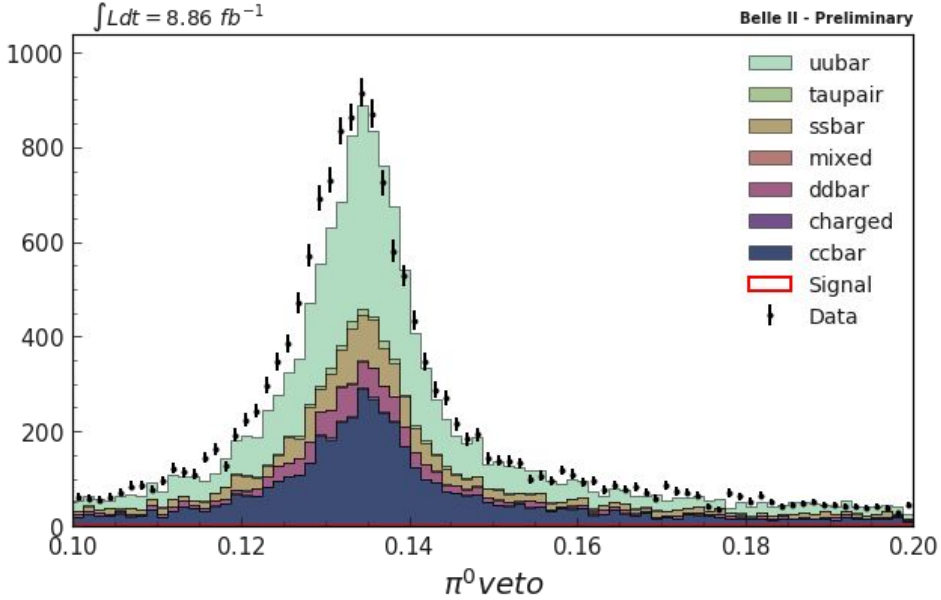
Invariant Masses

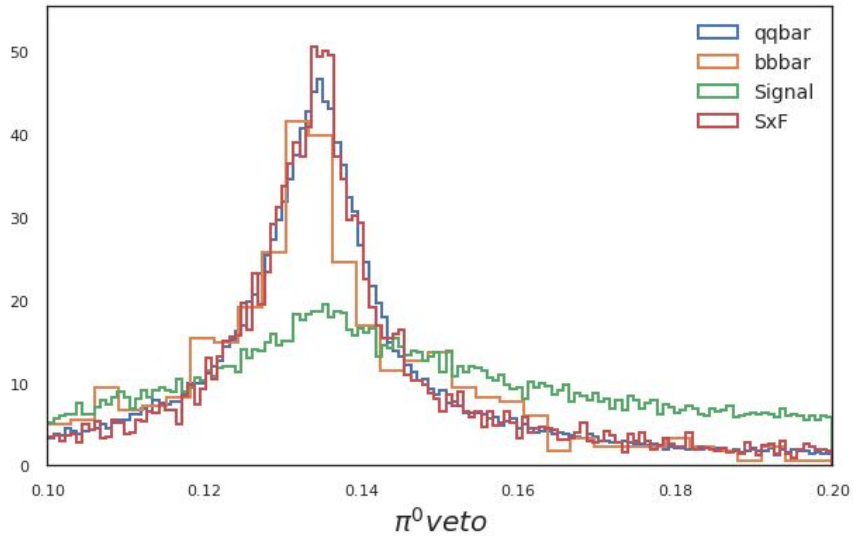




- Plots before Mass cuts
  - Nice eta' peak!
- Rho mass seems shifted in data wrt to MC
  - Ks peak clearly visible, hence the Mrho cut > 0.52

Pi0 veto





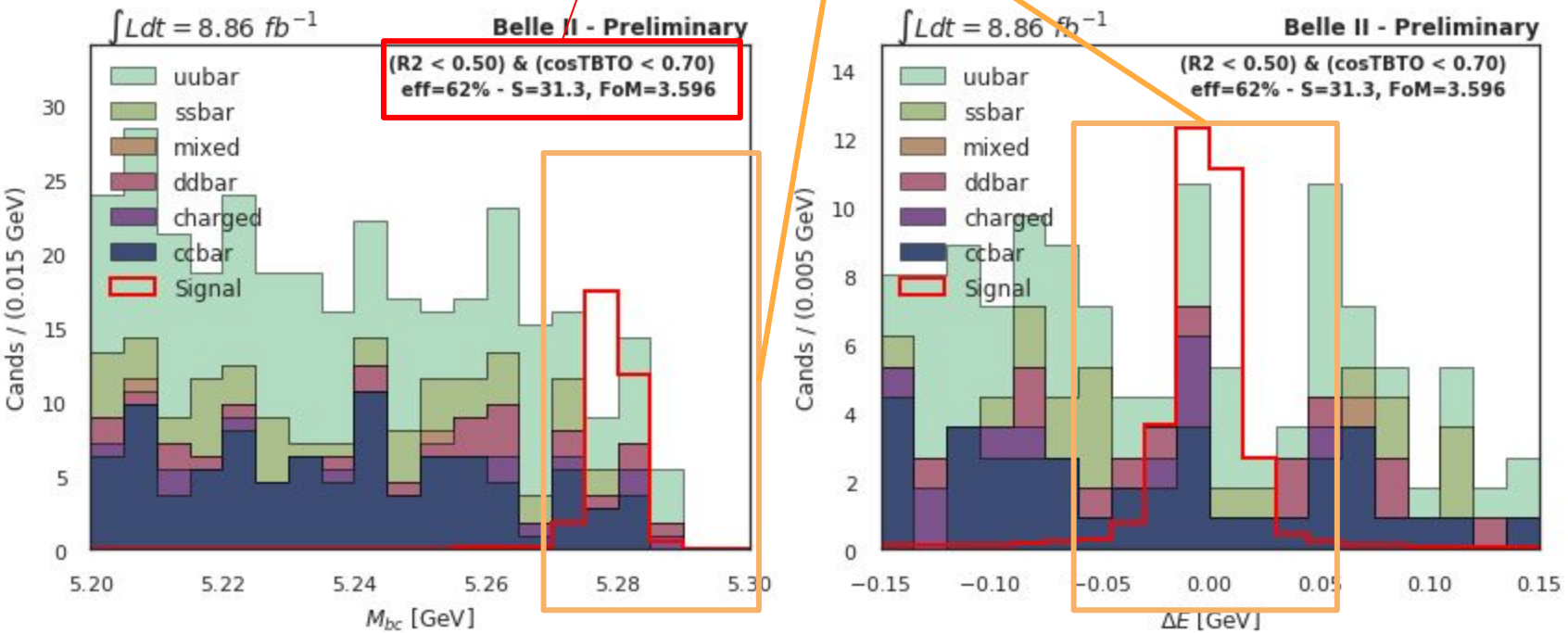
- Pi0 veto mass peak shifted in Data wrt to MC

- Significant signal loss if cut on pi0veto.
- No cut applied.
- Accumulation of signal close to Mpdg due to selection of pi0 veto

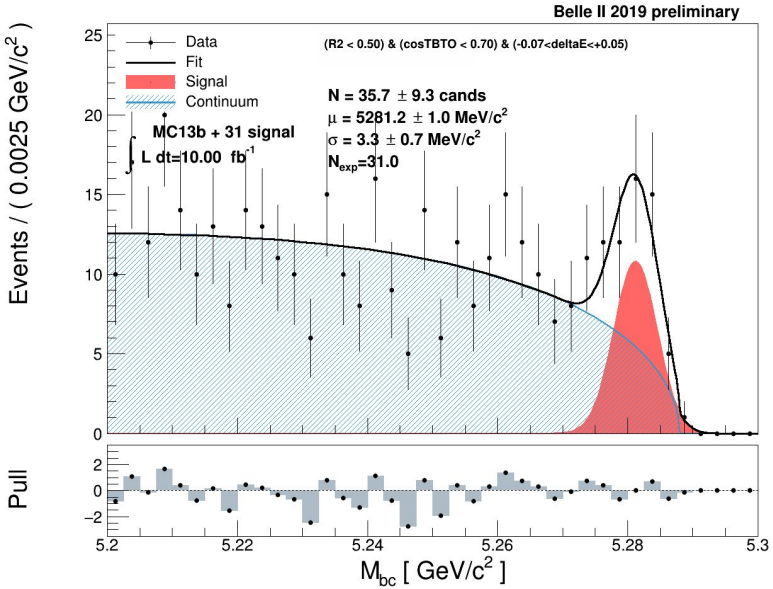
Continuum suppression

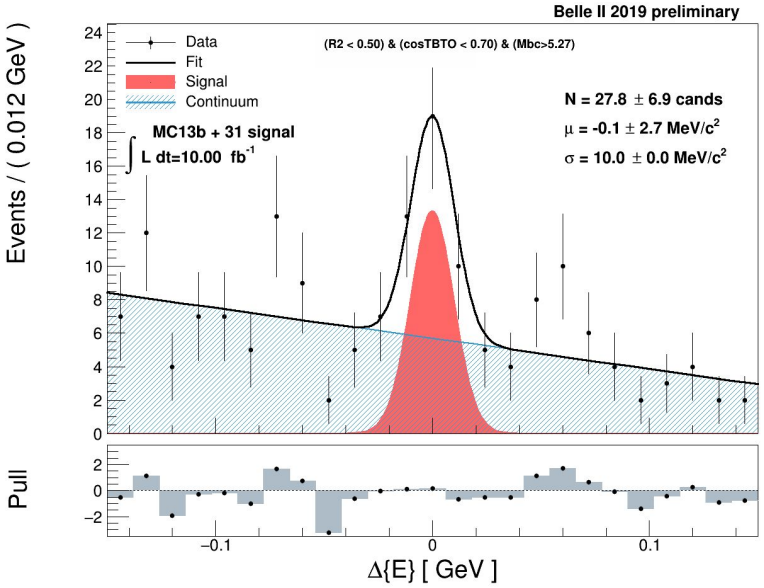
- Cont Suppression using only **R2 and cosTBTO**
- Simple optimization of S/sqrt(S+B) **in signal region**
- **R2<0.5, cosTBTO<0.7**

Signal Eff: 60%*26% = 16%
Belle: 14.1 %



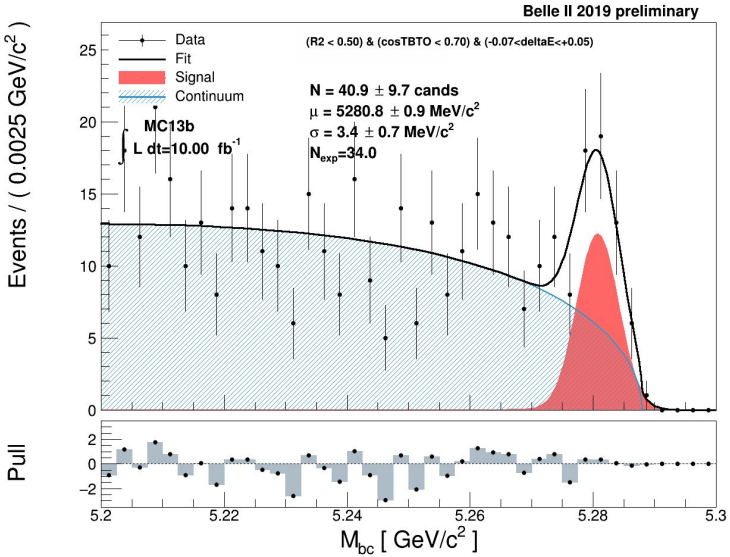
Try to fit signal: only MC + signal injection

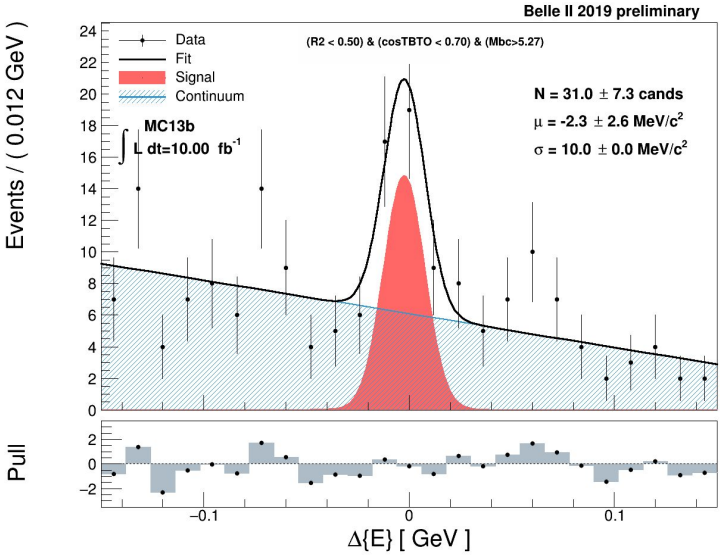




- Cut **Mbc>5.27 GeV/c²** and **-7<De<+5 MeV** in the other plot.
- No 2D fit (yet): working on it - **will look at Chiara code**
- Injected 31 events, seen 35.7+/-9 (Mbc) and 28+/-7 (De)

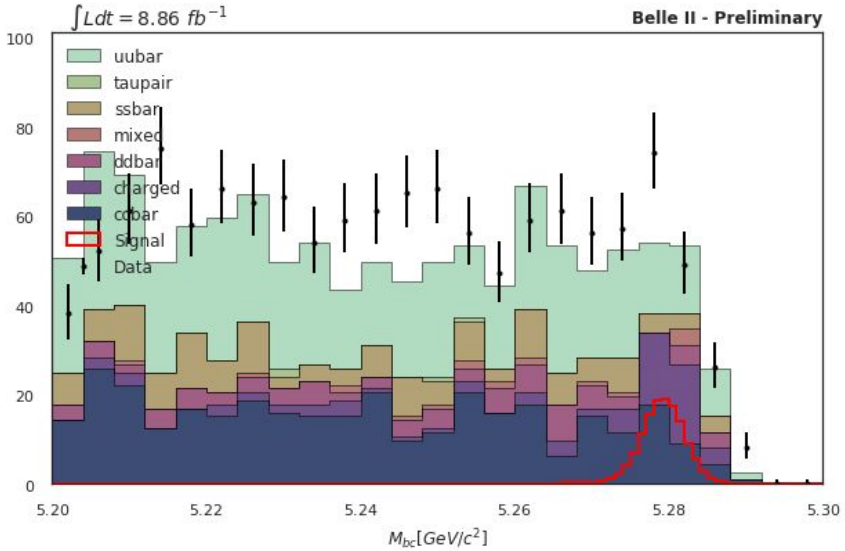
Try to fit signal: only MC (with its bb signal)

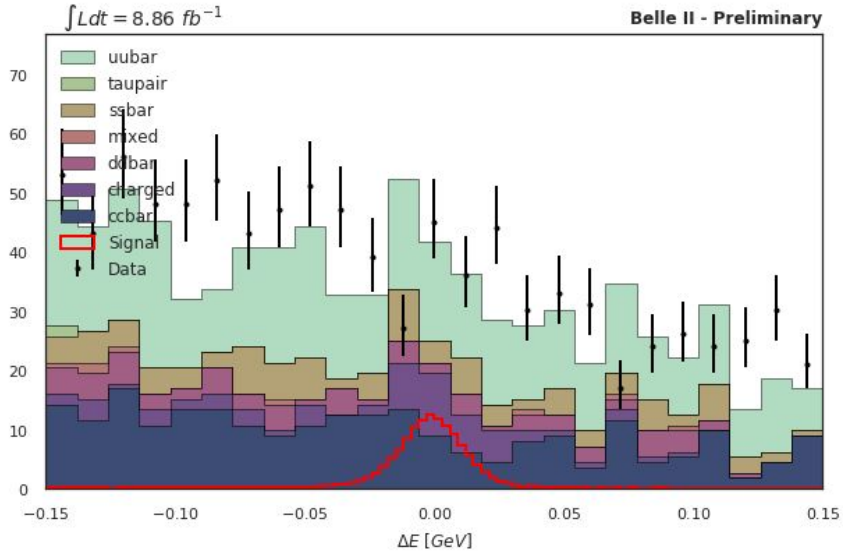




- Previously removed signal from generic BB
  - **Now use MC as data: signal not removed**
- There are 34 candidates in 10/fb of MC13b (expected 31 w/ CS cuts)
- Seen 41+/-10 (Mbc) and 31+/-7 (De)

Mbc and DeltaE: **Data** vs MC (w/ signal)

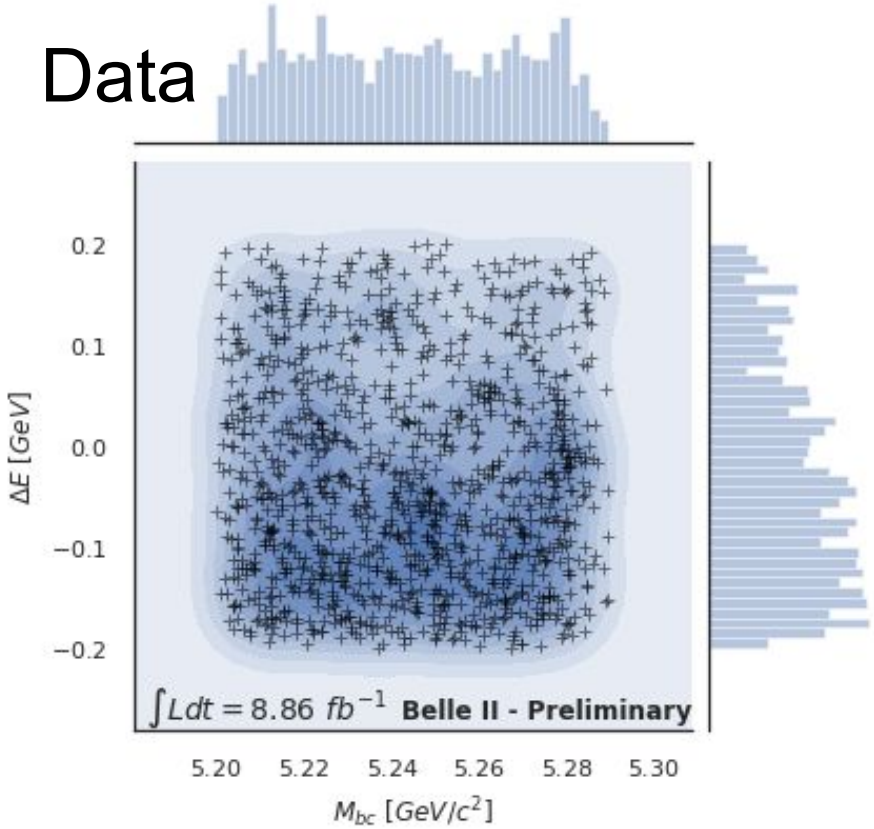




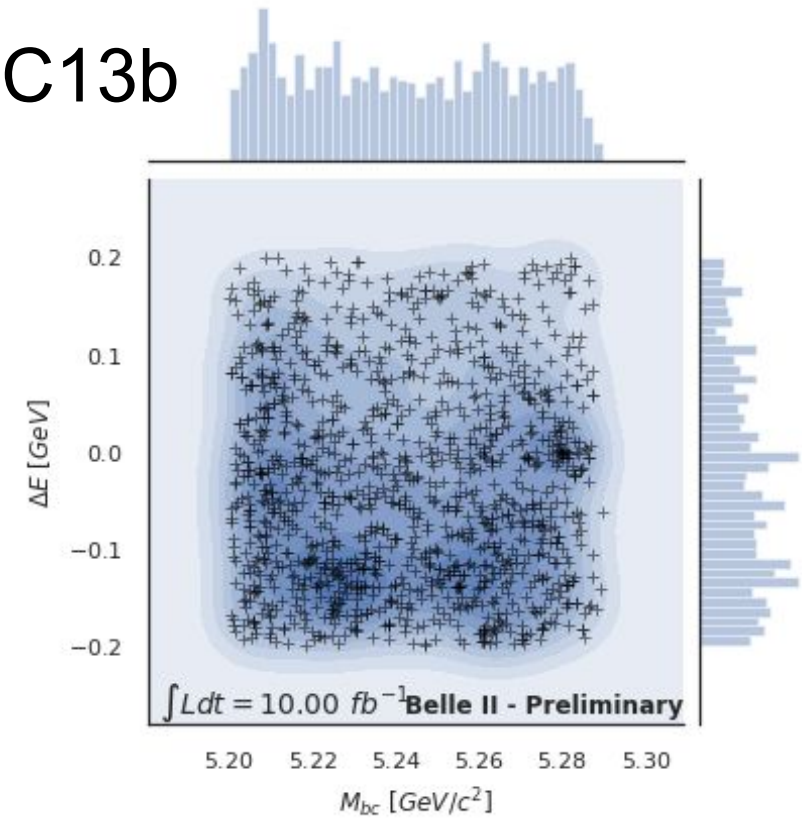
- **R2<0.5 cosTBTO<0.7**
- Signal is not removed from generic bb-bar MC (charged)
- High stat signal MC ovelaid for visualization purpose
- Within statistics, agreement is good

DeltaE vs Mbc

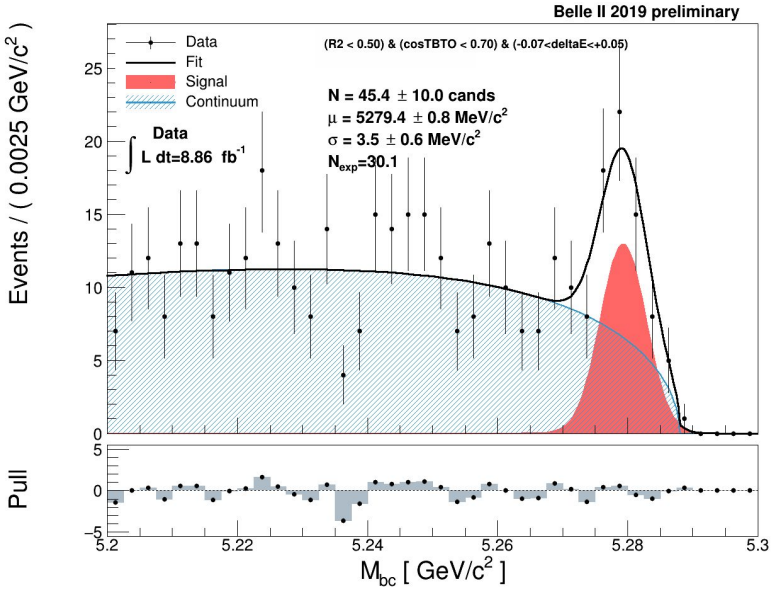
Data

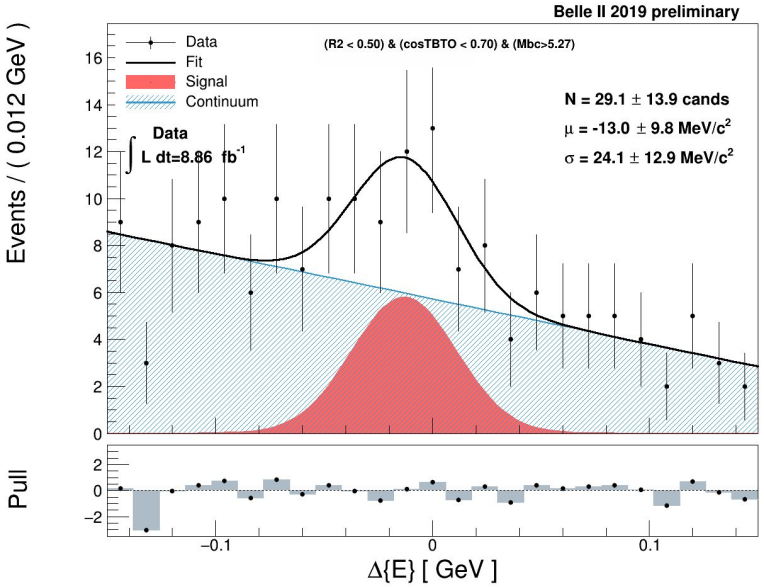


MC13b



Try to fit signal: Data

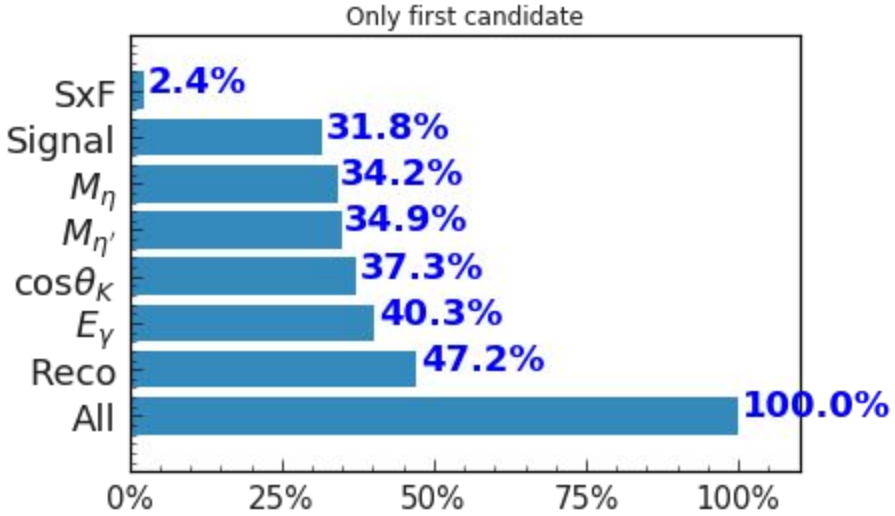


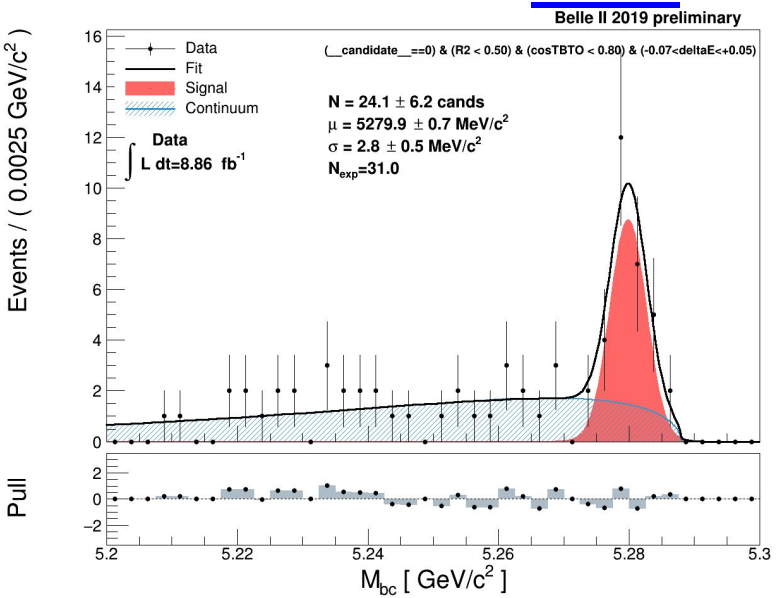


- Clear signal visible!
- seen 45.7+/-10 (Mbc) and 29.1.4+/-14 (De)
  - Expected: 34*0.886=31
  - Very preliminary!

B^+ -> η’ (->η (γγ) $\pi^+\pi^-$) K^+

- Simple signal selection
  - Signal eff 32% (40% reconstruction only)
  - SxF 2.4 (vs 7.1 %)
  - **w/ CS** eff: 32 * 0.75 = **24%**
  - **Belle was 22%**





Test on MC13b w/ signal injection and w/o signal removal on backup

Conclusion and outlook

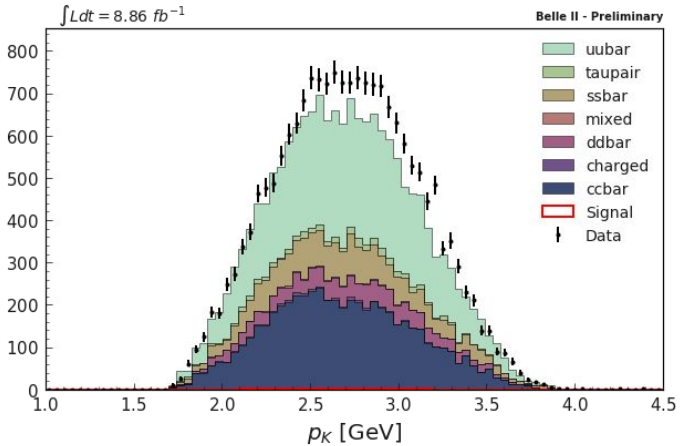
- First full scale test with Data and MC13 for **$B^+ \to \eta' K^+$**
  - **Focus on $\eta' \to \rho (\pi^+\pi^-) \gamma$**
- **Preliminary results are encouraging,**
  - Fixed issues with previous iteration
    - Other found
  - First signal selection in place for both final states
  - Nice agreement between Data and MC
  - **First signal fit on data are good**
- Plan:
  - **Rediscovery aimed for ICHEP (summer 2020)**
  - Finalize signal selection
  - Improve data/MC comparison
  - Replicate study on B^0 channels
  - Documentation

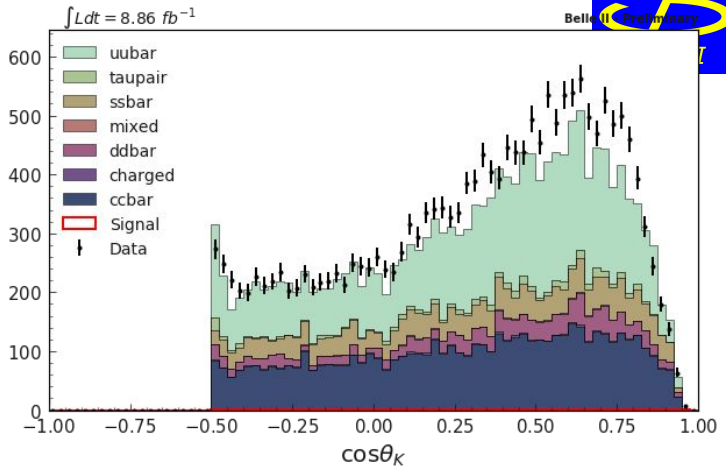
Backup

Data - MC comparison

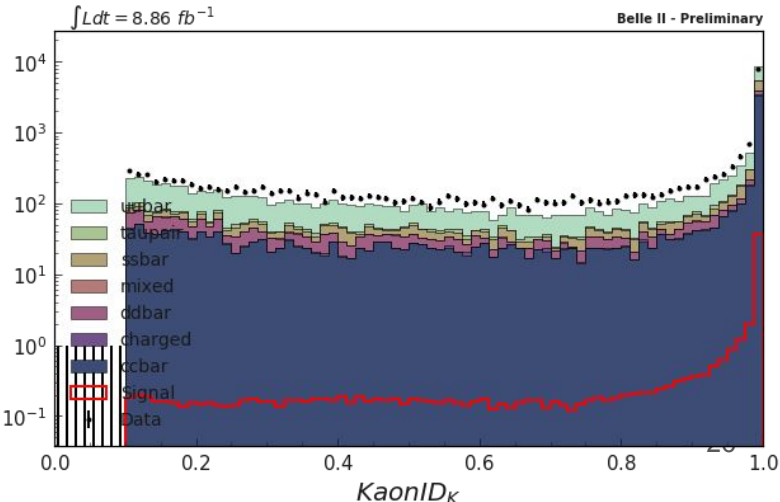
- Start comparing reconstructed quantities for Data and MC
- General idea is to apply selection only on variables that are well modelled by MC
- Start with rectangular cuts, MVA selection will follow later
  - MC: using qq-bar (udsc)
  - bb-bar generic (mixed and charged)
    - For background only study 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

Data MC comparison K

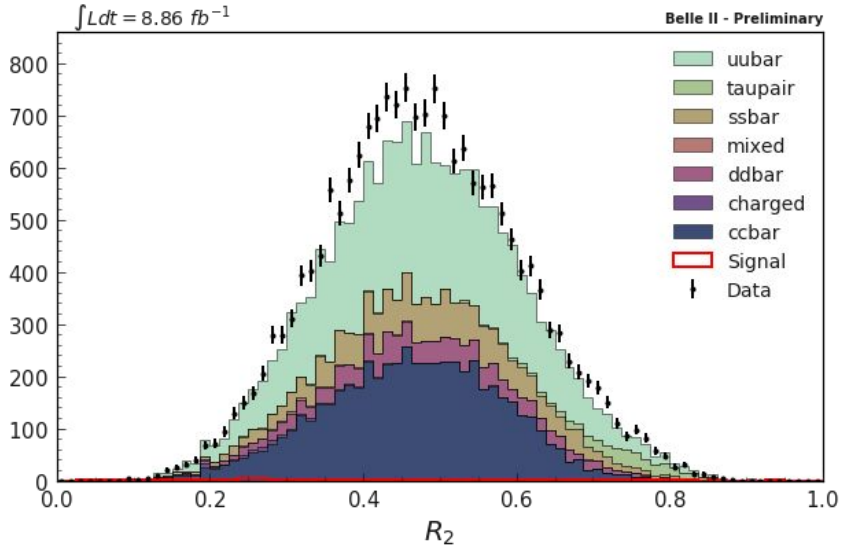


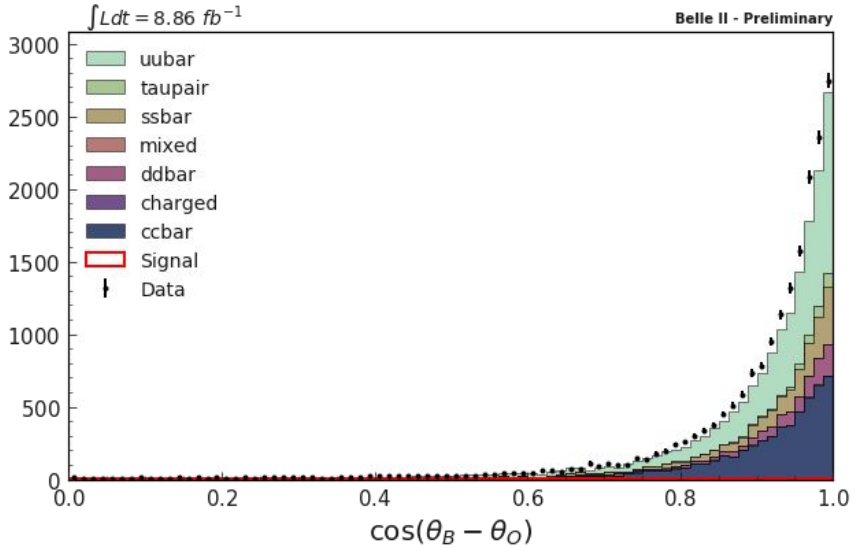


- Using Loose K^+
- Overall normalization is better, not perfect
- Shape decent, but not perfect as well



Cont Suppression variables

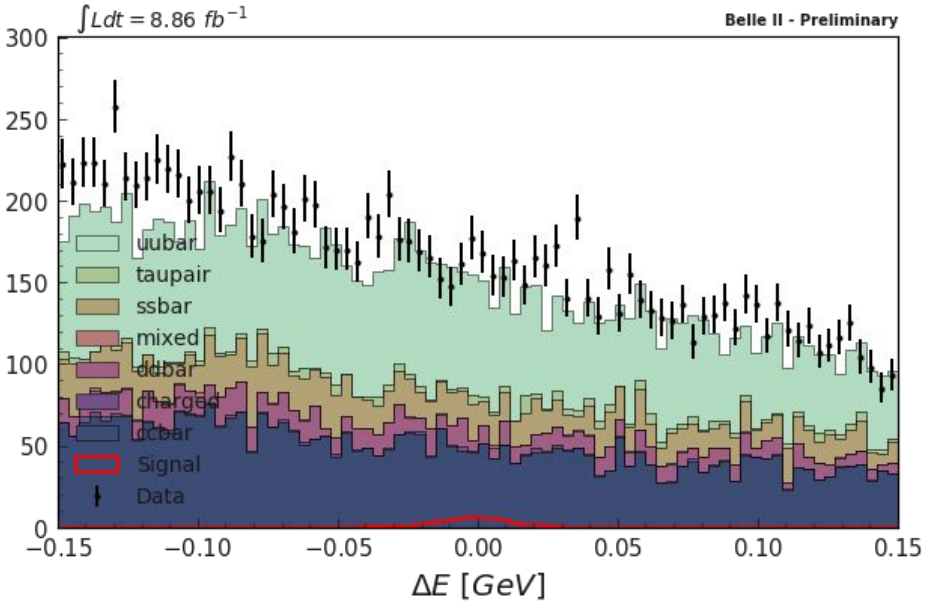


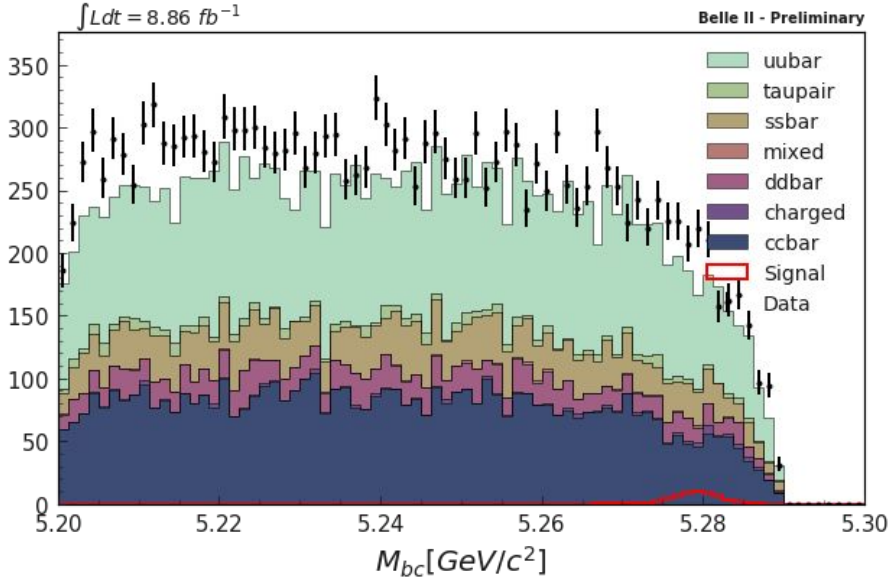


Nice agreement MC - Data, can be used for Continuum Suppression

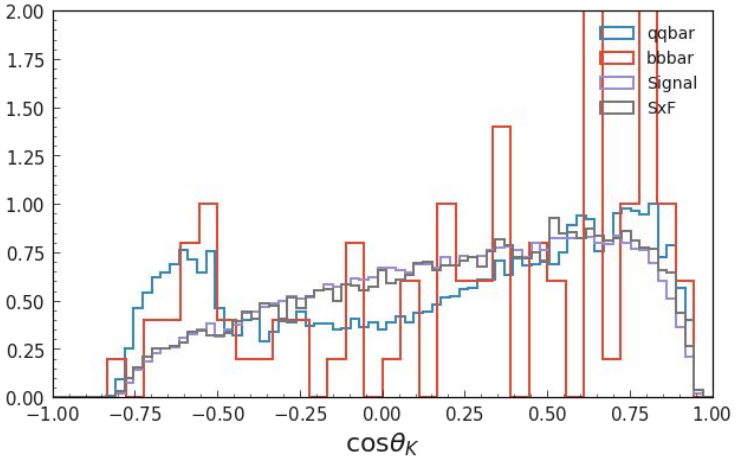
$B^+ \to \eta' K^+$, $\eta' \to \rho (\pi^+\pi^-) \gamma$ Data vs MC

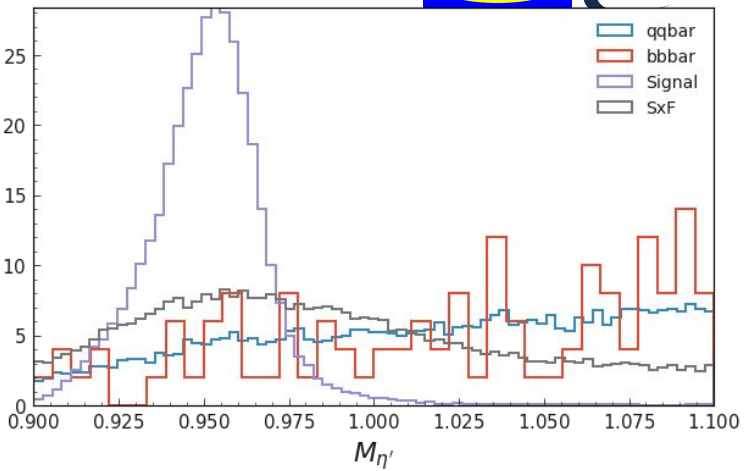
- Mbc and DeltaE
- No cont suppression yet

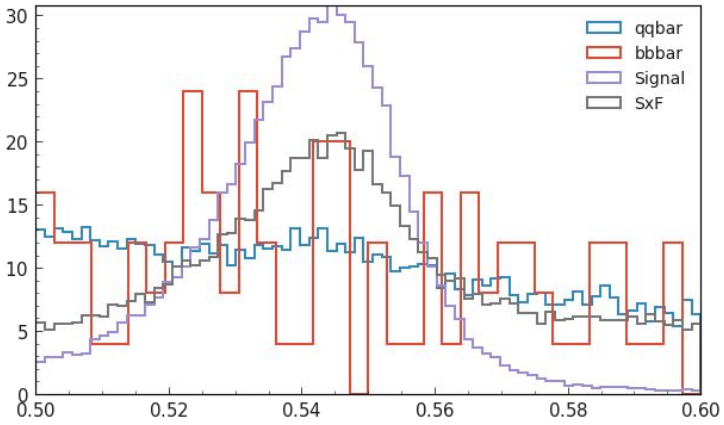


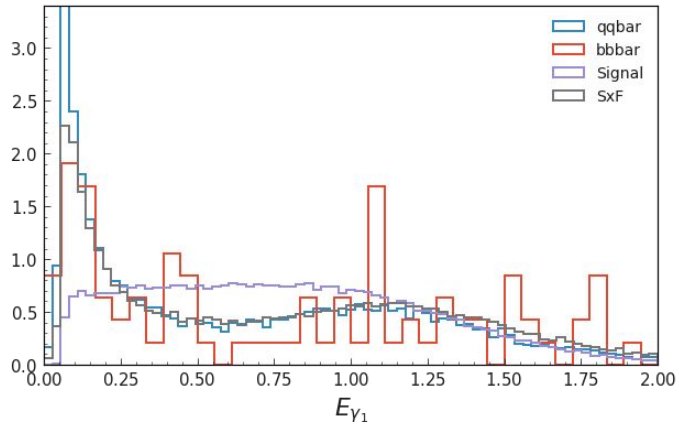


$B^+ \to \eta' (\to \eta (\gamma\gamma) \pi^+\pi^-) K^+$

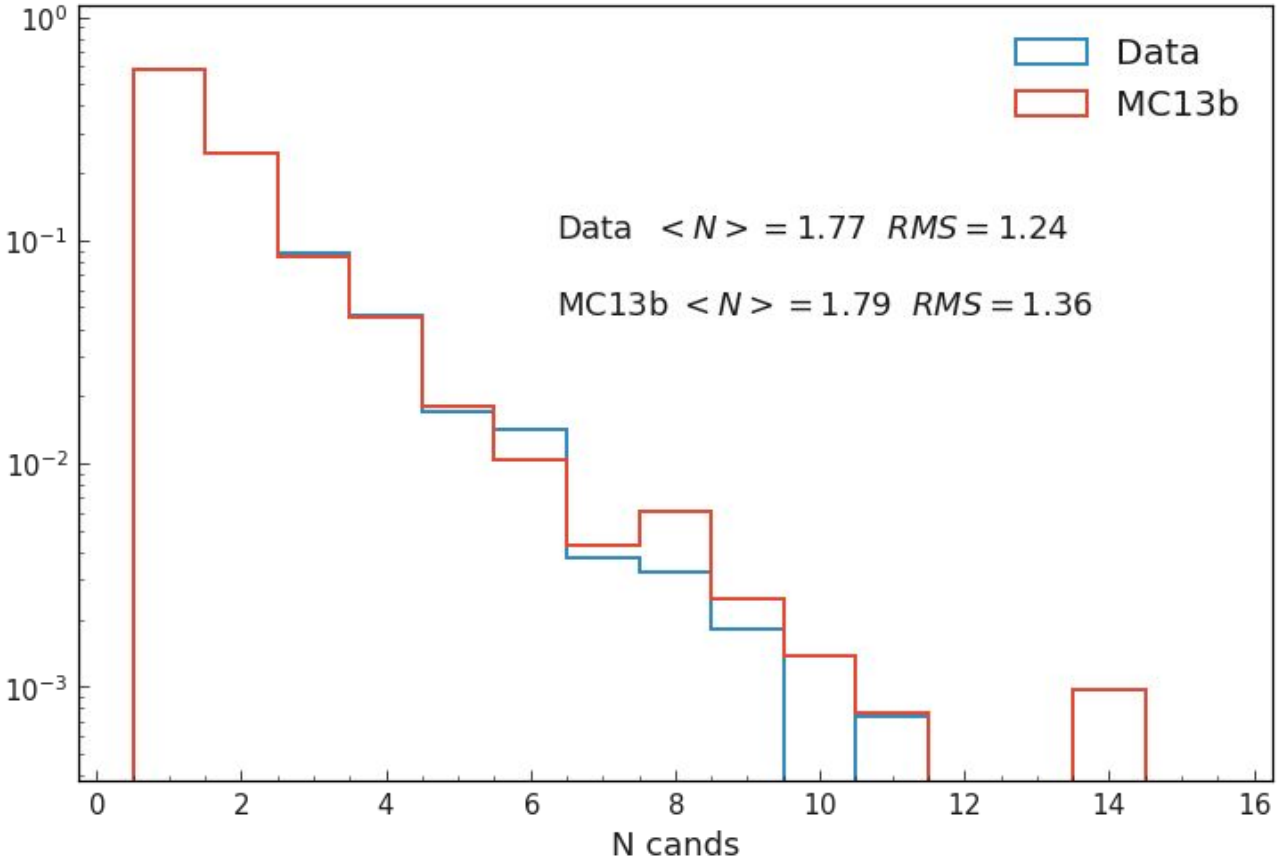




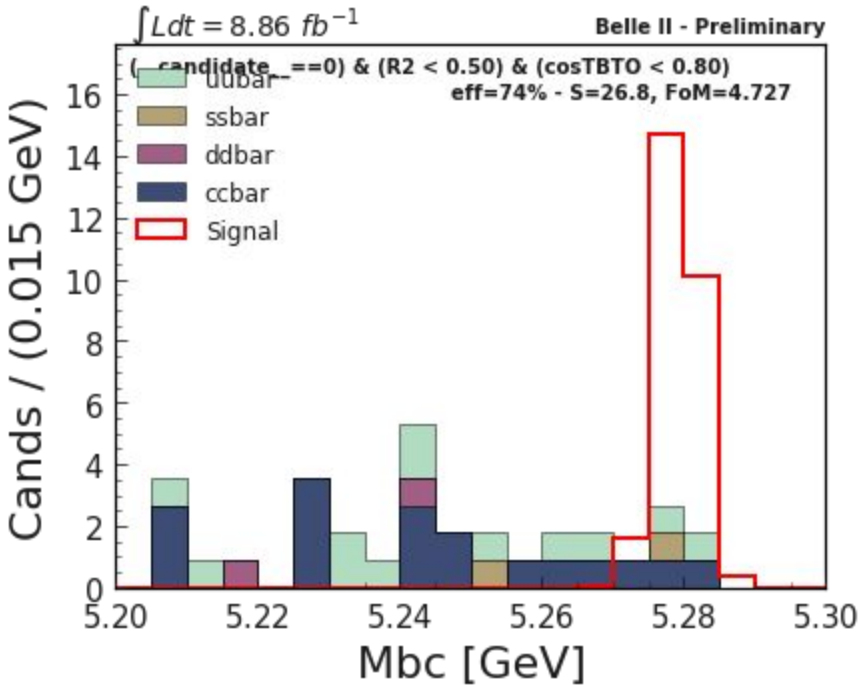


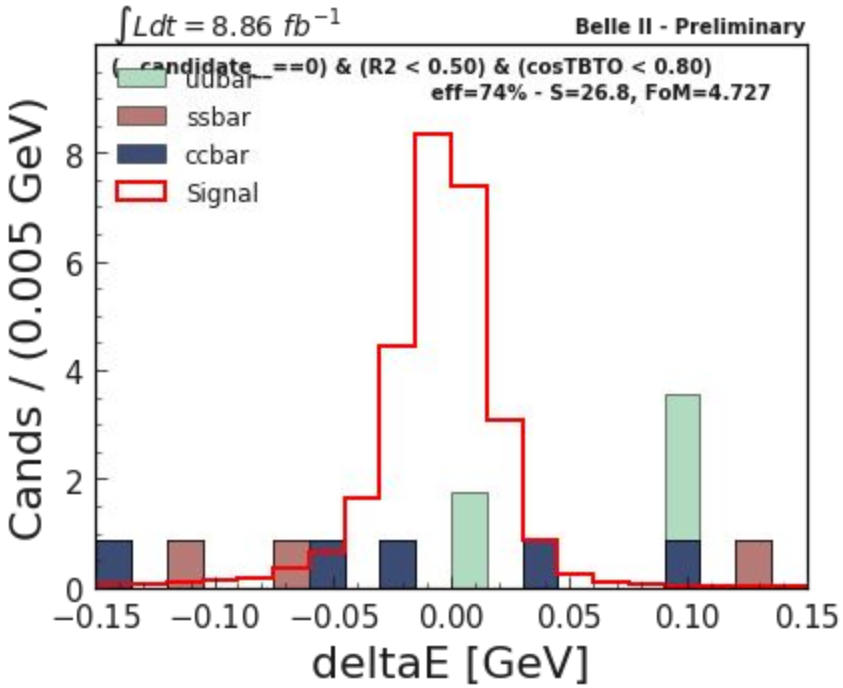


$B^+ \to \eta' (\to \eta (\gamma\gamma) \pi^+\pi^-) K^+$

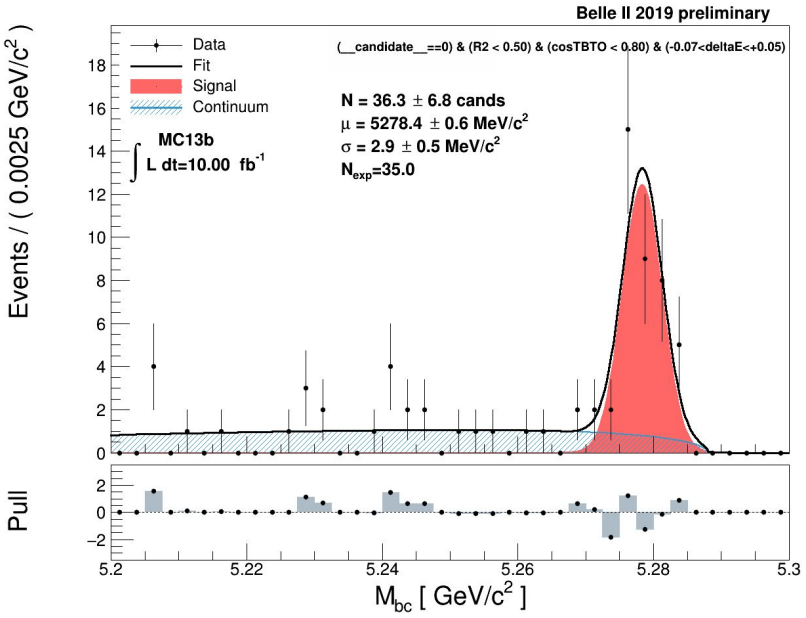


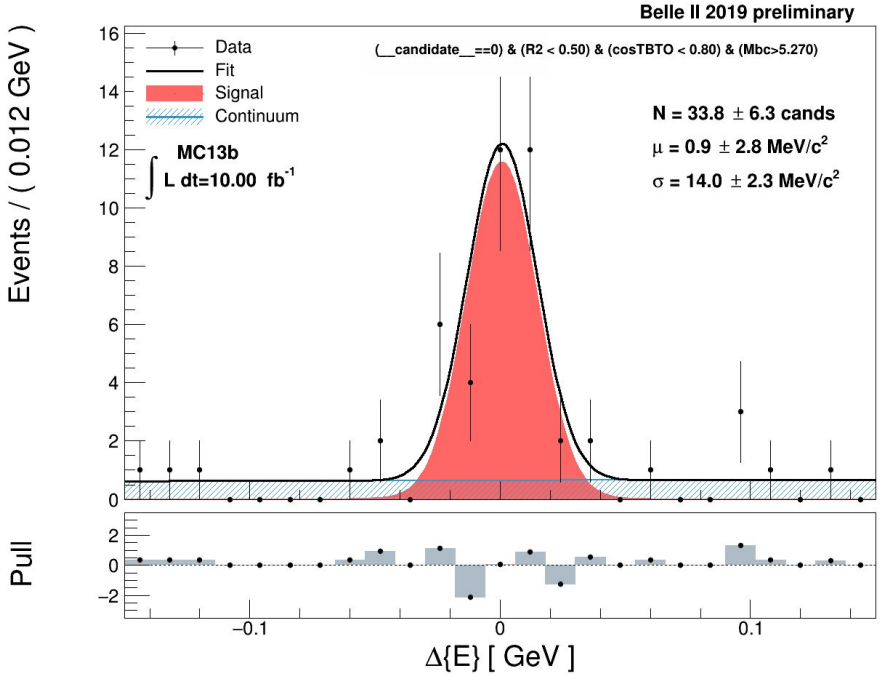
$B^+ \to \eta' (\to \eta (\gamma\gamma) \pi^+\pi^-) K^+$



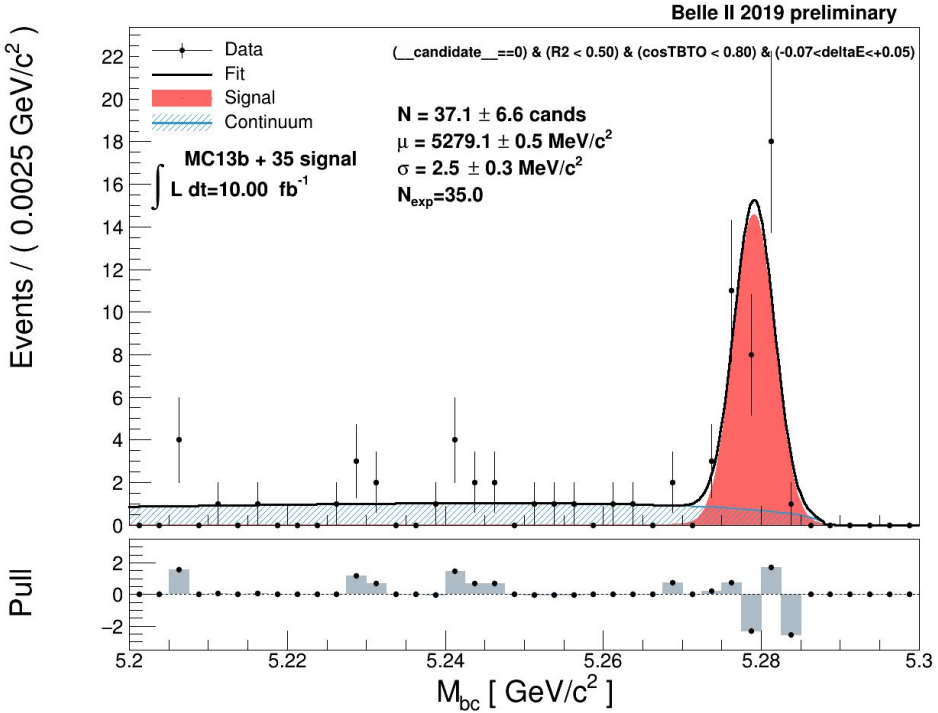


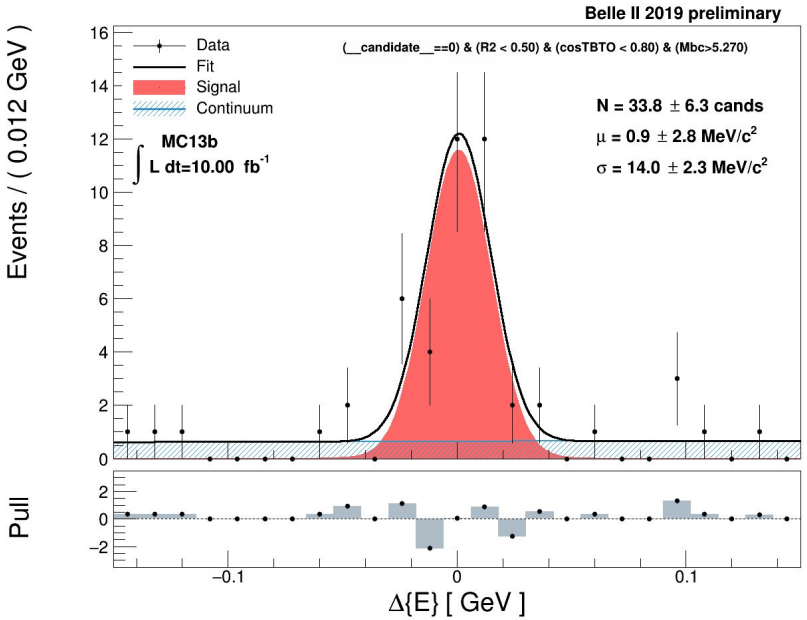
$B^+ \to \eta' (\to \eta (\gamma\gamma) \pi^+\pi^-) K^+$



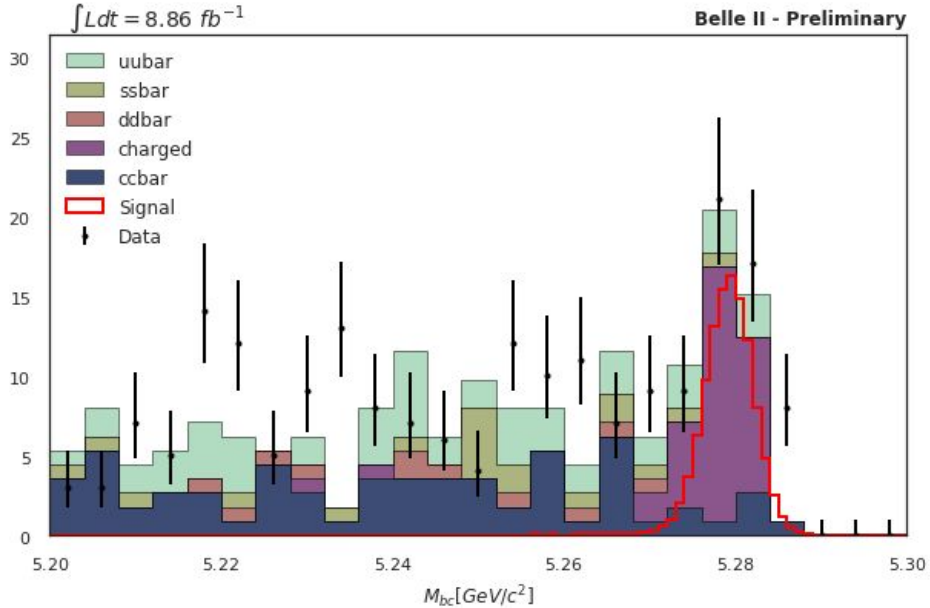


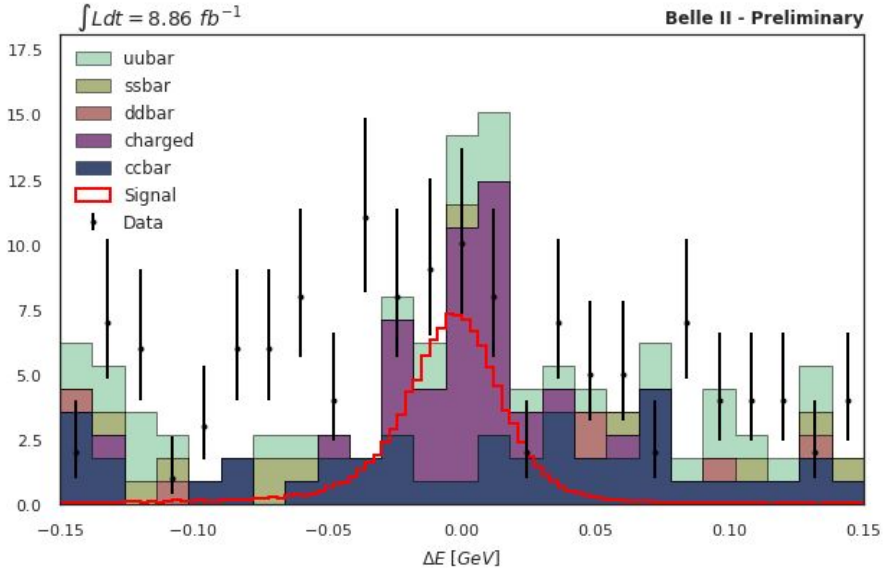
$B^+ \to \eta' (\to \eta (\gamma\gamma) \pi^+\pi^-) K^+$





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





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