EVTGEN: Maintenance and Usage in LHCb

MC4LHC Readiness Workshop

Paul Harrison, University of Warwick

CERN, 31st Mar. 2010

My Thanks to:

- Patrick Robbe
- Mark Whitehead
- Liming Zhang
- Will Reece

My Apologies

For not being at CERN today. My flight was cancelled without warning. The carrier could not find a replacement flight in time.

General usage and earlier mods to EvtGen by LHCb were comprehensively described earlier by Patrick Robbe:

- http://indico.cern.ch/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=44663
- http://indico.cern.ch/getFile.py/access?contribId=s1t22&resId=0&materialId=0&confId=a042880
- http://indico.cern.ch/getFile.py/access?contribId=s1t16&resId=0&materialId=0&confId=a042878

Maintenance of EVTGEN in 2009

- At EVTGEN Miniworkshop, Jan 2009, agreed to merge all changes by the various collaborations since 2003 into a single version
  - LHCb
  - ATLAS
  - CMS
  - BaBar
  - BELLE
  - CLEO
  - Etc.
- Anders Ryd agreed to do the work (thanks Anders) – see last talk.

LHCb Updates to EVTGEN

- The major code-merger inevitably broke some aspects of the code from the LHCb point of view. We tested the code and found some issues which we fixed (see later).
- We also updated the decay files for consistency with the 2008 PDG tables.
- Some apparently long-standing bugs (and-or short-cuts) were fixed

Updated Particle Properties to PDG 2008
(Mark Whitehead)

- BFs for the following initial-state particles were updated.

η ω η' $f_2(1270)$ $f_1(1285)$ $a_2(1320)$

K_s^0 K^{*+} $K_2^*(1430)$

J/Ψ $\Psi(2S)$ $\Psi(3770)$ $\eta_c(1S)$ $\eta_c(2S)$ χ_{c0} χ_{c1} χ_{c2}

D^0 D^+ D^{*+} D_s^+

$\Upsilon(1S)$ $\Upsilon(2S)$ $\Upsilon(3S)$

B^0 B^+

Λ^0 Σ^+

τ^-

- BFs not in the PDG 2008 tables not implemented.

Added New Decay Modes

- Many new decay modes were added
- PDG notation change implemented: K^0-> K_S^0
- Decay dynamics chosen
  - Either by analogy with existing similar modes
  - Or implemented as phase space.

Balancing the Branching Fractions

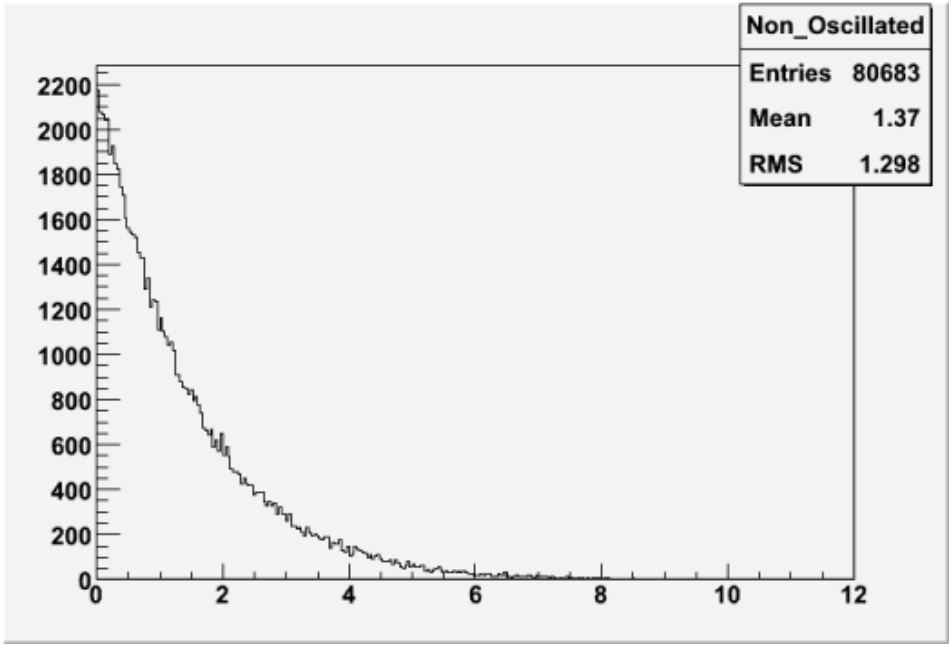
- Total BF must equal 1.
- Most initial state particles have <100% of their decay modes measured.
- PYTHIA used to generate additional decays to saturate the BF.
- When particles have a saturated total BF in PDG
  - Use quoted uncertainty on the BF from PDG.
  - Subtract a common fraction of the uncertainty from each mode
  - Adjust the fraction until the total BF is 1.

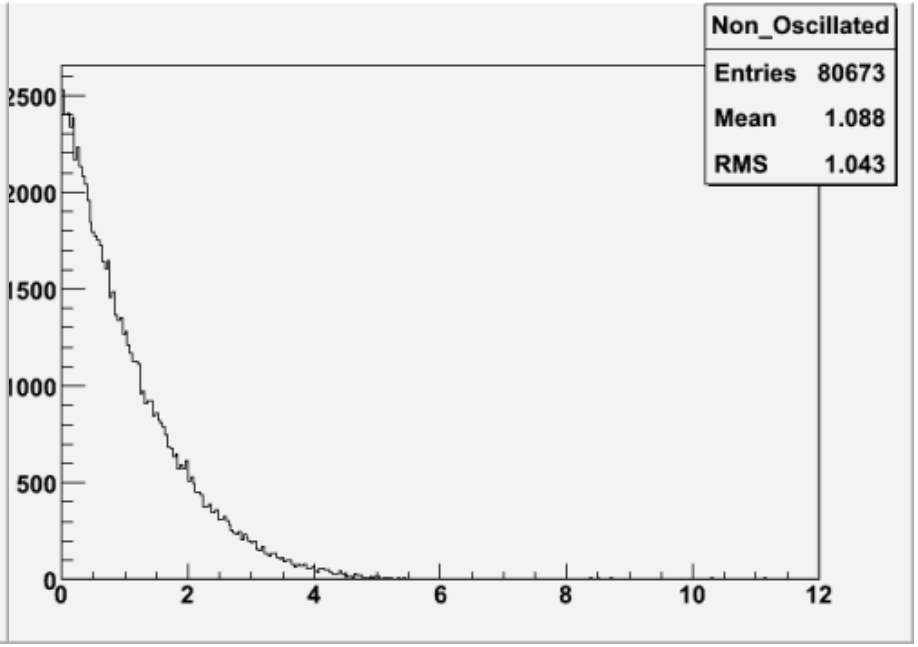
Fixing Neutral B Mixing
(PFH and Mark Whitehead)

- Found in merged version of EvtGen that B_0 and B_s generated with zero lifetimes and no mixing.
- Fixed by adding new weak eigenstates: B^0_L, B^0_H, B^0_{sL} and B^0_{sH}.
- Associate correct lifetime and mixing parameters with them in DECAY.DEC

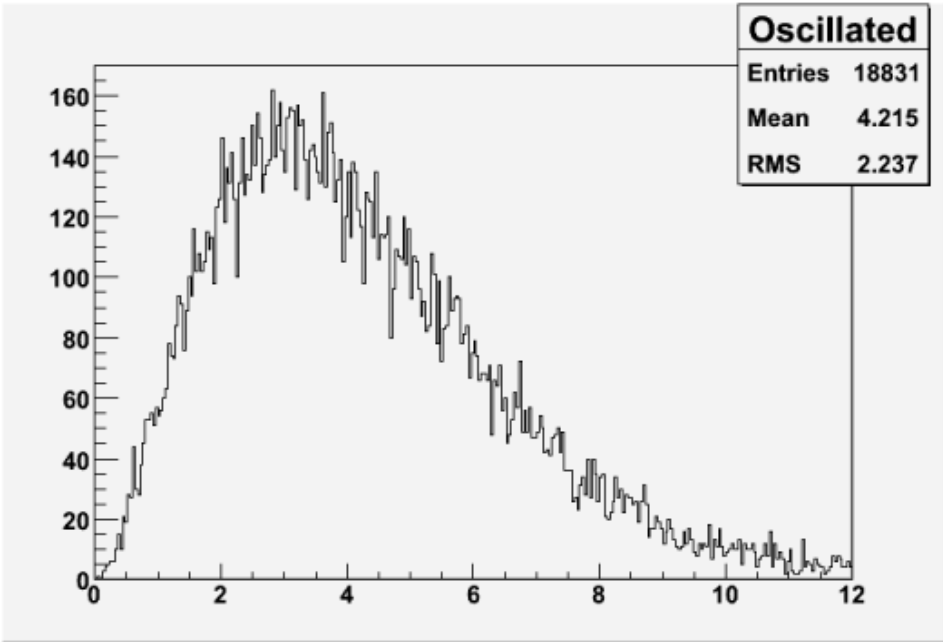
Other Bug Fixes in EvtCPUtil::incoherentMix

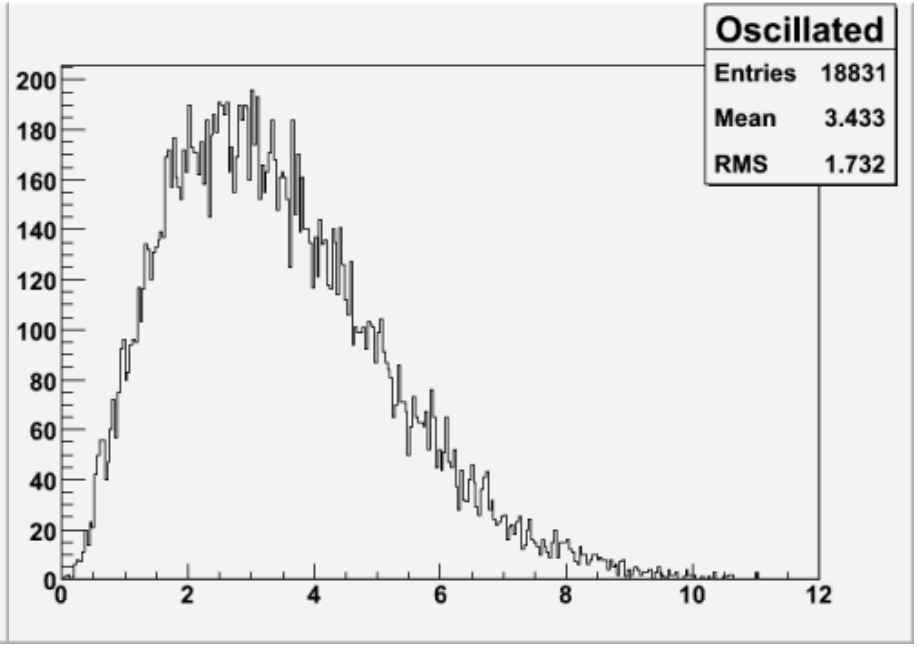
- Since for B_s, $\Delta\Gamma$ can be non-zero, some previous "short-cuts" had to be corrected to make sense for this case:
  - Calculate "average lifetime" as reciprocal of average width.
  - Use longer lifetime to define envelope in accept/reject method for mixed lifetime generation (to ensure weights <= 1).
  - Fixed calculation of "y" parameter
  - Fixed argument of oscillation cosine

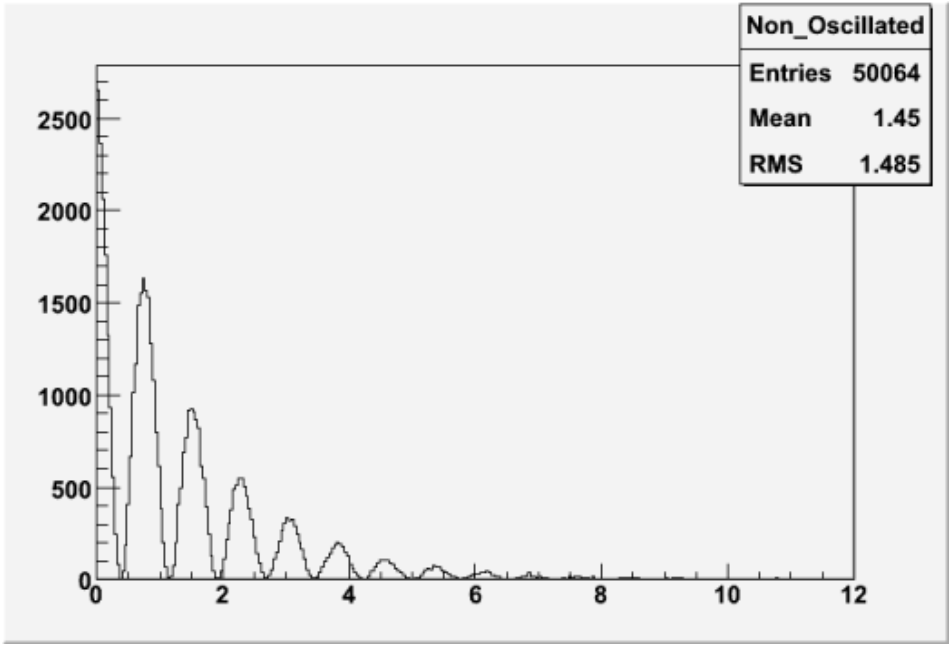


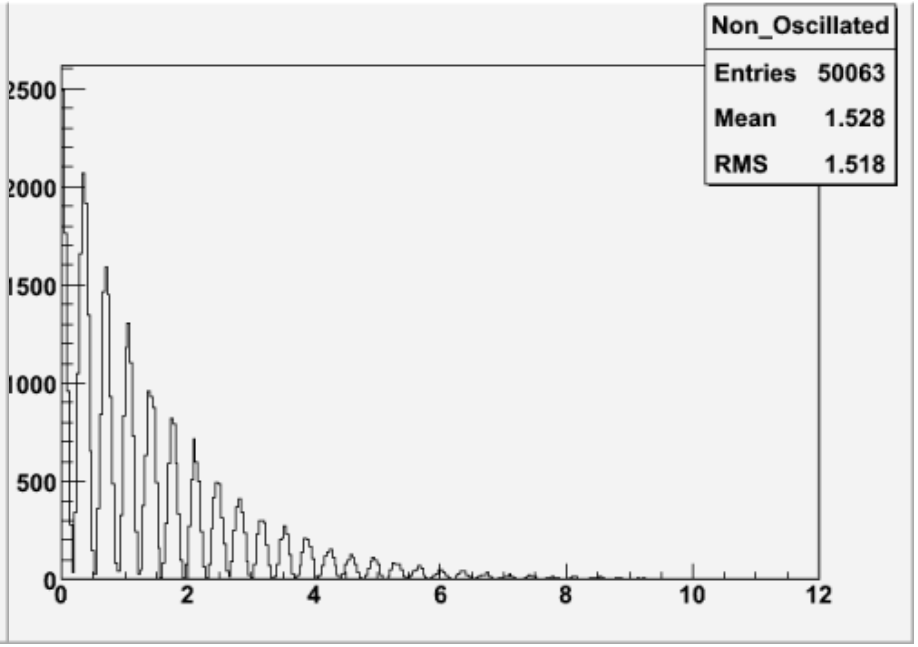


Before B0 After

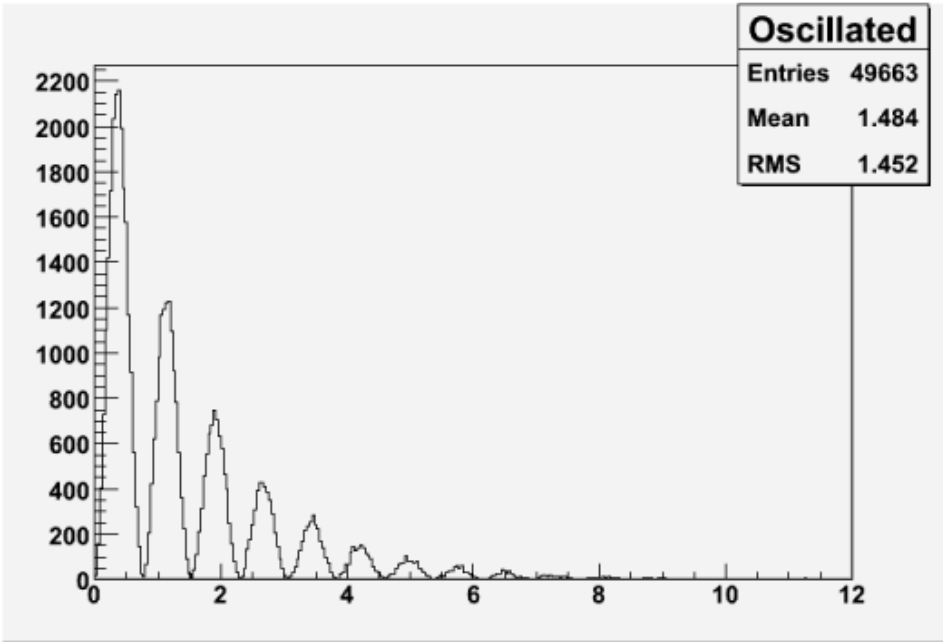


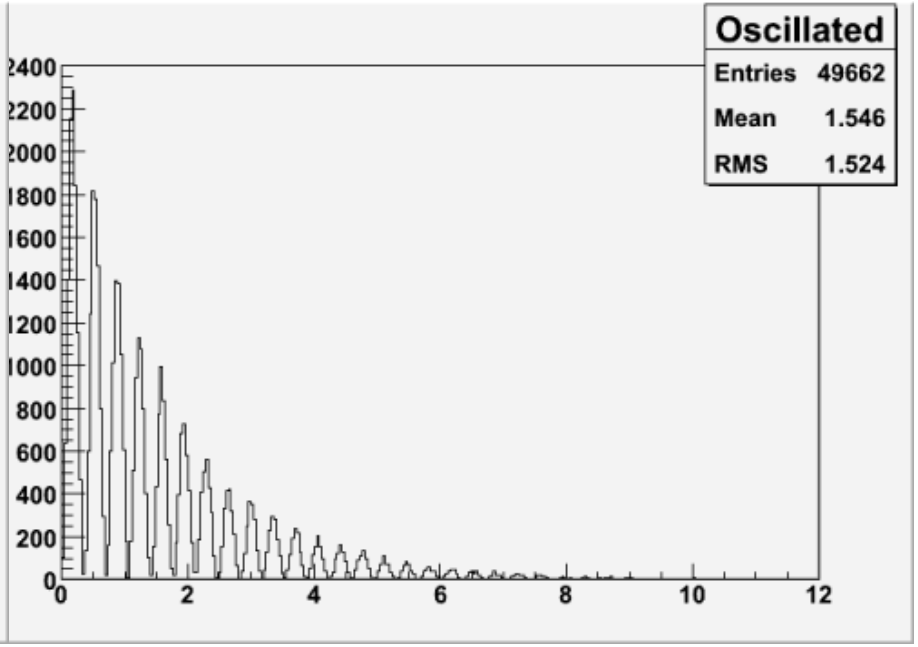




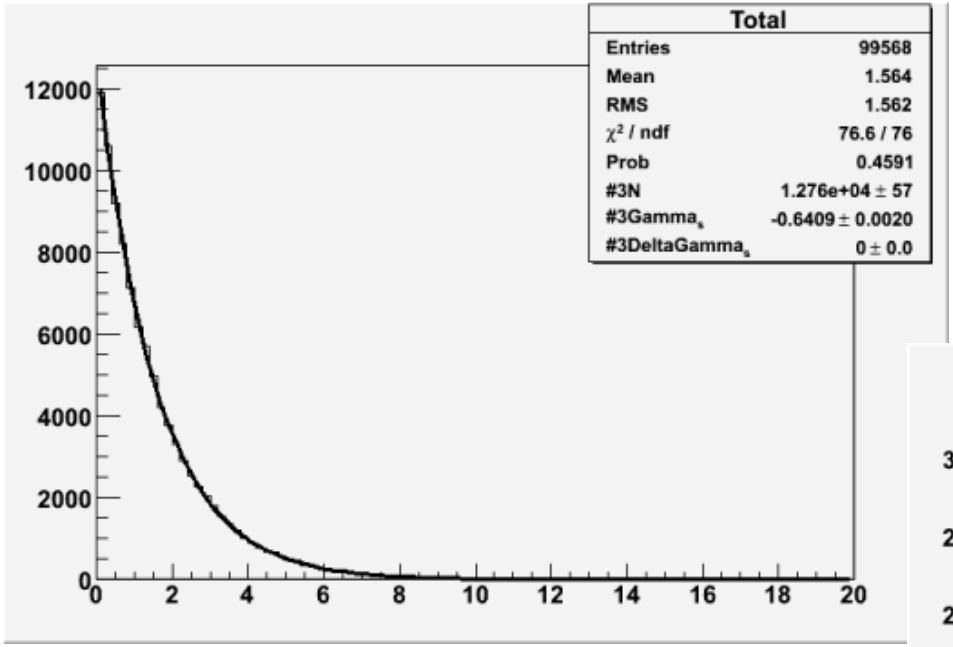


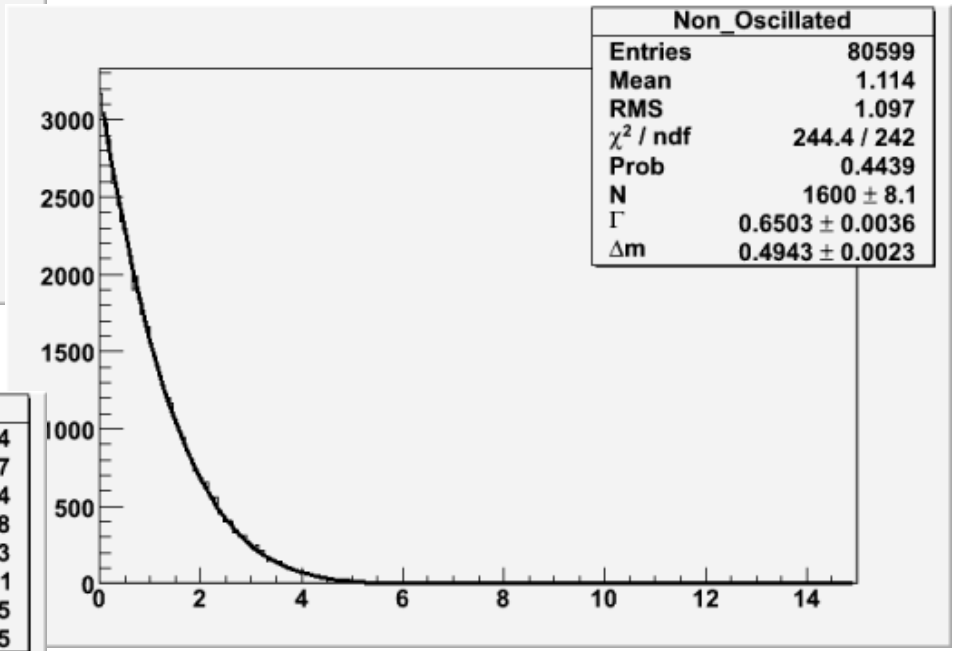
Before Bs After

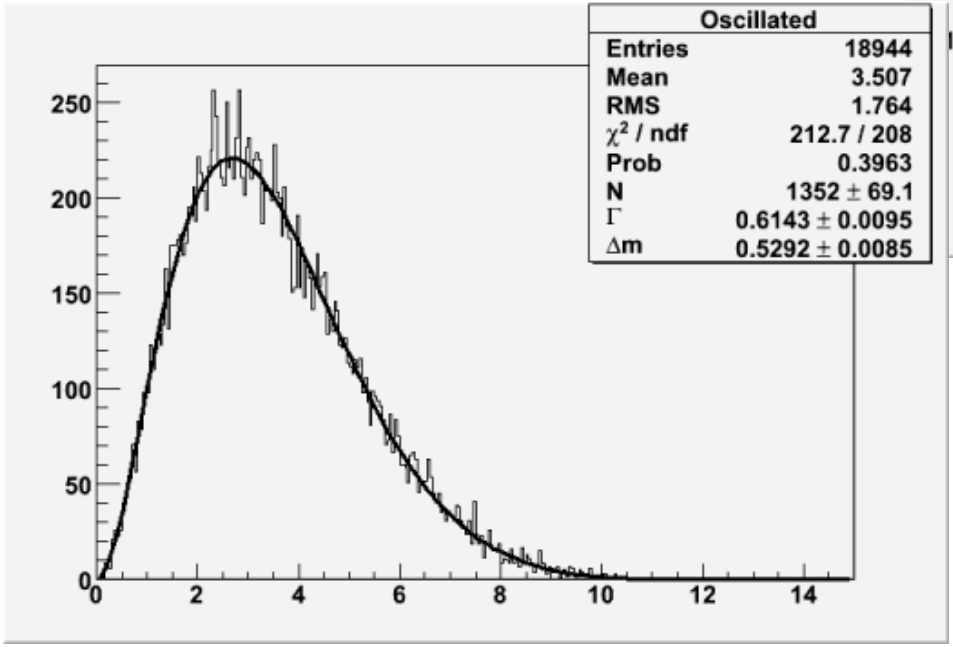




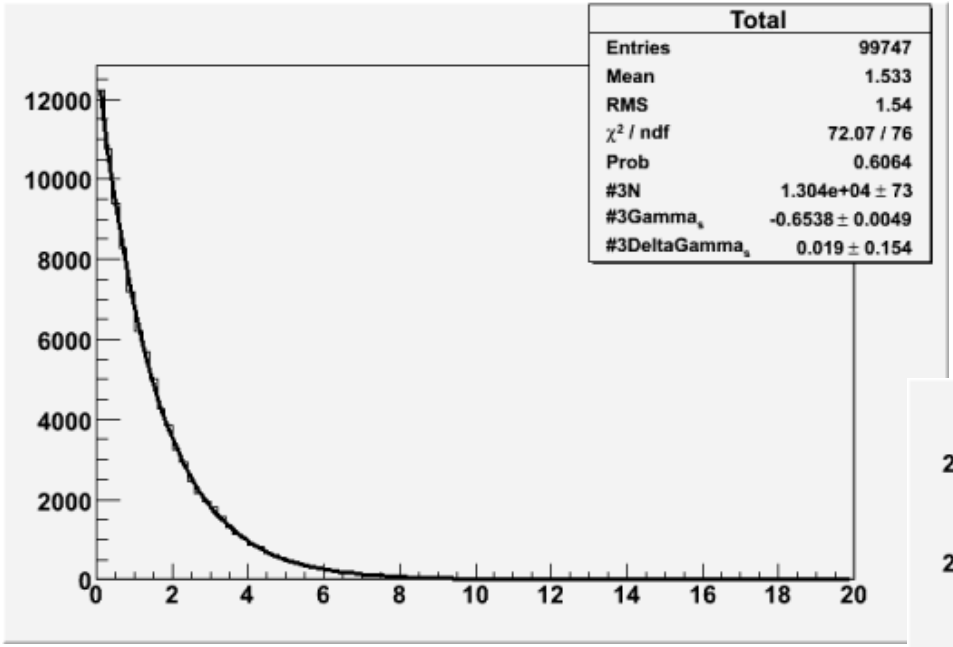
B0 Results

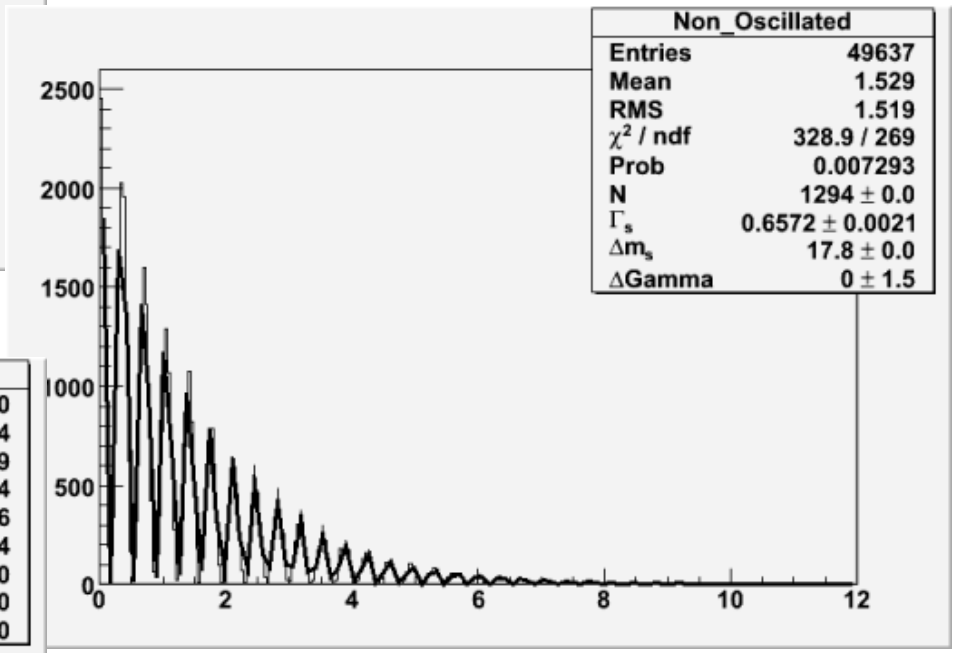

Total
Entries 99568
Mean 1.564
RMS 1.562
χ² / ndf 76.6 / 76
Prob 0.4591
#3N 1.276e+04 ± 57
#3Gamma_s -0.6409 ± 0.0020
#3DeltaGamma_s 0 ± 0.0

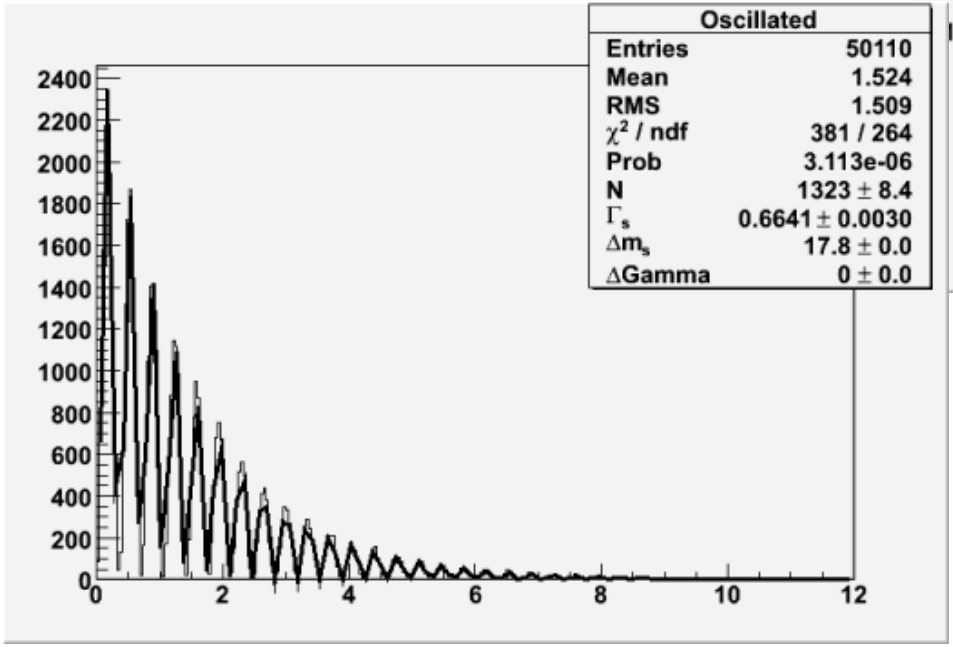

Non_Oscillated
Entries 80599
Mean 1.114
RMS 1.097
χ² / ndf 244.4 / 242
Prob 0.4439
N 1600 ± 8.1
Γ 0.6503 ± 0.0036
Δm 0.4943 ± 0.0023


Oscillated
Entries 18944
Mean 3.507
RMS 1.764
χ² / ndf 212.7 / 208
Prob 0.3963
N 1352 ± 69.1
Γ 0.6143 ± 0.0095
Δm 0.5292 ± 0.0085

Bs Results


Total
Entries 99747
Mean 1.533
RMS 1.54
χ² / ndf 72.07 / 76
Prob 0.6064
#3N 1.304e+04 ± 73
#3Gamma_s -0.6538 ± 0.0049
#3DeltaGamma_s 0.019 ± 0.154

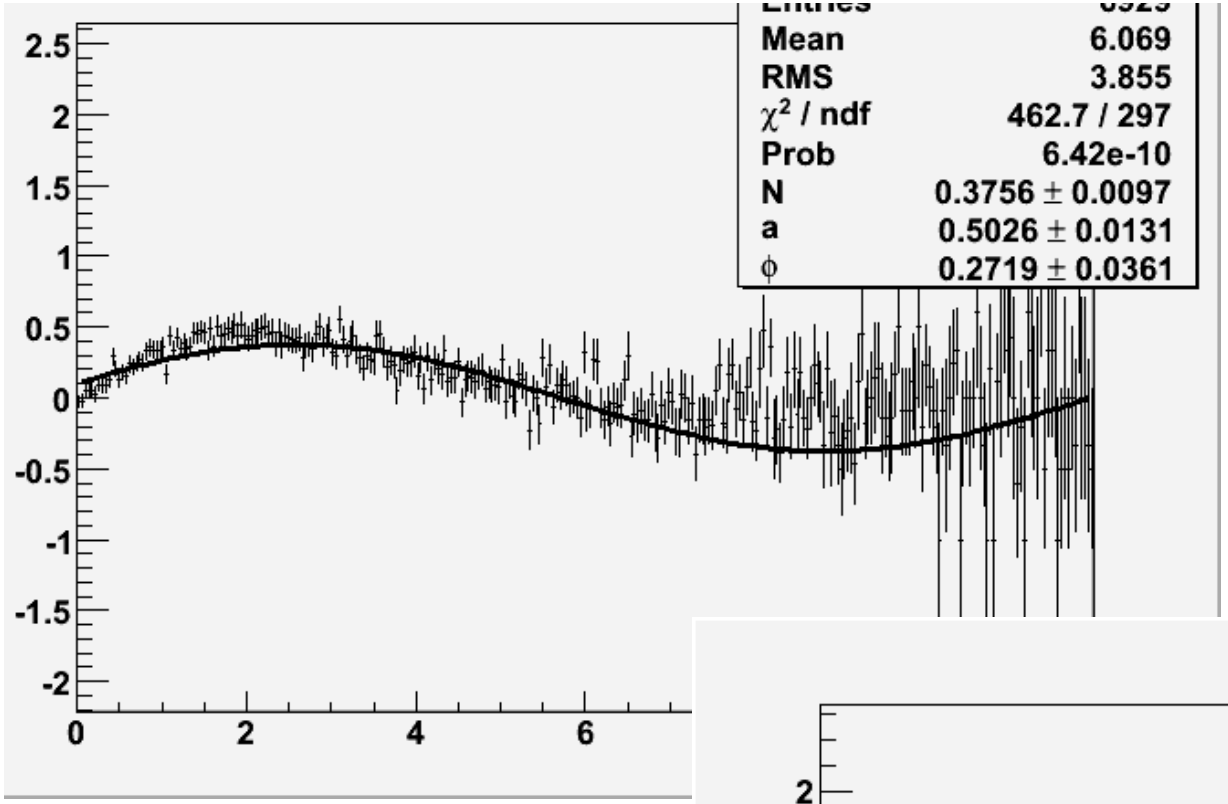

Non_Oscillated
Entries 49637
Mean 1.529
RMS 1.519
χ² / ndf 328.9 / 269
Prob 0.007293
N 1294 ± 0.0
Γ_s 0.6572 ± 0.0021
Δm_s 17.8 ± 0.0
ΔGamma 0 ± 1.5


Oscillated
Entries 50110
Mean 1.524
RMS 1.509
χ² / ndf 381 / 264
Prob 3.113e-06
N 1323 ± 8.4
Γ_s 0.6641 ± 0.0030
Δm_s 17.8 ± 0.0
ΔGamma 0 ± 0.0

Fixing Time-dependent CP Violation

(Patrick Robbe, Mark Whitehead
and Liming Zhang)

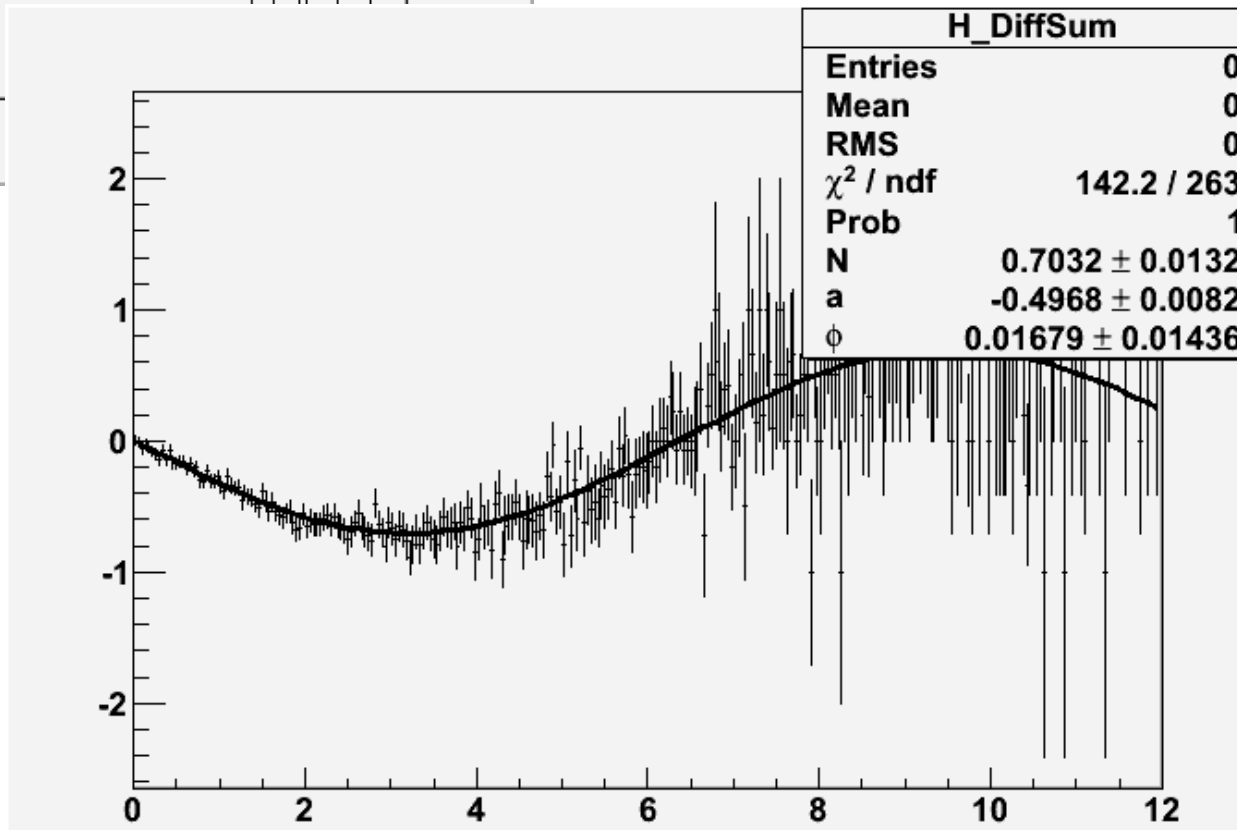
- After Ryd merge, we found unphysical behaviour in CP-violating signal modes.
- Reverted to an older version of EvtCPUtil::OtherB used by LHCb before Ryd updates (copied back from EvtIncoherentMixing::OtherB).
- This fixed unphysical behaviour.
- Some minor bugs were fixed in EvtSSDCP, the model for B decays to a scalar and another particle.



J/ψ K^0_s Time-dept. Asymmetry

<- v37r5 version
ie. after Ryd Updates, but before our fixes

V38r0p1 version ->
ie. after our fixes



Runtime Addition of New Models
(Will Reece)

- New Models may require additional libraries.
- To avoid link dependencies on them, EvtGen modified to allow them to be added to its internal list of models at run-time via a list of pointers.
- Implemented as an optional argument to the main EvtGen class:

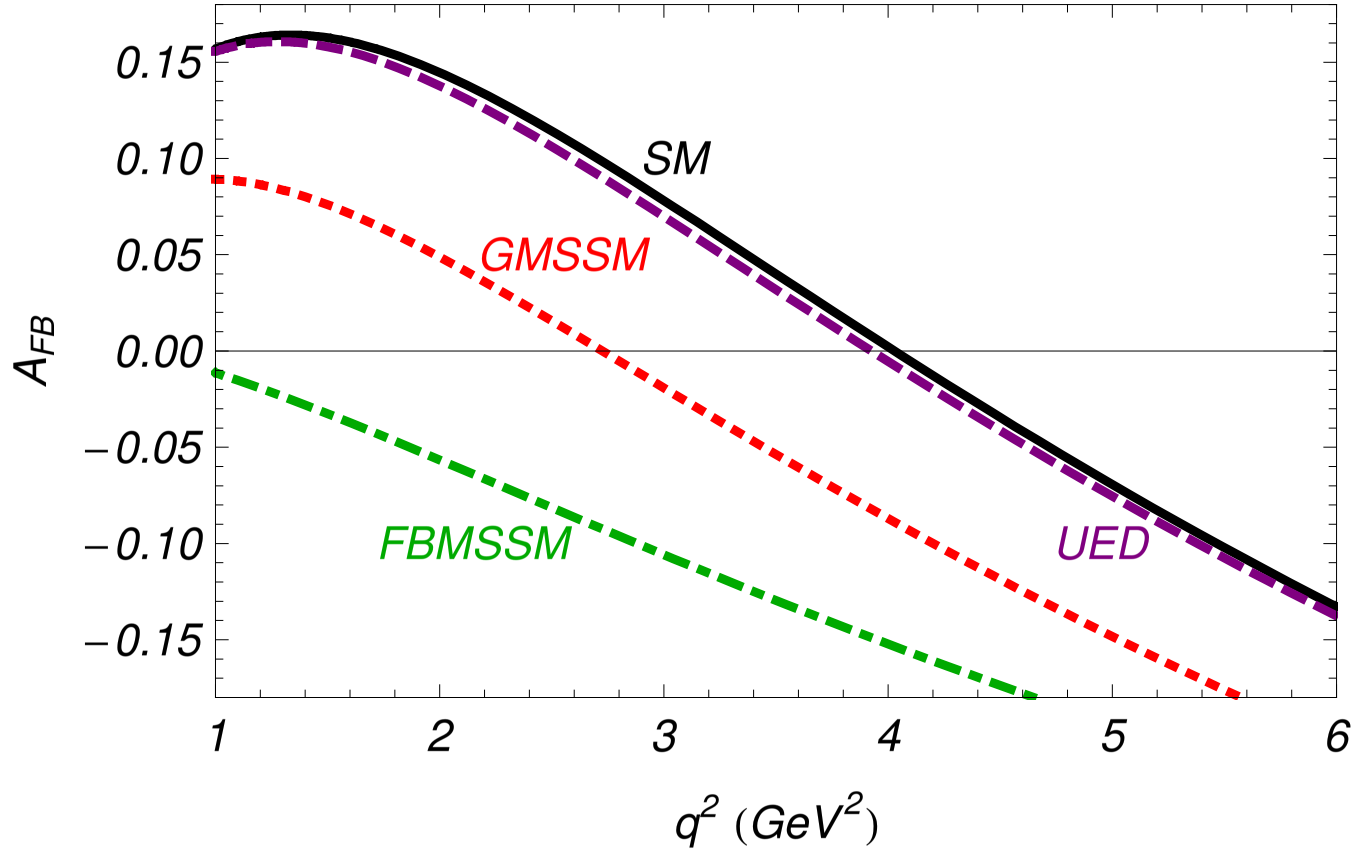
```
EvtGen(const char* const decayName,const char* const
pdtTableName, EvtRandomEngine* randomEngine=0,
EvtAbsRadCorr *isrEngine=0, const std::list<EvtDecayBase*>*
extraModels=0);
```

Eg. New Model for B_d->$K^*\mu^+\mu^-$

- Uses the GNU Scientific library
- Full model-independent implementation featuring a NLO SM treatment and LO generic new physics contributions
- Users can set the Wilson coefficients via the decay file.
- QCD factorisation and recent form factors

Used in LHCb Roadmap Document

Forward-Backward Asymm. in B_d->$K^*\mu^+\mu^-$:



Future of EvtGen in LHCb

- EvtGen to remain main decay engine in LHCb for foreseeable future
- Physics analysts will be main testers and maintainers
- Probably still some issues to be found and fixed, especially in respect of specific decay modes.
- Small team available for general maintenance and user support when issues arise.