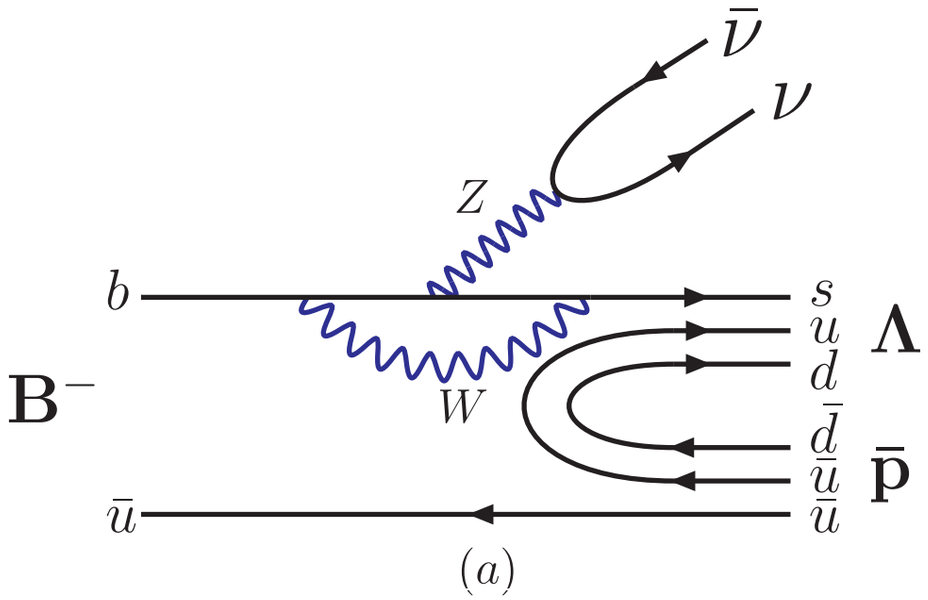
Update on sensitivity study for $B^- \to \Lambda \bar{p} \nu \bar{\nu}$ at phase 3

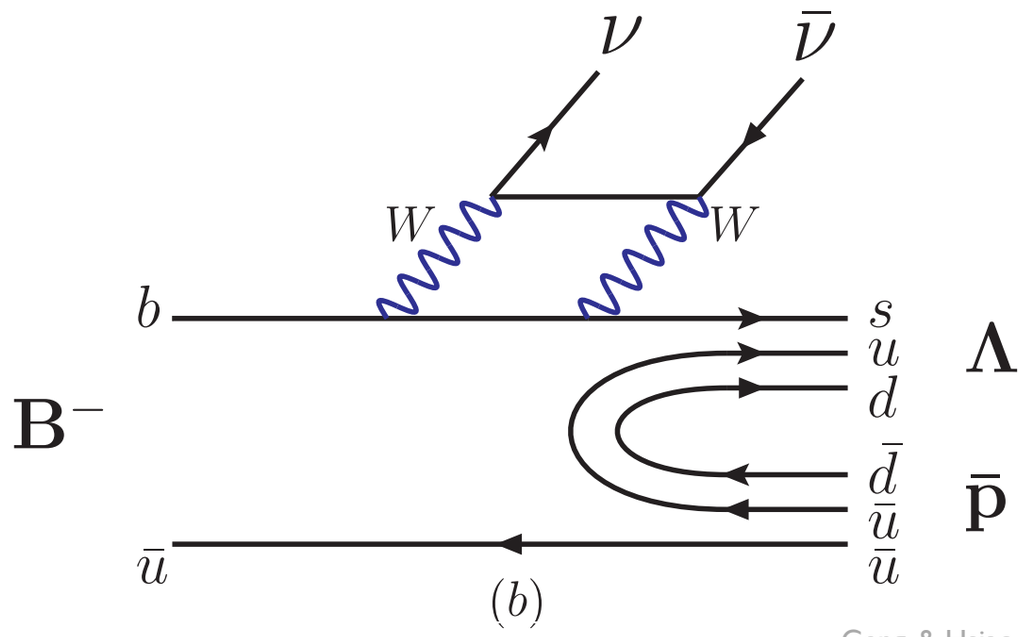
Robert Seddon
McGill University

WG1 - (Semi-)Leptonic and Missing Energy Decays, Leptonic sub-group meeting

12th September 2018

Details and motivation





Geng, & Hsiao

C.Q. Geng, Y.K. Hsiao.
Phys. Rev. D 85 (2012) 094019

Predict $\mathcal{B}(B^- \to \Lambda\bar{p}\nu\bar{\nu})$ = (7.9 ± 1.9) x 10^{-7}

- Rare decay (suppressed by the standard model)
- New physics potentially hiding in loops - will affect branching fraction
- Amenable to further study: angular asymmetries, T-odd observables *etc.*

$B^- \to K^-\nu\bar{\nu}$

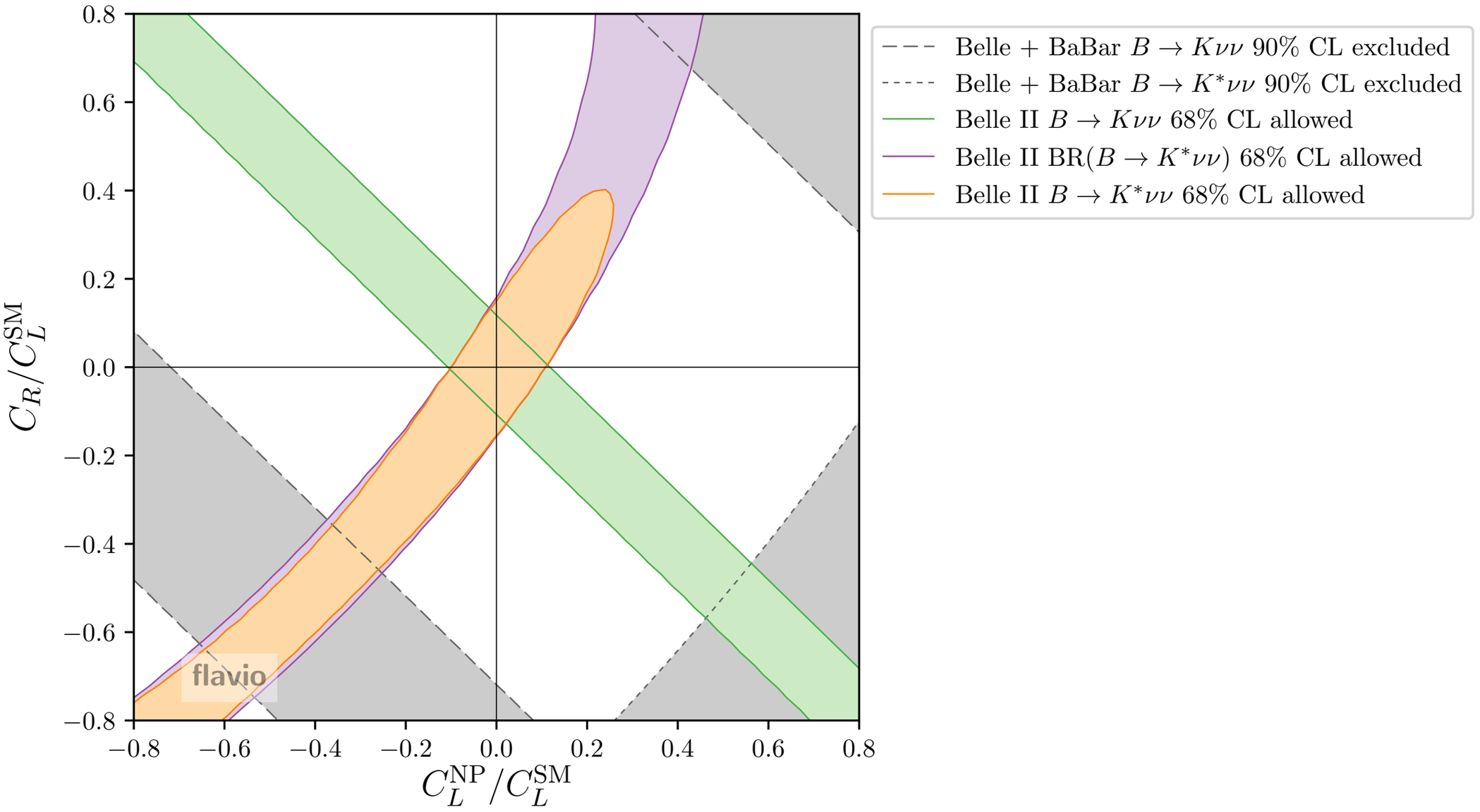
- Predicted: (4.5 ± 0.7) x 10^{-6} (J. High Energy Phys. 2009, 022)
- Measured:

BABAR (hadronic): <3.7 x 10^{-5} (Phys. Rev. D 87 (2013) 112005)
BABAR (semi-leptonic): <1.3 x 10^{-5} (Phys. Rev. D 82 (2010) 112002)
Belle (hadronic): <5.5 x 10^{-5} (Phys. Rev. D 87 (2013) 11110)

Details and motivation

New Physics

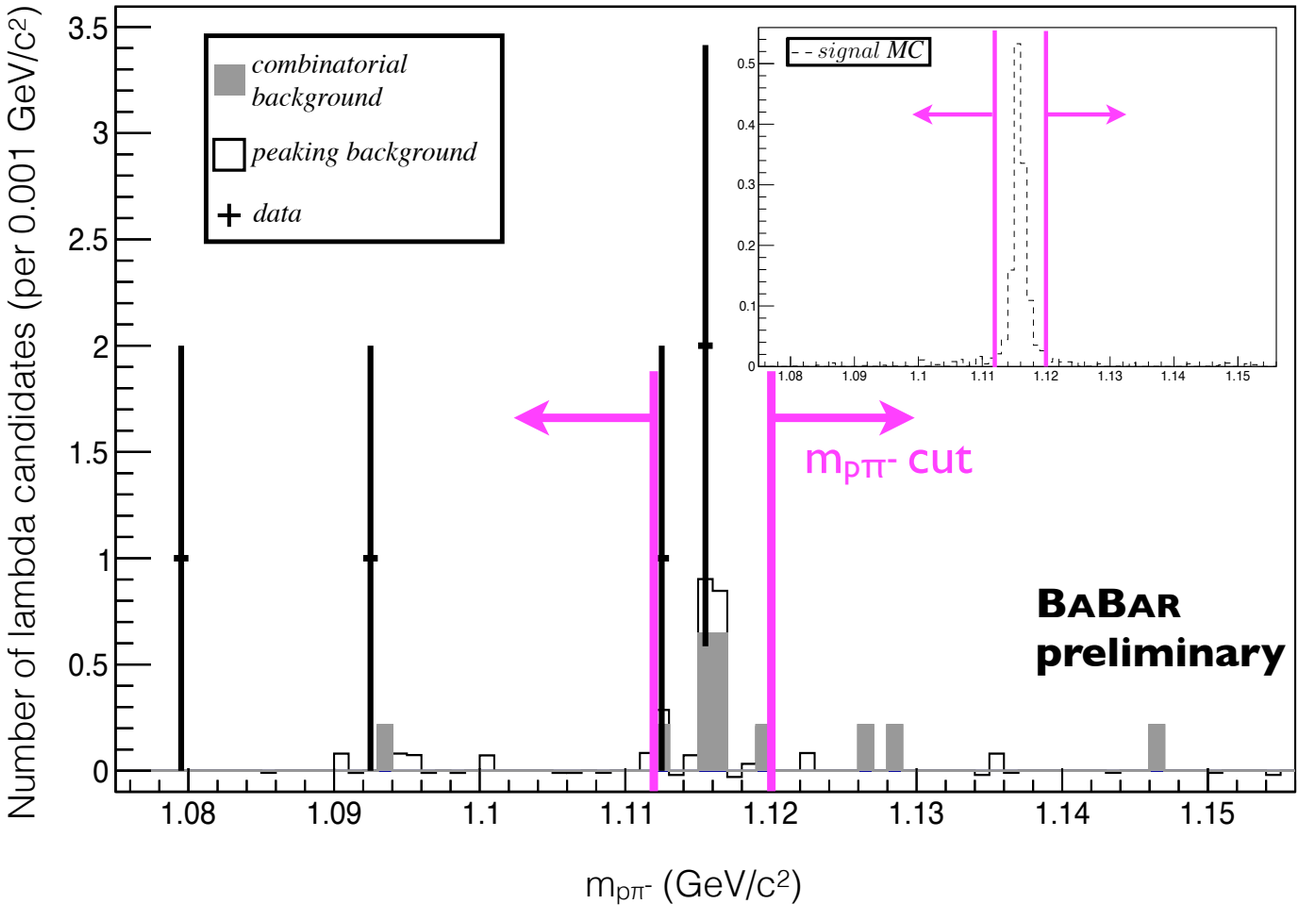
· Branching fraction measurement can provide constraints on Wilson coefficients for left- and right-handed weak currents, as already done by Belle and BaBar B -> Knunu analyses.



The Belle II Physics Book

BaBar result

- Presented at ICHEP 2018: indico.cern.ch/event/686555/contributions/2986950/



Data in signal region: 3 events

Final background estimate:
2.3 ± 0.7(stat.) ± 0.6(sys.)

Final signal efficiency:
(3.42 ± 0.08(stat.) ± 0.80(sys.)) x 10^{-4}

- First ever measurement of $B^- \to \Lambda\bar{p}\nu\bar{\nu}$. Results:

  BF central value: (0.4 ± 1.1(stat.) ± 0.6(sys.)) x 10^{-5}
  BF upper limit at 90% confidence level: 3.0 x 10^{-5}
  (Compare theory: (7.9 ± 1.9) x 10^{-7})

- No observation of signal or New Physics.

MC, FEI and skimming

- Use MC9 FEI skim "feiHadronicBplus": skim of first 1 ab^-1 generic Ups(4S) events

  Central FEI skim cuts
  - Mbc > 5.24 GeV
  - |deltaE| < 0.200 GeV
  - signal probability > 0.001

- SigMC: MC9, 10 M events, phase3, Ups(4S), BGx1
- Skim sigMC using same cuts (analysts need to skim their own signal MC).

Signal selection cuts

$$B^- \to \Lambda \bar{p} \nu \bar{\nu}$$
$$\hookrightarrow p\pi^-$$

Event-wide

- total number of tracks in event before FEI <= 10 (FEI can't reco Btags from >7 tracks)
- missing energy > 0 (neutrinos)

Btag

- remaining tracks in event after FEI == 3 (Lambda(p pi-)pbar)
- if >1 Btag candidate in an event, keep candidate with highest signal probability

Lambda reconstruction

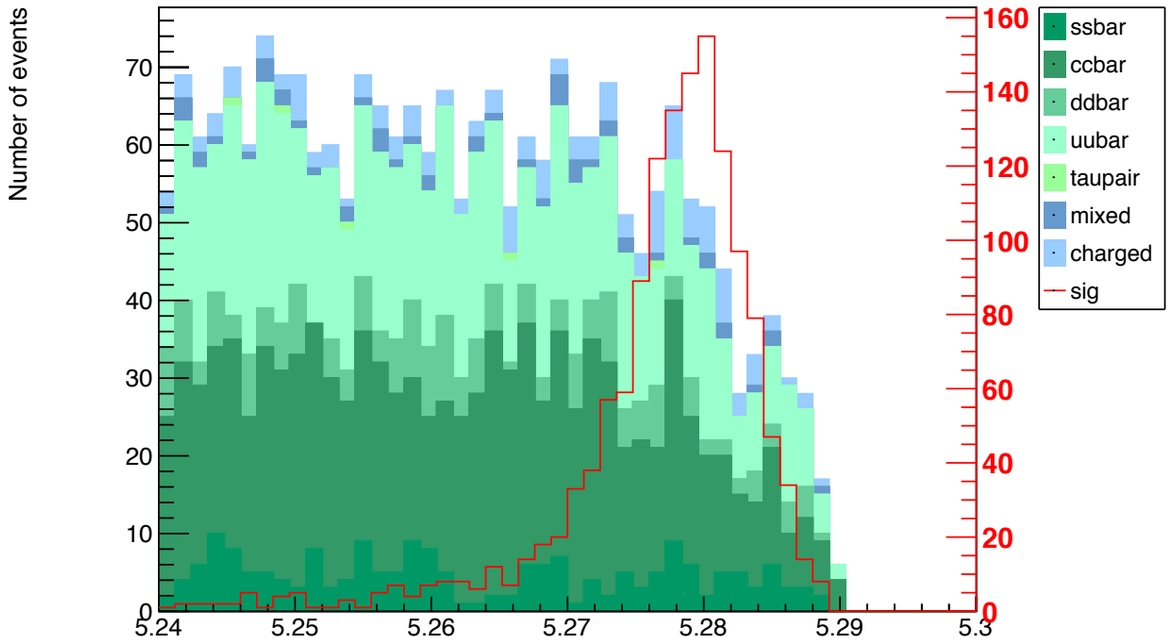
- 95% efficiency proton and pion ID on remaining tracks
- Lambda daughters must obey expected DOCA order (pbar < p < pi)
- Reconstruct lambda from PID'ed tracks, KFit
- Lambda mass: PDG ± 40 MeV
- If >1 lambda candidate, choose one with best significance-of-distance relative to IP

Other

- Reconstruct Bsig and Upsilon(4S) (imposes "no overlaps" and charge consistency)

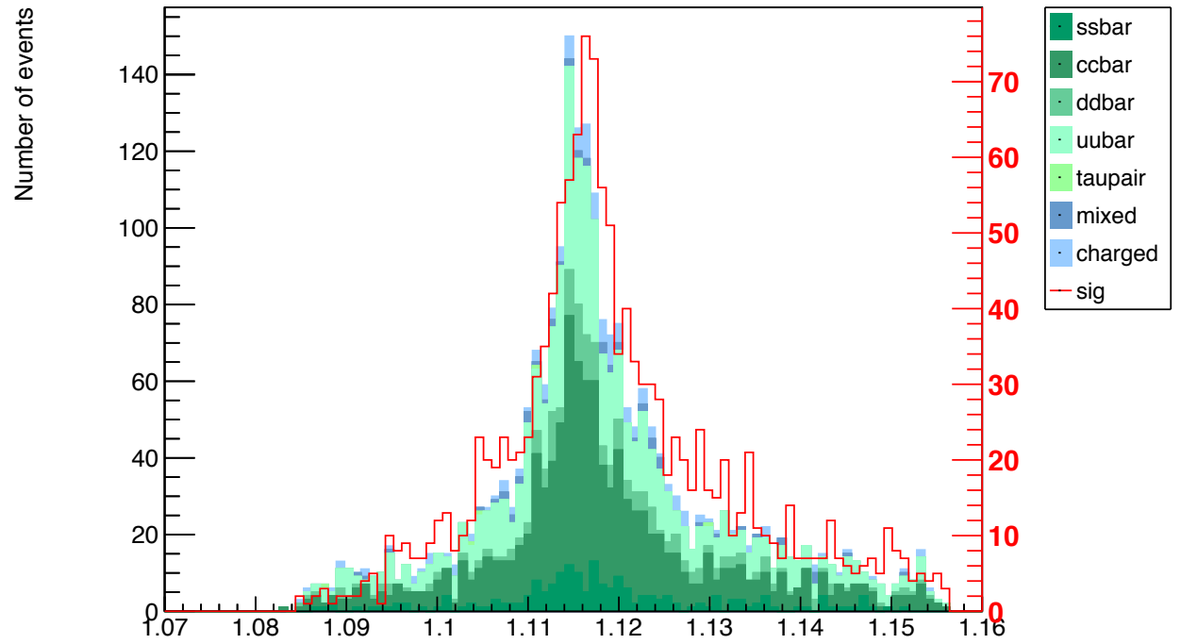
Signal selection cuts

Btag Mbc



Will only use Mbc > 5.27 GeV for final result.

Reconstructed Lambda mass



PDG Lambda mass = 1.116 GeV

May use tighter cut for final result.

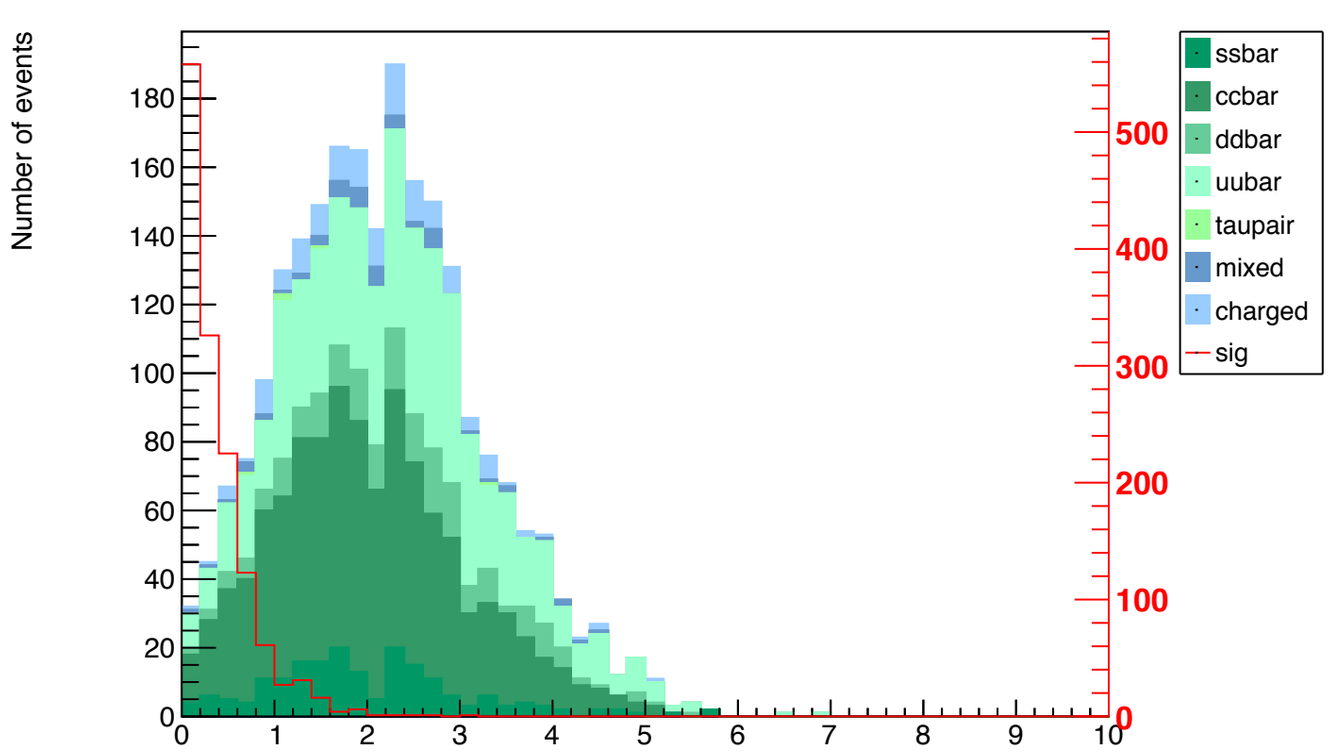
Signal selection cuts

$$B^- \to \Lambda \bar{p} \nu \bar{\nu}$$
$$\hookrightarrow p\pi^-$$

Eextra

- ECL energy from neutral particles that are not used in Btag reconstruction.
- Suppress beam background by requiring (https://confluence.desy.de/x/QGIHAg, thanks Mario!):

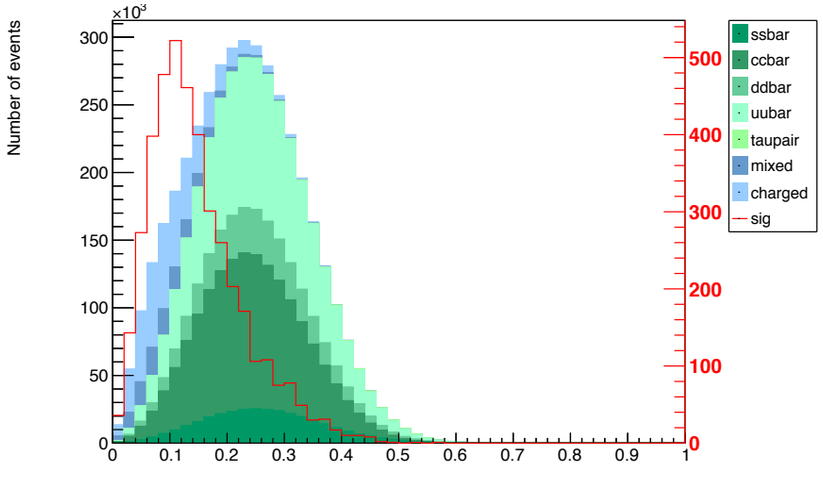
Detector region	forward	barrel	backward
Energy (MeV)	62	60	56
abs(cluster timing) (ns)	< 18	< 20	< 44



Continuum suppression

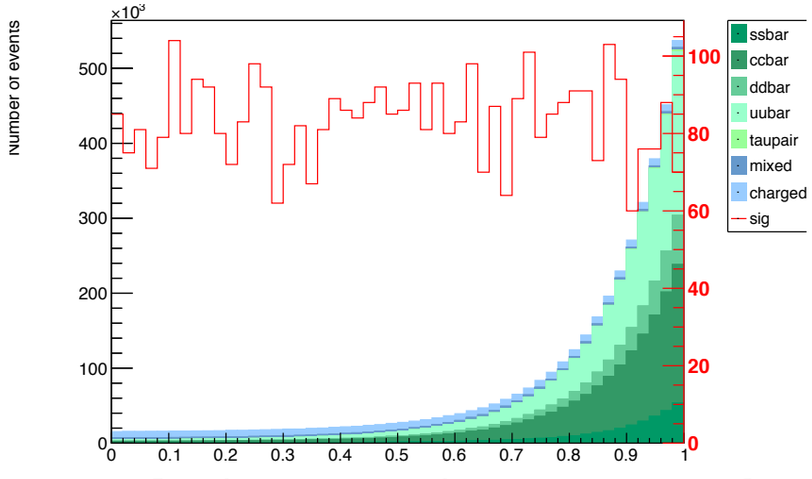
- Build a mutlivariate likelihood from:

R2



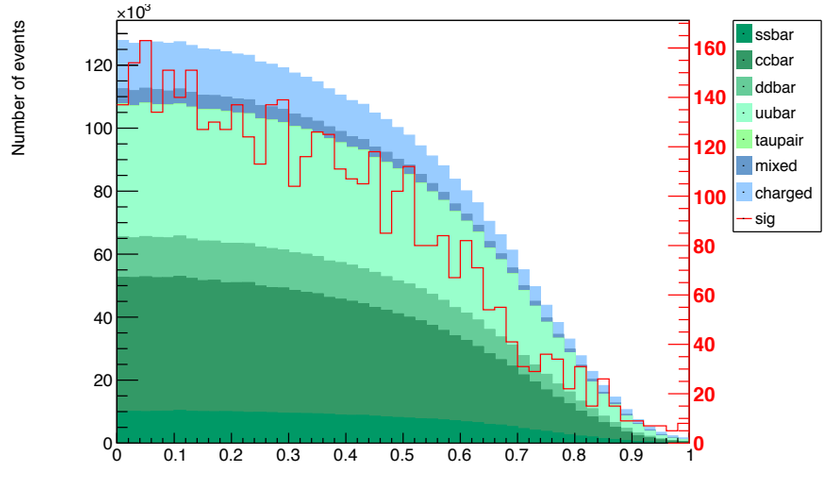
Reduced Fox-Wolfram moment

cos(TBTO)



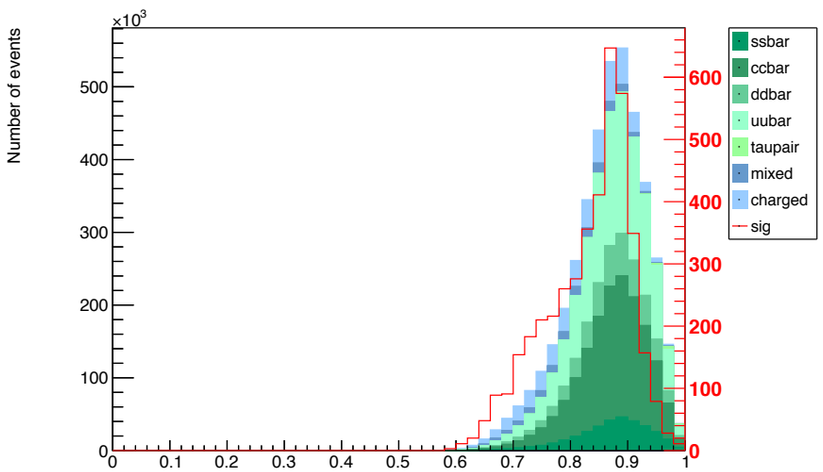
angle between thrust axis of Btag and thrust axis of ROE

cos(TBz)



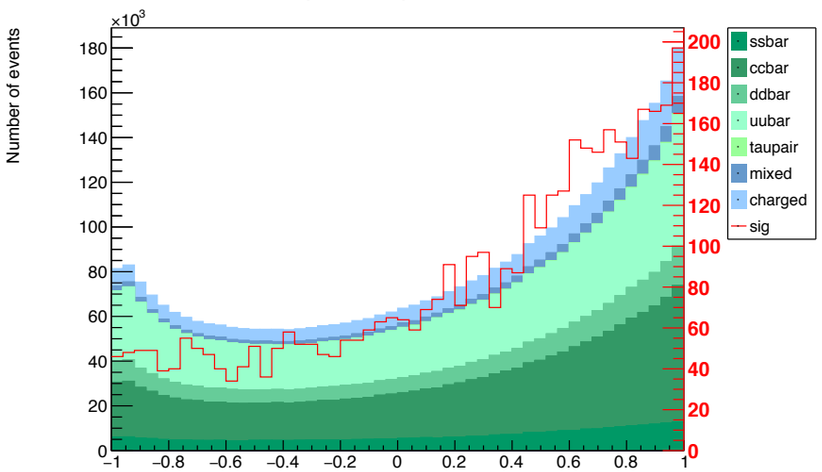
angle between thrust axis of Btag and z-axis

thrustBm



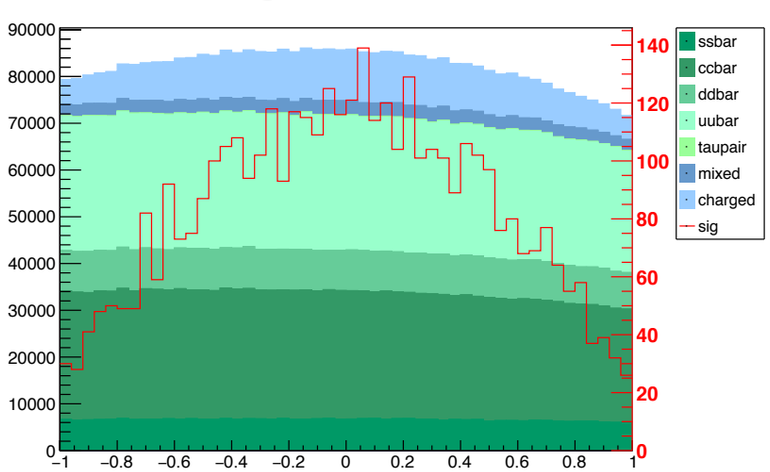
Magnitude of the Btag thrust axis

cos(missP), CM frame



angle between missing momentum and z-axis in CM frame

Btag_cosTheta_CM

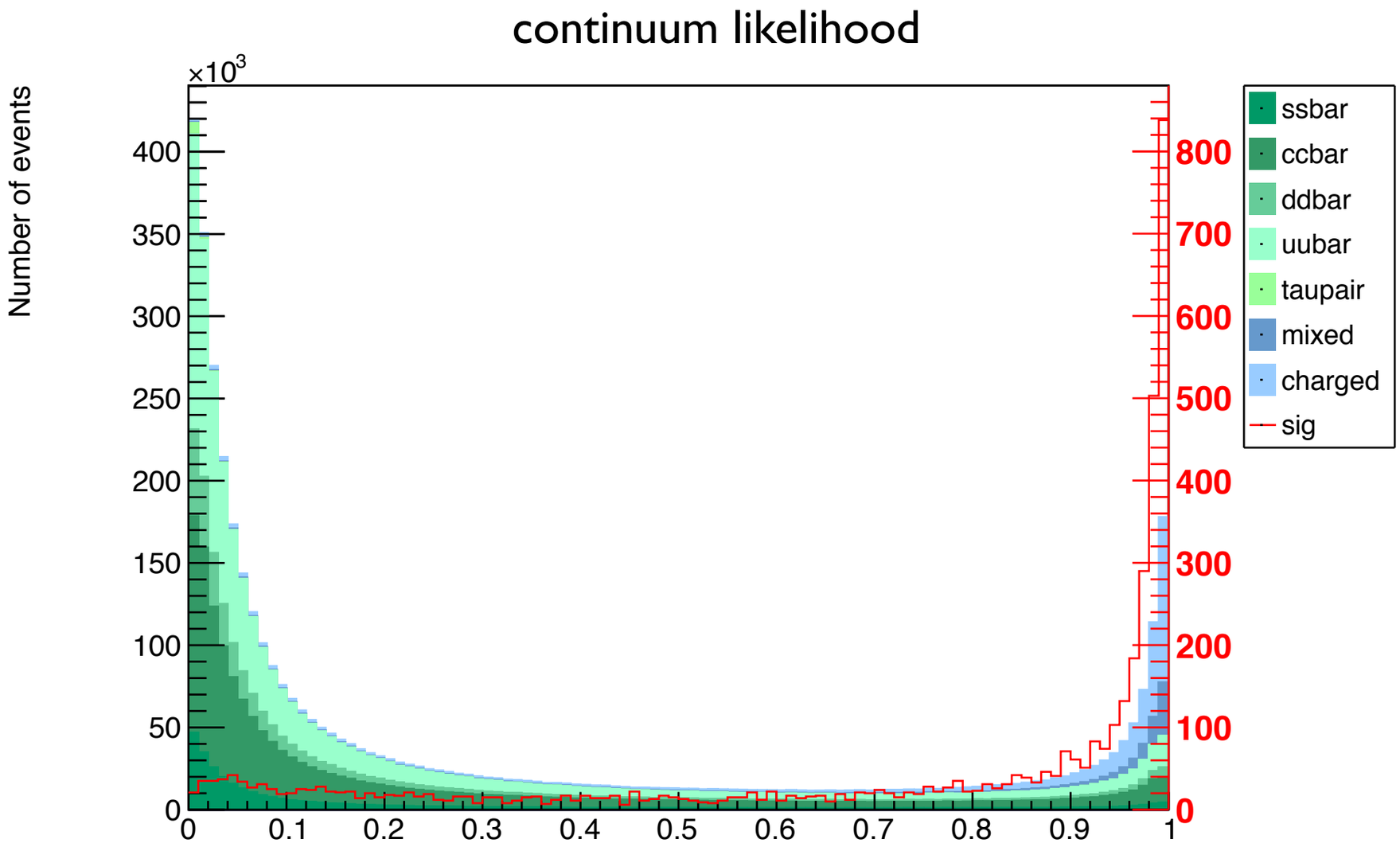


angle between Btag momentum and z-axis in CM frame

Continuum suppression

$$continuum\ likelihood = \frac{\prod_i P_{B\bar{B}}(x_i)}{\prod_i P_{B\bar{B}}(x_i) + \prod_i P_{cont}(x_i)}$$

where $P_{BB}(x_i)$ and $P_{cont}(x_i)$ are probability density functions describing BB and continuum events respectively for the variable x_i.



Plans and outlook

Plan

- Optimise cuts on Eextra, continuum likelihood.
- Reweight signal MC to match theory predictions for invariant masses, helicity angles.
- Aim to complete an MC-only sensitivity study ASAP.

- Does MC need reweighting?

Constraints

- FEI in phase 2: efficiency is factor of two lower in data than MC:
  https://docs.belle2.org/record/1111 → §3.1.1
- Lambda reco in phase 2 prod 5 is factor of two lower in data than MC:
  https://confluence.desy.de/x/dyWdAw → 4 Sep → Updates of proton-ID with Λ

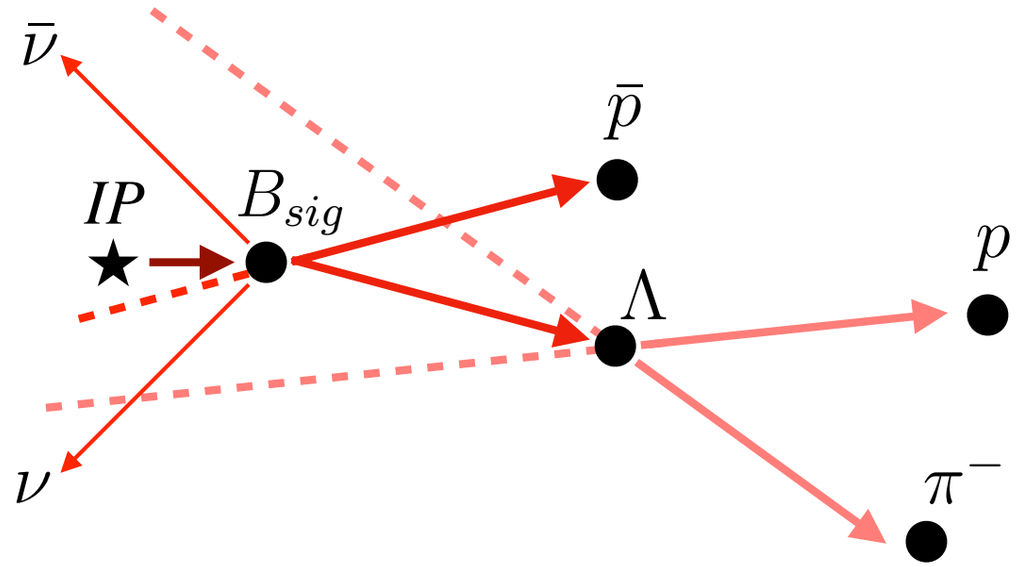
→ Phase 2 results suggest MC and data disagree buy at least a factor of four…

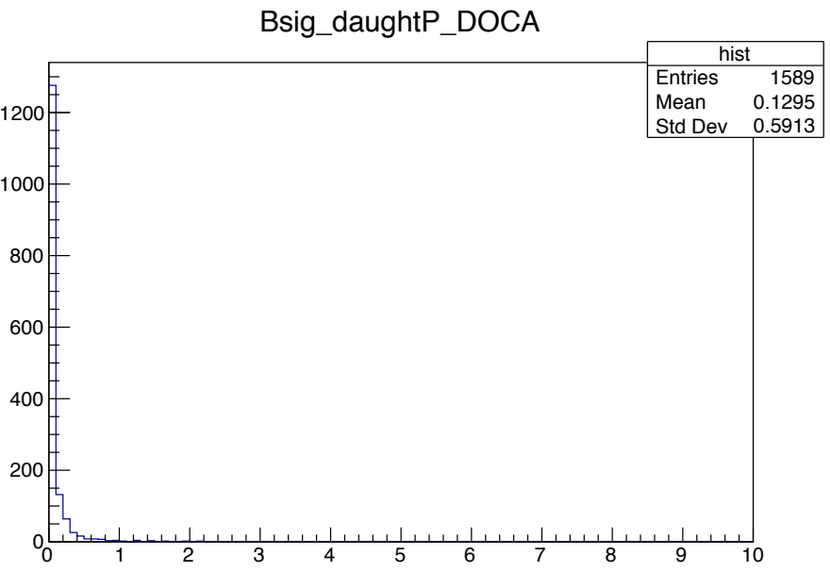
Backup

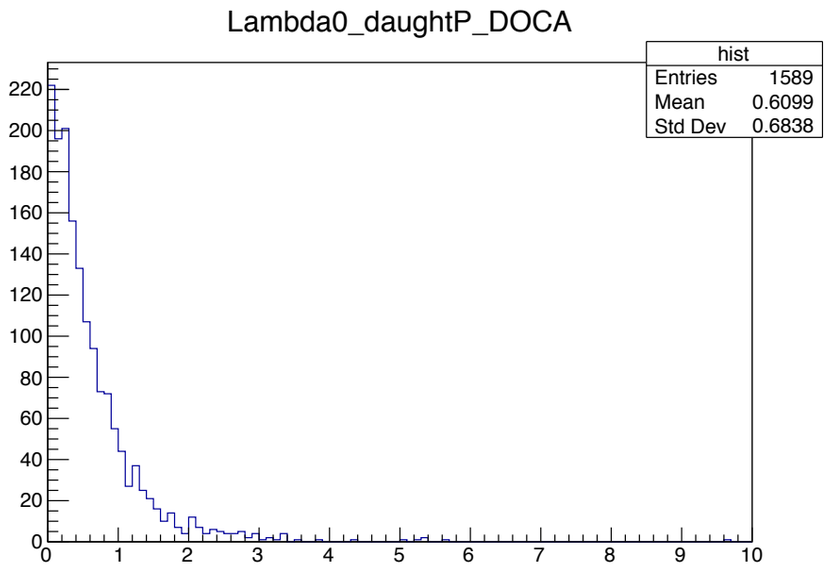
DOCA

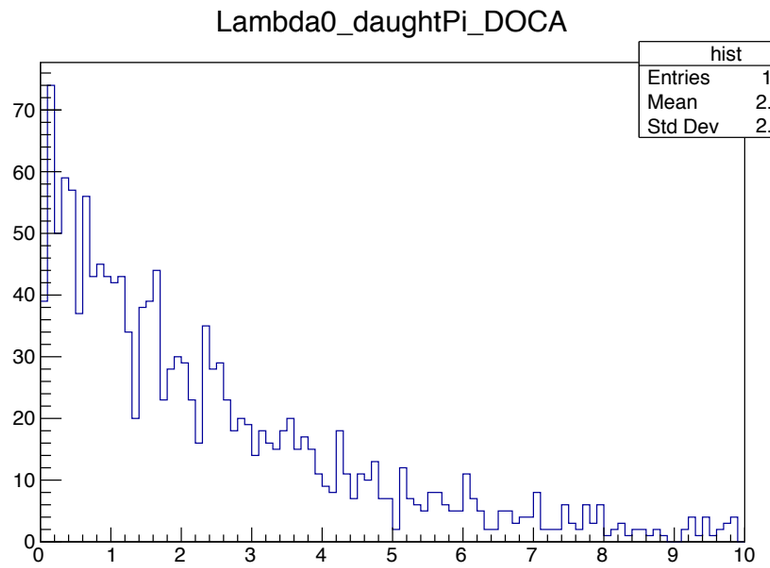
- **D**istance **o**f **C**losest **A**pproach of a track to the IP

Expect: Lowest DOCA - proton from B
Middle DOCA - proton from lambda
Highest DOCA - pion









Preliminary tests show that at an intermediate stage of the selection, the DOCA cut causes 13% drop in signal efficiency but 60% drop in background.