Update on $B^0 \rightarrow J/Psi\ K_L$

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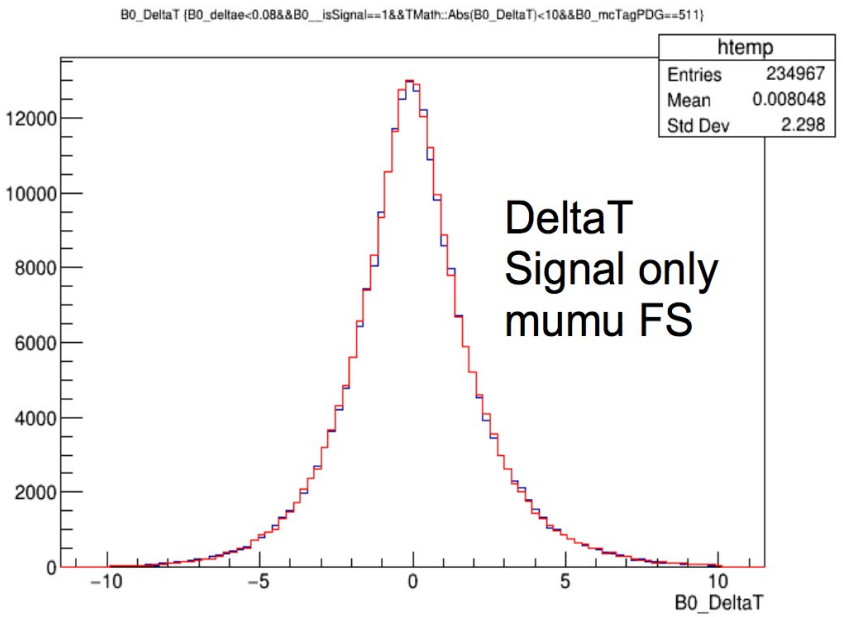
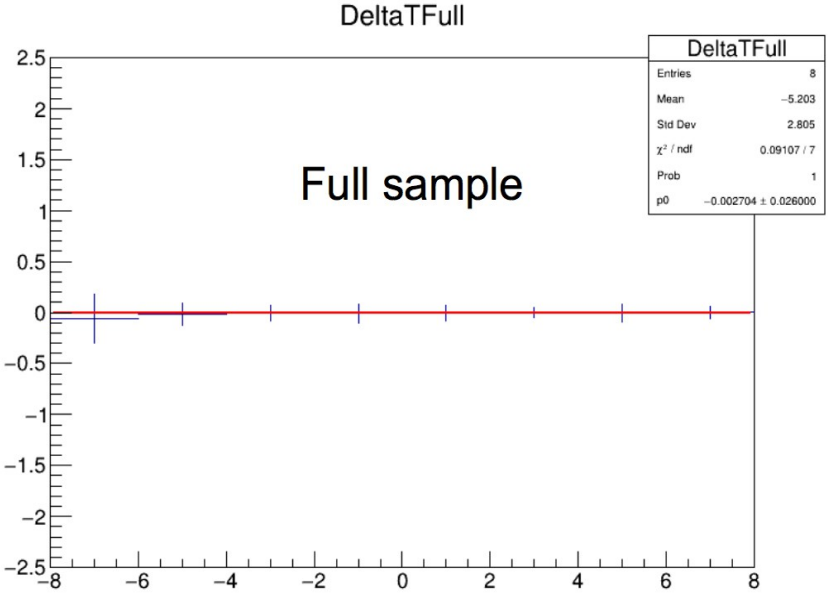
Foreword

- In Trieste I showed the results of the TDCPV analysis on a 48 ab^{-1} equivalent sample of “J/Psi cocktail”, i.e. $B^0 \rightarrow X \rightarrow J/Psi\ Y$ sample produced of the 8th MC campaign, unfortunately..

B2IM, Trieste 4th May 2017

..there is no CPV at all!





What's new

- In fact many key ingredients were missing in previous analysis:
  - No CPV in MC sample

    → **new DEC file with CPV in B^0 decays used in MC9 (GRID)**
  - No beam-bkg included

    → **first evaluation of beam-bkg effect (GRID)**
  - K_L reconstructed separately in ECL and KLM

    → **prototype of combined ECL-KLM K_L list** **(under development not yet on GRID)**
  - No FlavorTagger information because of issues running on grid

    → **workaround: run selection on grid, dump as mdst (instead of PList) run FlavorTagger on local release** (not shown today)
  - Non-J/Psi bkg missing

    → not shown today but expected to be small, some issues with the grid

New DEC file

- To get CP asymmetry we need to fit different bkg components which may have non trivial CP structure → we have to simulate CPV

- New DEC file is available @:
  https://agira.desy.de/browse/BII-2713
- It was developed from Belle2 default DECAY.DEC in
  /externals/v01-04-01/share/evtgen/
- I kept Belle2 default BF and parameters and just changed the decay models for appropriate channels based on BaBar-like decay models, e.g.:
  - SVS, PHSP → SSD_CP
  - SVV_HELAMP → SVV_CP

B^0 to 2-body ($b \rightarrow u$)

```
# 2- and 3-body modes revised Feb.2005  Markus Cristinziani, SLAC
#vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
#    B0 -> CP eigenstates  (some exclusive b -> u)   sum=0.00036
#
0.000005130 pi+     pi-    PHSP; #[Reconstructed PDG2011]
0.000001620 pi0     pi0    PHSP; #[Reconstructed PDG2011]
0.0000010  pi0  eta     PHSP;
0.000001200 pi0     eta'    PHSP; #[Reconstructed PDG2011]
0.000001  pi0  a_00    PHSP;
0.000001  pi0  f_0     PHSP;
# pi0 rho0 is with the 3-body modes
0.000001  omega pi0    SVS;
0.000001  a_10  pi0    SVS;
0.000001  b_10  pi0    SVS;
0.000001  eta  eta     PHSP;
0.000001  eta  eta'    PHSP;
0.000001  eta  a_00    PHSP;
0.000001  eta  f_0     PHSP;
0.000001  rho0 eta     SVS;
0.000000940 omega    eta    SVS; #[Reconstru
0.000001  a_10 eta     SVS;
0.000001  b_10 eta     SVS;
0.000001  eta' eta'    PHSP;
0.000001  eta' a_00    PHSP;
0.000001  eta' f_0     PHSP;
```

Belle2 default

With CPV

```
#-----------------------------------------------------------------------------
# 2- and 3-body modes revised Feb.2005 Markus Cristinziani, SLAC
#vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
# B0 -> CP eigenstates (some exclusive b -> u) sum=0.00036
#
0.000005130 pi+ pi- SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001620 pi0 pi0 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.0000010 pi0 eta SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001200 pi0 eta' SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 pi0 a_00 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma -1.0 minusGamma;
0.000001 pi0 f_0 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
# pi0 rho0 is with the 3-body modes
0.000001 pi0 omega SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 pi0 a_10 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 pi0 b_10 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma -1.0 minusGamma;
0.000001 eta eta SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 eta eta' SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 eta a_00 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma -1.0 minusGamma;
0.000001 eta f_0 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma -1.0 minusGamma;
0.000001 eta rho0 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 eta omega SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 eta a_10 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 eta b_10 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma -1.0 minusGamma;
0.000001 eta' eta' SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma 1.0 minusGamma;
0.000001 eta' a_00 SSD_CP dm 0.0 1.0 minusTwoBeta 1.0 gamma -1.0 minusGamma;
```

$B^0 \to K^*_0 c\bar{c}$ decays

- $B^0 \to K^*_0 c\bar{c}$ decays are non trivial
- In Belle2, single decay no CPV:

  0.001330000 J/psi K*0 SVV_HELAMP PKHminus PKphHminus PKHzero PKphHzero PKHplus PKphHplus; #[Reconstructed PDG2011]
- BaBar-like, splitted in 3 decays, 2 CP eigenstates:

  0.000215 J/psi K*S SVV_CP beta dm 1 Aplus phAplus Azero phAzero Aminus phAminus;

  0.000215 J/psi K*L SVV_CP beta dm -1 Aplus phAplus Azero phAzero Aminus phAminus;

  0.000801 J/psi K*0T SVV_HELAMP PKHplus PKphHplus PKHzero PKphHzero PKHminus PKphHminus;
- I kept BF ratios from BaBar and rescaled to match Belle2 default:

  0.000221 J/psi K*S SVV_CP beta dm 1 Aplus phAplus Azero phAzero Aminus phAminus;

  0.000221 J/psi K*L SVV_CP beta dm -1 Aplus phAplus Azero phAzero Aminus phAminus;

  0.000887 J/psi K*0T SVV_HELAMP PKHplus PKphHplus PKHzero PKphHzero PKHminus PKphHminus;

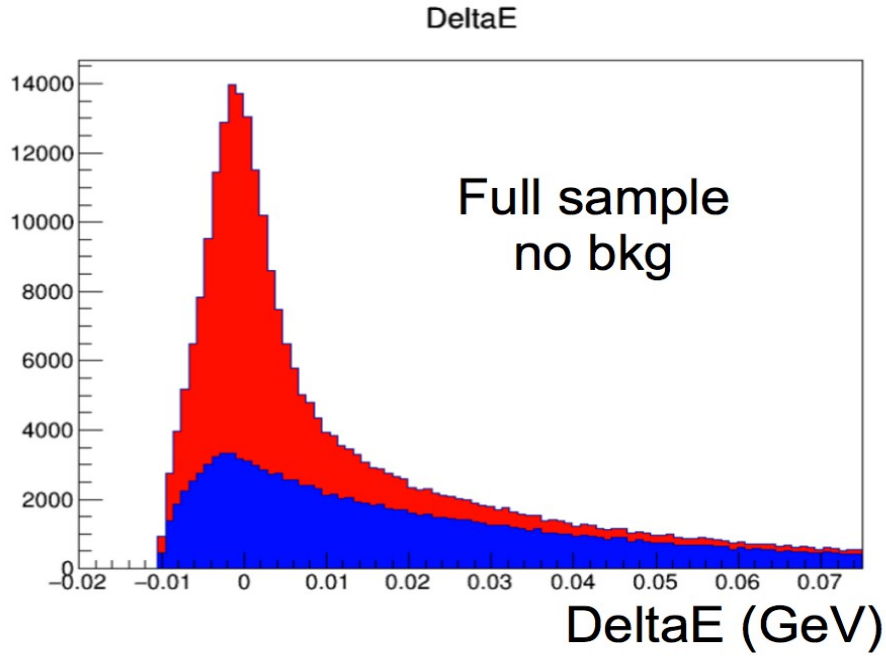
Further development of DEC file

- The new DEC file in its current version will be used for DR3 (Phase-3 Dress Rehearsal), however:
- I found differences between BaBar and Belle CPV decay models
- BaBar has more CPV modes (93 to ~50)
- BaBar uses a single decay model SSD_CP for all B decays to scalar + something else, B→ S X, while Belle uses 3 different models depending on the spin of X (SSS_CP, SVS_CP, STS_CP)
  - These differences have to be studied ion some more detail
  - We also have to evaluate the use of SSS_CP_PNG, SVS_CP_PNG, STS_CP_PNG which include penguin contributions
- All BFs have to be updated to PDG 2017 (will be done asap)
- Based on this experience I have been asked to serve as liaison for the TDCPV group in the EvtGen task-force and accepted (main duty: validate and keep BFs and decay models updated)

MC9 without beam-bkg

- Dataset: 4 ab^{-1} of J/Psi cocktail centrally produced
  - Analysis on grid → default particle lists, i.e. K_L candidates separately from KLM and ECL (as std gamma) → double counting
- Selection basically the same as MC8 (refinement in ECL cluster selection)
- Take just one candidate per event, the one with lowest |DeltaE|
- Comparing to MC8:

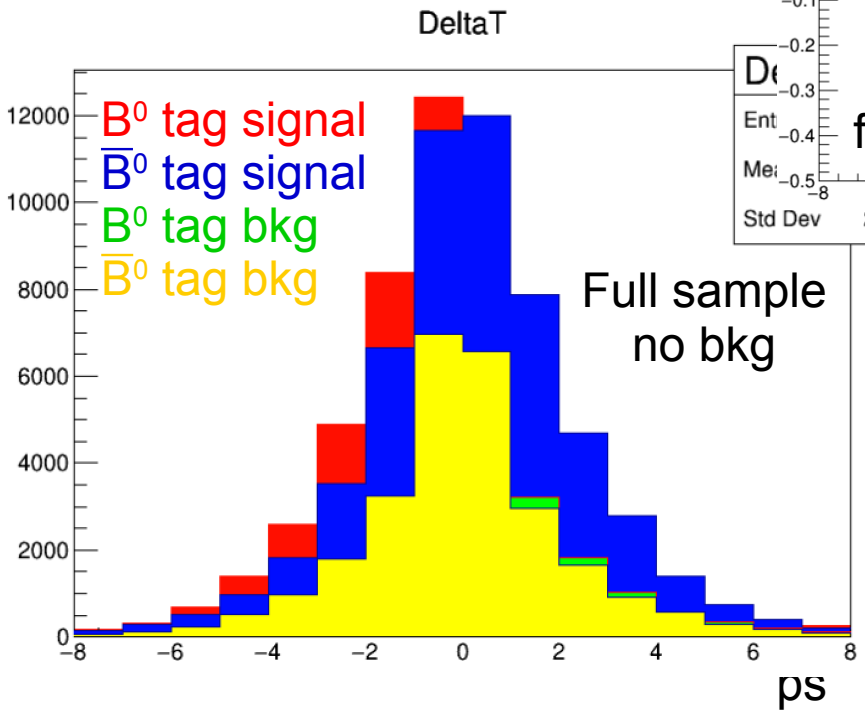
  yields: +25% in KLM, purity: 64% (was 74%), -4% ECL, 75% (was 67%)
- Ratio (J/Psi → *ee* / J/Psi → μμ): 78%, 77% respectively

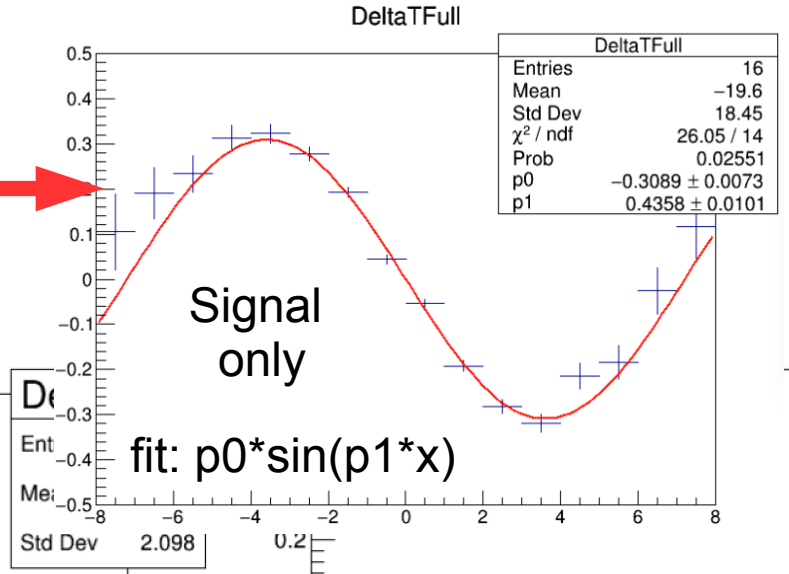


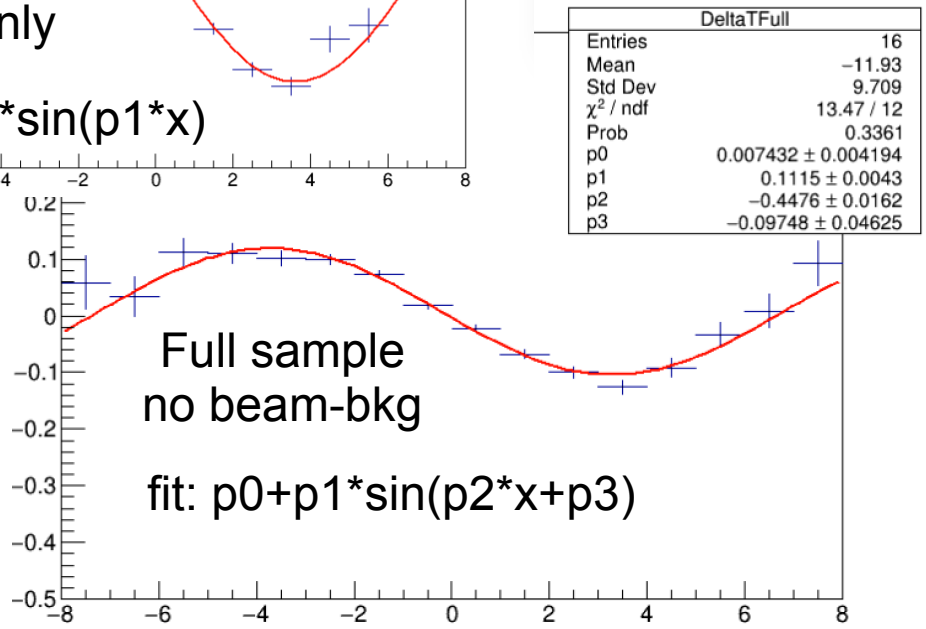
TDCPV

- Finally we have CPV in MC! (in the following mcTag is used)
- J/Psi bkg contributions points to non trivial CP structure
- New DEC file needs further validation

(signal is defined as an event with a B → J/Psi K_L, no strong match → dilution)







MC9 Yields

	BaBar 2009	Belle 2012	MC8**	MC9**
Luminosity (fb^{-1})	465	711	$48x10^3$	$4x10^3$
# tags	5.813	15.937	1.168.420	103.992
Purity (%)	56	63	70	67.5
Yield/fb^{-1}	12.5	22.4	24.3	26
Notes	B. Aubert et al., Phys. Rev. D79, 072009, (2009).	I. Adachi et al., Phys. Rev. Lett. 108, 171802 (2012).	June B2GM	This analysis

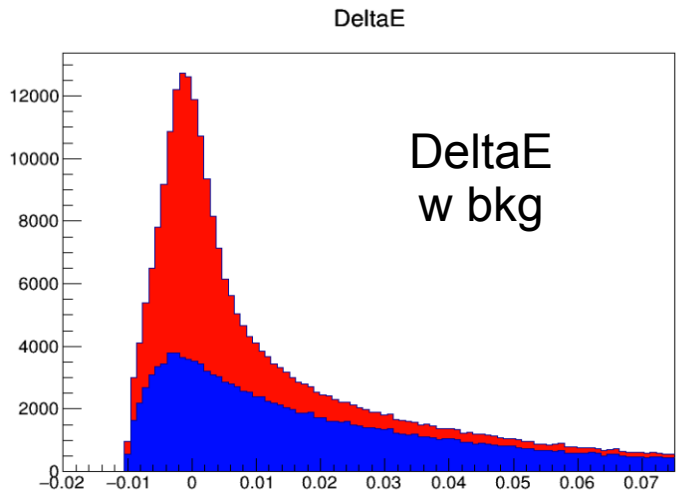
- Analysis is performed separately for ECL & KLM K_Ls → double counting
- **Assuming the K_L interactions rates (from a talk by J.F. Krohn): ~21% ECL only, ~35% both ECL&KLM, ~30% KLM only, after correction

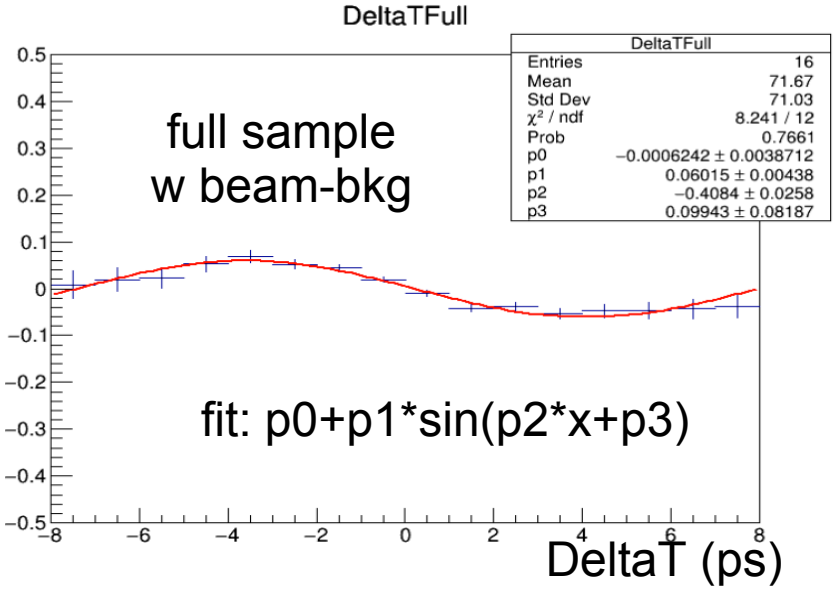
  analysis is in rough agreement with Belle expectations
- Change in KLM yield causes differences w.r.t. MC8
- Analysis identical to MC8 → difference no yet understood
- Still numbers might be optimistic considering that not all bkg is included

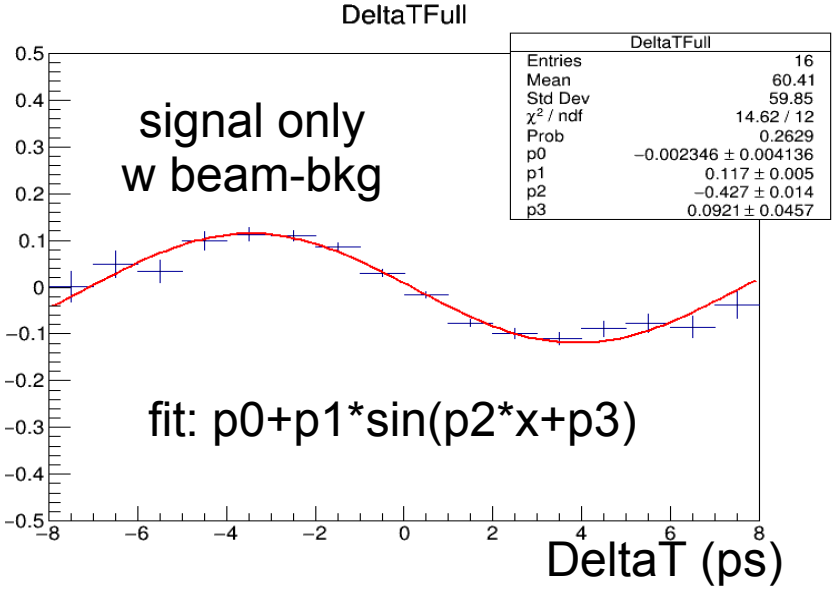
MC9 with beam-bkg

- ~10% increase in event yield mostly from ECL K_L candidates
- Significant increase in bkg rates in ECL (purity 75 → 64%), moderate in KLM (purity 64 → 61%)

	No bkg	Bkg
Luminosity (ab^{-1})	4	4
# tags	103992	115005
Purity (%)	67.5	62
Yield/fb^{-1}	26	28.7







Towards a new K_L list (1)

- Current default K_L list in analysis package is based on KLM clusters only
- In order to get a K_L list on both KLM and ECL clusters:
  - reconstruction.py is modified in order to run existing (yet unused) ClusterMatcher module: Cluster dataobject is created, ECL clusters and KLM clusters are matched if angular separation is within a certain cone
  - ParticleLoader module and Particle dataobject are modified in order to construct a K_L list from ECL clusters under neutral hadron hyp.
  - If two clusters are matched they correspond to a single entry in the K_L list (for the time being only info of one sub-detector is used in this case → temporary solution, will use all available information in future)

Towards a new K_L list (2)

- Keep in mind: currently we have 2 different lists of clusters
  - Hypothesis 5 = photon assumption → clustering is optimized in order to give the best energy resolution
  - Hypothesis 6 = neutral hadron → clustering for best K_L ID and $\bar{p}$ resolution
- Obviously the the two sets are build up starting from the same sets of crystals but in general the 2 corresponding StoreArrays differ
- We have to avoid double counting i.e. that the "same" physical cluster is used as gamma if already used as K_L , this requires modifications to:
  - RestoOfEventBuilder: a photon is removed from ROE if the corresponding cluster is built up on the same Connected Region (CR) used for the K_L
  - ParticleCombiner: a photon is removed from signal candidates under the same assumptions (yet missing, although only few modes affected e.g. $B^0 \to K_L \pi^0 X$)
- Since the new list requires modifications to many key parts of the analysis pkg we decide to not include them in release-01 as more time is needed for test

Towards a new K_L list (3)

- To test new K_L list I produced:
  - 100 fb^{-1} equivalent of J/Psi cocktail
  - 10^4 single K_L events with spectrum according to K_L from generic $B\bar{B}$
  - In 10^4 single K_L events we get the following candidates:

4480+6211=10691 candidates w double counting

4480 from KLM clusters (2600 with no E in ECL in evt)

6211 from ECL clusters (E>100MeV)*

*corresponds to ~3600 evts

4480-2600=1880 KL which interacted in both ECL & KLM

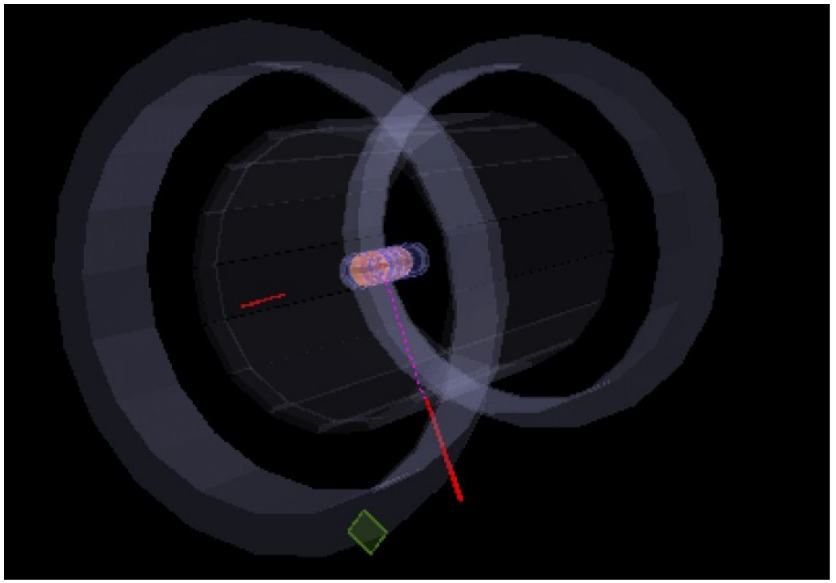
9685 entries in our K_L list → 1006 out of 1880 are matched

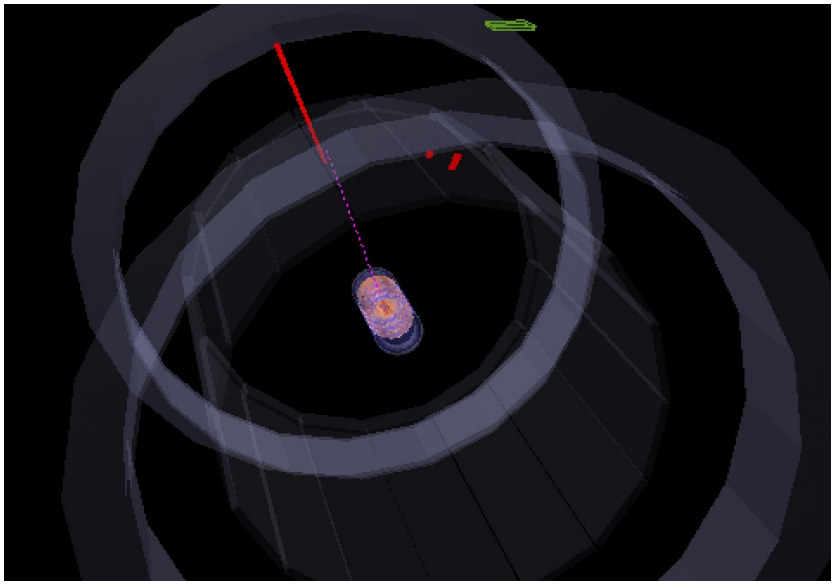
874 residual double counting

- These numbers do not match at all with the reference we used for analysis: 30% interaction rate for KLM only, 20% for ECL only and 35% in both
- Moreover from the B → J/Psi KL analysis we get a yield of ~32 evt/fb^{-1}, almost 30% higher compared to current analysis (max 1 candidate/event)
- A deeper study is needed to understand how our list can most efficiently represent underlying physics, nevertheless it can already be used to perform physics analysis (double counting in K_L reco can be avoided)

Towards a new K_L list (4)

- Low matching efficiency, most likely due to high ECL cluster multiplicity and large ECL/KLM cluster displacement





- A new version of the eclSplitterN2, i.e. the ECL hadron “splitter” will be committed soon → improved resolution and reduced multiplicity for ECL K_L candidates (details in my second talk this afternoon)
- Study of better matching criteria, i.e. a continuous variable instead of boolean matching will start once new eclSplitterN2 is committed

Grid issues

- In Trieste I complained about slow download from the grid: issue is nicely solved solved by writing output directly on gridui.pi.infn.it
- New issue: before last B2GM (~10 days) I tried to include generic MC9 samples

Phase III Y(4S) generic (4 x 1 ab-1)

Sample	Number of events (10^6)	Ratio without/with background	Production ID without/with background	LPN***
mixed	534.6	0.2/0.8	2166/2288	prod00002166/e0000/4S/r00000/mixed
charged	565.4	0.2/0.8	2167/2289	prod00002167/e0000/4S/r00000/charged
uubar	1605	0.2/0.8	2168/2290	prod00002168/e0000/4S/r00000/uubar
ddbar	401	0.2/0.8	2169/2311	prod00002169/e0000/4S/r00000/ddbar
ssbar	383	0.2/0.8	2170/2312	prod00002170/e0000/4S/r00000/ssbar
ccbar	1329	0.2/0.8	2171/2321	prod00002171/e0000/4S/r00000/ccbar
taupair	919	0.2/0.8	2172/2322	prod00002172/e0000/4S/r00000/taupair

- O(15000) jobs launched, no way of getting them done
- Most of them should be quite fast in principle (uds etc..)
- My feeling was that #running jobs ~ 1/#(submitted jobs)
  - With O(100) submitted jobs ~10-30% jobs running simultaneously
  - With O(10^4) submitted you end up with O(1) jobs running simultaneously..

Outlook

- New DEC file with CPV for B^0 decays is available
  - Validation (also) from other WGs would be very appreciated
  - I will update BFs to PDG 2017 asap
  - Work will continue to test various decay models
- New K_L list under development, prototype is working, needs changes to reconstruction and analysis packages → major change which requires careful testing → not in release-01
  - I managed however to have modified reconstruction.py in release-01 which allows to use centrally produced MC to test the new list
- Various things still need to be understood in analysis:
  - Unexpected increase in KLM K_L yield and purity drop on MC9
  - Efficiency for J/Psi → ee significantly lower than J/Psi → μμ, tracking?
  - Etc..
- Need to include and tune FlavorTagger for more realistic estimates

Backups