Measurement of the Λ_c^+ lifetime at Belle II

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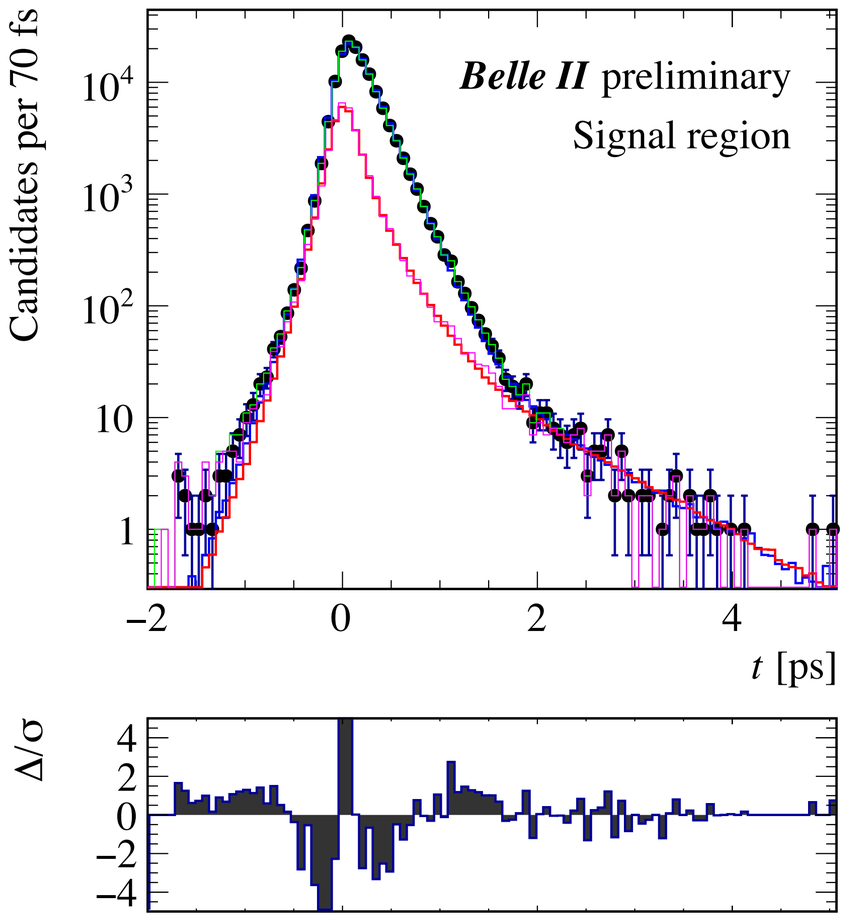
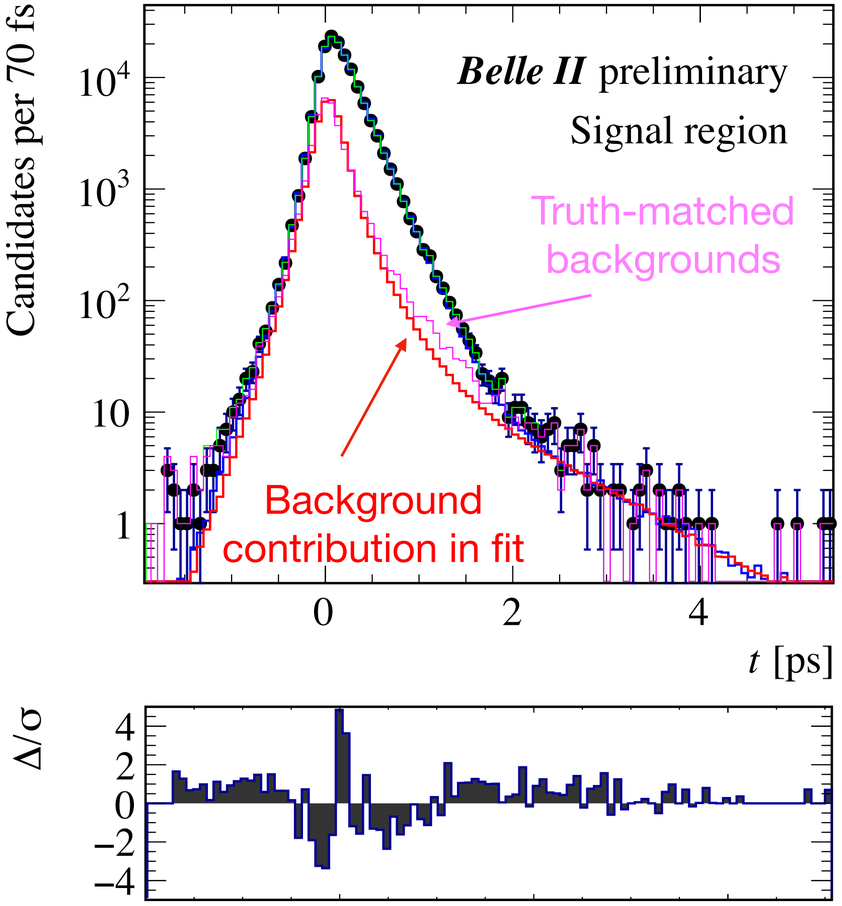
Status

- Some instability in the fit due to the remaining charm backgrounds
- Proposals:
  - Try to further reduce backgrounds
  - Tighten mass range
  - Revisit PID cuts
  - Tighten chiProb cut
  - Restrict proton momentum to “good region”
- Updating to:
  - MC14ri_a (200/fb)
  - proc12 (exp 7-12)



Sideband events included in likelihood, float all parameters

$\tau = 0.192 \pm 0.001$

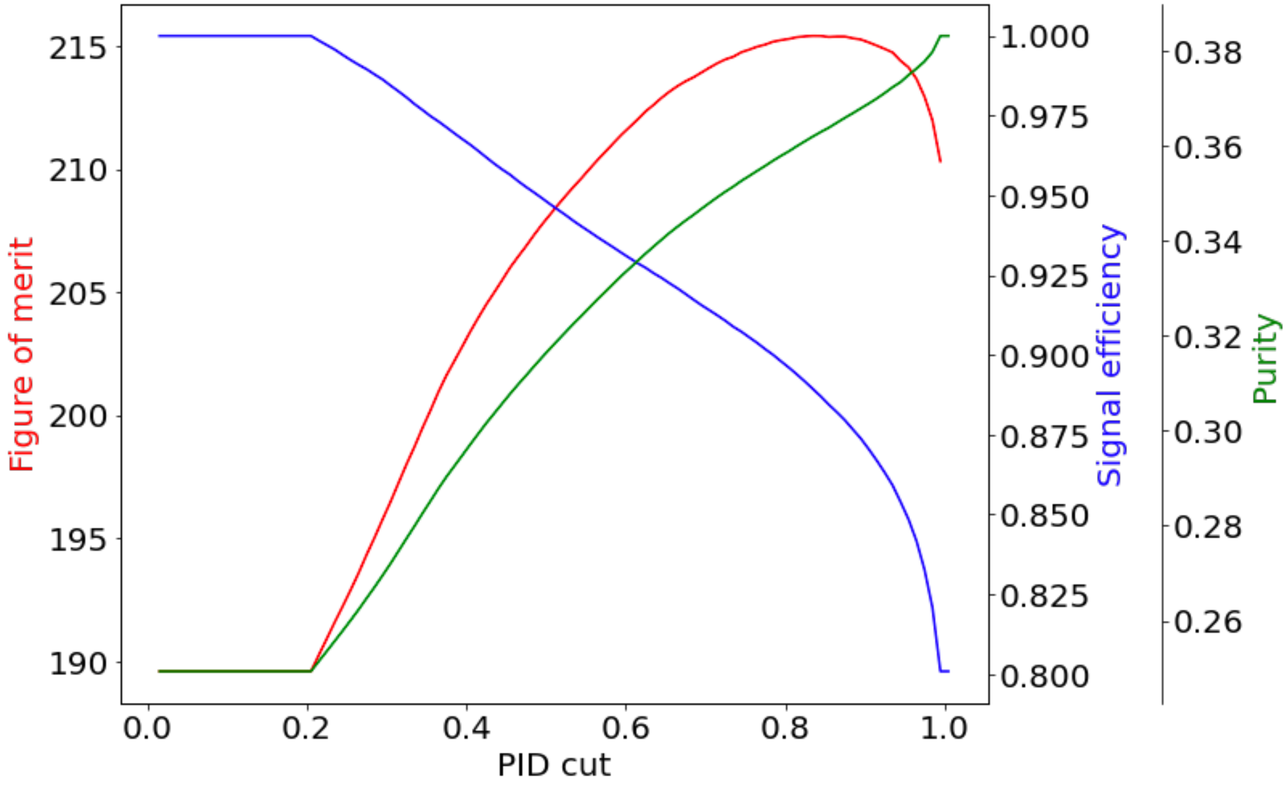


Only signal region events included in likelihood, float all parameters

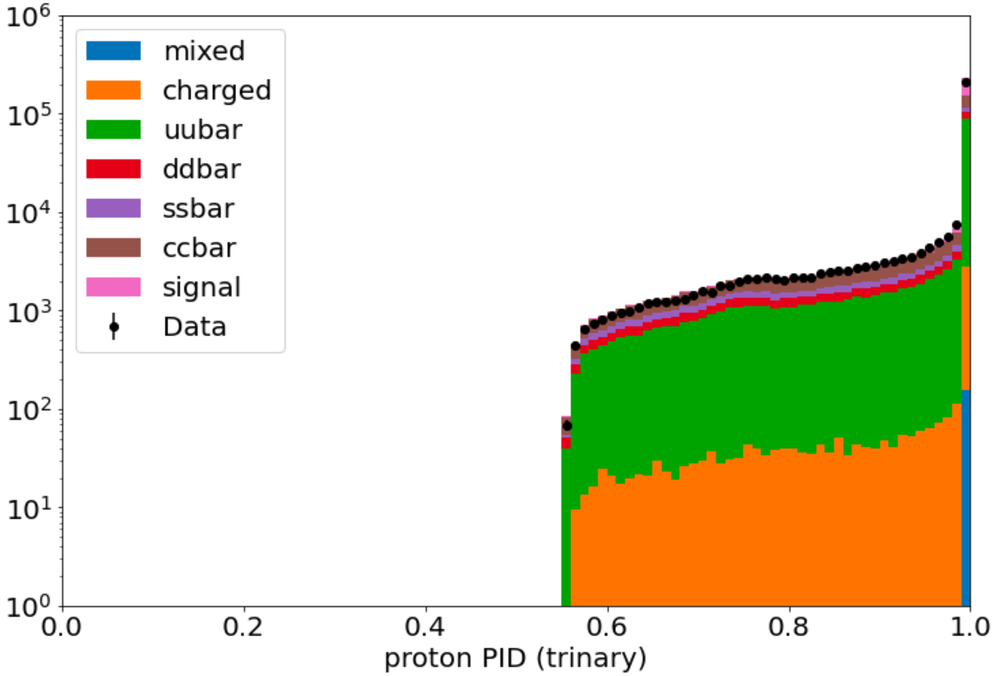
$\tau = 0.201 \pm 0.001$

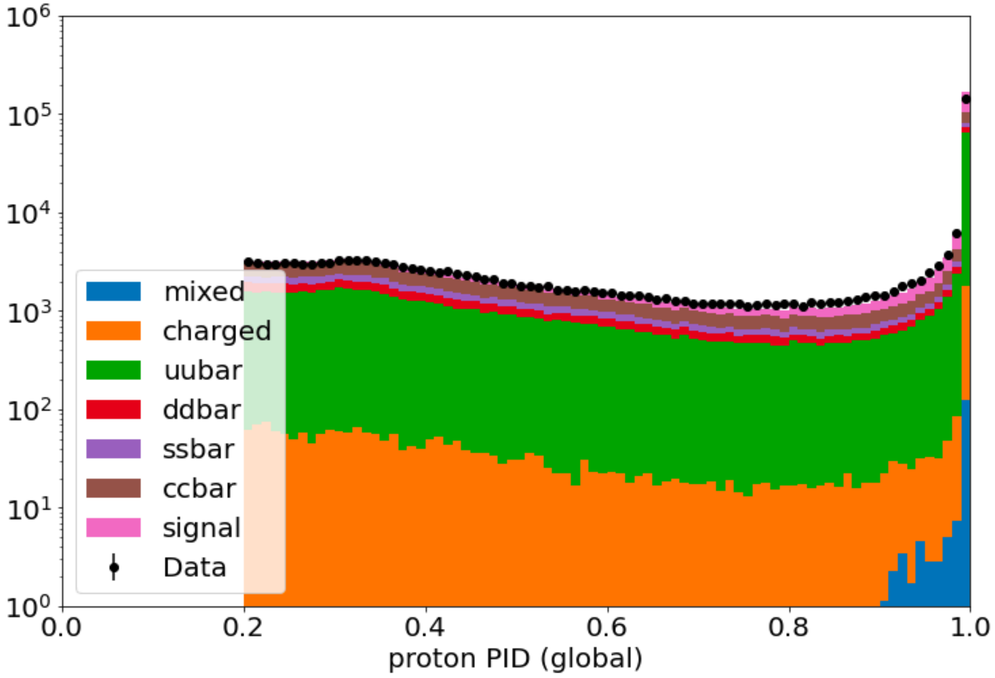
Revisiting PID

- Reasonably good data/MC agreement for all variables
- No FOM max for trinary proton PID



Proton global (FOM max at 0.8)





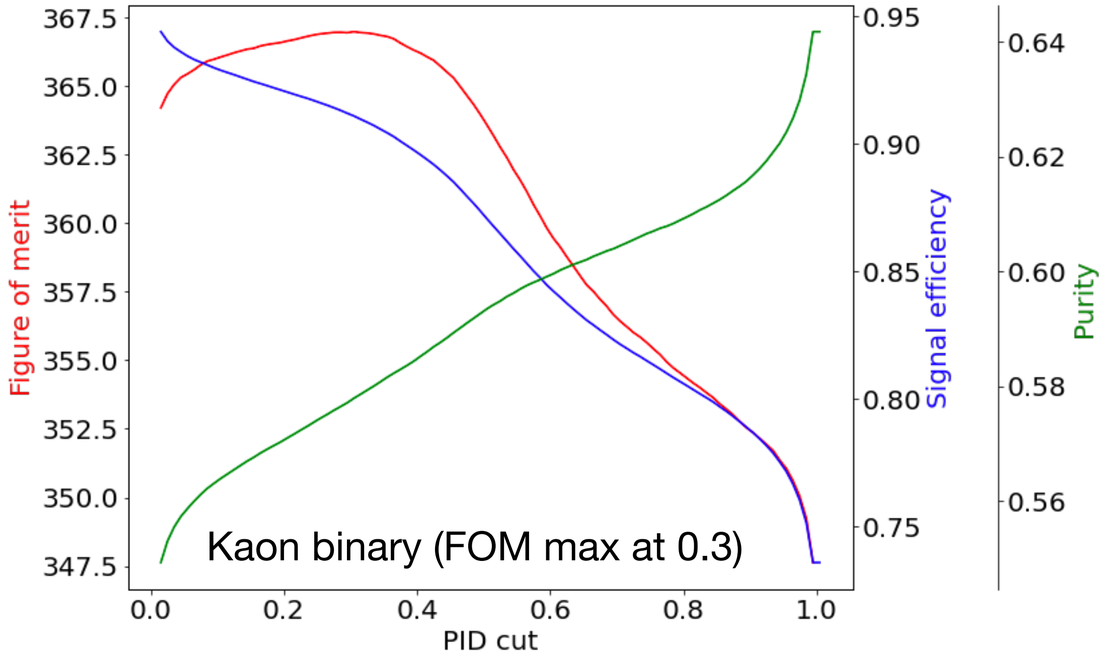
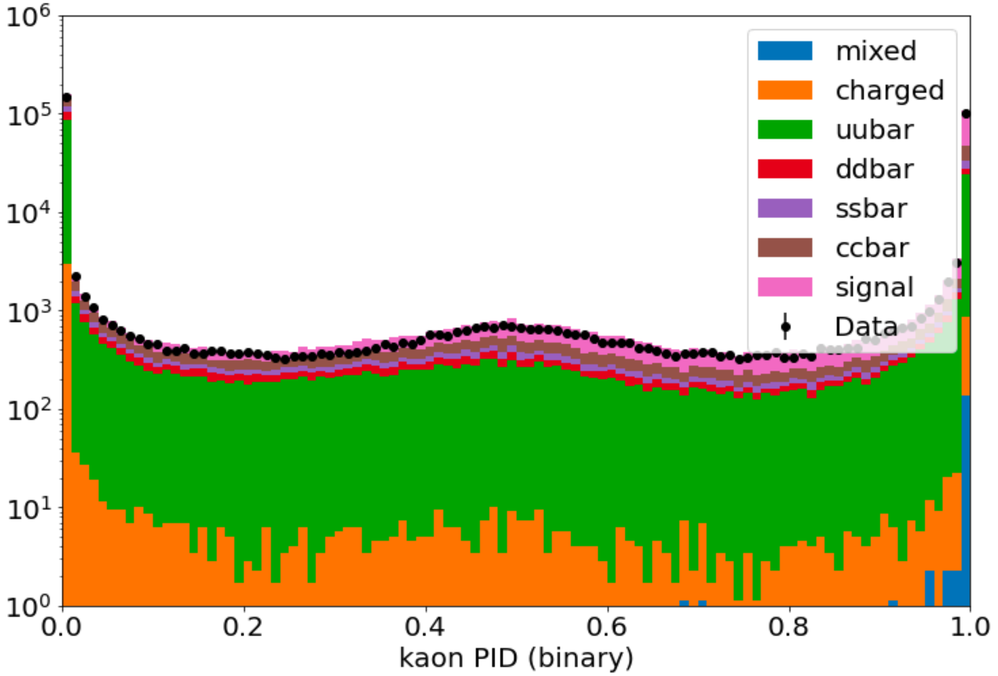


Figure of merit
Signal efficiency
Purity
PID cut
Kaon binary (FOM max at 0.3)


mixed
charged
uubar
ddbar
ssbar
ccbar
signal
Data
kaon PID (binary)

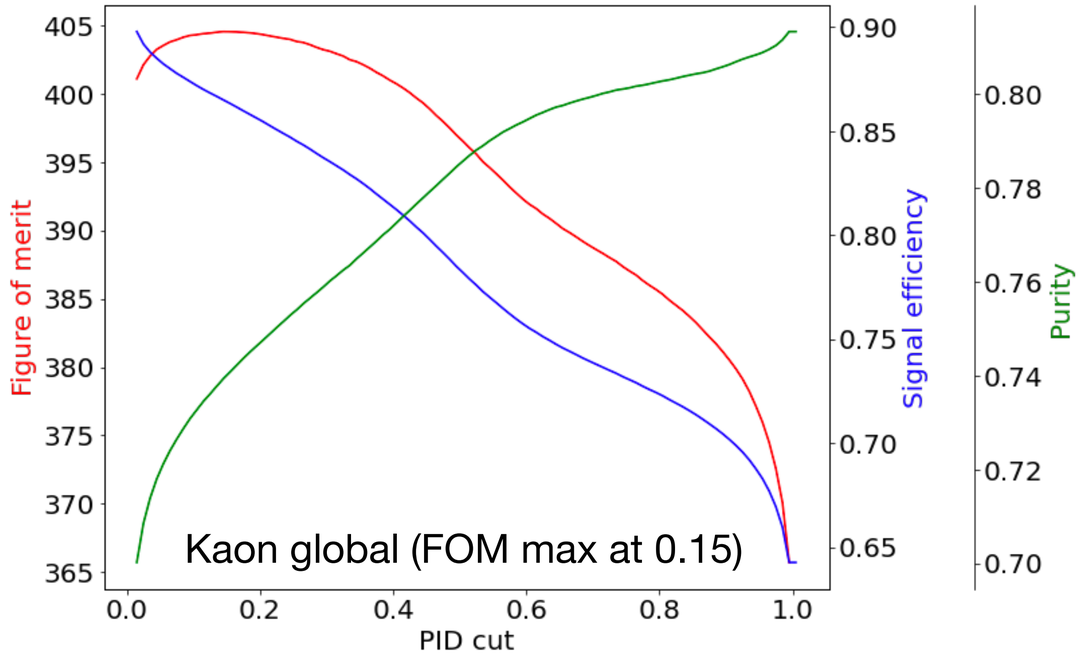
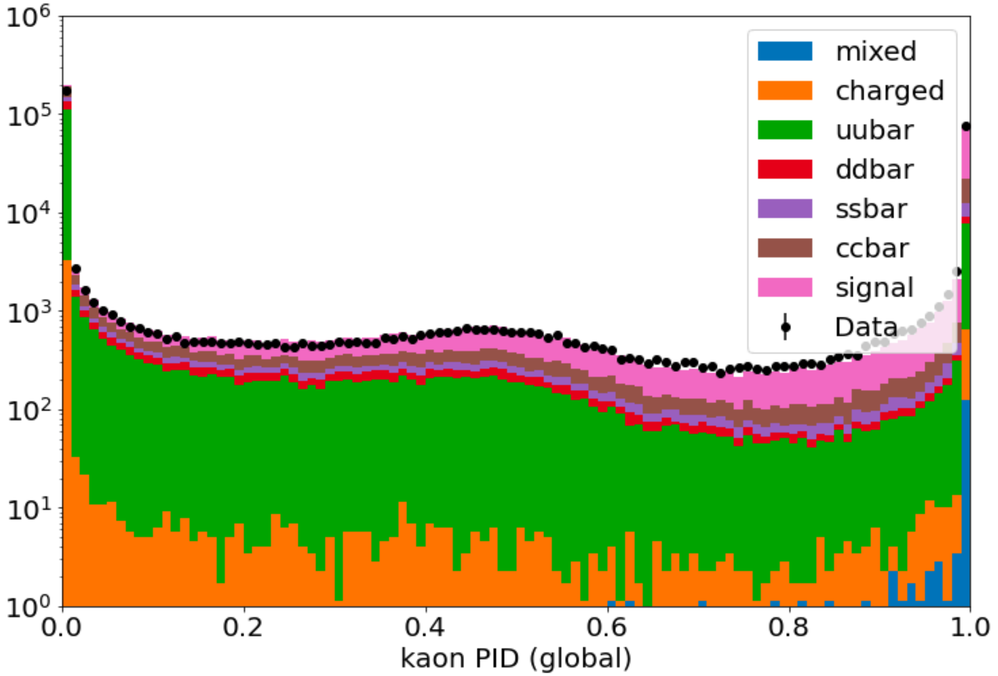
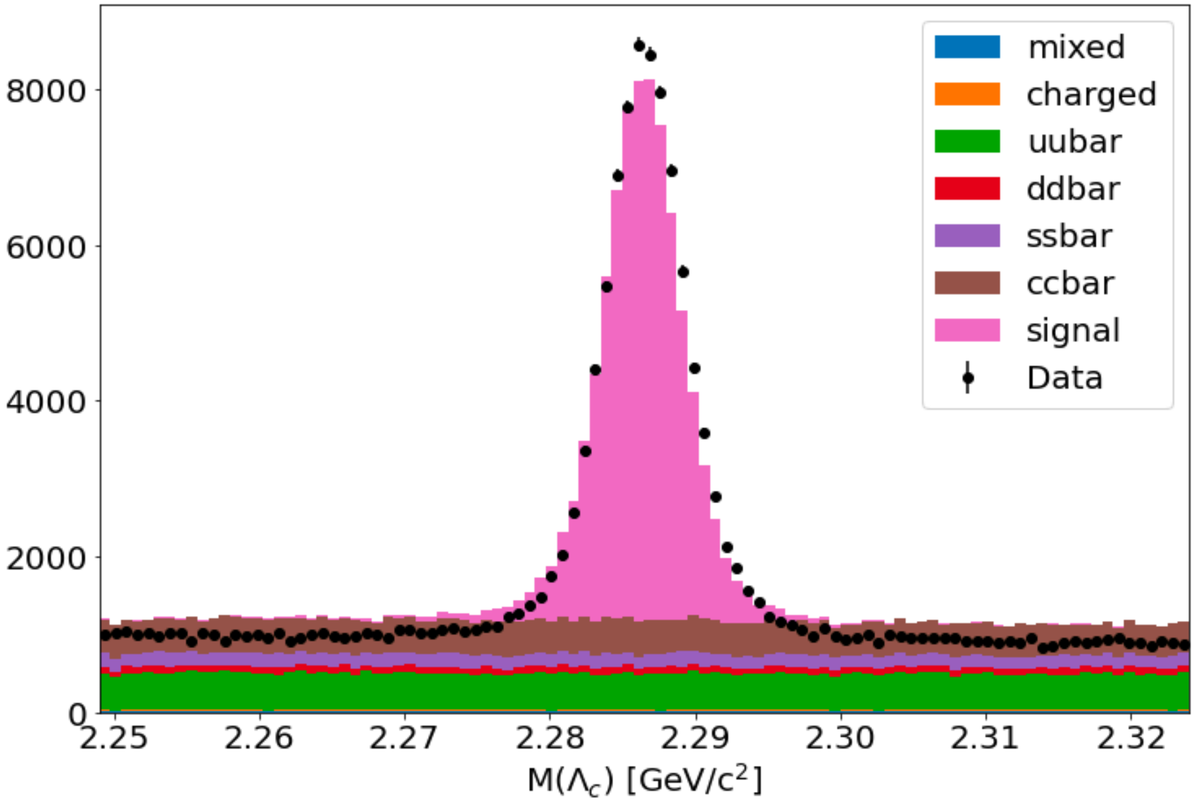


Figure of merit
Signal efficiency
Purity
PID cut
Kaon global (FOM max at 0.15)


mixed
charged
uubar
ddbar
ssbar
ccbar
signal
Data
kaon PID (global)

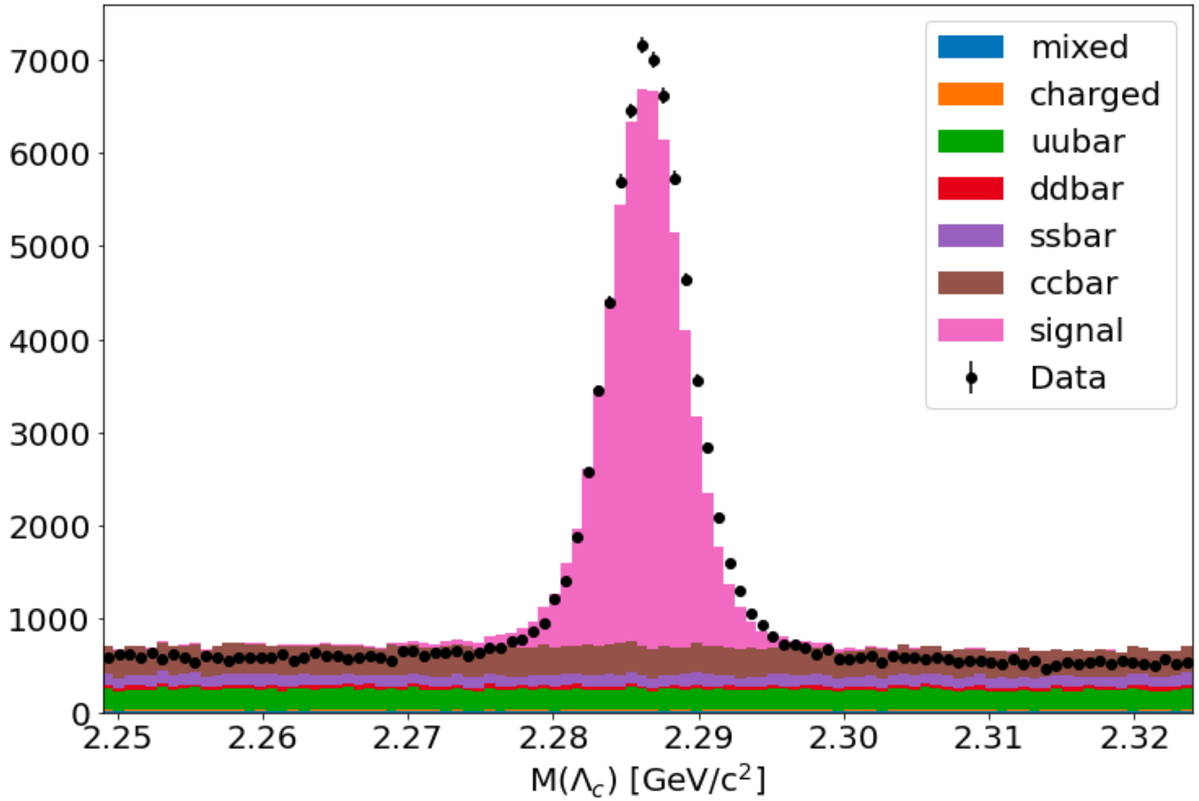
Tightening PID cuts

Kaon PID (global) > 0.15, proton PID (global) > 0.8



Purity in signal region ~73%

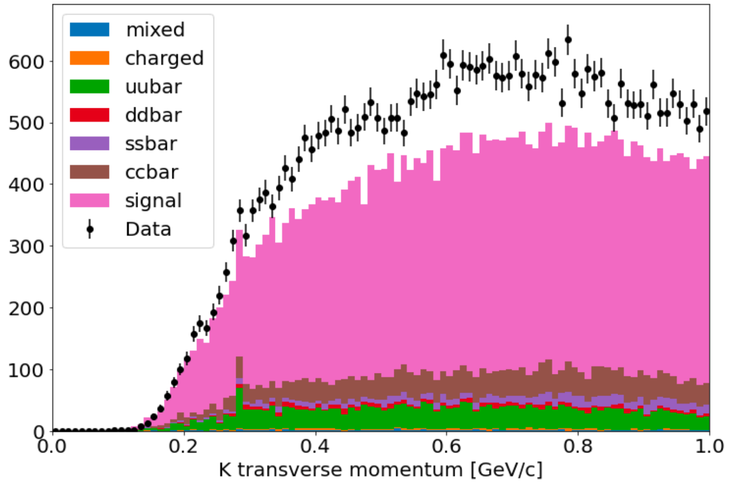
Kaon PID (global) > 0.6, proton PID (global) > 0.9

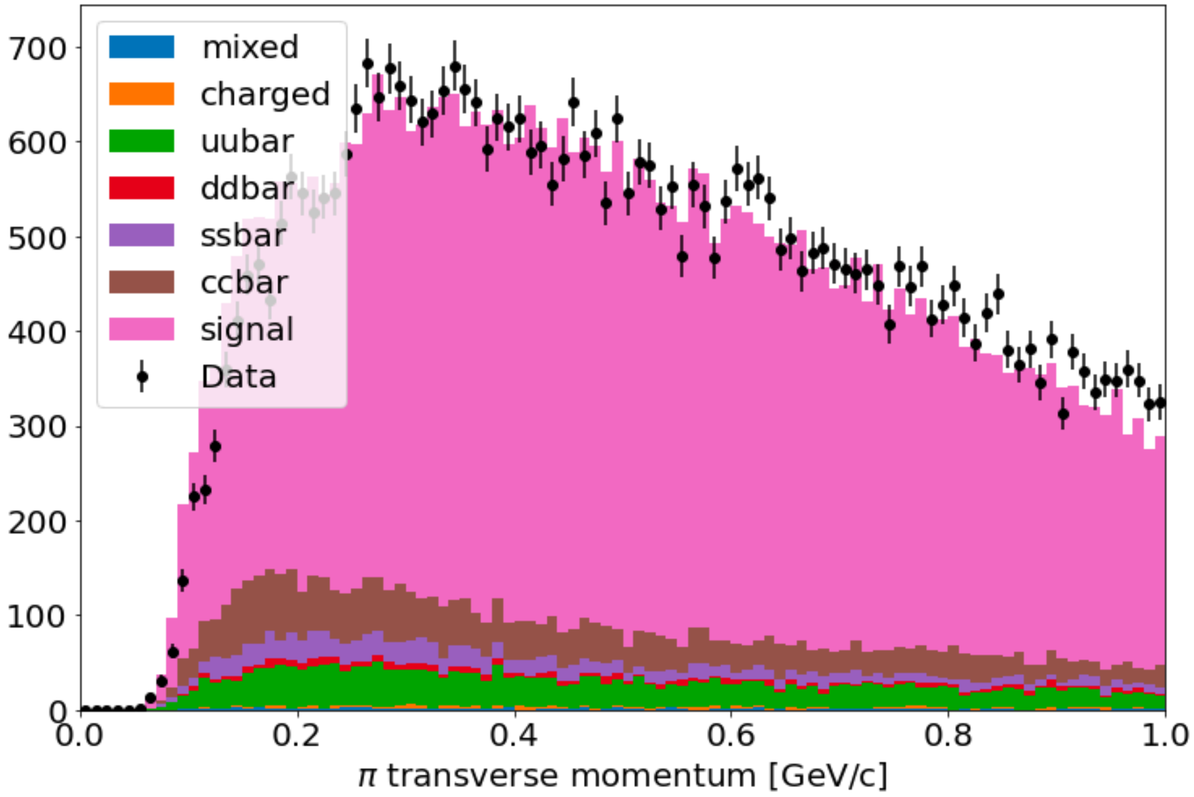


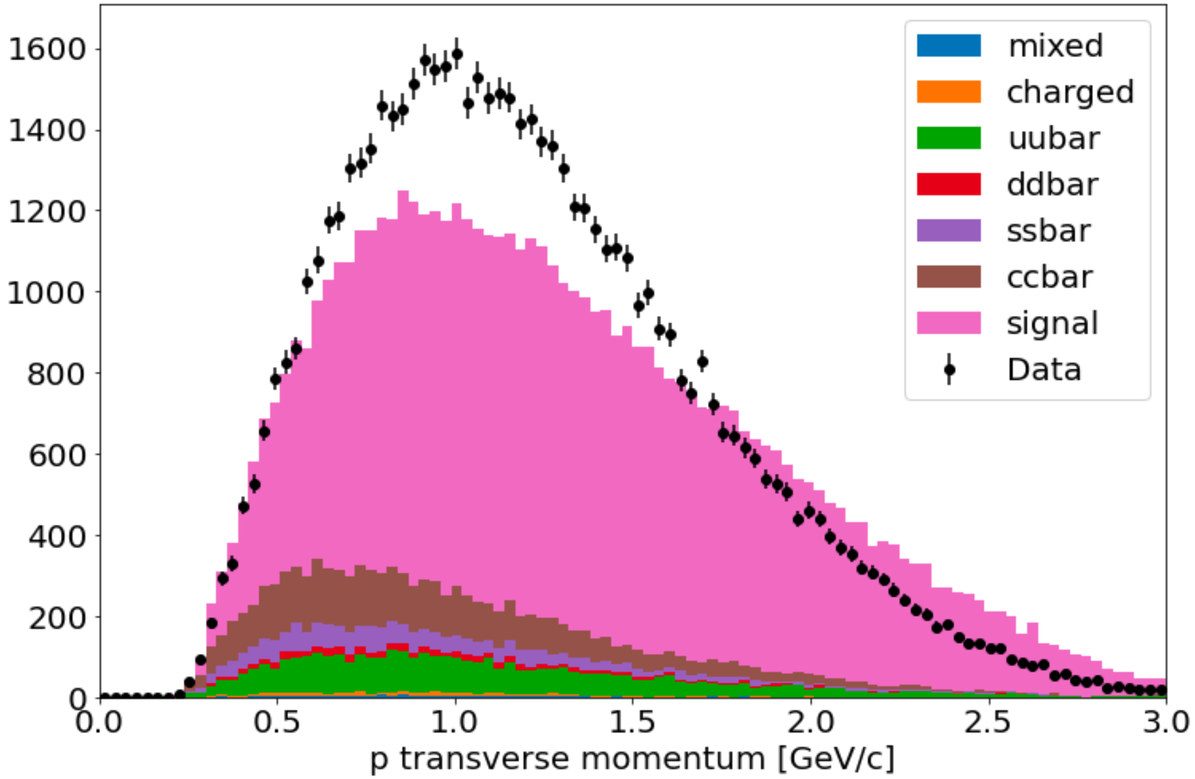
Purity in signal region ~79%

Track momentum cuts

- Remove charm backgrounds with restrictions of transverse momentum of pion and proton tracks
  - $p_t(\pi) > 0.3, p_t(p) > 0.8$

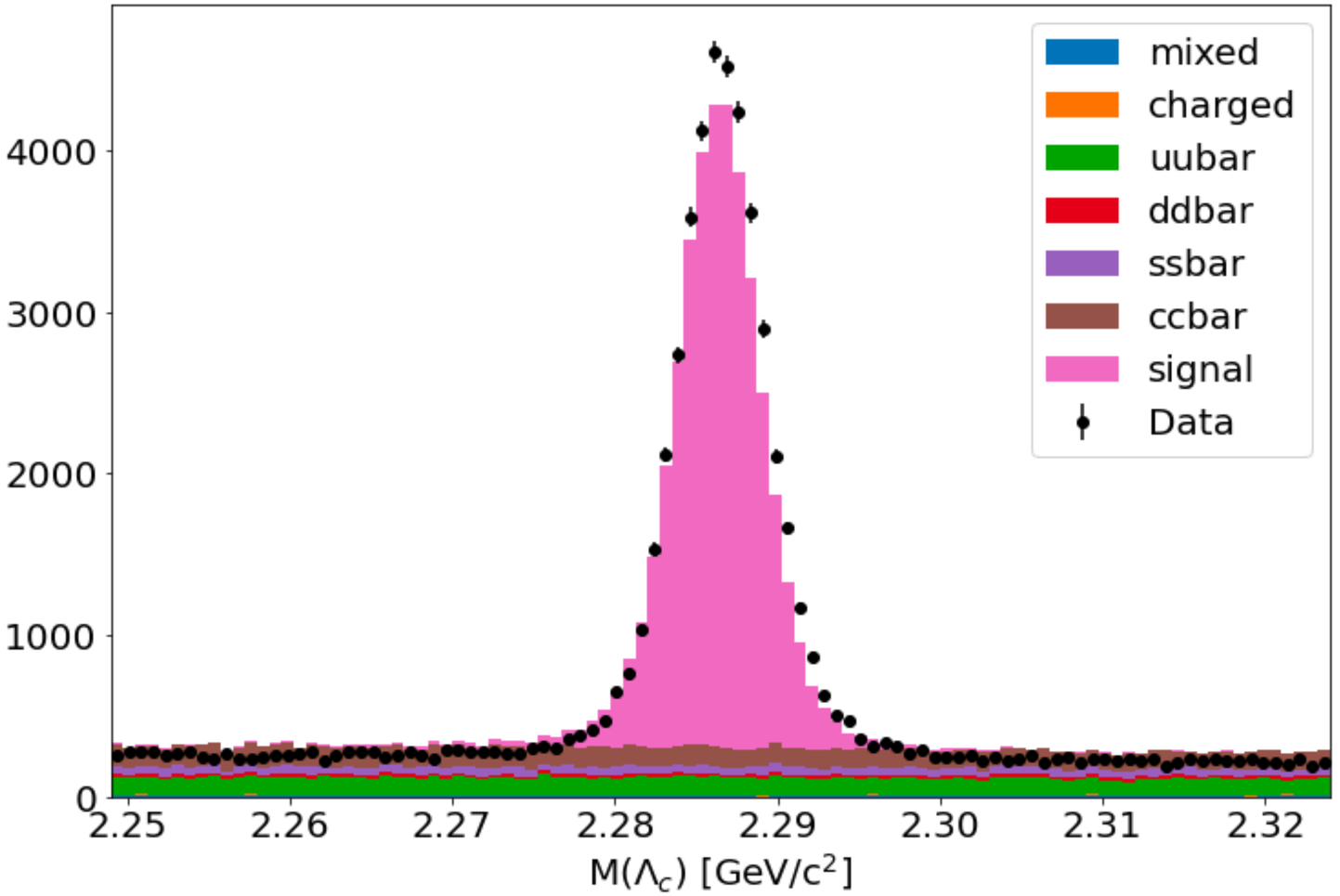






Event selection criteria

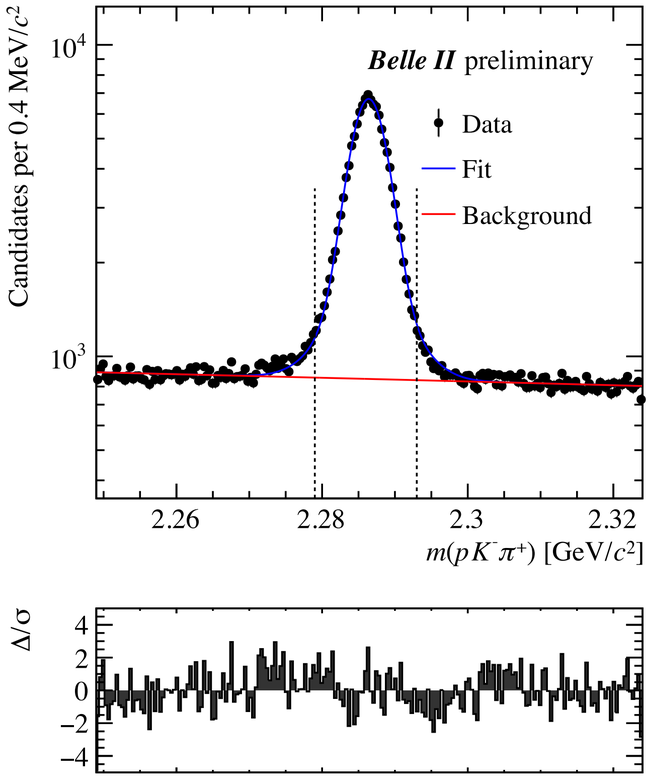
- Tracks must be in the CDC acceptance and have at least 20 CDC hits, at least one PXD hit, and the first SVD hit layer > 2
- $d_0 < 0.5$ cm, $|z_0| < 2$ cm (standard track cuts)
- Vertex fit (TreeFitter with IP constraint) conf_level > 0.01
- Λ_c CM momentum > 2.5 GeV
- Proton PID (global) > 0.9
- Kaon PID (global) > 0.6
- Remove charm backgrounds by cutting on M(pKπ) with pion hypothesis for proton track
- $p_t(\pi) > 0.3$, $p_t(p) > 0.8$



Purity in signal region ~85%

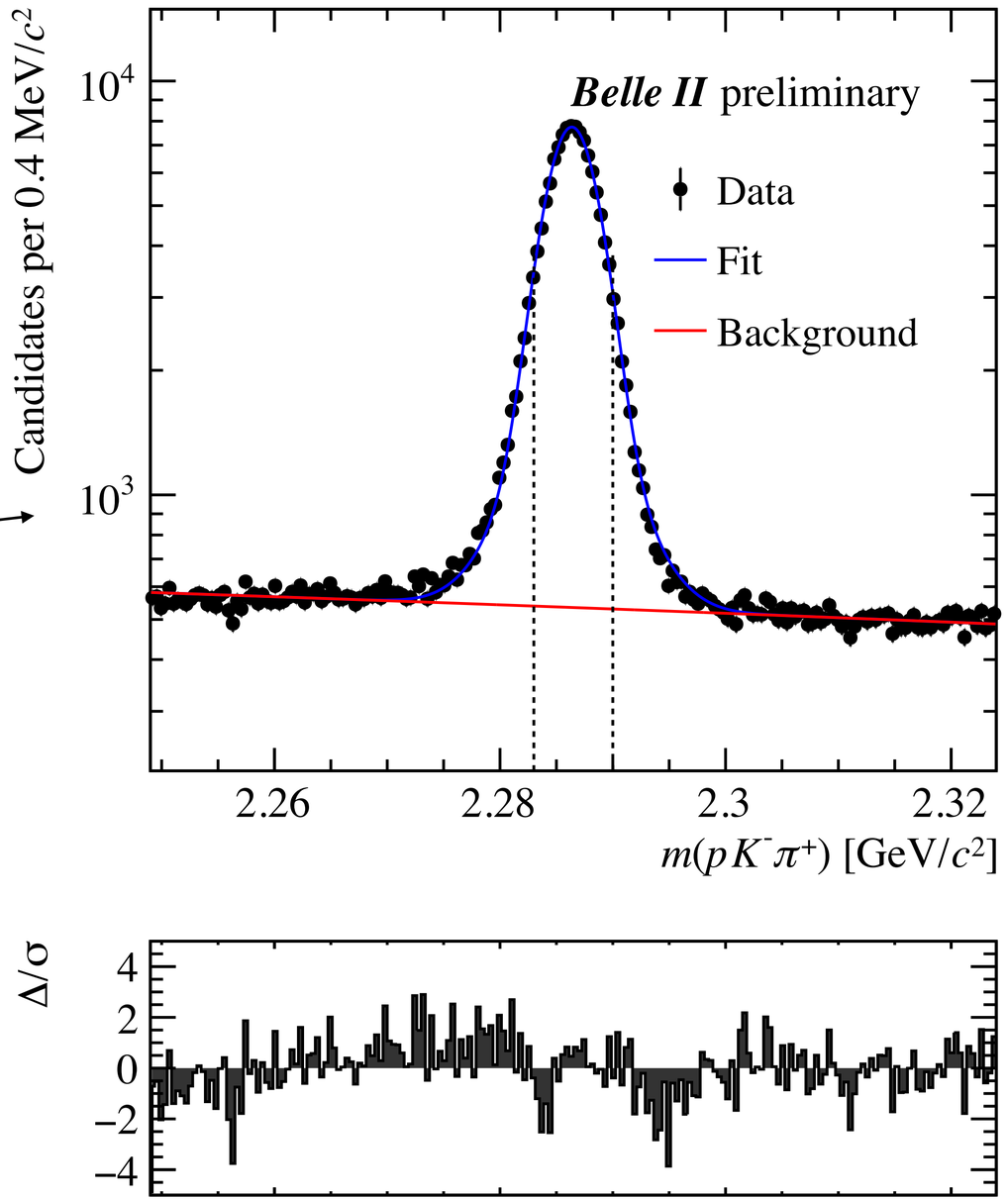
Invariant mass fit

- Fit to invariant mass spectrum
  - Extract background ratio in signal region
  - Add as Gaussian constraint (penalty) in lifetime fit



New selection:
Background fraction in signal region [2.283000,2.290000] =
0.090193 +- 0.000101

Old selection:
Background fraction in signal region [2.279000,2.293000] =
0.258031 +- 0.000106

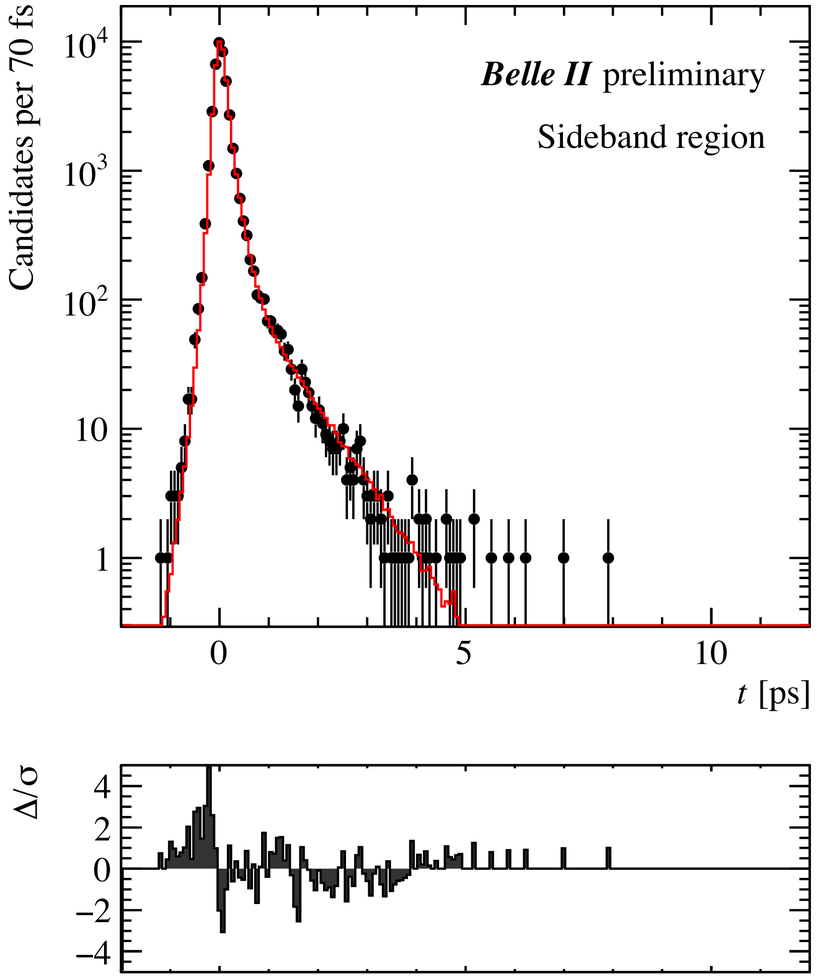


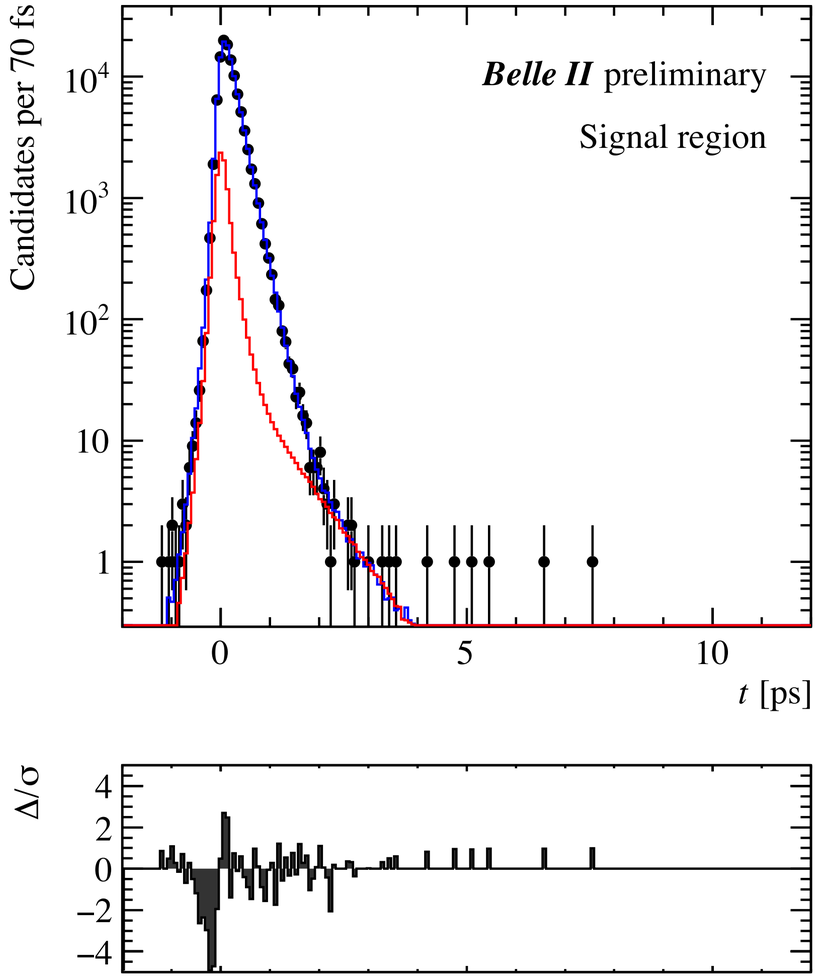
Double-Gaussian resolution: $R(t-t_{true}\,|\,\sigma_t,\mu,f,s,s_{wide}) = f\;G(t-t_{true}\,|\,\mu,s,\sigma_t) + (1-f)G(t-t_{true}\,|\,\mu,s_{wide},\sigma_t)$

Lifetime fit results

$$(1-f_{bkg})\times pdf(t,\sigma_t\,|\,\tau,\mu,f,s,s_{wide}) + f_{bkg}\times pdf(bkg)$$

$$pdf(bkg) = f_{bl}[f_{\tau 1}pdf(t,\sigma_t\,|\,\tau_{bkg1},\mu_{bkg},f,s,s_{wide}) - (1-f_{\tau 1})pdf(t,\sigma_t\,|\,\tau_{bkg2},\mu_{bkg},f,s,s_{wide})] + (1-f_{bl})R(\sigma,\mu_{bkg},f,s,s_{wide})pdf(\sigma_t)$$





$\tau_{true} = 0.200$

$\tau = 0.1995 \pm 0.0009$

$\mu = 0.0016 \pm 0.0006$

$f = 0.979 \pm 0.005$

$s = 1.136 \pm 0.008$

$s_{wide} = 2.665 \pm 0.161$

$f_{bkg} = 0.0902 \pm 0.0001$

$f_{bl} = 0.314 \pm 0.009$

$f_{\tau_1} = 0.835 \pm 0.009$

$\tau_{bkg1} = 0.155 \pm 0.005$

$\tau_{bkg2} = 0.763 \pm 0.026$

LHCB, $\tau = 203.5 \pm 1.0 \pm 1.3 \pm 1.4\ fs$

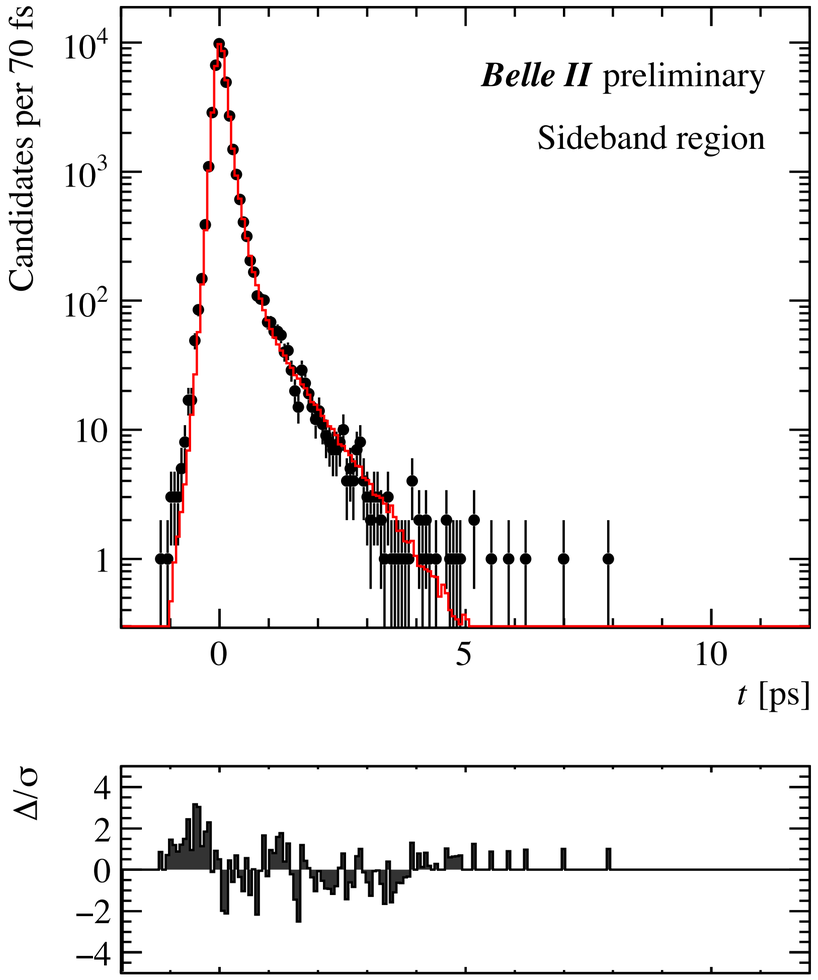
CLEO, $\tau = 179.6 \pm 6.9 \pm 4.4\ fs$

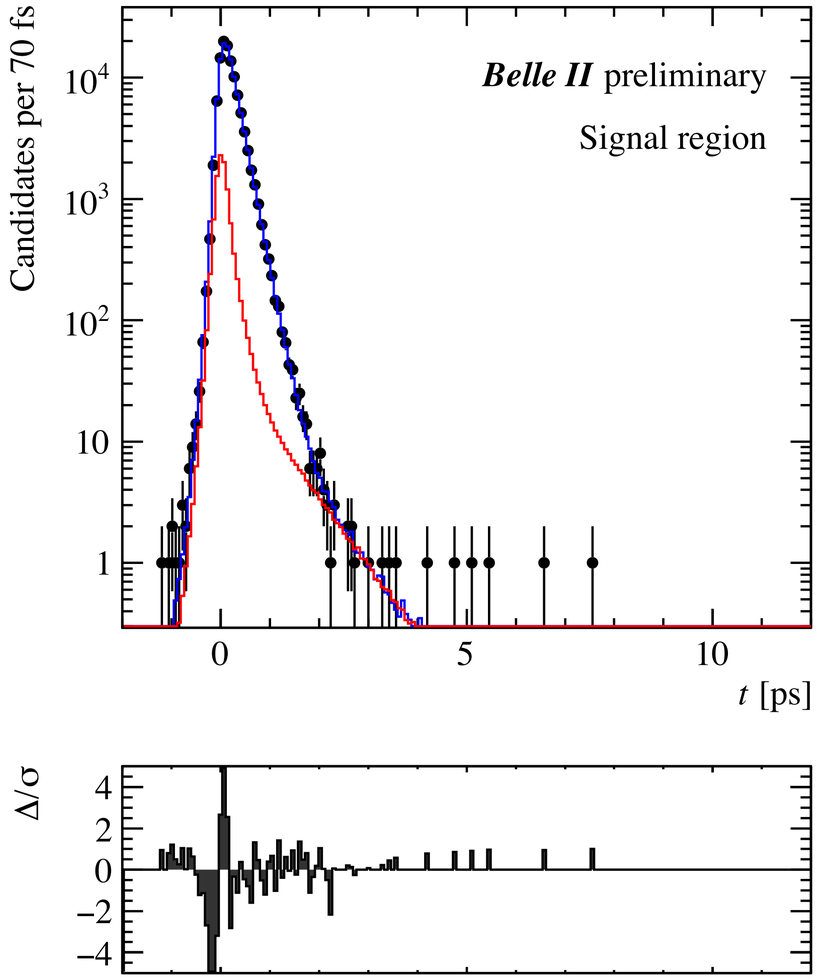
Single-Gaussian resolution: $R(t - t_{true} \,|\, \sigma_t, \mu, f, s, s_{wide}) = G(t - t_{true} \,|\, \mu, s, \sigma_t)$

Lifetime fit results

$$(1 - f_{bkg}) \times pdf(t, \sigma_t \,|\, \tau, \mu, s) + f_{bkg} \times pdf(bkg)$$

$$pdf(bkg) = f_{bl}[f_{\tau 1} pdf(t, \sigma_t \,|\, \tau_{bkg1}, \mu_{bkg}, s) - (1 - f_{\tau 1}) pdf(t, \sigma_t \,|\, \tau_{bkg2}, \mu_{bkg}, s)] + (1 - f_{bl}) R(\sigma, \mu_{bkg}, s) pdf(\sigma_t)$$





$\tau_{true} = 0.200$

$\tau = 0.1979 \pm 0.0007$

$\mu = 0.0033 \pm 0.0004$

$s = 1.200 \pm 0.004$

$f_{bkg} = 0.0902 \pm 0.0001$

$f_{bl} = 0.287 \pm 0.007$

$f_{\tau_1} = 0.827 \pm 0.011$

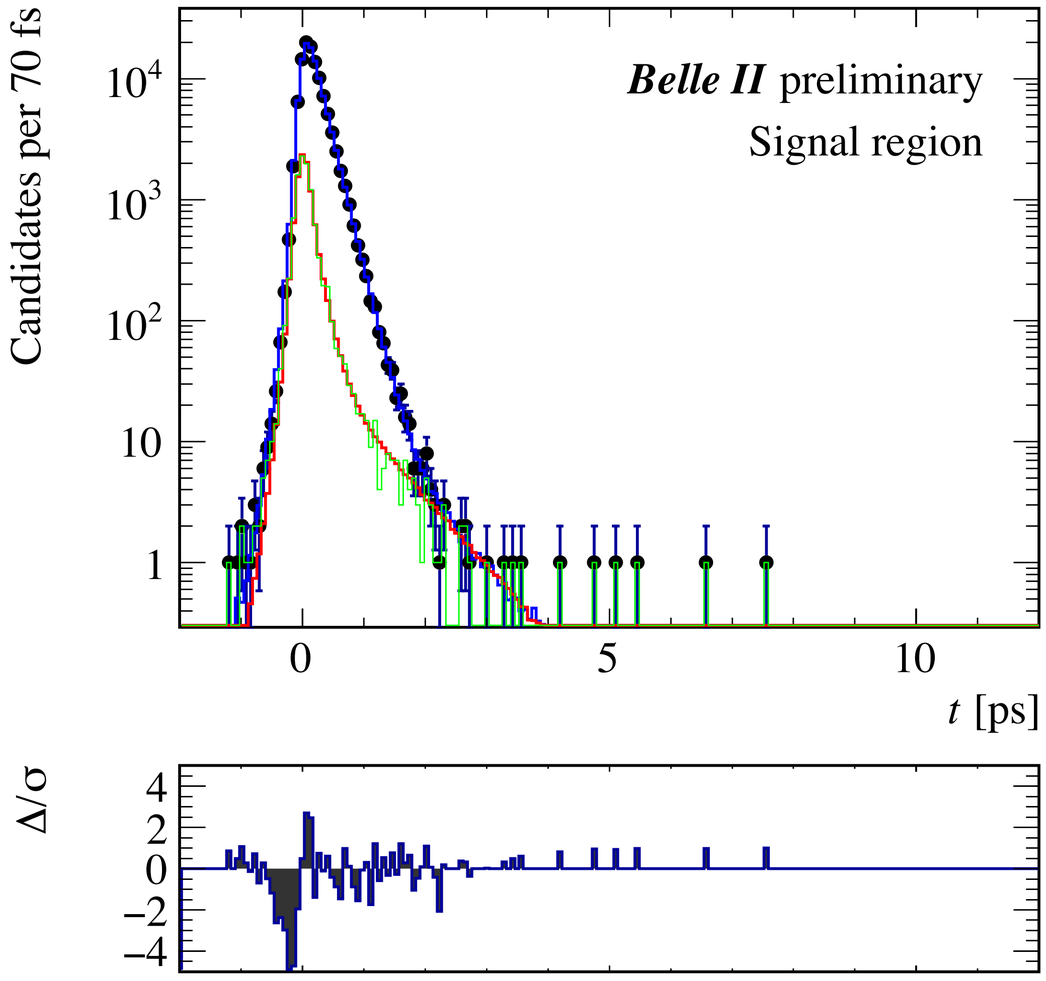
$\tau_{bkg1} = 0.165 \pm 0.006$

$\tau_{bkg2} = 0.775 \pm 0.031$

LHCB, $\tau = 203.5 \pm 1.0 \pm 1.3 \pm 1.4$ *fs*

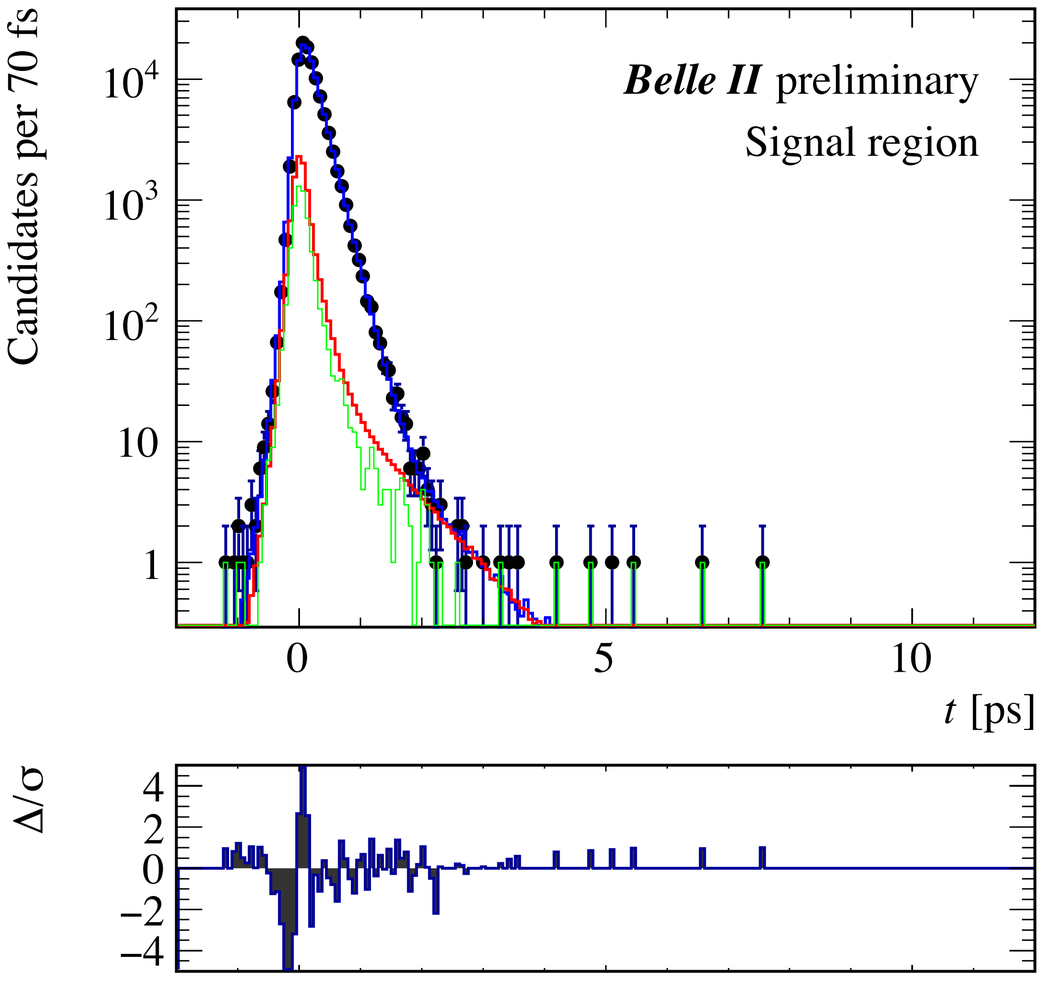
CLEO, $\tau = 179.6 \pm 6.9 \pm 4.4$ *fs*

Comparison with true backgrounds



2D Gaussian resolution function

$\tau = 0.1995 \pm 0.0009$



1D Gaussian resolution function

$\tau = 0.1979 \pm 0.0007$