K_L ID and B -> J/Psi K_L

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Disclaimer

- Today I will discuss two topics which, although in principle related, are disjoint in what I'll show:

- We studied K_L reco in ECL in order to improve ID as well as momentum reconstruction -> related to development of the eclN2Splitter module (not finalized yet)

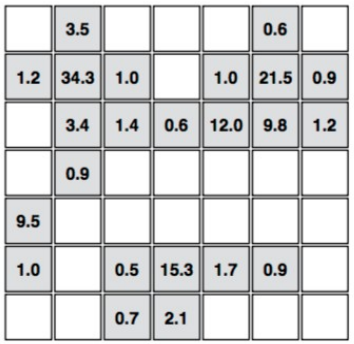
- We have very recently joined TDCP group (wg 3) and started to work on B -> J/Psi K_L using default analysis tools and SW,
  i.e. the analysis does not benefit (yet) from the work done on K_L ID

K_L ID in the ECL

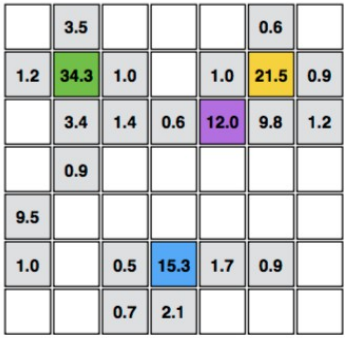
- We want the best possible K_L identification (ID) using all information available at eclConnectedRegion (CR) level
  - Split / extend CR
  - Introduce new combinations of CalDigits related quantities to improve K_L ID
- We also want best reconstruction of K_L direction
  - Not necessarily requires same splitting as previous point

reminder: eclCRFinders and Splitters

Connected Region Finder.



Use only digits with E>0.5MeV.



Digits with E>10MeV are seeds.

Neighbours are grouped with the seed.

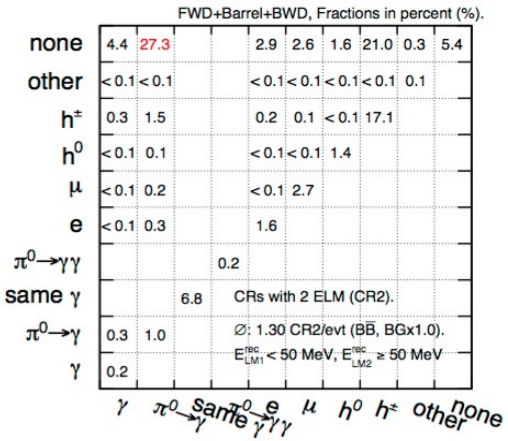
Overlapping CRs are merged.

Neighbours of digits with E>1.5MeV are added as well (continued).

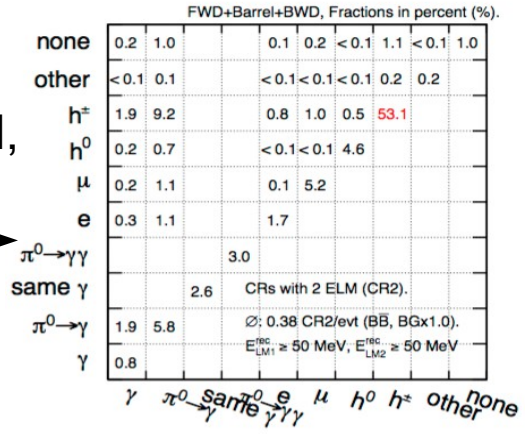
reminder: eclCRFinders and Splitters

- Once you got your CR you may want to split it depending on the assumption on the local maxima. e.g.
- eclSplitterN1 = all photons assumption: digit energy within a CR is shared between different LMs based on distance to the LM.
- Iterative procedure via recalculation of the shower positions. Iteration is aborted once the positions are stable (BaBar method)
- Shower size is later re-optimized based on energy dep., bkg level etc..
- EclSplitterN2 = neutral hadron hypothesis: less obvious how (if) the CR should be splitted because of irregular shape, “split-offs”, lower contamination from other particles -> detailed study needed

CR with 2 LM,
E_1>50 MeV
$E_{2<}$50 MeV



CR with 2 LM,
E>50 MeV

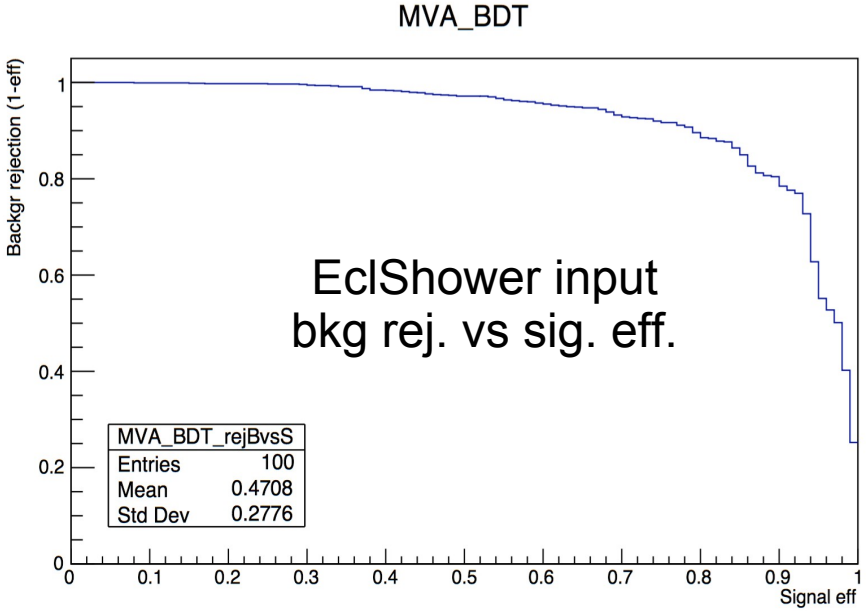


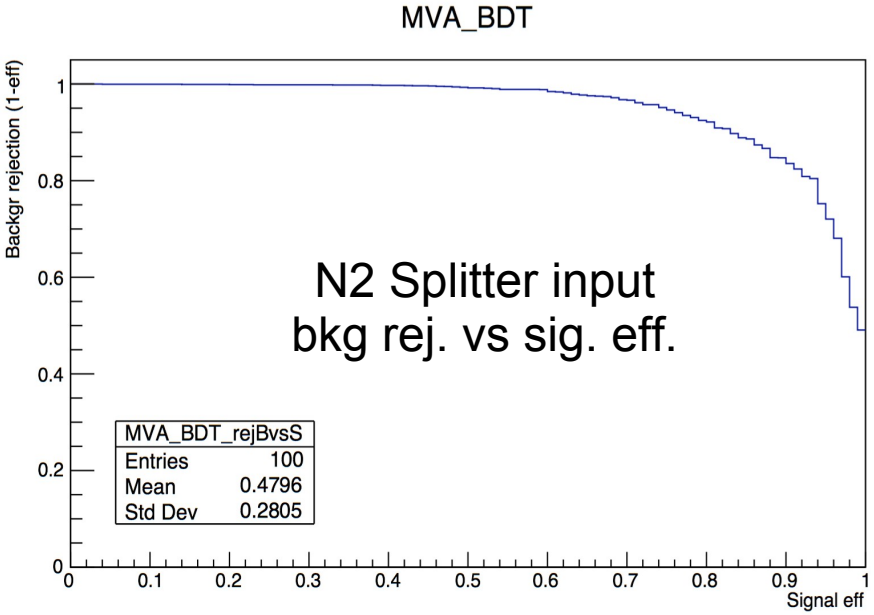
Step 0

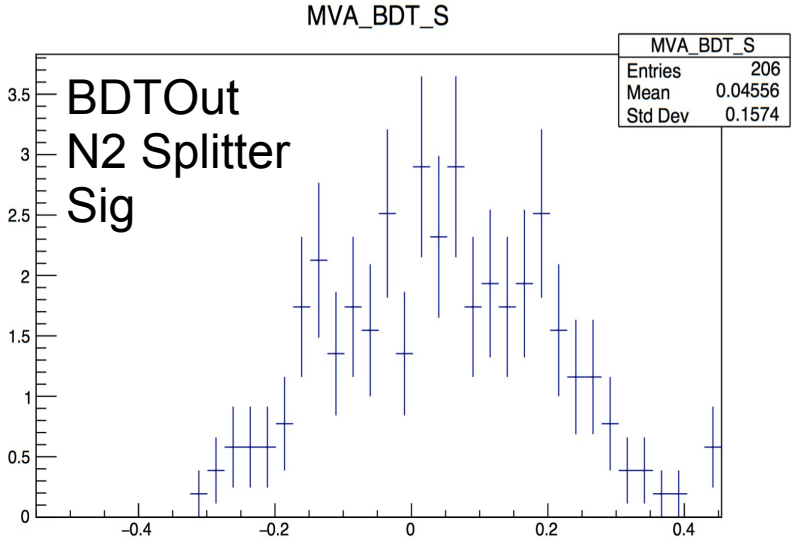
- Compare K_L ID performance for existing (i.e. Belle heritage) eclShower (i.e. eclCRFindingAndSplitting) objects vs full eclCR (i.e. eclCRFinder + eclCRSplitterN2)
- I used my own BDT from Root MVA tools
- Training samples: single K_L, π, π^0, μ (0.5 – 3 GeV), γ (0.05 – 3 GeV) w and w/o beam bkg ((5000) 1000 K_L evt, 1000 (500) for other modes)
- Use all shower shape quantities currently available as input
- Pre-release-08-XX build
- Some problems in proper signal definition because of issues in MCMatching at sim level (details in backups)
- Signal definition: a shower matched to a K_L outside the CDC volume OR a shower matched to a daughter of the K_L created outside CDC

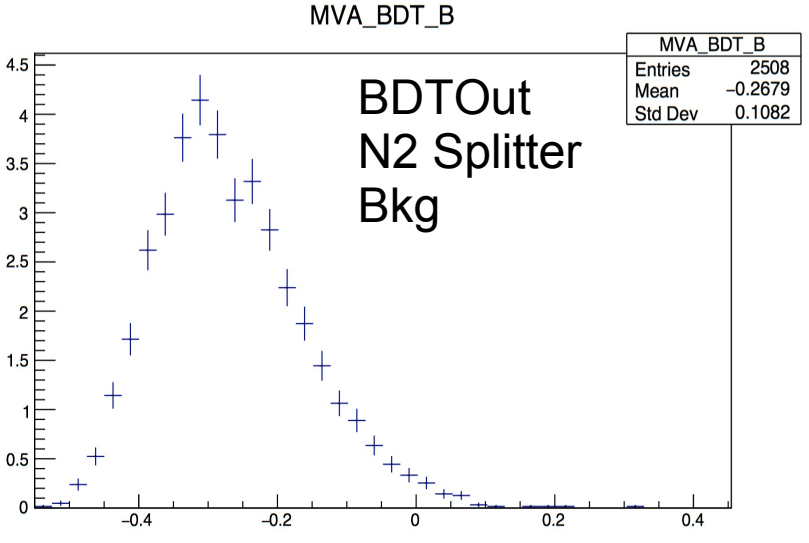
KL ID: shower vs CR w/o bkg

- Input samples: E>0.1 GeV, noTrackMatch, |t| < 125 ns



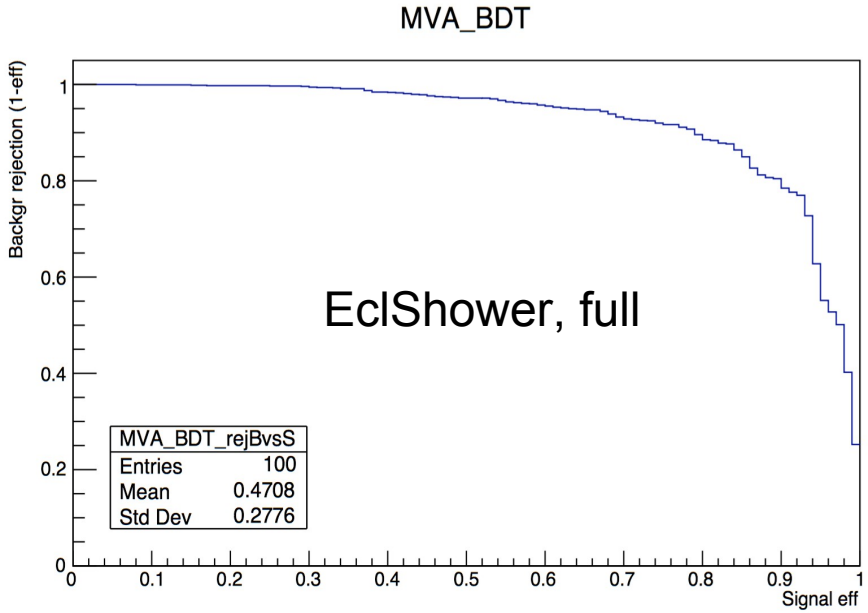


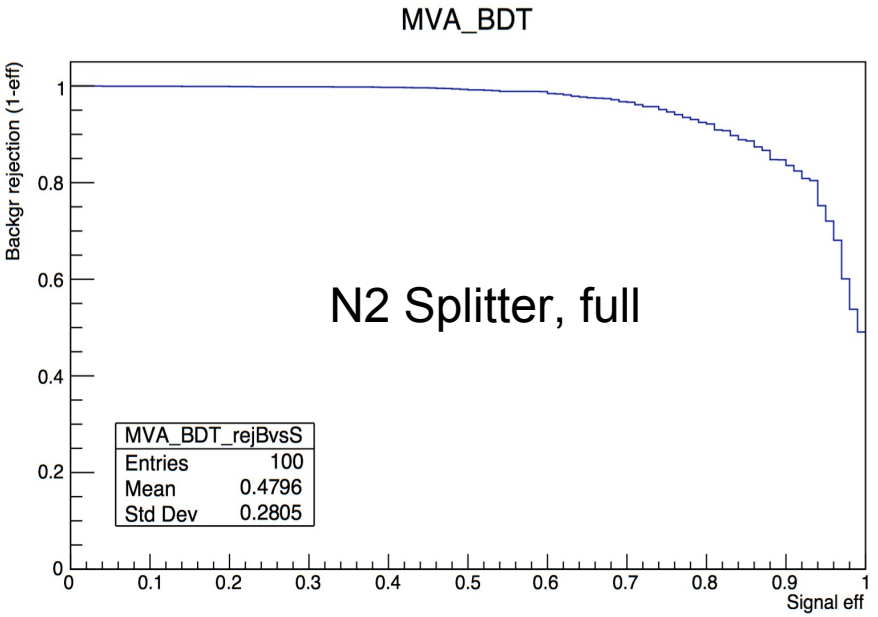


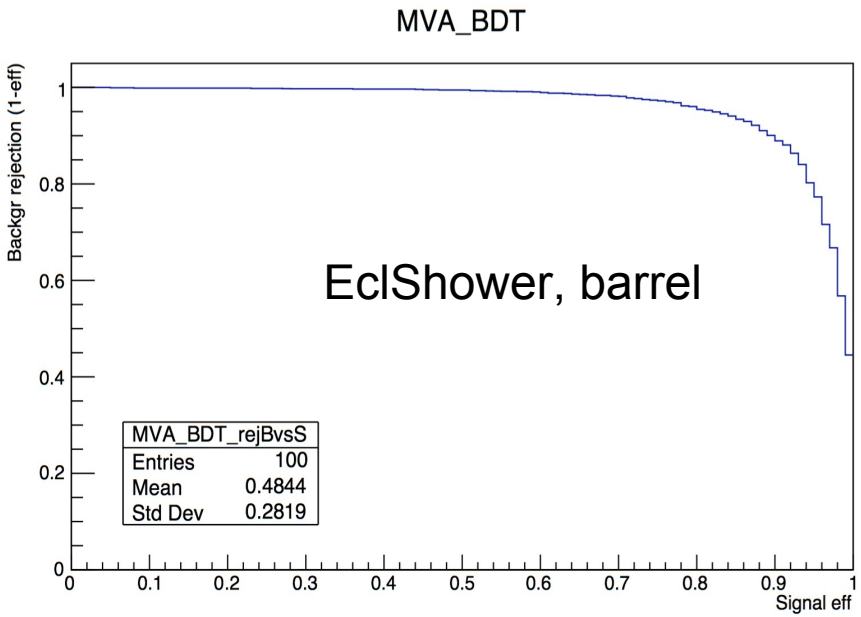


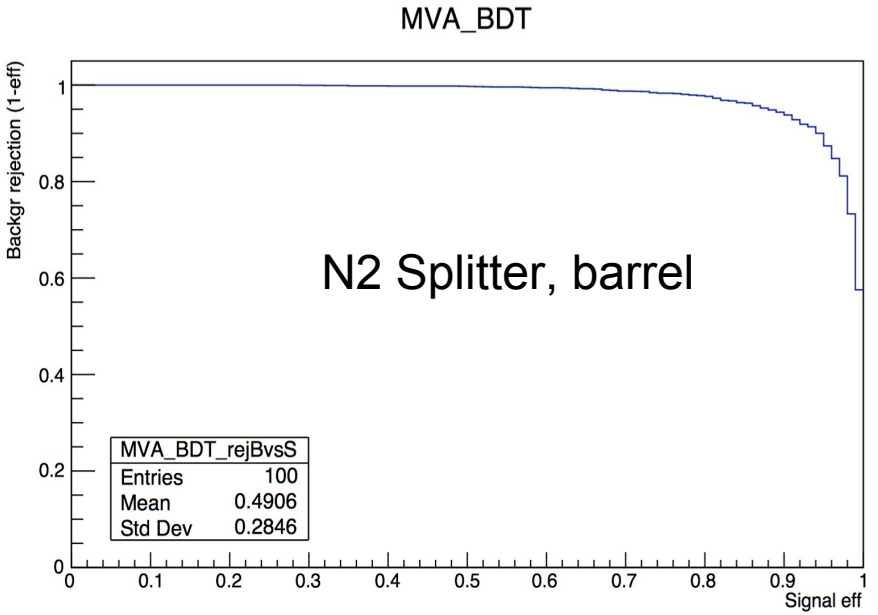
KL ID: shower vs CR w/o bkg

- Lower perfor. in endcaps (barrel: generation 40 < theta < 120)



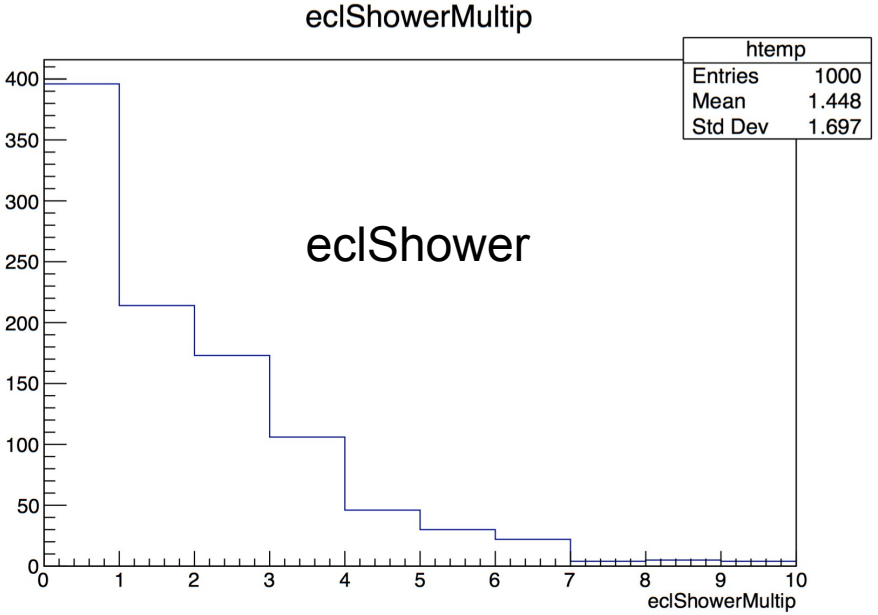


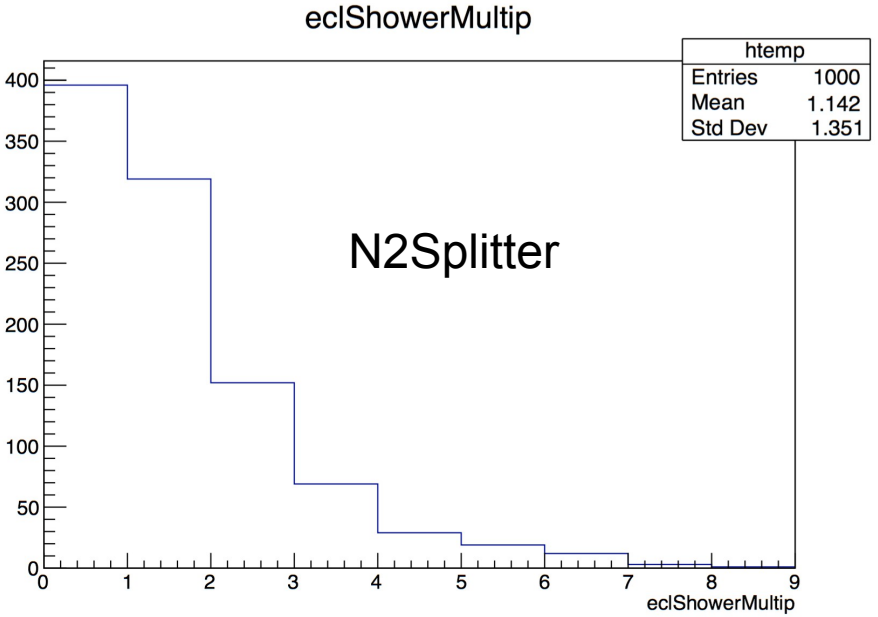


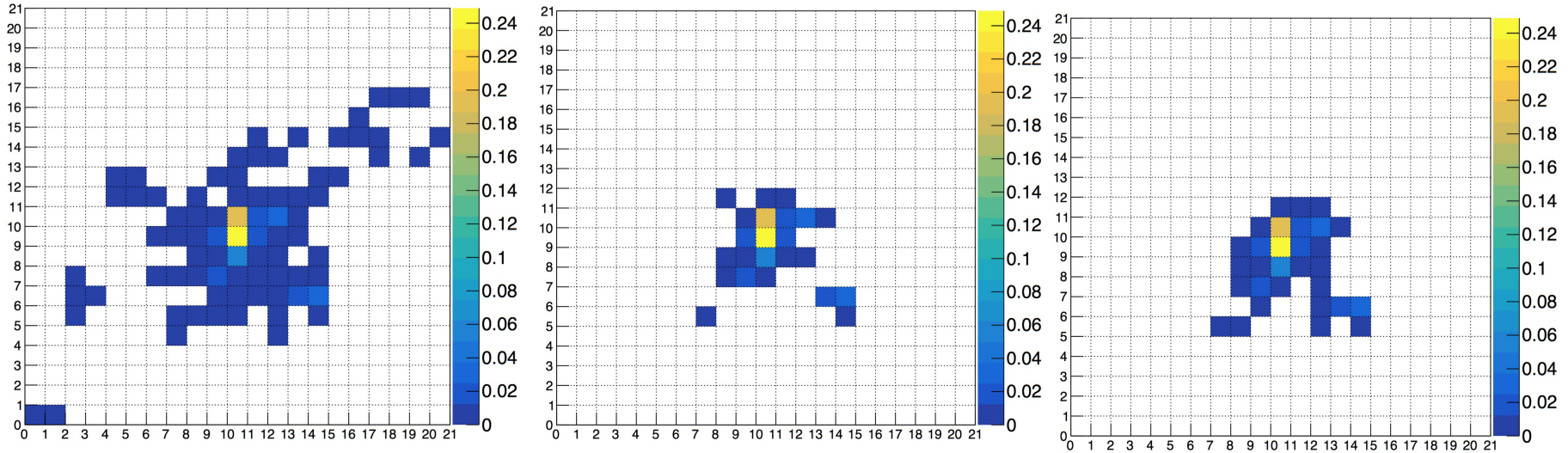


Shower vs CR w/o bkg, comment

- Similar multip., mostly CR does Not include split-offs -> bad for ID (?)



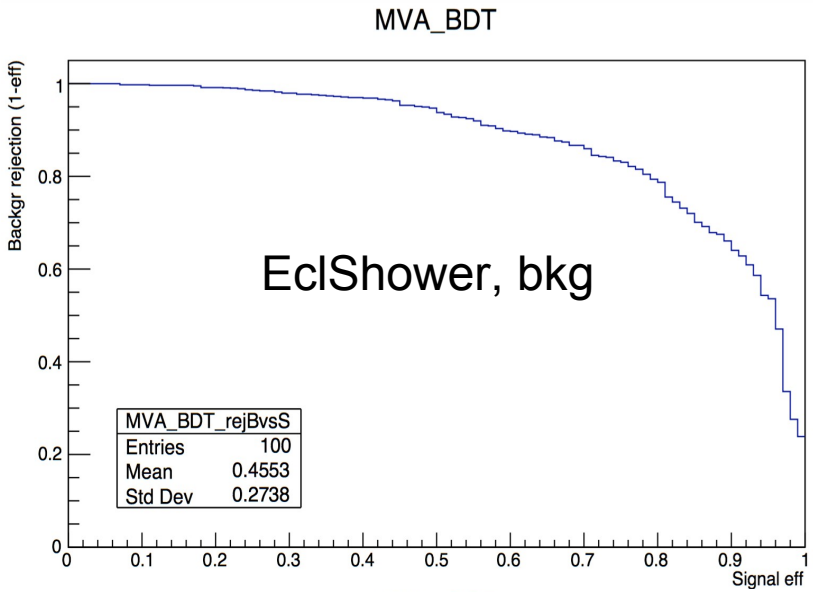


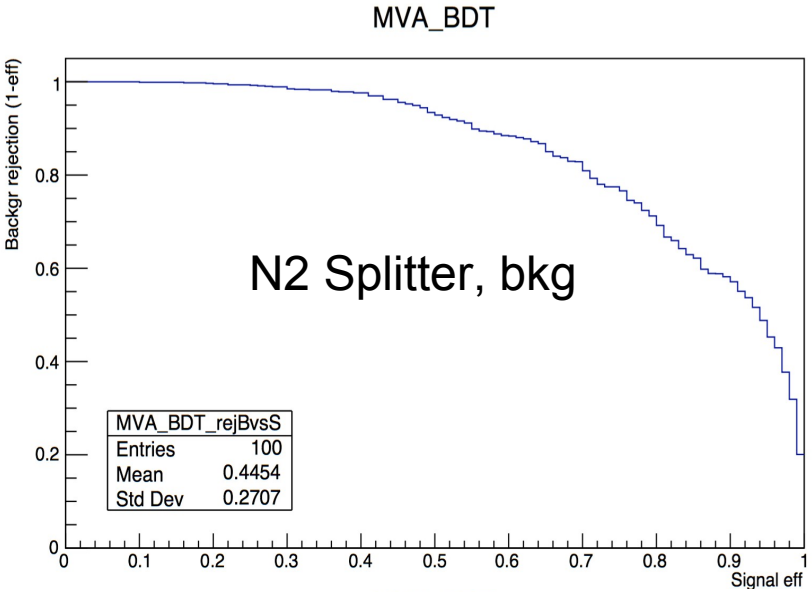


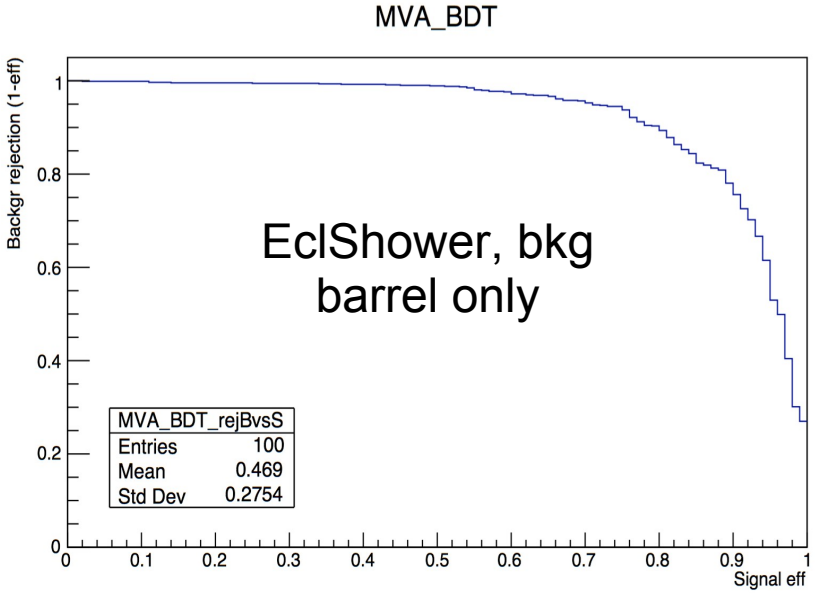
Evt. 1: CalDigits 4 Showers 3 CRs

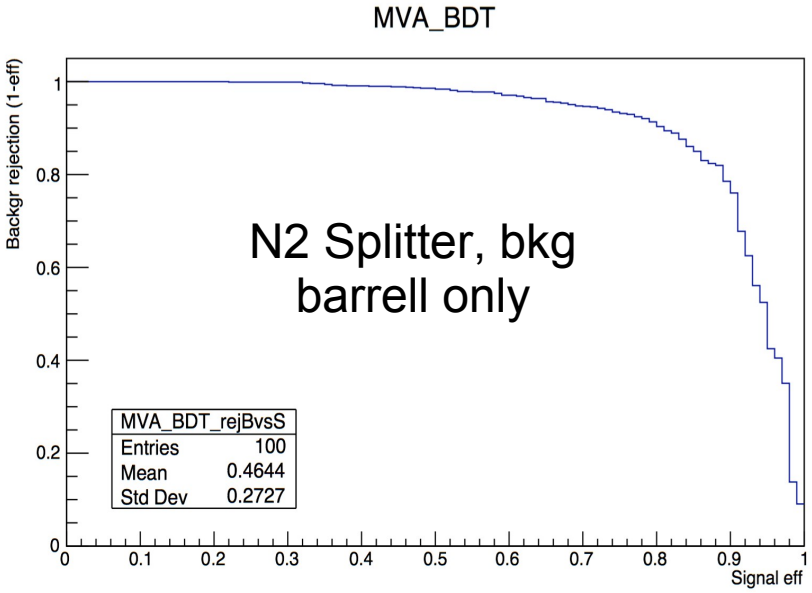
KL ID: shower vs CR w bkg

- The eclShower revenge: better performace in endcaps



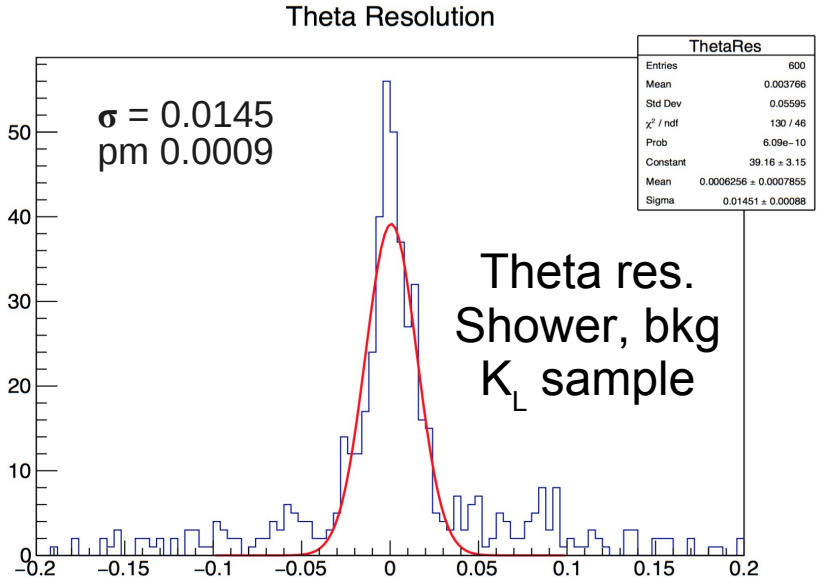


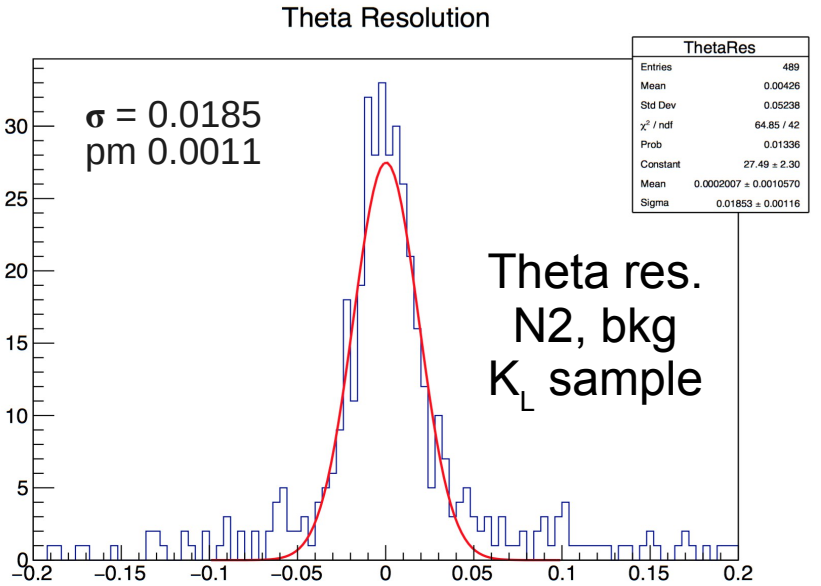


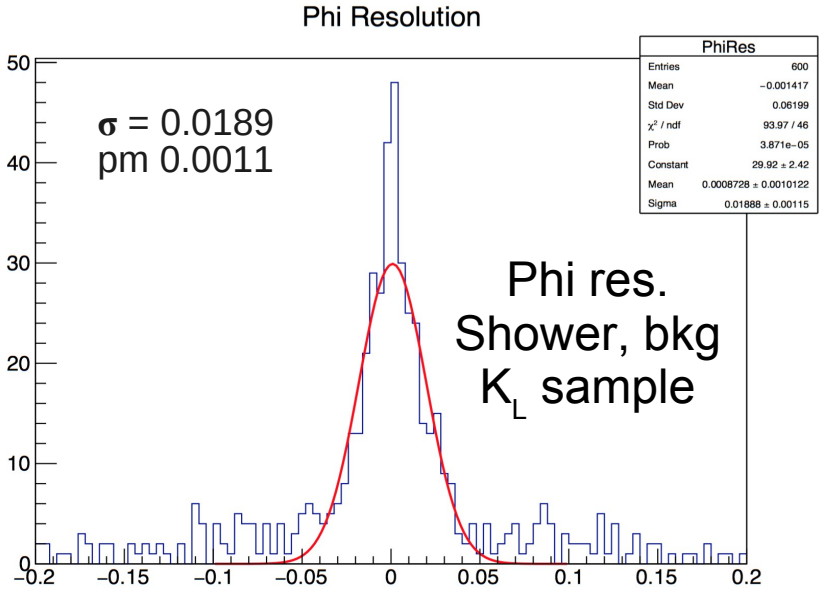


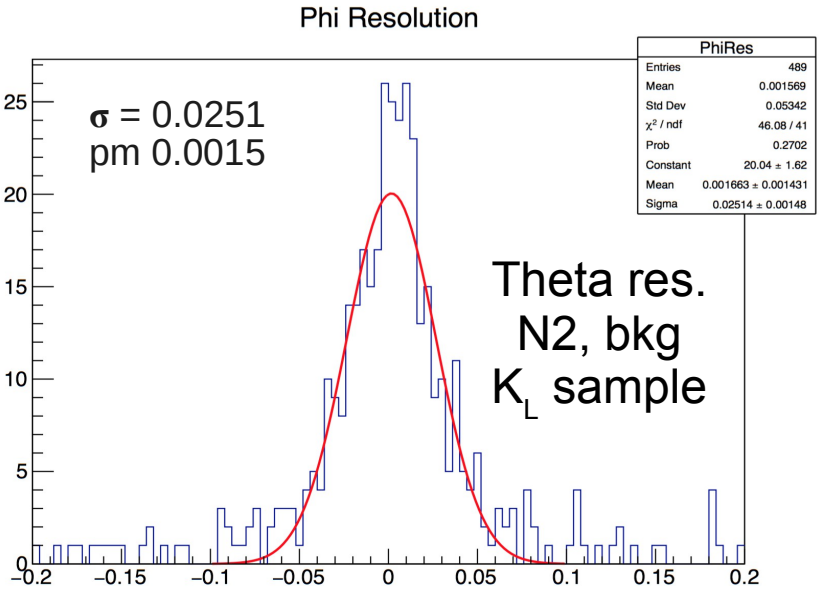
Resolution w bkg

- Resolution obtained from default Shower better w.r.t. CR



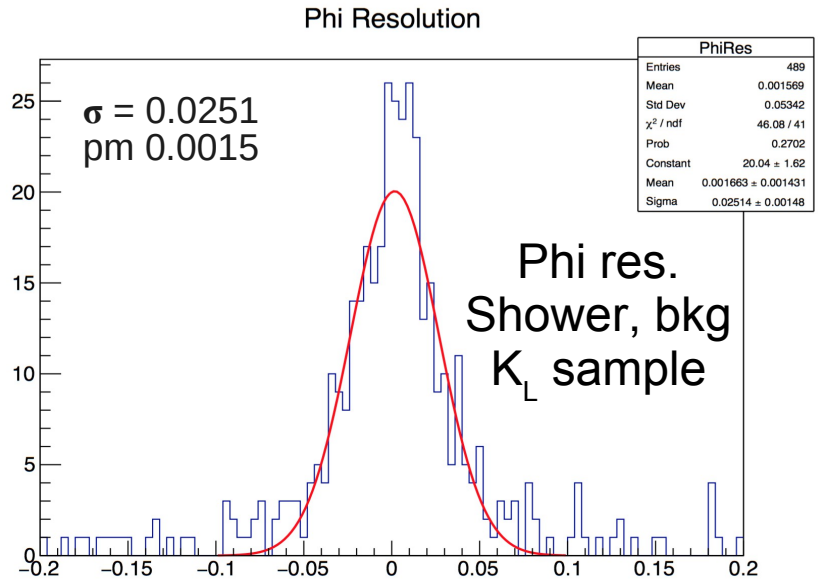


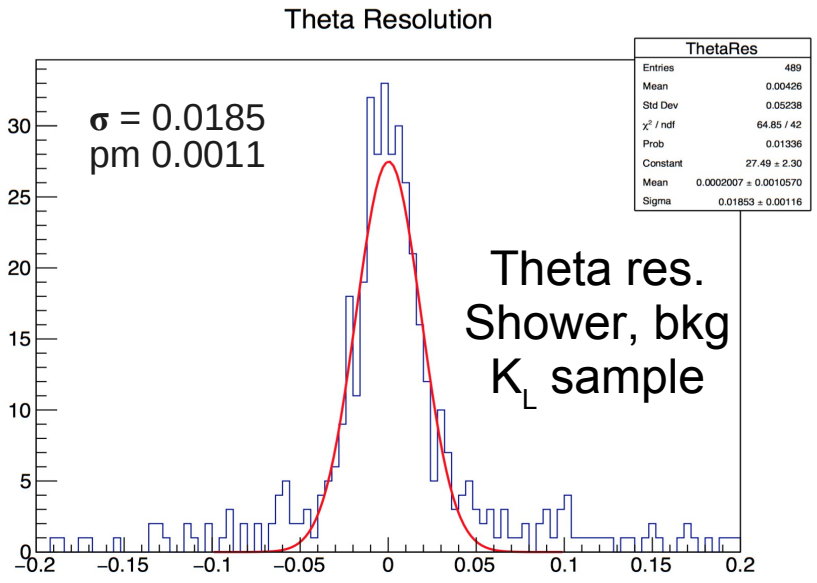


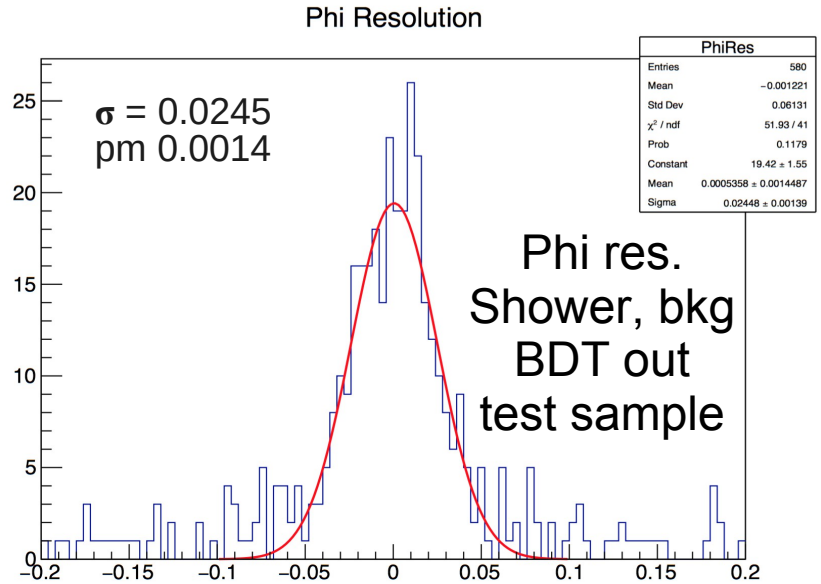


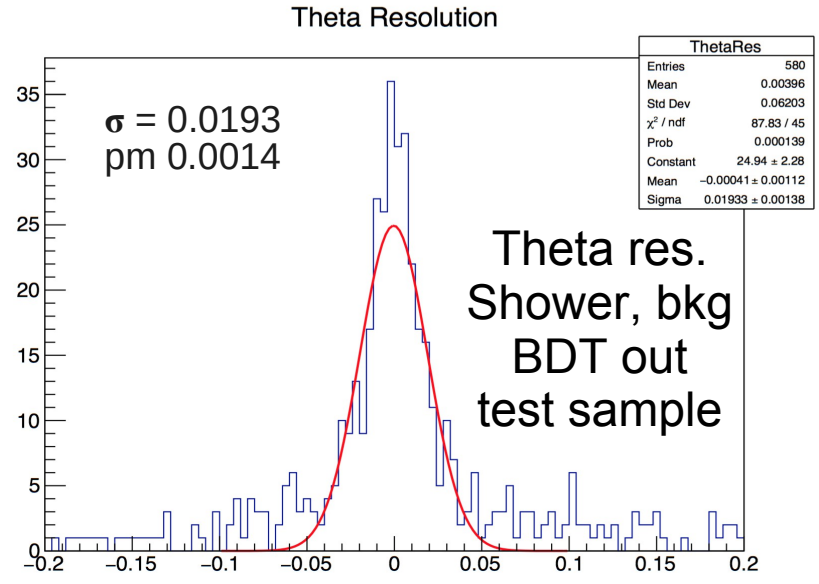
Resolution, N2 and BDT out

- No strong bias from BDT is seen



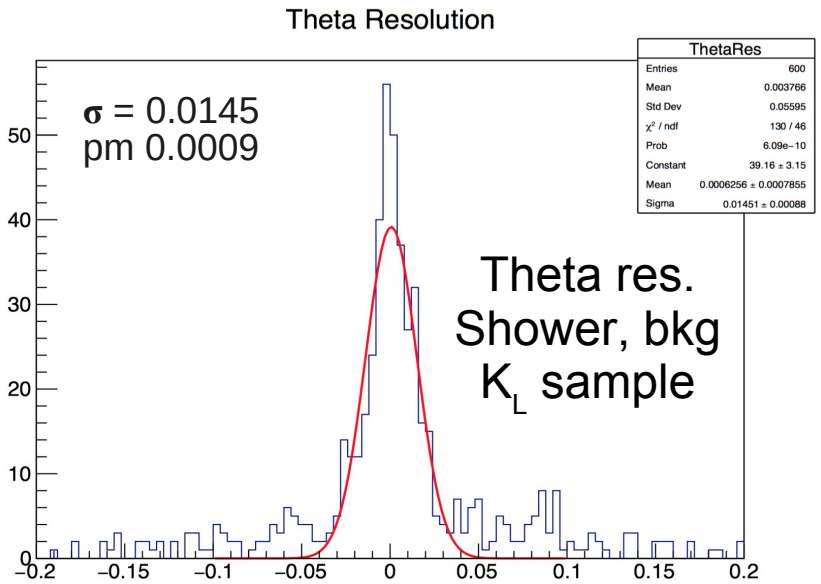


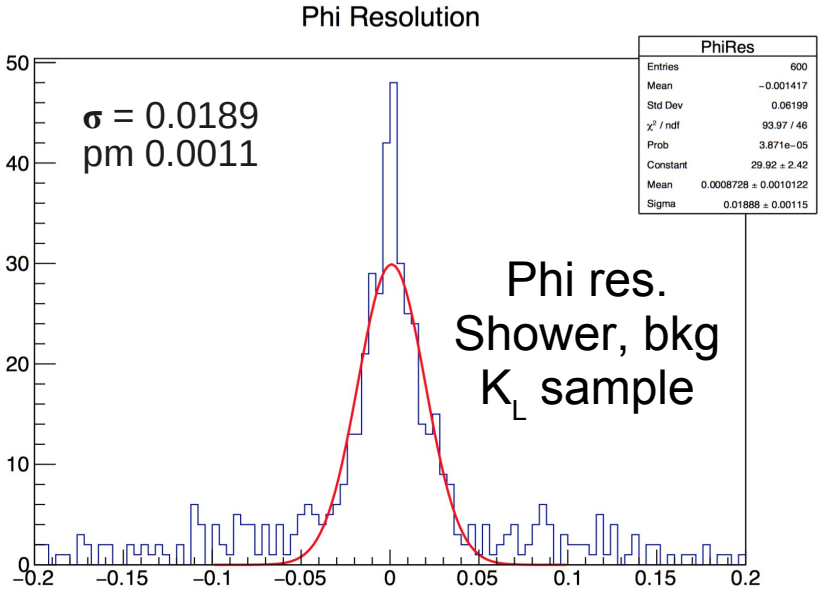


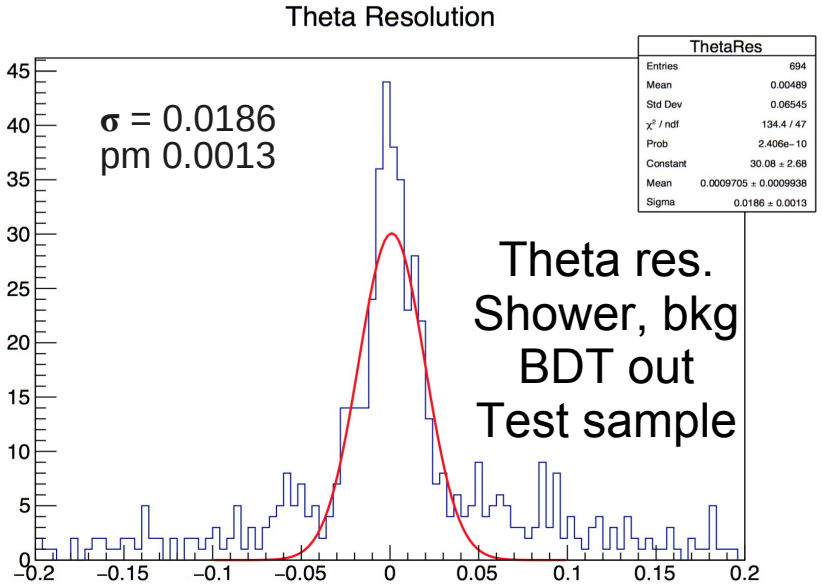


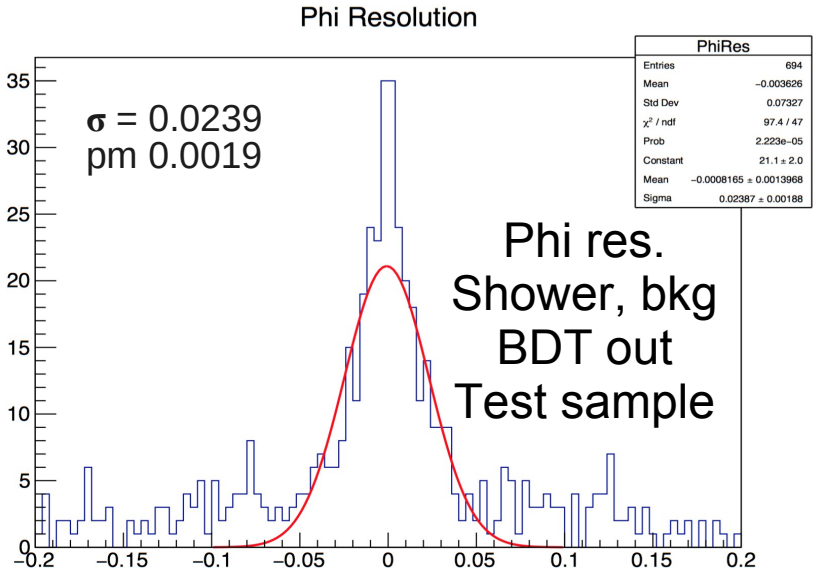
Resolution, Shower and BDT out

- Worse resolution in BDT out



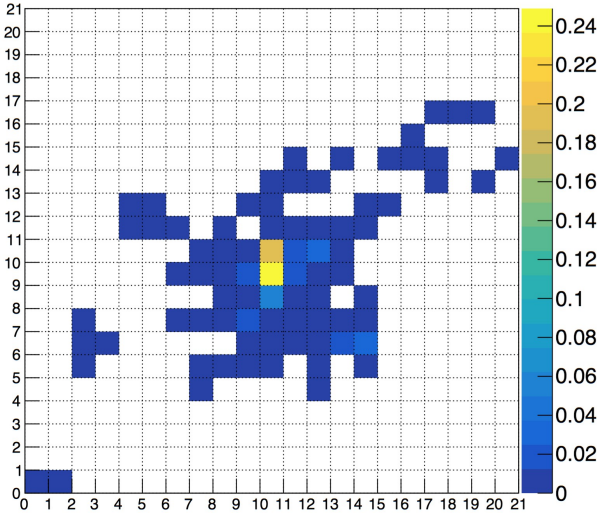




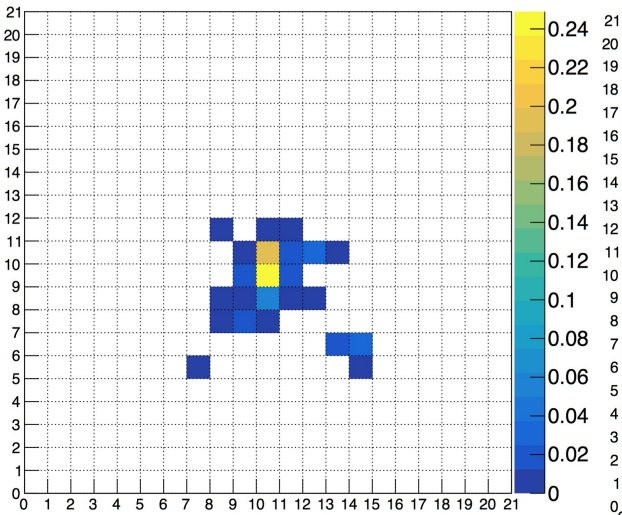


Splitters

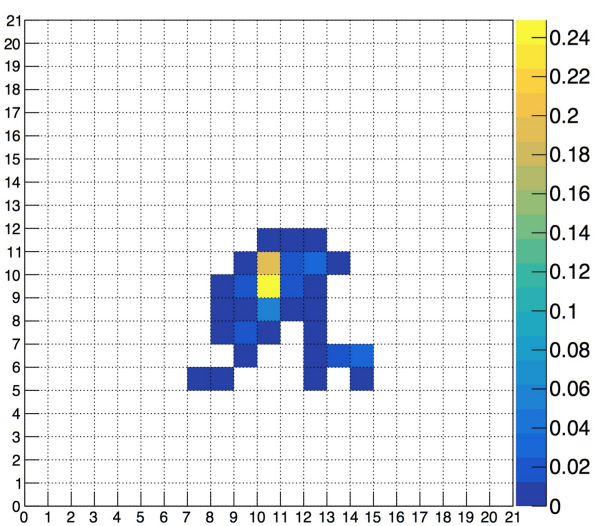
- First tests with fancy splitters:



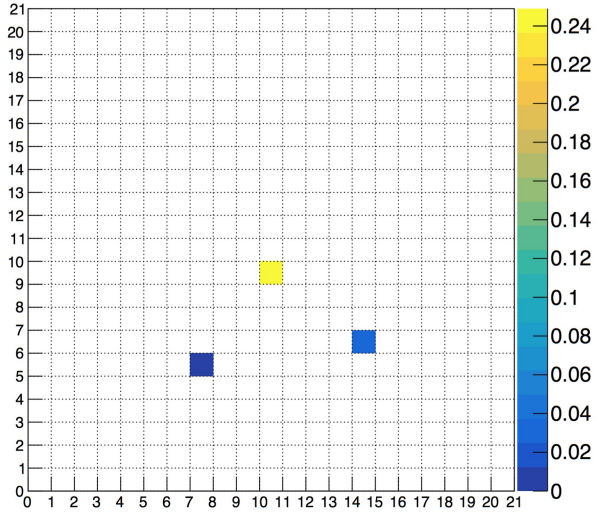
Evt. 1: CalDigits



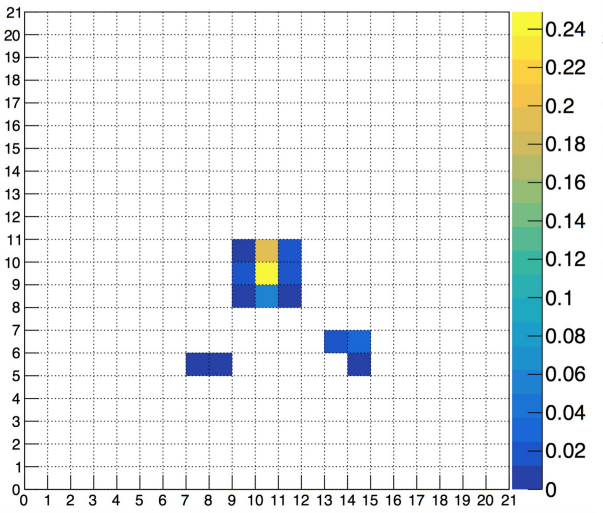
4 Showers



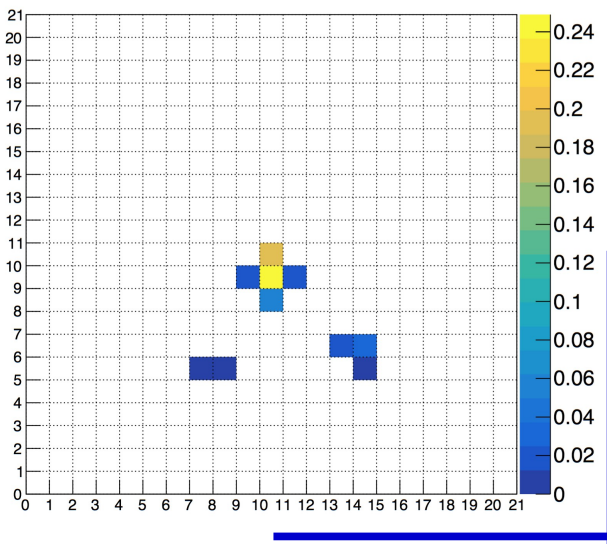
3 CRs



Evt. 1: SplitterN2_1



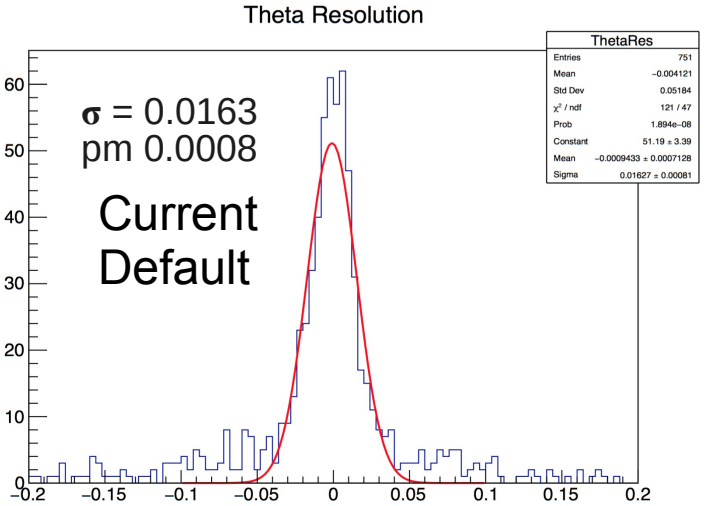
SplitterN2_3x3

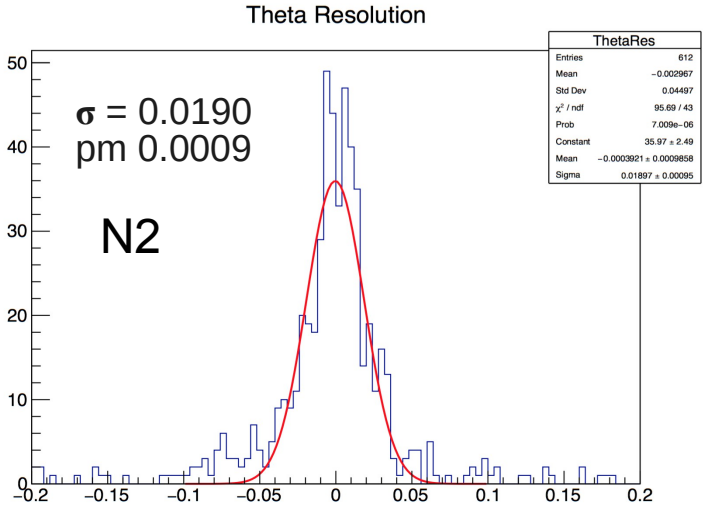


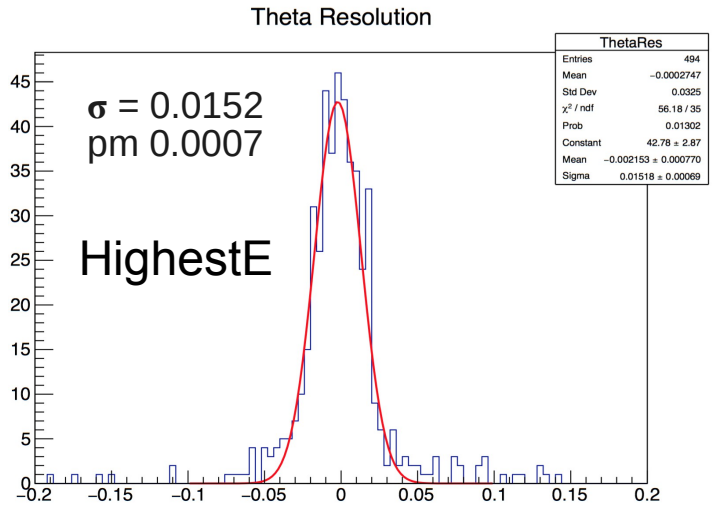
SplitterN2_X

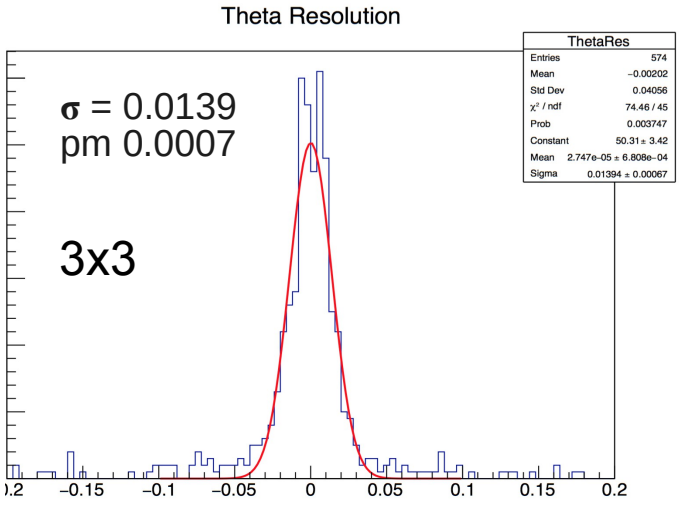
Splitters (2)

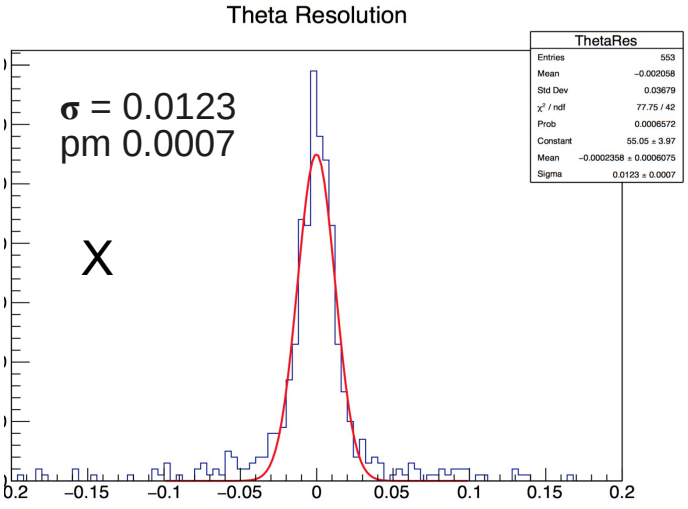
- First tests with fancy splitters: best results on reco with 3x3-like splits











Barrel Only!

Physics ID performance

- Use weights from previously trained BDT on B -> J/Psi K_L (CC) samples, J/Psi -> mu mu
- Typical output (cut on BDT out = -0.05 (not optimized!), expect 50% sig efficiency, 10% bkg eff. based on training-like sample):
  - EvtGenBkg_JPsi_generic_default:

    Cut on BDT output: -0.05 -> 866 selected candidates from 38077 total clusters, 1206 “true candidates”, 395 correct selections in 1000 events.

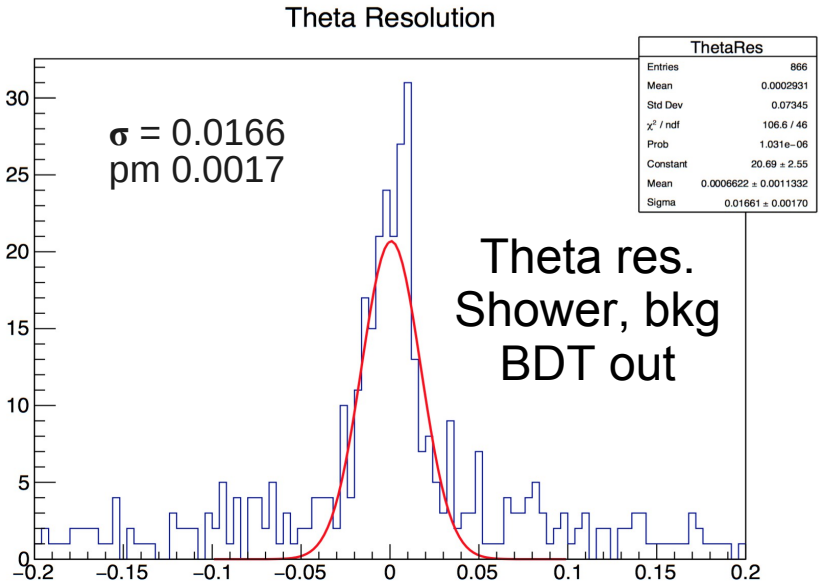
    395 KL, 57 pi, 323 photons, 25 muons, and 66 other particles
  - EvtGenBkg_JPsi_generic_N2:

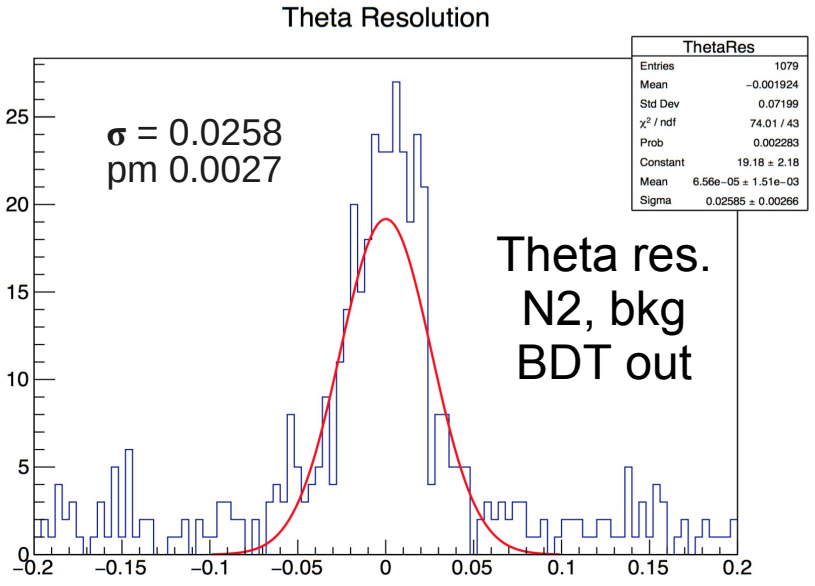
    Cut on BDT output: -0.05 -> 1079 selected candidates from 32744 total clusters, 1037 “true candidates”, 469 correct selections in 1000 events.

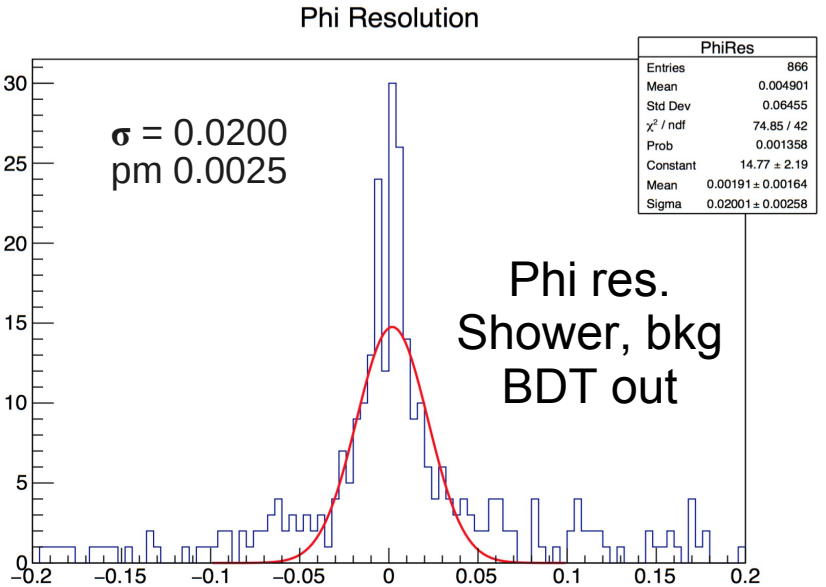
    469 KL, 77 pi, 438 photons, 38 muons, and 57 other particles

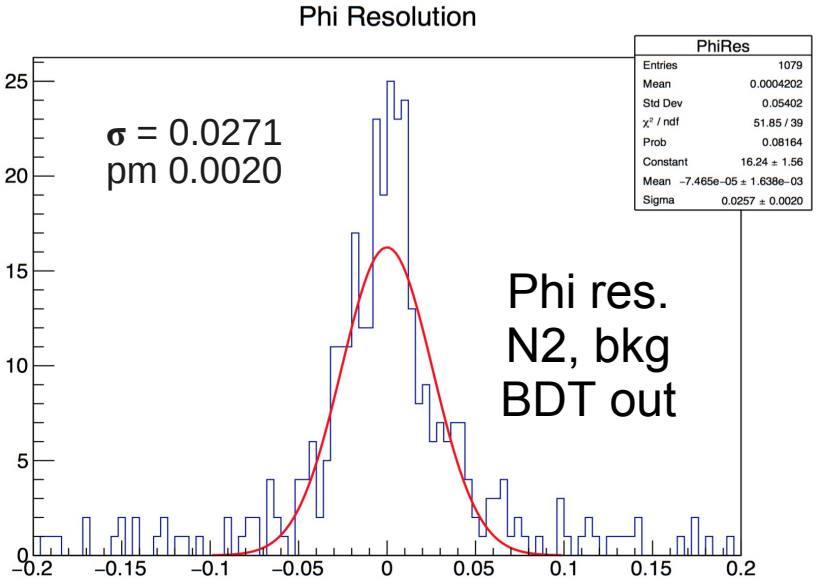
Physics reco performance

- B -> J/Psi K_L (CC) samples





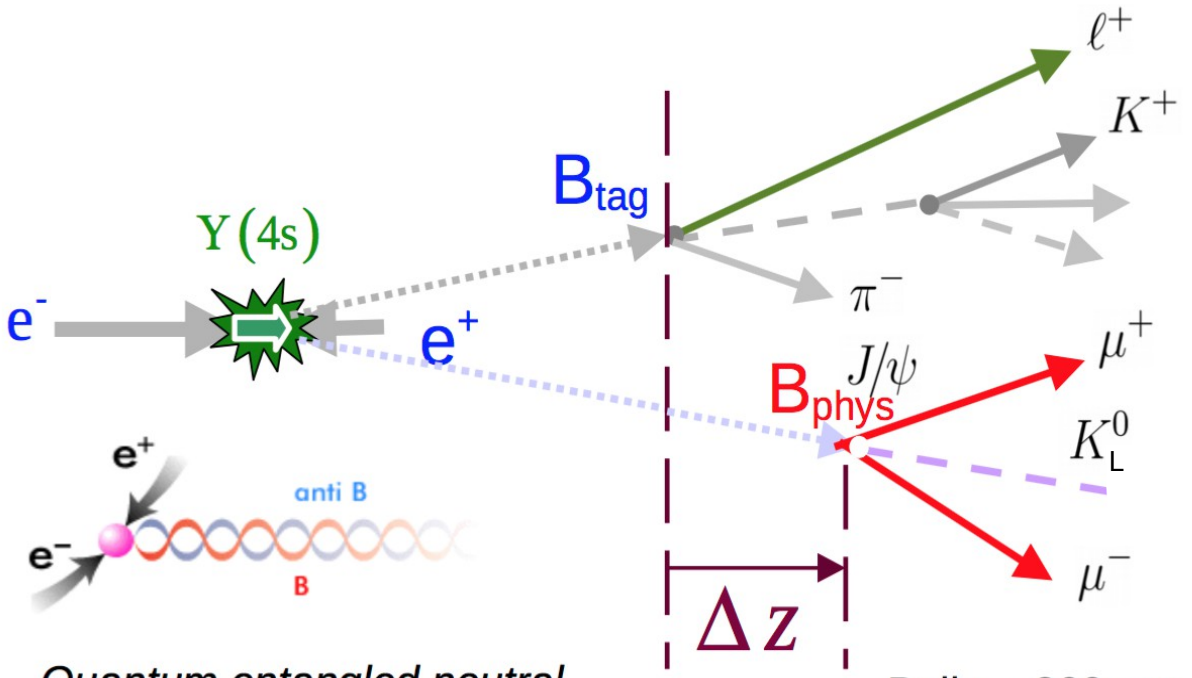




TDCP in B -> J/Psi K_L

$$\Delta t = \frac{\Delta z}{\beta \gamma c}$$

Resolution on Δt will be dominated by the resolution of the tagging side vertex



Quantum entangled neutral B meson pair production

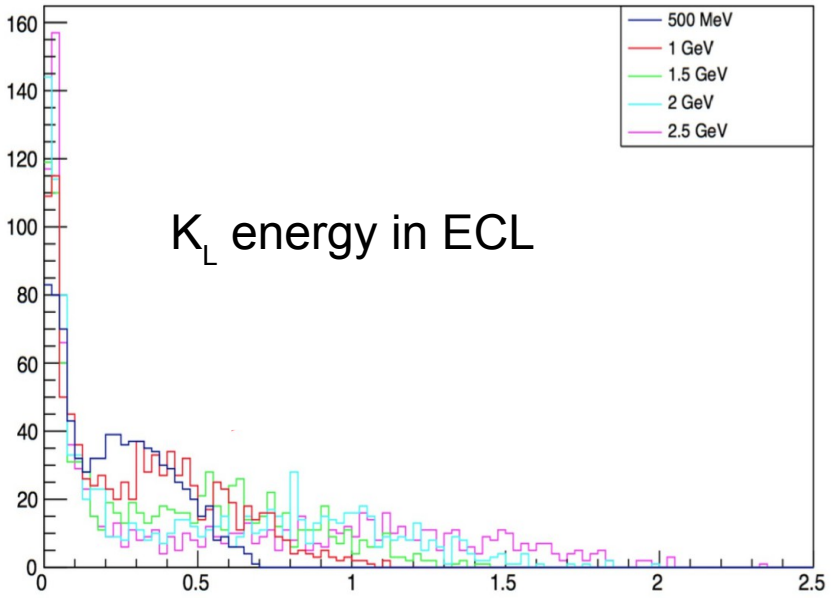
Belle ~ 200 μm
Belle II ~ 130 μm

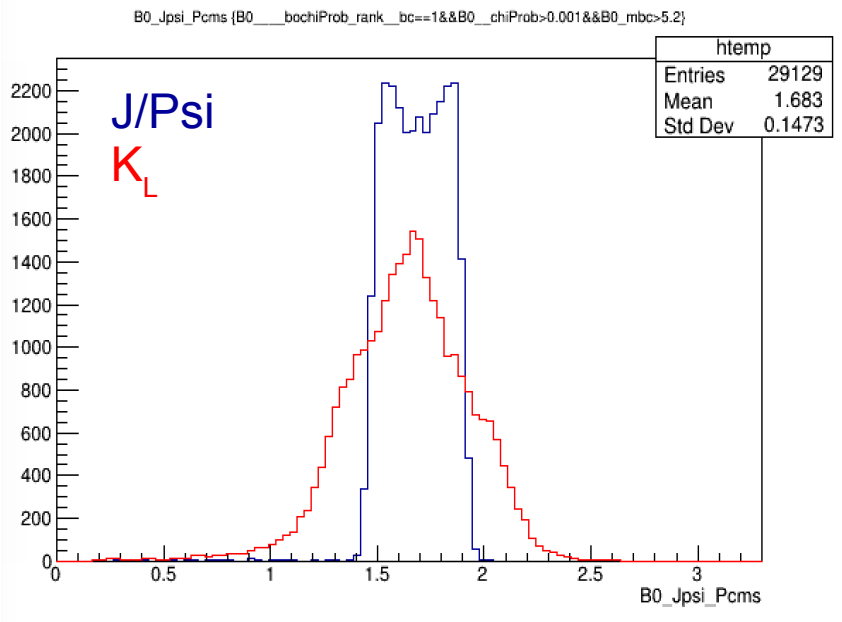
Δt probability parametrization $\mathcal{P}(\Delta t, q) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}\left[1 + q\left(\mathcal{A}_{CP}\cos\Delta m_d \Delta t + \mathcal{S}_{CP}\sin\Delta m_d \Delta t\right)\right]$

Picture from L. Li Gioi's talk @ MIAPP B2TiP November 2016

B -> J/Psi K_L, K_L reco

- Interest: CP(J/Psi KL) = - CP(J/Psi KS), J/Psi-> mu mu, J/Psi-> e e
- Main difficulty KL reconstruction
- Strategy get direction info from ECL and KLM clusters -> reconstruct momentum magnitude assuming p(KL)T = - p(J/Psi)T
- New module to handle 2 body decays with missing p is being developed and will be included in official analysis package



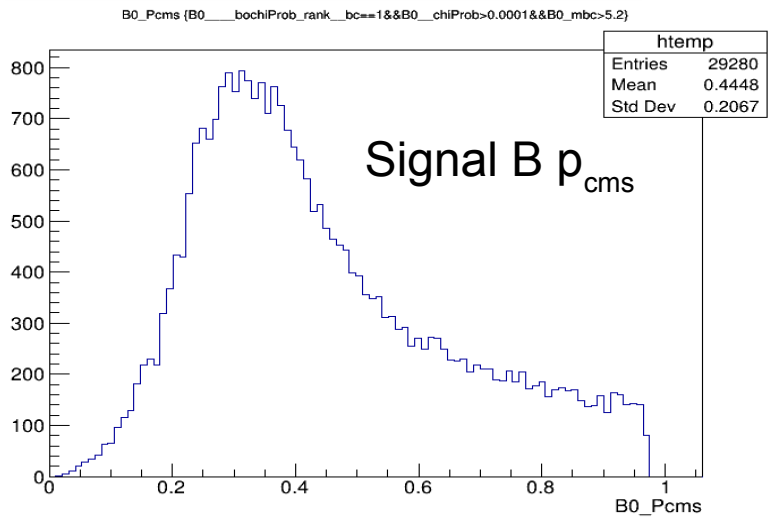


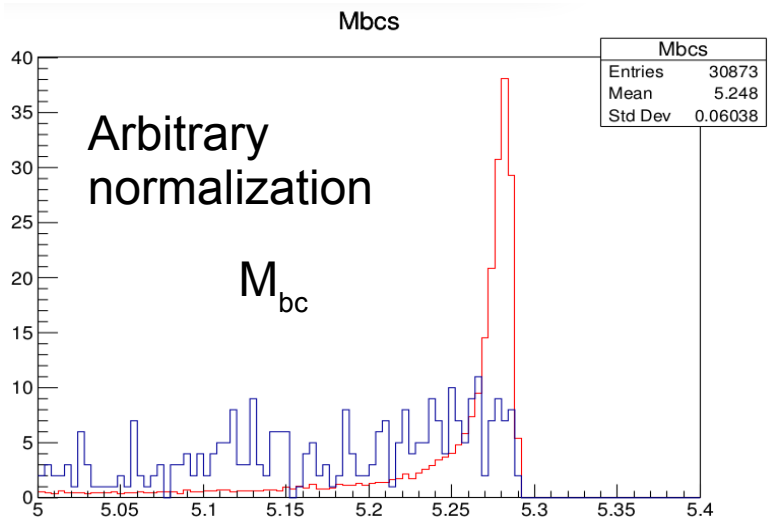
B -> J/Psi B proto-analysis

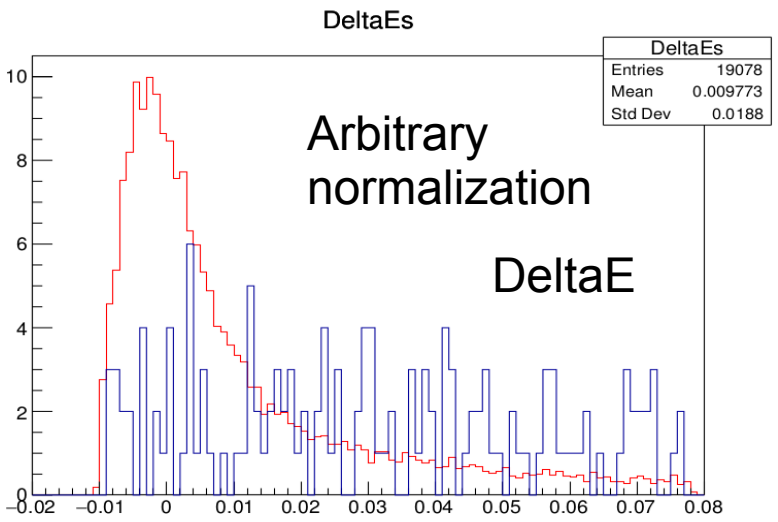
- Take best K_L (E>0.1) candidate based on fit_prob (prob >0.001)
- M_{bc} > 5.27 GeV, Abs(DeltaE)<0.01
- 3.06<M(J/Psi)<3.16, 1.4<p(K_L)<2
- MCTruth-tag

  $B\overline{B}$ evts

  B^0 -> J/Psi K_L







B -> J/Psi B proto-analysis

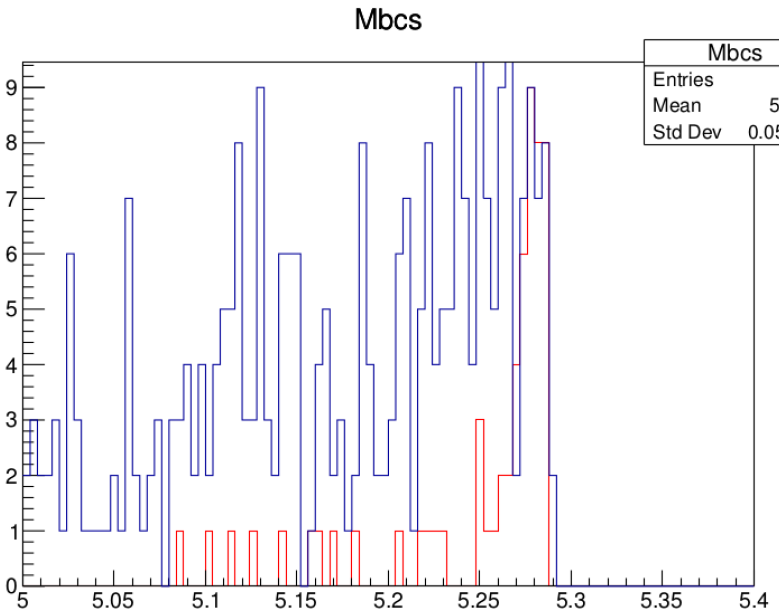
- 2 10^6 generic $B^0\overline{B}^0$ evts
- 10^5 signal evts:

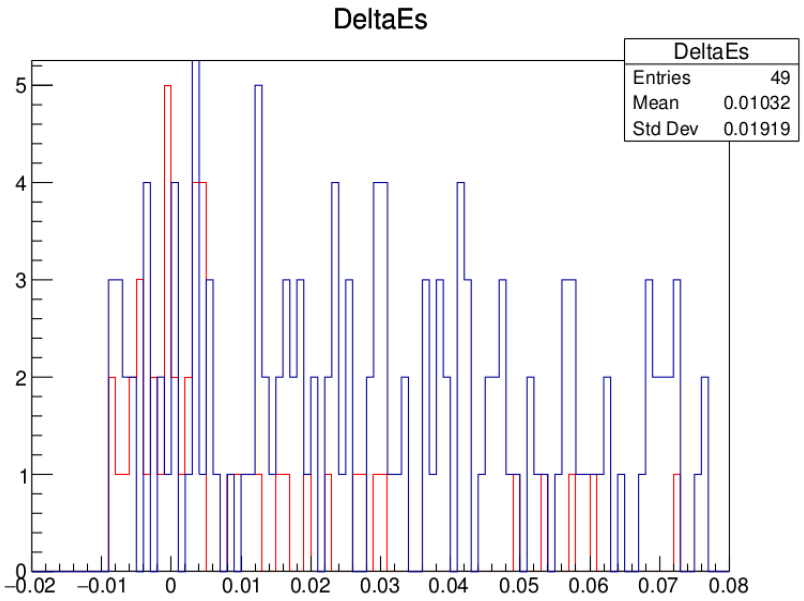
  1st B^0 -> J/Psi K_L

  2nd B^0 -> generic
- Yeld: 33 sig, 34 bkg

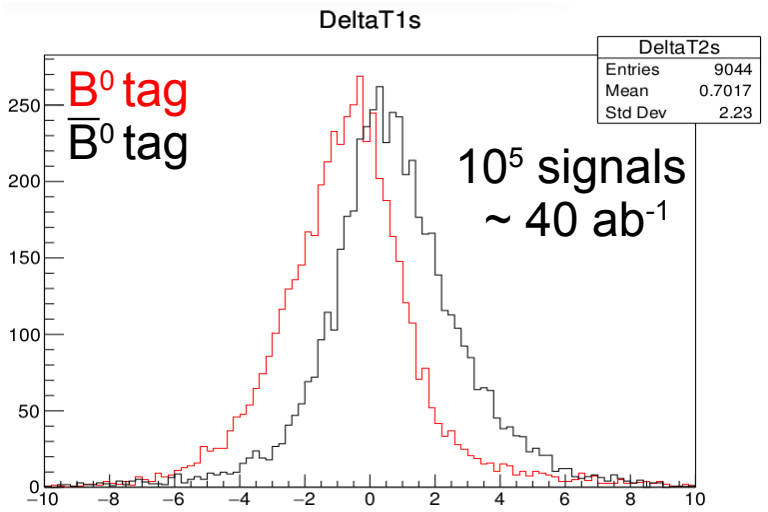
BaBar 23 fb-1 Phys.Rev.Lett.86:2515-2522,2001

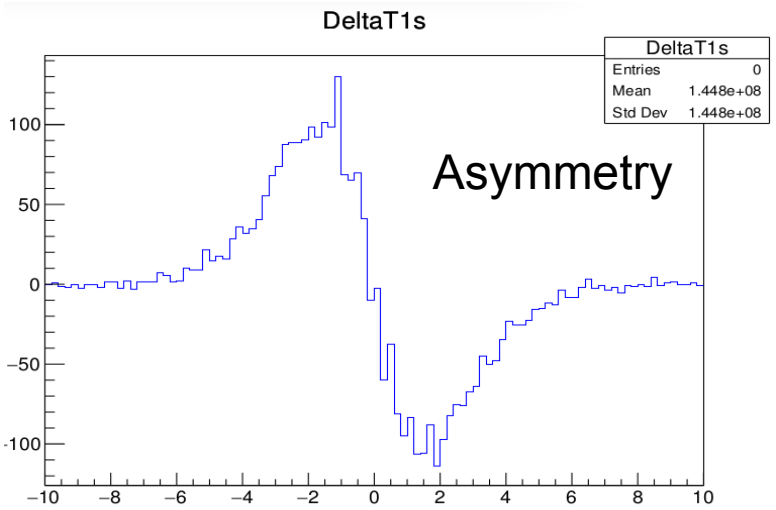
Sample	N_{tag}	Purity (%)	sin2β
$J/\psi\, K^0_S,\ \psi(2S) K^0_S$	273	96 ± 1	0.25 ± 0.22
$J/\psi\, K^0_L$	256	39 ± 6	0.87 ± 0.51
Full CP sample	529	69 ± 2	0.34 ± 0.20

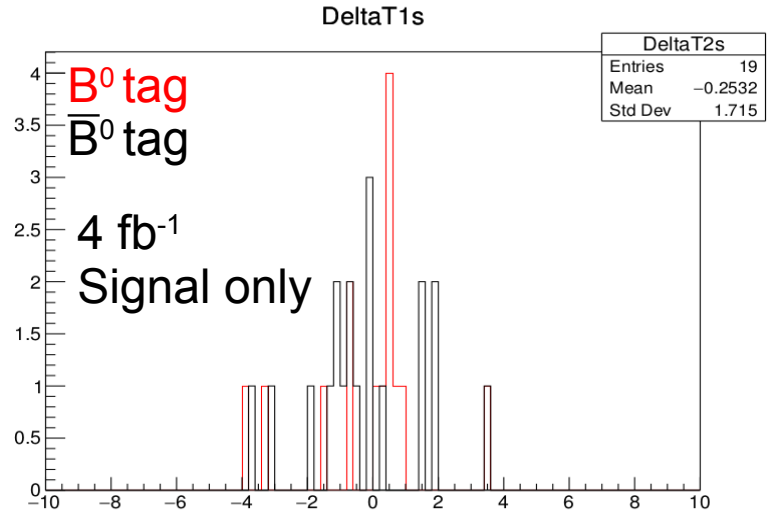


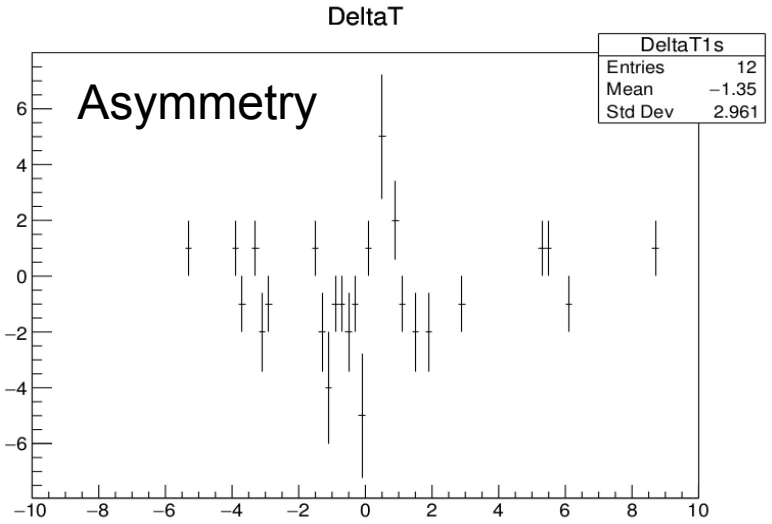


B -> J/Psi DeltaT





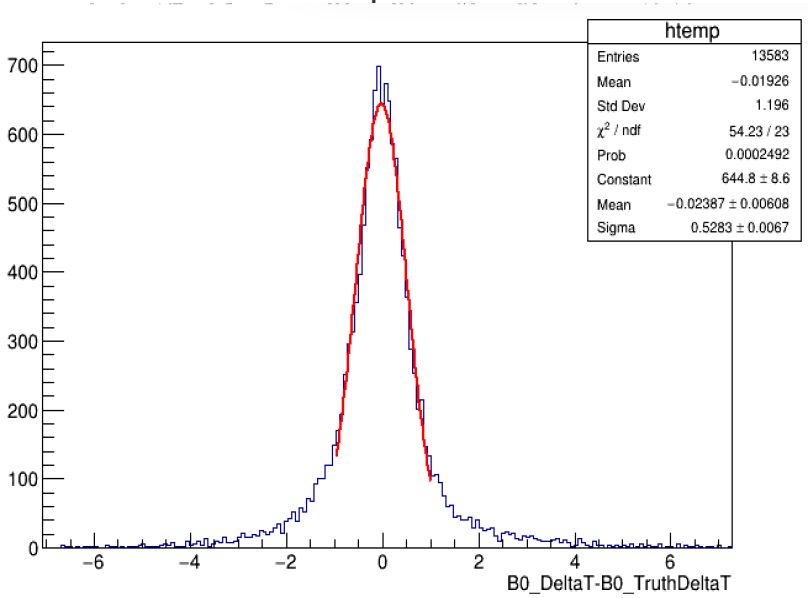




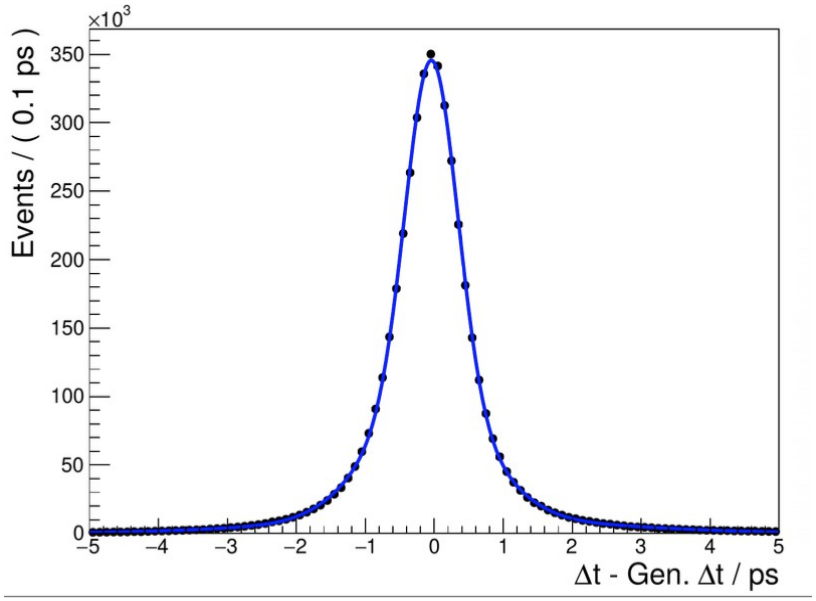
B -> J/Psi K_L T resolution

- Cross-check: resolution comparable to similar analysis B -> J/Psi K_S

B -> J/Psi K_l , this



Li Gioi's @ MIAPP B2TiP Nov. 2016



Belle II
- Bias = -0.003 ps
- Resolution = 0.77 ps

Summary

- BDT selectors work best (mostly) on non-splitted CRs
- For the time being best option is probably to use CR for ID and the split for reco optimization
- Error on reconstructed direction seems to be already close to limit value even with trivial fancy splitters
- Proto-eclSplitterN2 module implementing is on track
- Different optimization for endcaps would be better solution
- Work on digit level approach for better K_L ID
- Need to solve MC-related issues

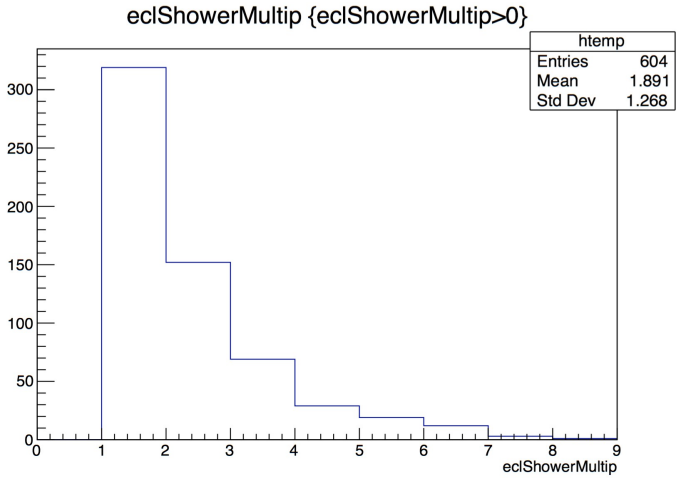
- Work on B-> J/Psi K_L has started, waiting for large MC7 samples to go on

Backups

Physics ID performance, comment

- Be aware: actual efficiency for KL ID is not that of BDT, e.g. 469/1037:
  - EvtGenBkg_JPsi_generic_N2:

    Cut on BDT output: -0.05 -> 1079 selected candidates from 32744 total clusters, 1037 “true candidates”, 469 correct selections in 1000 events. 469 KL, 77 pi, 438 photons 38 muons, and 57 other particles were
- BDT runs over showers, sigTagMultip/event: ~2, sigTagEvt/Evts ~ 60%



- Estimate for previous efficiencies:

  default shower: 314 / 0.6*1372 = 38%, N2: 396 / 0.6*1372 = 48%

MCMatching

- Various (non trivial) problems arise when secondary particles are stored and/or hadronic interactions are involved

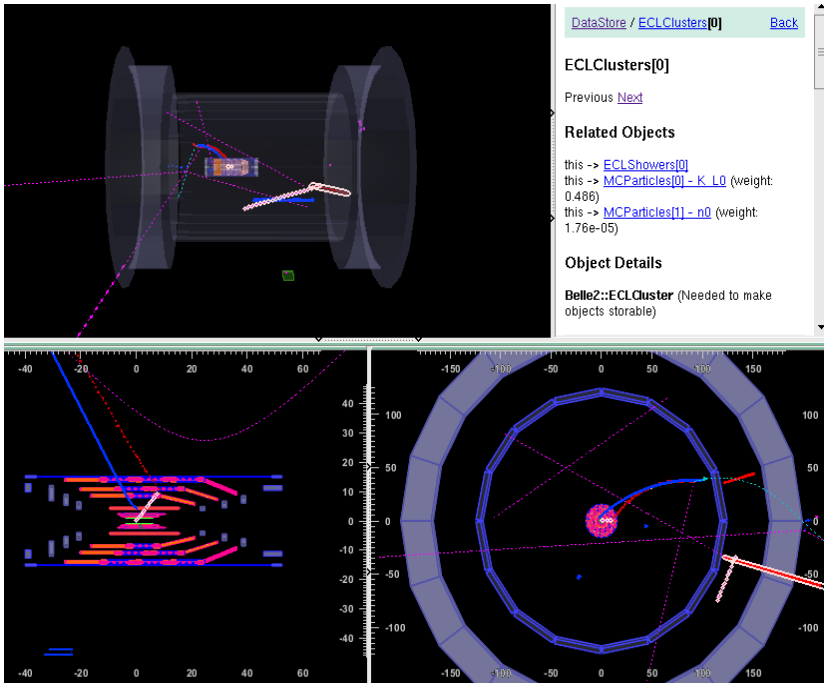
- Two cases which clearly show this issue: brems-photons and K_Ls
  - 1) usually brems-photons are not stored -> brems-photon cluster is associated to mother electron
  - Switch StoreAllSecondaries=1 to keep your brems-photon -> the photon (whether primary or not) isn't associated any longer to the cluster. Why? If secondaries are stored shower energy is shared among all daughters of the impinging photon but the photon itself hasn't any energy loss associated from the pair formation (i.e. no SimHit) hence it is not associated
  - Completely different MC signature w.r.t. electrons
  - Problem reported also by tracking guys -> need solution asap

MCMatching (2)

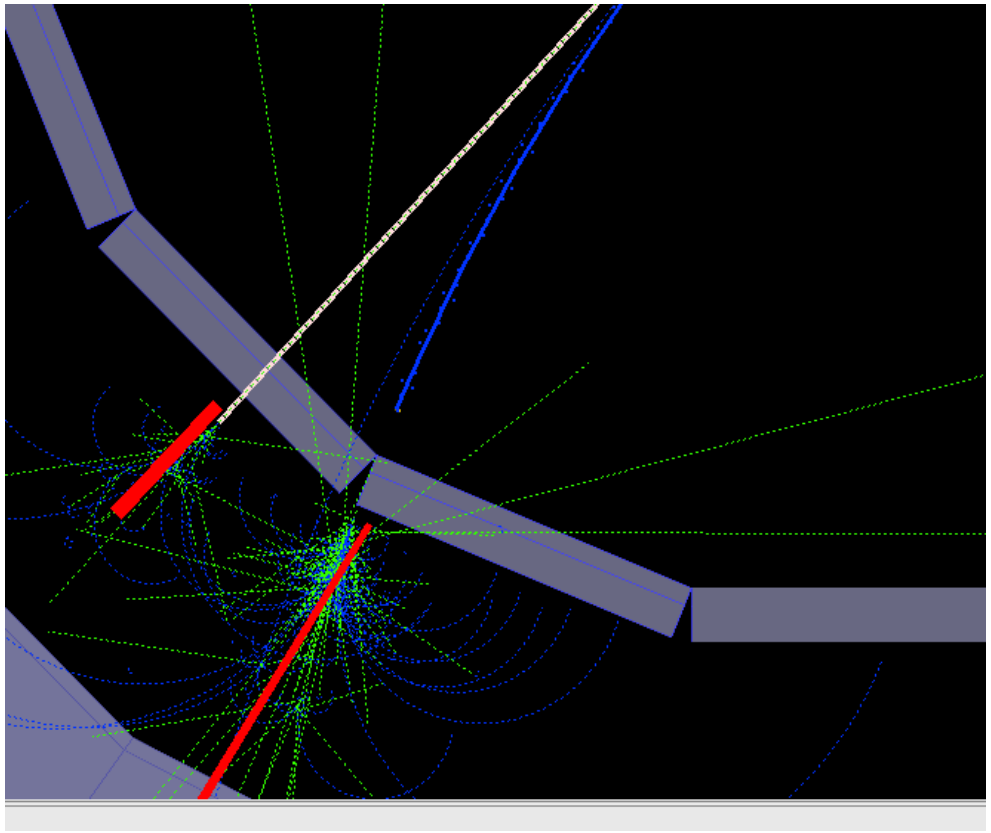
- 2) less trivial case: K_Ls
- For some reason in hadronic interactions sometimes secondaries are saved sometimes are not (haven't found out a clear rule)
- Variety of scenarios:
  - 1 - K_L interacts somewhere, n clusters far from each other in ECL all associated to K_L -> wrong, or at least useless
  - 2 - K_L interacts before ECL, single (or few) secondary carrying almost all energy, 1 cluster not associated to K_L -> correct, but would be useful for reconstruction
  - 3 – K_L interacts in ECL, highest E cluster matched to e.g. a pion, while some distant split offs associated to K_L -> wrong (?) but useful
  - ..etc, etc.. (split-offs, backscattering... and so on..)

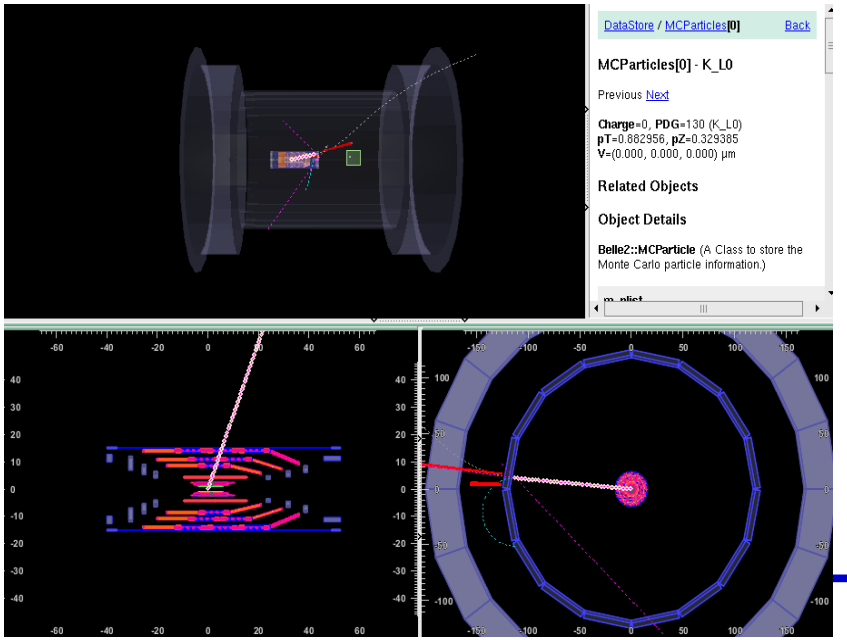
MCMatching (3)

K_L



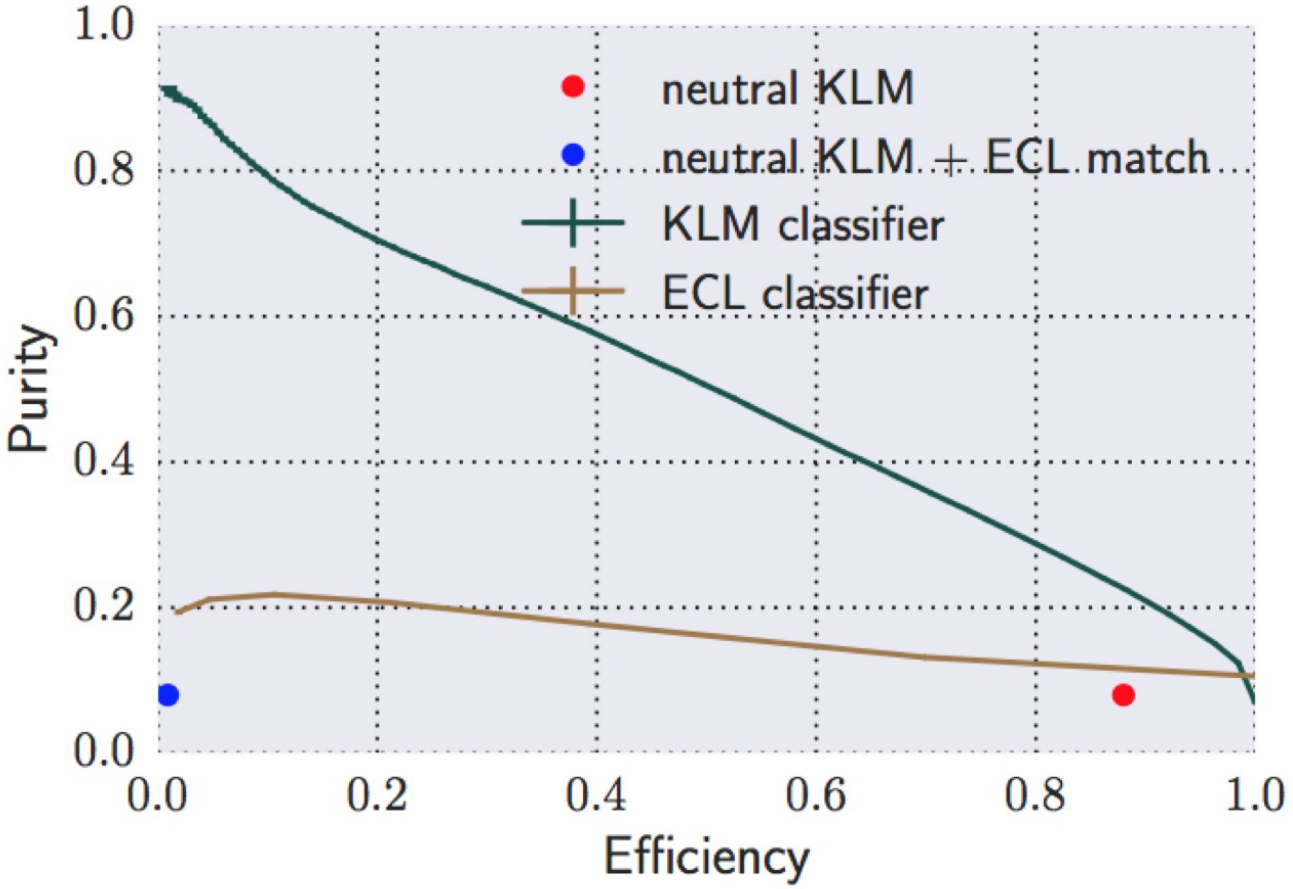
Brems-gamma mismatch by T. Hauth





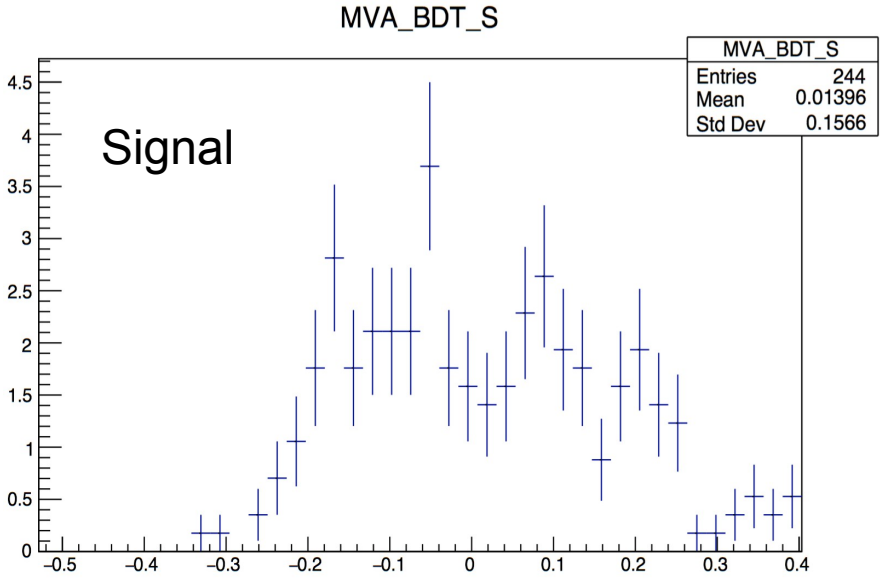
Previous results on K_L ID

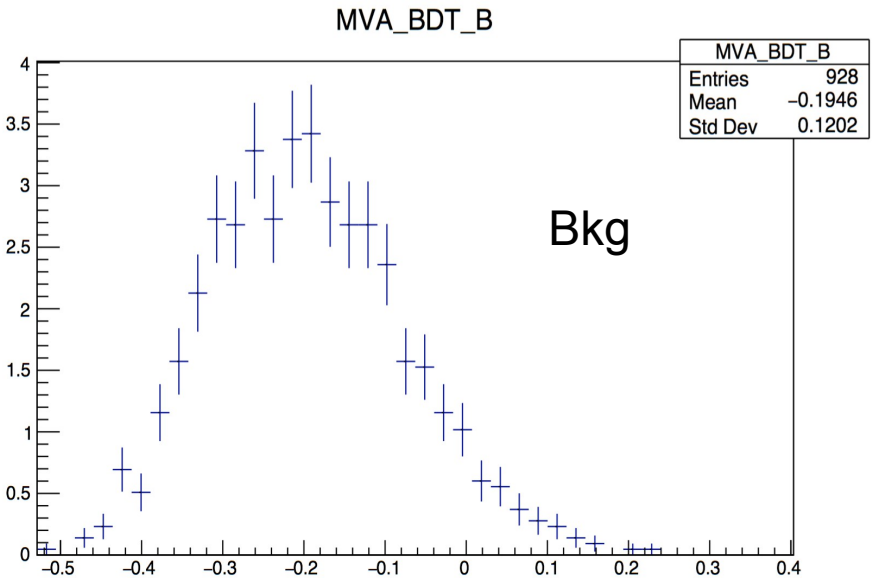
- J. F. Krohn 21 September 2016 (performance meeting (?))

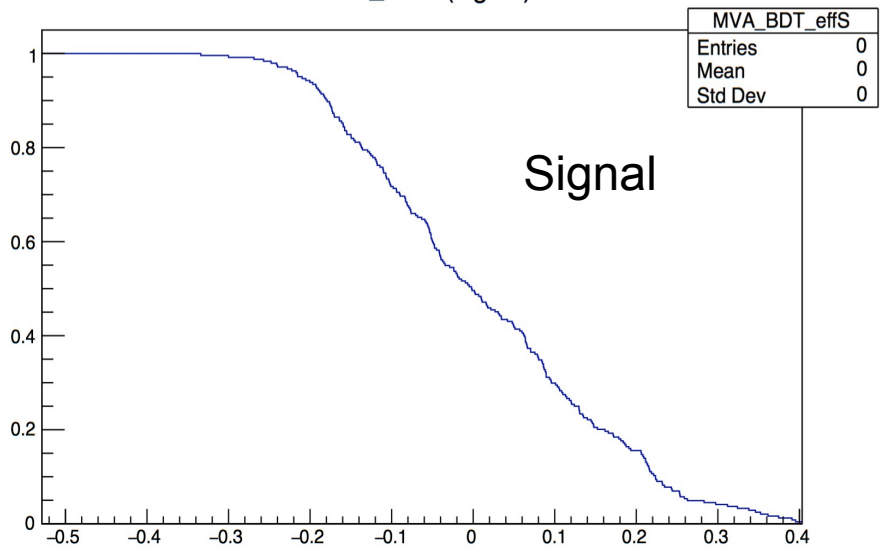


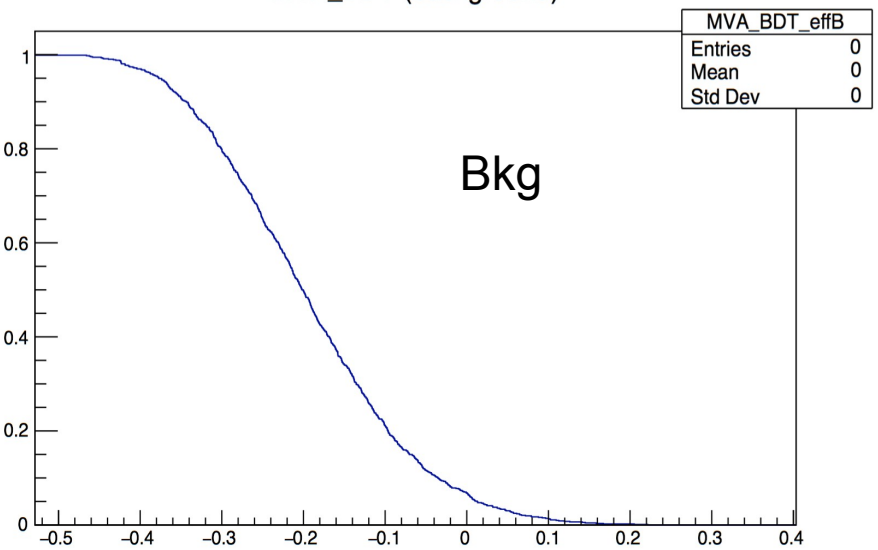
EvtGen Test BDT

- BDT performance:



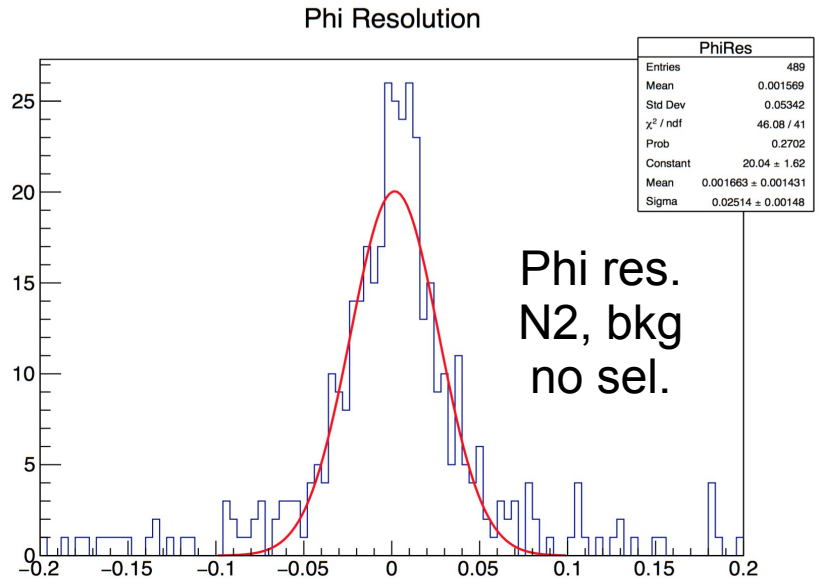


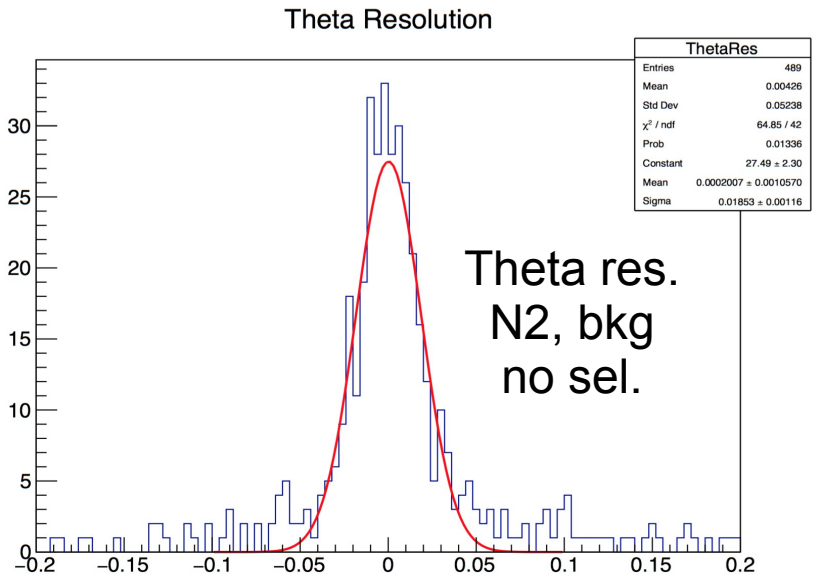




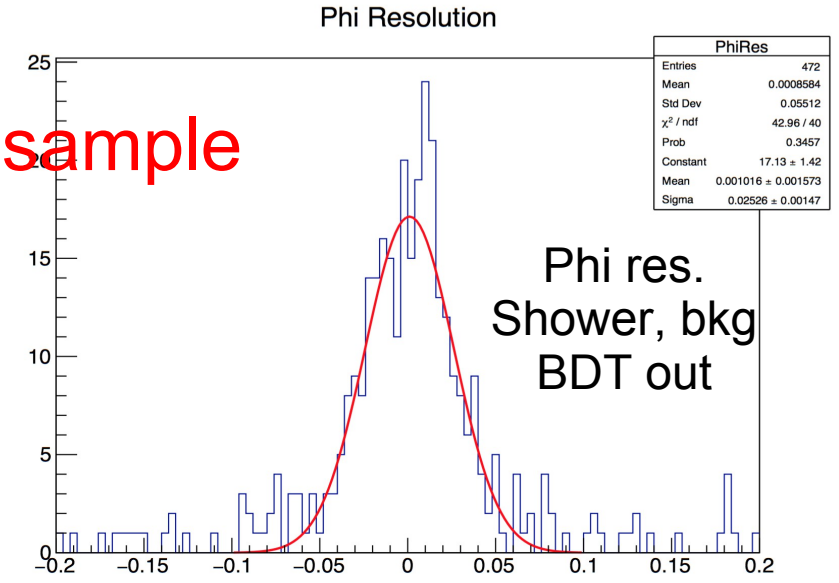
Resolution, N2 and BDT out

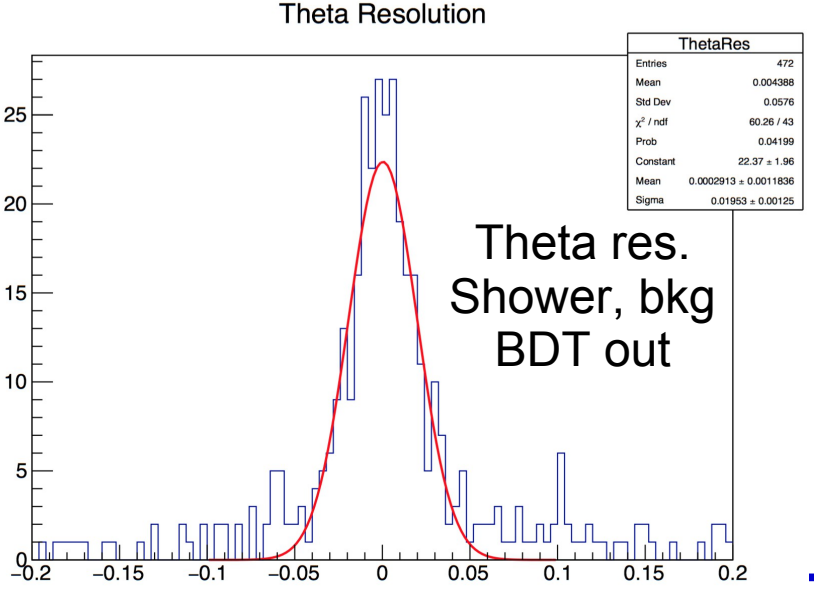
- No clear bias from BDT is seen





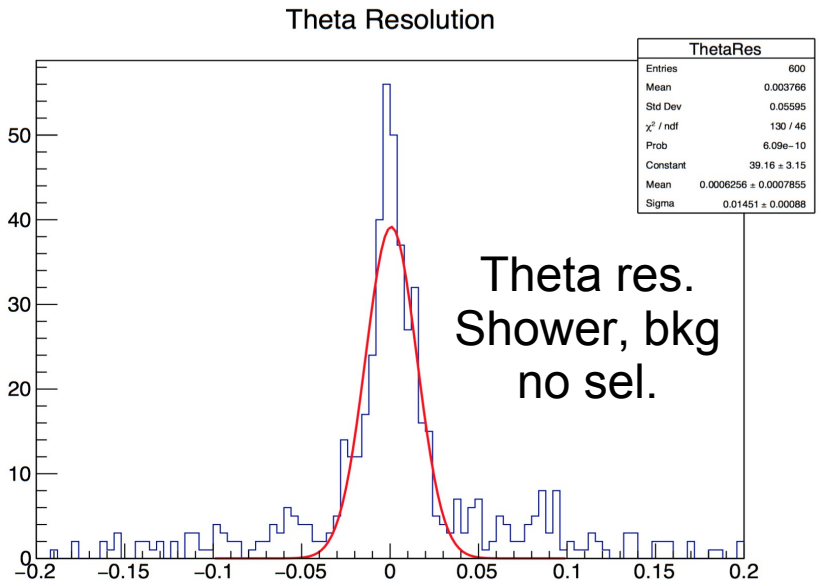
KL sample

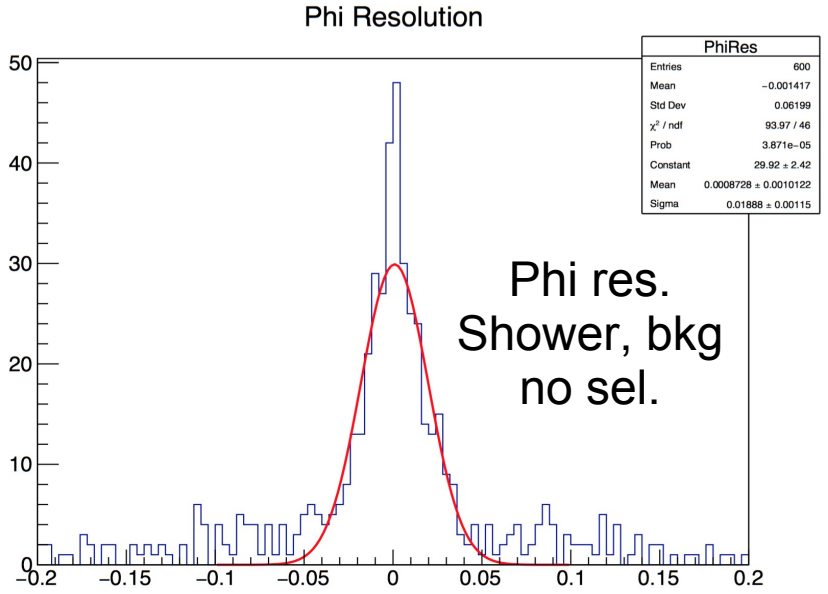




Resolution, shower and BDT out

- No clear bias from BDT is seen





KL sample