Branching fraction measurement of $\Xi_c^+ \to \Sigma^+\pi^+\pi^-$ decay at Belle II

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Outline

- Motivation
- Selection Criteria: $\Xi_c^+ \to \Sigma^+\pi^+\pi^-$
- FastBDT
- Reference Mode: $\Xi_c^+ \to \Xi^-\pi^+\pi^+$
- Fit

Motivation

- CP asymmetries in charm baryon decays relatively unexplored
- LHCb measured CP asymmetry in Λ_c^+ decays

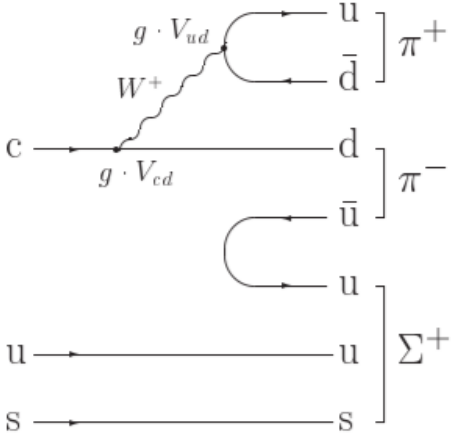
$$\Delta A_{CP}^{wgt} = A_{CP}(pK^-K^+) - A_{CP}^{wgt}(p\pi^+\pi^-) = (0.03 \pm 0.91 \pm 0.61)\%$$

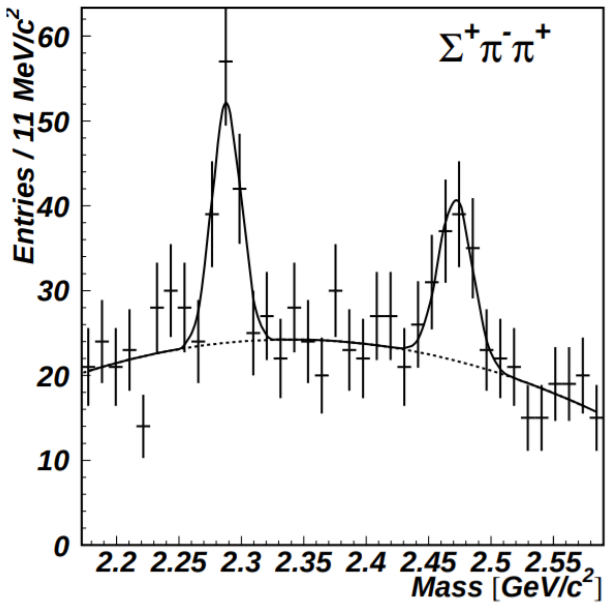
[JHEP 03 (2018) 182]

- Explore CP asymmetry in three body decay of charm hadron decay.:
  A_{CP} $(\Xi_c^+ \to \Sigma^+\pi^+\pi^-)$ combined with U-spin sum rules decay in flavor SU(3) limit. (arxiv:1811.11188)

Branching fraction of $\Xi_c^+ \to \Sigma^+\pi^+\pi^-$

- Single measurement by SELEX in 2008
  - Branching fraction: $\frac{B(\Xi_c^+ \to \Sigma^+\pi^+\pi^-)}{B(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = 0.48 \pm 0.20$
    [Phys. Lett. B 666, (2008), 299-304]





$\Xi_c^+ \to \Sigma^+\pi^+\pi^-$

- Decay Chain: $\Xi_c^+ \to (\Sigma^+ \to p(\pi^0 \to \gamma\gamma))\pi^+\pi^-$
- Loose selection criteria applied at reconstruction level

Description	Selection criteria
charged track $\pi^\pm$ p	thetaInCDCAcceptance nCDCHits>0
protonID (p)	> 0.2
γ	$E_{forward} > 0.080$ [GeV] $E_{barrel} > 0.030$ [GeV] $E_{backward} > 0.060$ [GeV]
π^0	$0.120 < M < 0.145$ [GeV/c^2]
Σ^+	$1.159 < M < 1.219$ [GeV/c^2]
Ξ_c^+	CM momentum>= 2.5 [GeV/c] $2.4 < M < 2.55$ [GeV/c^2]
vertex fit	Loose quality cut mass-constrain Σ^+

Fast BDT

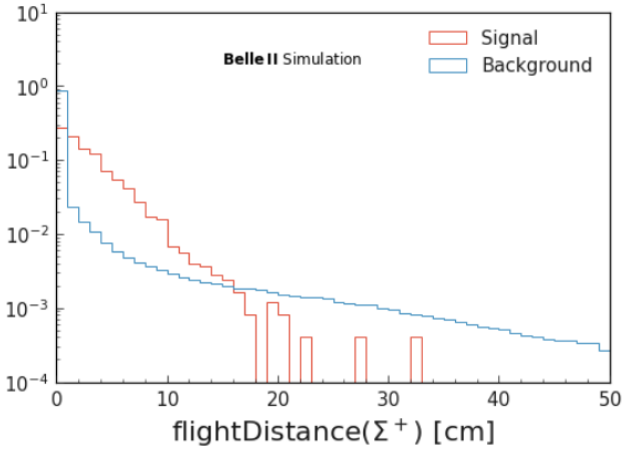
Before BDT: protonID(p) > 0.9

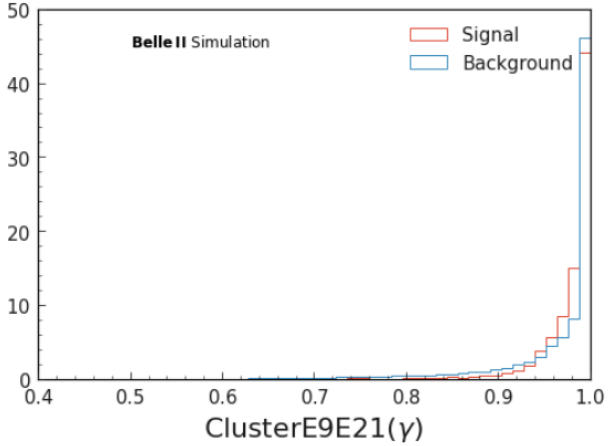
- **Train sample**: Boosted Signal + generic background.
- **Test sample**: Boosted Signal + generic background.
- Independent train and test sample with same signal to background ratio.

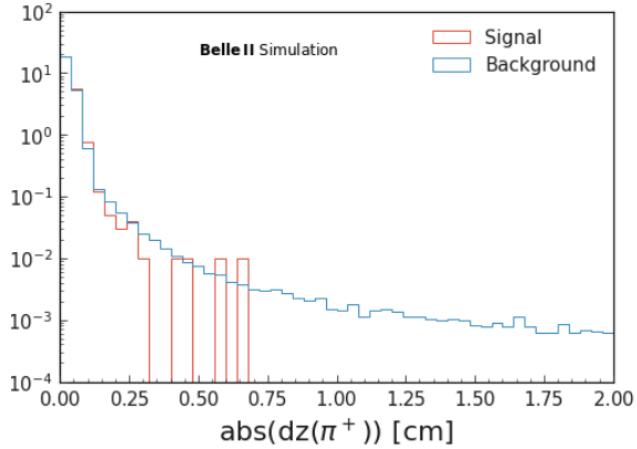
Variables used in FastBDT:

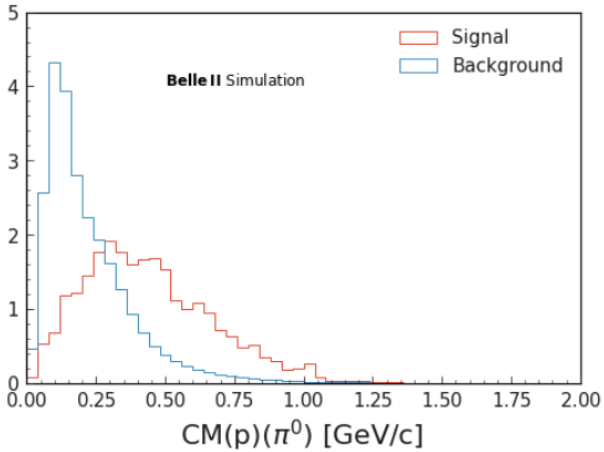
- flightDistance (Σ^+)
- clusterE9E21 (γ)
- CM momentum (π^0)
- dr and dz from IP ($\pi^\pm$)
- χ^2 of vertex fit

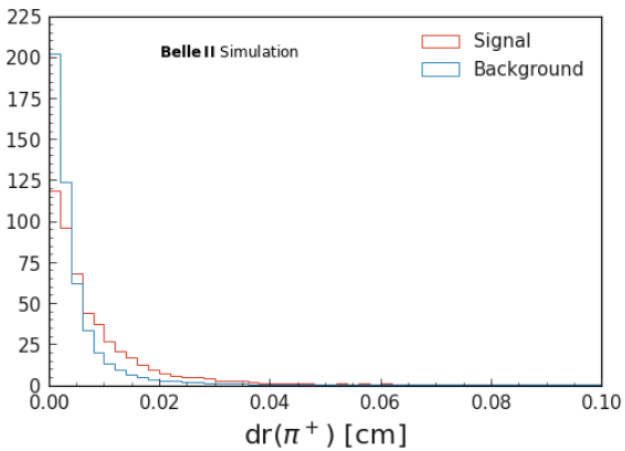
Variables Signal Background separation

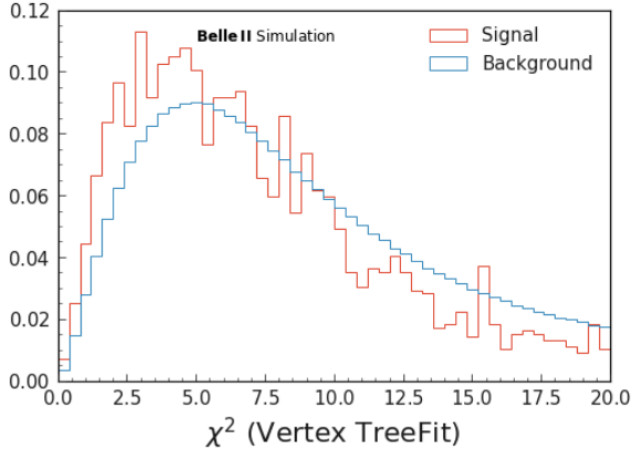




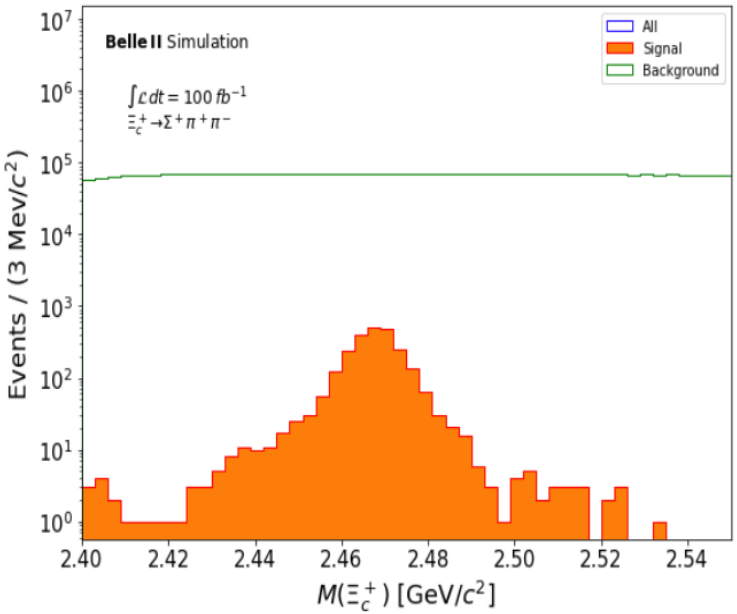


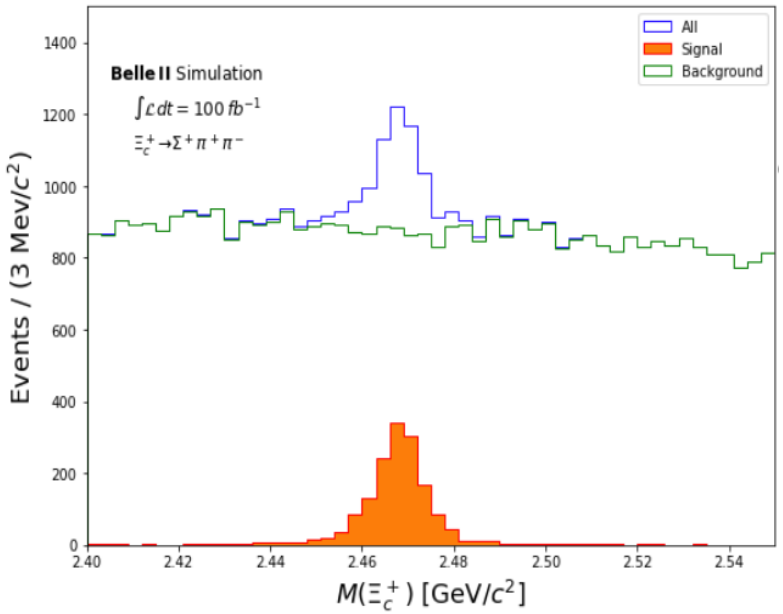






100 fb^{-1} MC14_ria sample: Before and After FastBDT



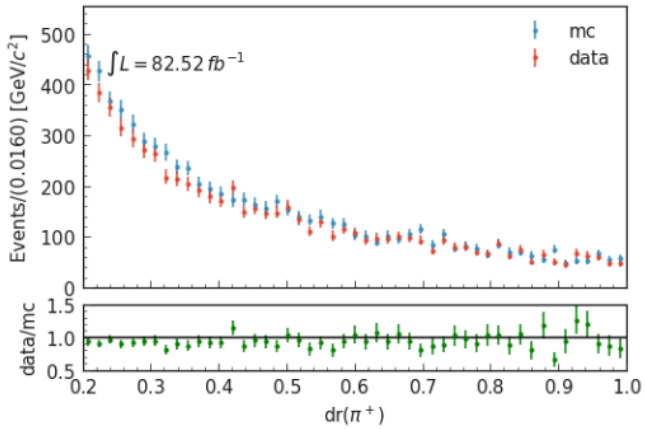


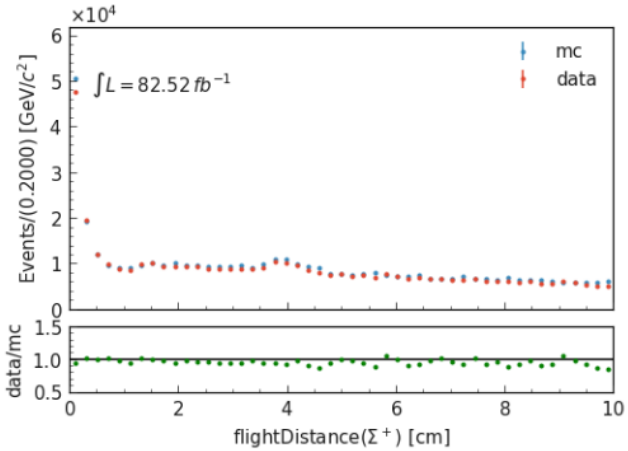
MVA > 0.36 (optimized FOM $\frac{S}{\sqrt{(S+B)}}$)

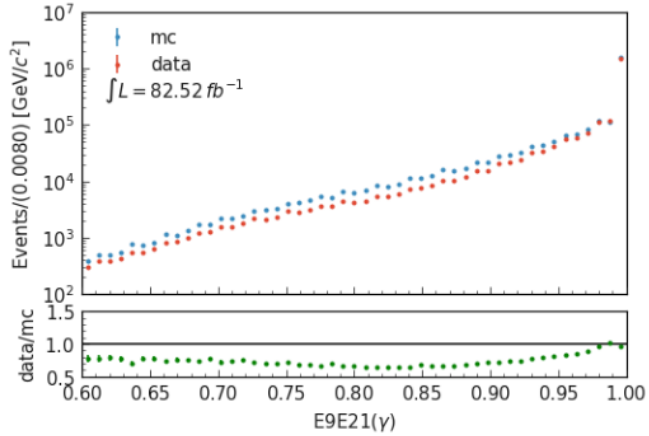
- Signal retention: 63%
- Background Rejection: 99%

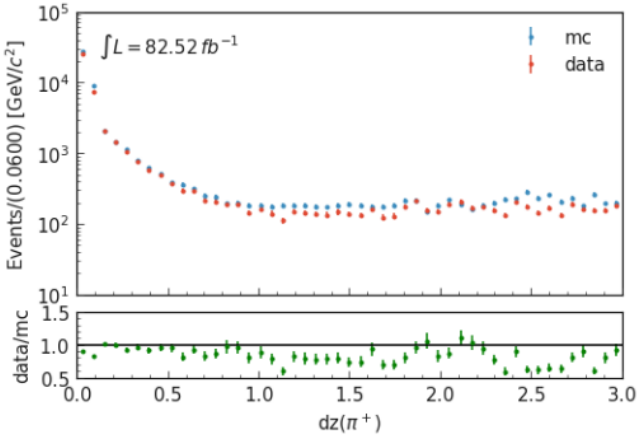
Control Channel : $\Lambda_c^+ \to \Sigma^+\pi^+\pi^-$

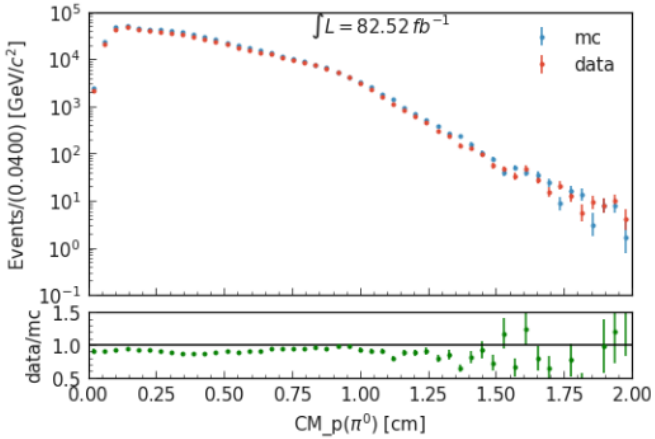
Look at Data - MC comparison. Helps Validate FastBDT.

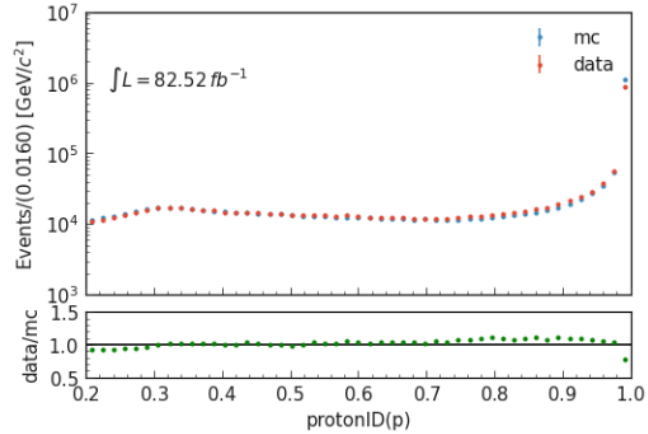




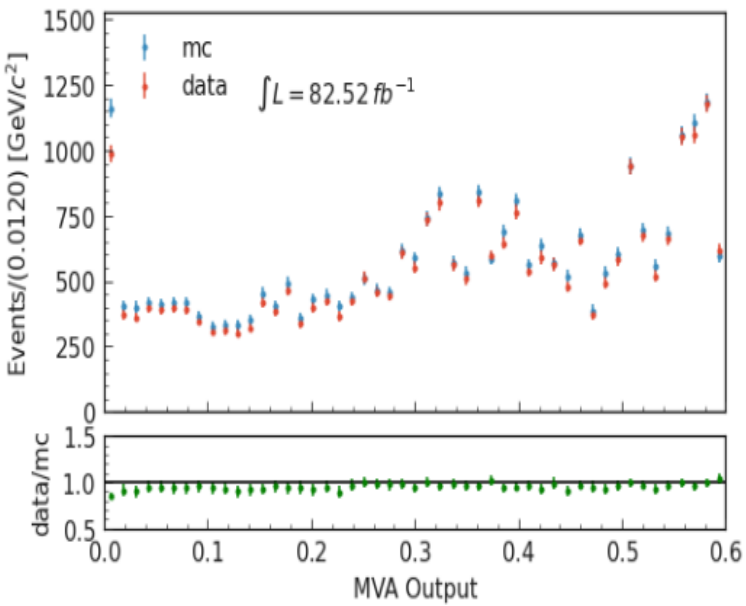


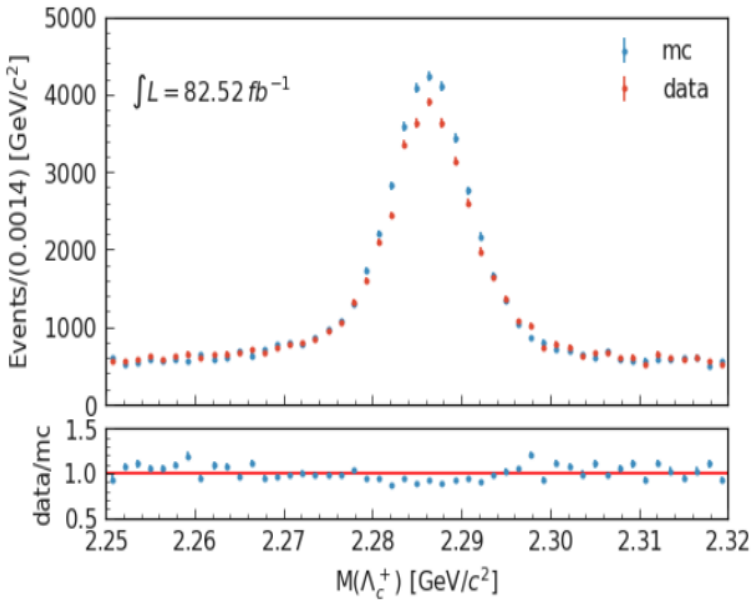






Control Channel : $\Lambda_c^+ \to \Sigma^+\pi^+\pi^-$





- MVA output Data/MC around 1.
- Mass plot after BDT cut , Data/MC around 1.
- Validates the Main channel.

Normalization channel: $\Xi_c^+ \to \Xi^-\pi^+\pi^+$

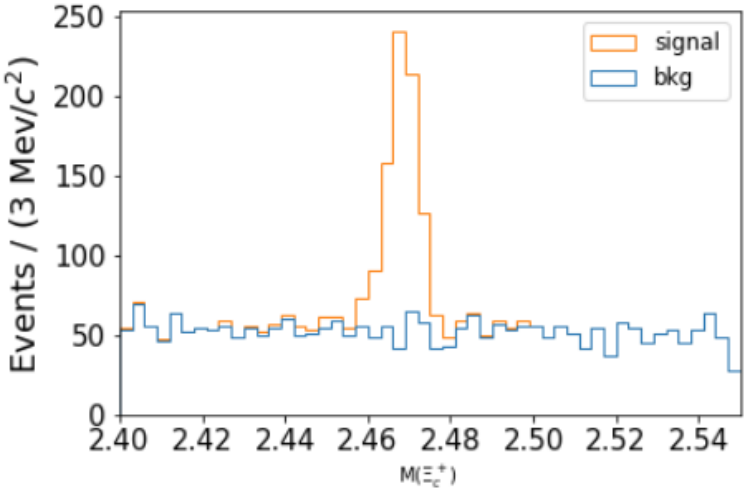
- Decay Chain: $\Xi_c^+ \to (\Xi^- \to (\Lambda^0 \to p\pi^-)\pi^-)\pi^+\pi^+$

Reconstruction

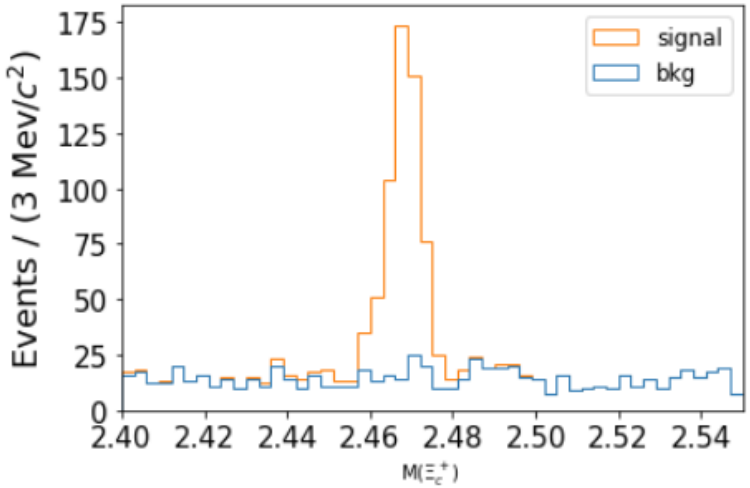
Description	Selection criteria
charged track $\pi^\pm$ p	thetaInCDCAcceptance nCDChits > 0
protonID (p)	> 0.2
Λ^0	$1.113 <$ M < 1.118 (2.5 σ)
Ξ^-	$1.314 <$ M < 1.329 (2.5 σ)
Ξ_c^+	useCMSFrame(p)$>= 2.5$ $2.4 <$ M < 2.55
vertex Fit	Mass constrain Ξ^- chiProb > 0.001

Normalization channel: $\Xi_c^+ \to \Xi^-\pi^+\pi^+$

Reconstruction:



After_cut:



cut:

- Loose cut on dr and dz for π (from Ξ_c^+) , protonID > 0.9
- flightDistance(Ξ^-) > 0.09

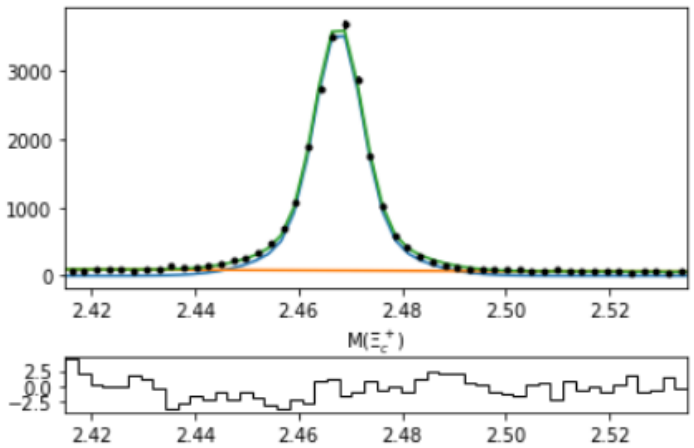
Signal Retention: 82 %
Bkg Rejection: 73 %

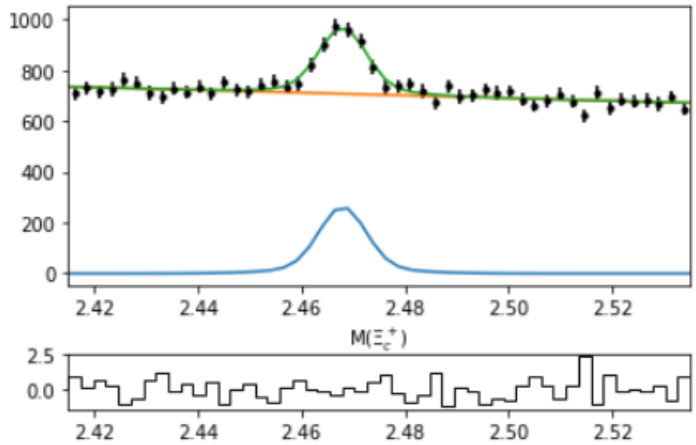
Fit: $\Xi_c^+ \to \Sigma^+\pi^+\pi^-$

Double gaussian + 1st order polynomial

Signal MC (254000 events)

100 fb^{-1} MC14_ria





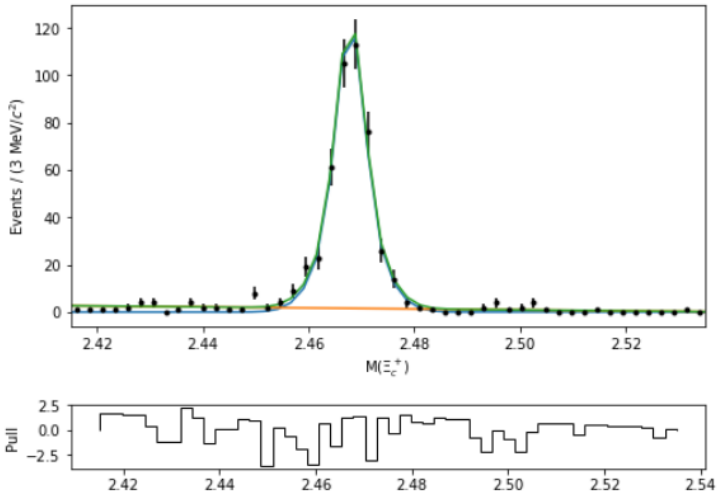
name	value	minuit_hesse
sig_yield	21130	+/- 1.7e+02
bkg_yield	3848	+/- 1.1e+02
fg1	0.3355	+/- 0.021
mu1	2.468	+/- 4.5e-05
s1	0.01112	+/- 0.00044
s2	0.00447	+/- 9e-05
a	-0.2483	+/- 0.03

name	value	minuit_hesse
sig_yield	1386	+/- 1.6e+02
bkg_yield	35190	+/- 2.4e+02
fg1	0.1936	+/- 0.16
mu1	2.468	+/- 0.00039
a	-0.04524	+/- 0.0094

Fit: $\Xi_c^+ \to \Xi^-\pi^+\pi^+$

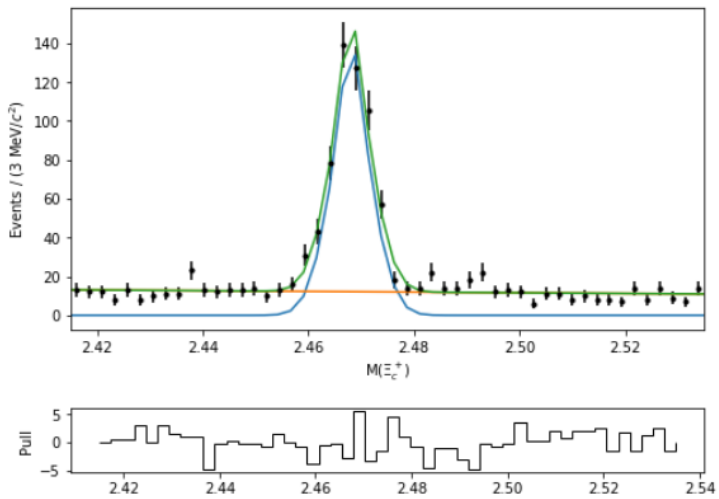
Double gaussian + 1st order polynomial

Signal MC (45000 events)



name	value	minuit_hesse
sig_yield	437.3	+/- 22
bkg_yield	70.59	+/- 10
fg1	0.5204	+/- 0.18
mu1	2.468	+/- 0.00019
s1	0.005178	+/- 0.00077
s2	0.002504	+/- 0.00041
a	-0.8811	+/- 0.18

100 fb^{-1} MC14_ria



name	value	minuit_hesse
sig_yield	511.6	+/- 26
bkg_yield	601.4	+/- 28
fg1	0.8738	+/- 0.12
mu1	2.468	+/- 0.00021
s1	0.004156	+/- 0.00035
s2	0.001708	+/- 0.00079
a	-0.08923	+/- 0.074

BF values:

Decay mode	MC type	fit	MC truth	efficiency (truth matched)
$\Xi_c^+ \to \Sigma^+\pi\pi$	generic MC14ria 100/fb	1386 ± 160	1568	N/A
$\Xi_c^+ \to \Sigma^+\pi\pi$	SignalMC (254000)	21130 ± 170	20421	0.083 ± 0.0007 (0.0803)
$\Xi_c^+ \to \Xi^-\pi\pi$	generic MC14ria 100/fb	512 ± 26	537	N/A
$\Xi_c^+ \to \Xi^-\pi\pi$	SignalMC (45000)	438 ± 22	455	0.0097 ± 0.0005 (0.0101)

$$\frac{B(\Xi_c^+ \to \Sigma^+\pi^+\pi^-)}{B(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = \frac{N(\Xi_c^+ \to \Sigma^+\pi^+\pi^-)}{\epsilon_1 B(\Sigma^+ \to p\pi^0)} \frac{\epsilon_2 B(\Xi^- \to \Lambda^0\pi^-) B(\Lambda^0 \to p\pi^-)}{N(\Xi_c^+ \to \Xi^- \pi^+\pi^+)}$$

BF	Belle2dec	fit	MC truth
$\frac{BF(\Xi_c^+ \to \Sigma^+\pi\pi)}{BF(\Xi_c^+ \to \Xi^-\pi\pi)}$	0.479	0.40 ± 0.05	0.46

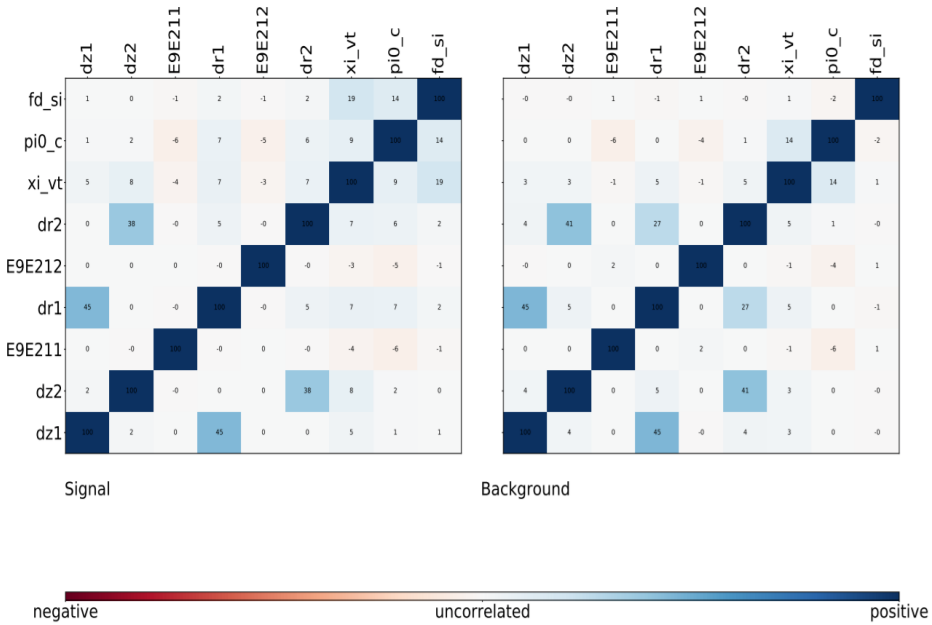
Conclusion

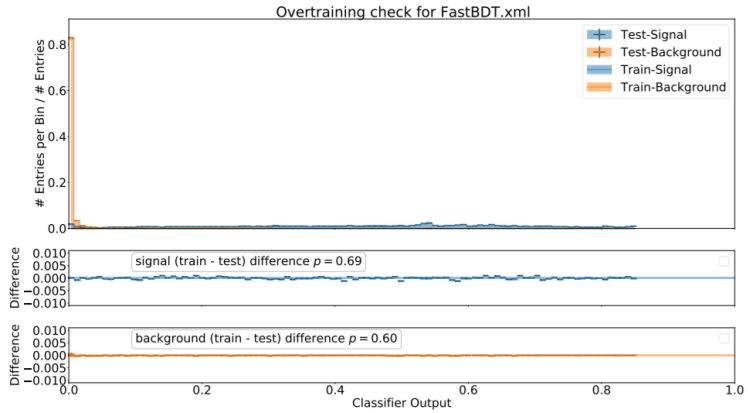
- MC study at Belle II is looking promising with FastBDT
- validated with control channel.
- start on the systematic study.
- Look at anti-decay for A_{CP} measurement.

Back UP

Correlation and over-training check

- Variables are not correlated
- Over-training check looks good.

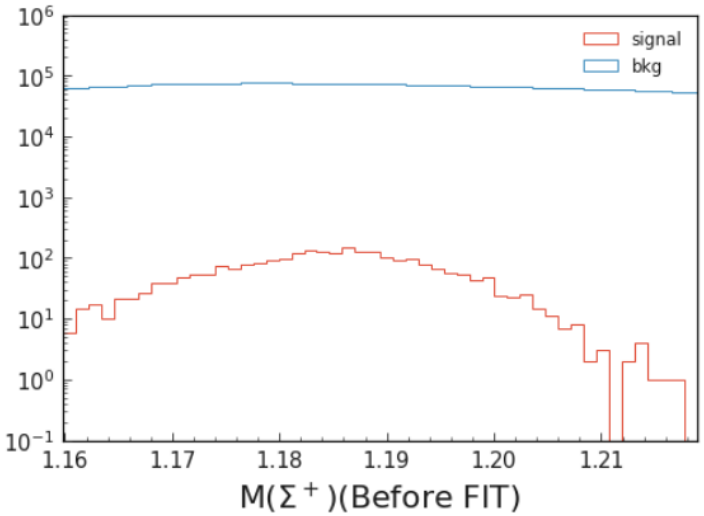




Σ^+ Before Fit)

$\Xi_c^+ \to \Sigma^+\pi^+\pi^-$

Before MVA



After MVA (> 0.36)