Oscillation in different samples

Herwig: can record both states initial and oscillated,
and corresponding decay products.

e.g. mix: $\overline{B_s^0} \rightarrow B_s^0 \rightarrow D_s^- \pi^+$
$unmix$: $B_s^0 \rightarrow B_s^0 \rightarrow D_s^- \pi^+$
creation time: t1 t2 t3

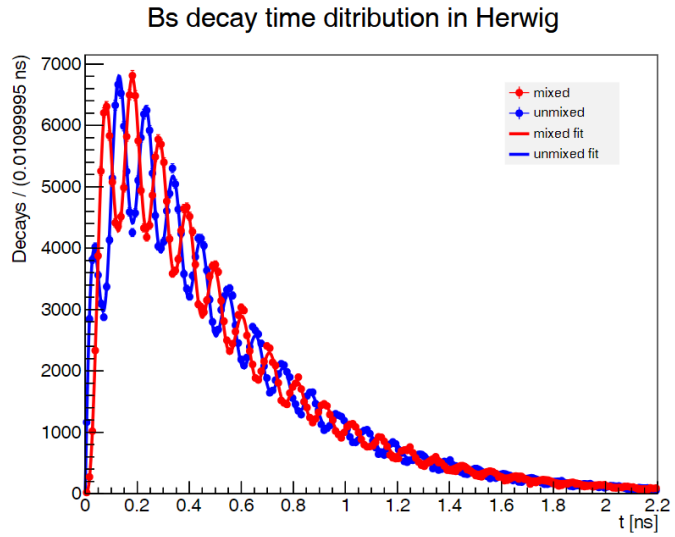
Whizard: can only record initial state, if there is oscillated
can be proved by decay products.

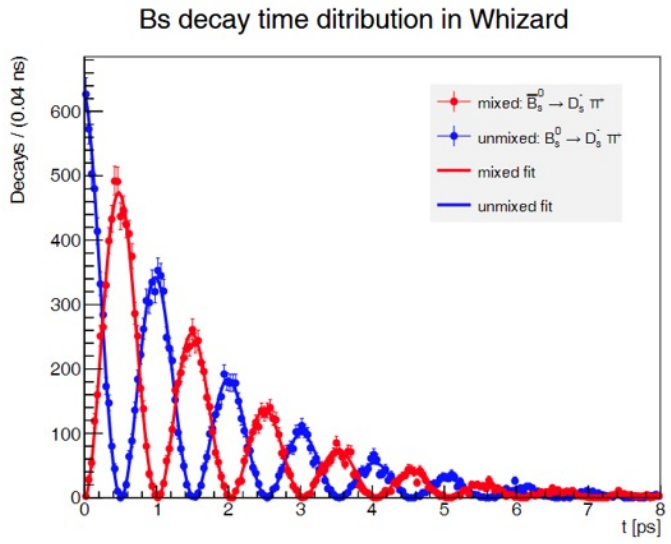
e.g. mix: ~~$\overline{B_s^0} \rightarrow B_s^0$~~ $\rightarrow D_s^- \pi^+$
$unmix$: ~~$B_s^0 \rightarrow B_s^0$~~ $\rightarrow D_s^- \pi^+$

e.g. mix: $\overline{B_s^0} \rightarrow D_s^- \pi^+$
$unmix$: $B_s^0 \rightarrow D_s^- \pi^+$
creation time: t1 t3

Sherpa: Not find yet…

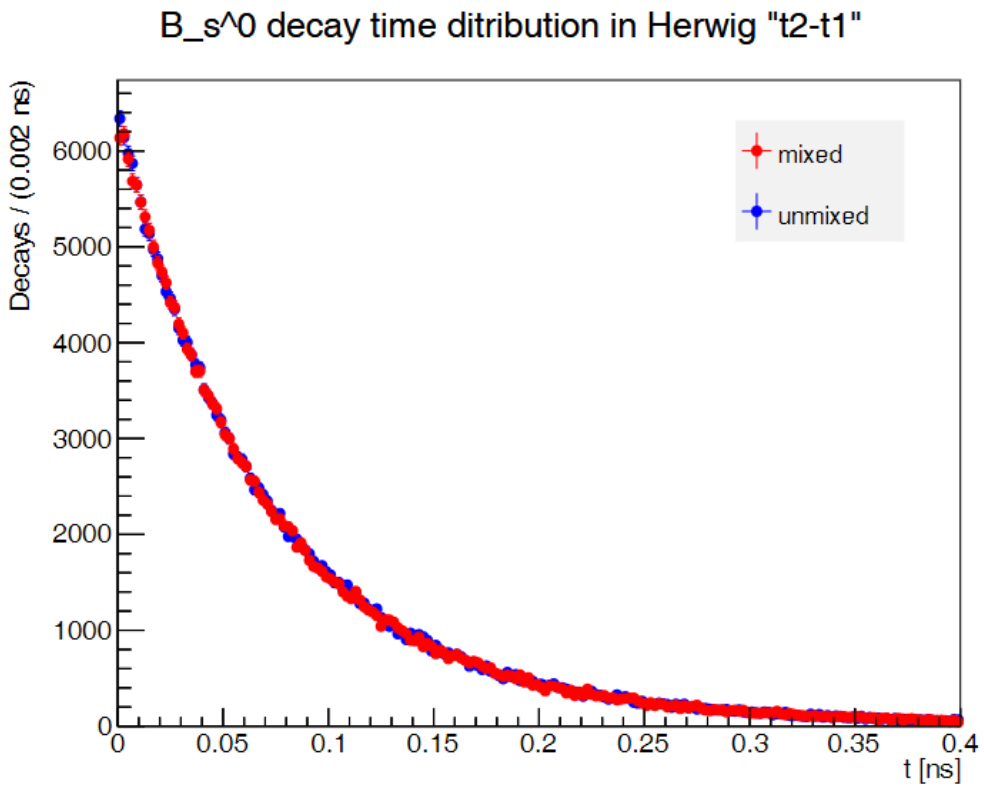
Decay time: t3 - t1



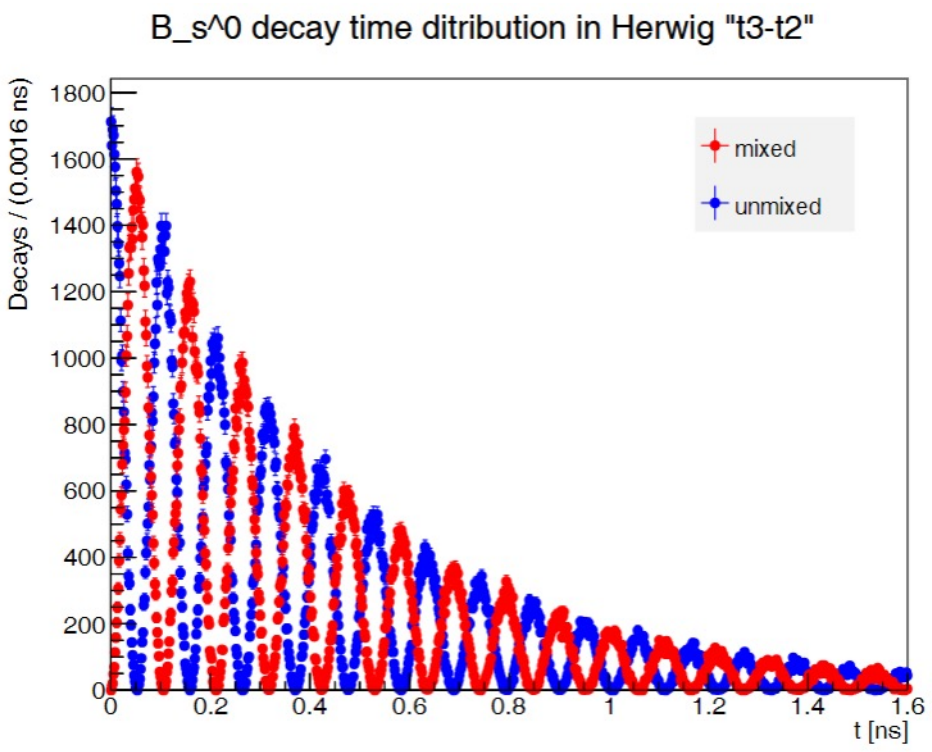


Mixed decays is which the initially produced meson mixed into its antiparticle before decaying

T2-t1 and t3-t2



exp(−at)



$$P(t) \approx e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + C\cos(\Delta m_s t)\right],$$

https://arxiv.org/pdf/1304.4741

Decay time PDF

The decay time of a particle is measured as

$$t = \frac{Lm}{p},$$

L is the distance between the production vertex and the decay vertex of the particle,
m its reconstructed invariant mass,
p its reconstructed momentum.

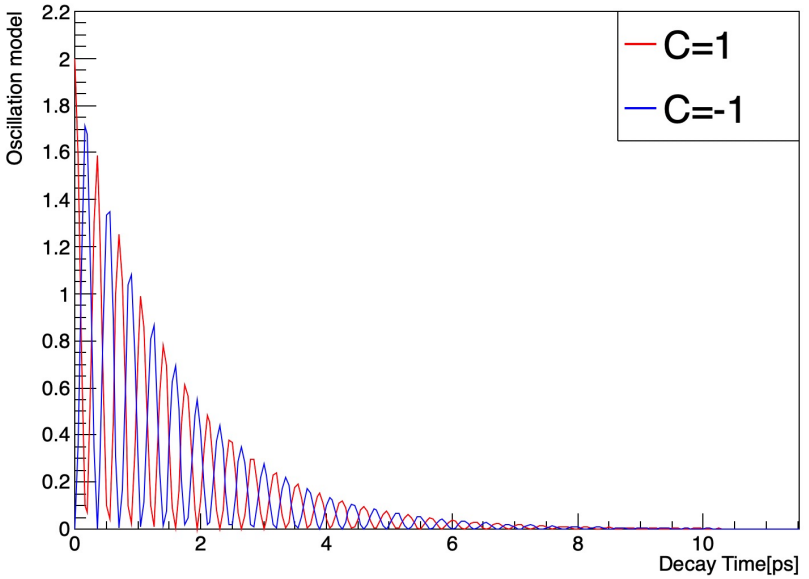
1. The theoretical distribution of the oscillation decay time t, ignoring any detector resolution:

$$P(t) \approx \mathrm{e}^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + C\cos(\Delta m_s t)\right],$$

$\Gamma_s = \frac{1}{\tau} = 0.66\times10^{12}s^{-1}$ *is the* B_s^0 *decay width,*

$\Delta\Gamma_s = (0.085 \pm 0.004)\times10^{12}s^{-1}$,

$\Delta\mathrm{m}_s = (17.7683 \pm 0.0051)ps^{-1}$,



Double-check Decay-time di

Maybe this a question about decay channel?

Different decay channels cannot change
Decay time distribution.

$B_s^0 \to anything$ could find oscillation.

The time scale is still a question,
read hepmc to check if it is truth level sample next.

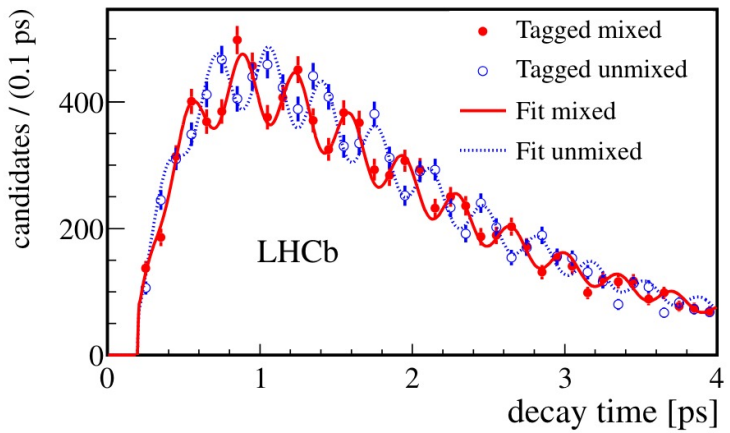
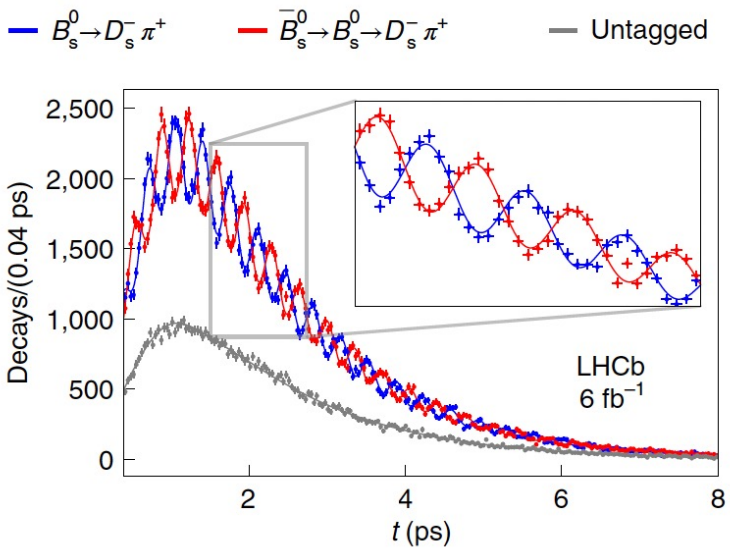
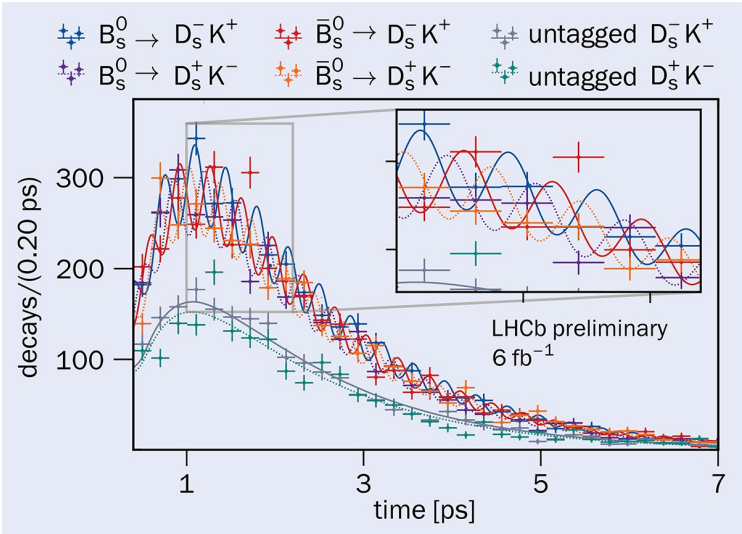


Figure 2. Decay time distribution for the sum of the five decay modes for candidates tagged as mixed (different flavour at decay and production; red, continuous line) or unmixed (same flavour at decay and production; blue, dotted line). The data and the fit projections are plotted in a signal window around the reconstructed B_s^0 mass of 5.32–5.55 GeV/c^2.





Read Herwig output-hepmc

zpole_bb_91000.hepmc

```
P 10043 531 2.2634218525383737e+01 -1.1968894180988148e+01 -1.2034945255715167e+01 2.8795821904723923e+01 5.3662999999999998e+00 11 0 0 -34 0
V -26 0 3.2596823979085712e-11 -8.1136915833612168e-12 -5.4780624302882000e-12 3.7046183892100465e-11 0 2 0
P 10044 -311 5.5671242813411637e-01 -5.2165478221324335e-01 -3.1598492850752063e-01 9.6413300243941358e-01 4.976
P 10045 311 3.7222285518026790e+00 -1.0524198754119287e+00 -1.4554770401523756e+00 4.1627683015430792e+00 4.9764
V -27 0 1.3940925488353212e-11 -1.9564392025221228e-11 -5.3550845733665066e-12 3.0322035858386211e-11 0 2 0
P 10046 211 7.7566376929120592e-02 -8.0044395846072813e-01 -1.0479797978554913e-01 8.2291526002289761e-01 1.3957
P 10047 -211 3.9275163703714011e-01 -5.5872441751073798e-01 -3.8907134475314720e-01 7.9830017510415219e-01 1.395
V -28 0 1.5931939955064158e-11 -1.2527634835829384e-11 -3.1752640112402748e-12 2.5115428791754816e-11 0 2 0
P 10048 311 4.5581334209969315e-01 -5.5331757751858590e-01 -4.1079980063694566e-01 9.6453934732310487e-01 4.9764
P 10049 211 1.0643390854094412e+00 -1.0146025390403650e+00 -5.0046579731005425e-01 1.5595453986273633e+00 1.3957
V -29 0 1.3943144358365353e-11 -1.0739825462863992e-11 -1.3807899667970550e-12 2.2252315499477015e-11 0 2 0
P 10050 221 3.0045446196624198e-01 -9.4948697062095566e-01 1.3702966632142102e-01 1.1447028078623500e+00 5.47511
P 10051 111 2.1742218034426378e-01 1.2147687614665086e-01 1.8185172172114908e-01 3.3662744561118008e-01 1.349776
V -30 0 -3.0540609762664447e-10 3.5710779800791617e-10 1.9036501711543887e-10 2.5352259650355953e-10 0 2 0
P 10052 -523 -2.6249670488339703e+01 2.1348528482459074e+01 1.4755095579340013e+01 3.7294414489640822e+01 5.3250
P 10053 211 -2.5949677347390359e+00 2.1086041794411194e+00 1.8491565069121556e+00 3.8234707730142250e+00 1.39570
V -31 0 -1.3445195144206924e-10 2.1736287134646852e-10 9.1444913190322144e-11 1.0778026234678331e-11 0 2 0
P 10054 -213 -9.1306193443339831e-02 -8.0546414364274010e-01 1.9610076223913148e-01 1.1603257389773238e+00 8.067
P 10055 111 -2.4903726644821206e-01 -2.9238722854342428e-03 -7.6140512744720013e-01 8.1239450374420052e-01 1.349
V -32 0 -1.0299681025686186e-10 1.8731623700406949e-10 7.3674721137556550e-11 -2.4819302342407197e-11 0 2 0
P 10056 -211 2.3151141191629321e-01 -7.5225228606134775e-01 3.9629547845232933e-02 8.0033203855627921e-01 1.3957
P 10057 213 4.0673537172008800e-01 -1.8361788101400807e+00 -9.1725429510592249e-01 2.2454760997001135e+00 8.1475222431021987e-01 2 0 0 -66 0
V -33 0 -1.0610786251547977e-10 1.9106276430012142e-10 7.5497776043646566e-11 -2.5763395834971932e-11 0 2 0
P 10058 111 -3.1623817959089195e-01 1.9056632147957919e-01 -1.1476806690692345e-01 4.0952749699688251e-01 1.3497
P 10059 -211 -4.0570697586275500e-01 1.6440408626902980e-01 5.6514212097415961e-01 7.2834902752050201e-01 1.3957
V -34 0 9.0055756936796353e-07 -4.7575838455689084e-07 -4.7866641099238844e-07 2.0071109026954137e-01 0 1 0
P 10060 531 2.2634218525383737e+01 -1.1968894180988148e+01 -1.2034945255715167e+01 2.8795821904723923e+01 5.3662
V -35 0 5.3093609780181827e+00 -2.8075711840036233e+00 -2.8230649376163934e+00 6.9554124751283712e+00 0 6 0
```

HEPMC2_manual

6.1 Basic IO_GenEvent Structure

BLOCK KEYS

- **begin event block**: *HepMC::IO_GenEvent-START_EVENT_LISTING*
- **end event block**: *HepMC::IO_GenEvent-END_EVENT_LISTING*

LINE KEYS

- **E**: *general GenEvent information*
- **N**: *named weights*
- **U**: *momentum and position units*
- **C**: *GenCrossSection information: This line will appear ONLY if GenCrossSection is defined.*
- **H**: *HeavyIon information: This line will contain zeros if there is no associated HeavyIon object.*
- **F**: *PdfInfo information: This line will contain zeros if there is no associated PdfInfo object.*
- **V**: *GenVertex information*
- **P**: *GenParticle information*

V - GENVERTEX INFORMATION

- **int**: *barcode*
- **int**: *id*
- **double**: *x*
- **double**: *y*
- **double**: *z*
- **double**: *ctau*
- **int**: *number of "orphan" incoming particles*
- **int**: *number of outgoing particles*
- **int**: *number of entries in weight list (may be zero)*
- **double**: *optional list of weights*

P - GENPARTICLE INFORMATION

- **int**: *barcode*
- **int**: *PDG id*
- **double**: *px*
- **double**: *py*
- **double**: *pz*
- **double**: *energy*
- **double**: *generated mass*
- **int**: *status code*
- **double**: *Polarization theta*
- **double**: *Polarization phi*
- **int**: *barcode for vertex that has this particle as an incoming particle*
- **int**: *number of entries in flow list (may be zero)*
- **int, int**: *optional code_index and code for each entry in the flow list*

Read Herwig output-hepmc

Hepmc/Bshepmc_reader.cpp

```
if ((*am)->pdg_id() == - (*p)->pdg_id())
{
    GenVertex* prod_vertex = (*p)->production_vertex();
    GenVertex* end_vertex = (*p)->end_vertex();

    if(prod_vertex && end_vertex) {
        HepMC::FourVector prod_pos = prod_vertex->position();
        HepMC::FourVector end_pos = end_vertex->position();
        //double flight_time = (end_pos.t() - prod_pos.t()) / (*p)->momentum().t();
        double flight_time = (end_pos.t() - prod_pos.t());
        t1 = flight_time;
        cout << "Particle ID: " << (*p)->pdg_id() << ", Flight Time-t1: " << t1 << endl;

        double dx = end_pos.x() - prod_pos.x();
        double dy = end_pos.y() - prod_pos.y();
        double dz = end_pos.z() - prod_pos.z();
        double distance = sqrt(dx*dx + dy*dy + dz*dz);
        double speed = (*p)->momentum().t() / (*p)->momentum().m();
        double flight_time1 = distance / speed;
        t2 = distance;
        t3 = flight_time1;
        cout << "Particle ID: " << (*p)->pdg_id() << ", Flight Time-t3: " << t3 << endl;
```

```
root [8] OutputTree->GetEntries("t1!=0||t2!=0||t3!=0")
(long long) 0
```

```
root [10] OutputTree->Show(3)
======> EVENT:3
 t1               = 0
 t2               = 0
 t3               = 0
 Bs_M             = 5.3663
 Bs_E             = 28.7958
 B_s0             = 0
 antiB_s0         = 0
```

The vertex information is not stored when reading a hepmc file

```
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
parent ID: 23
```

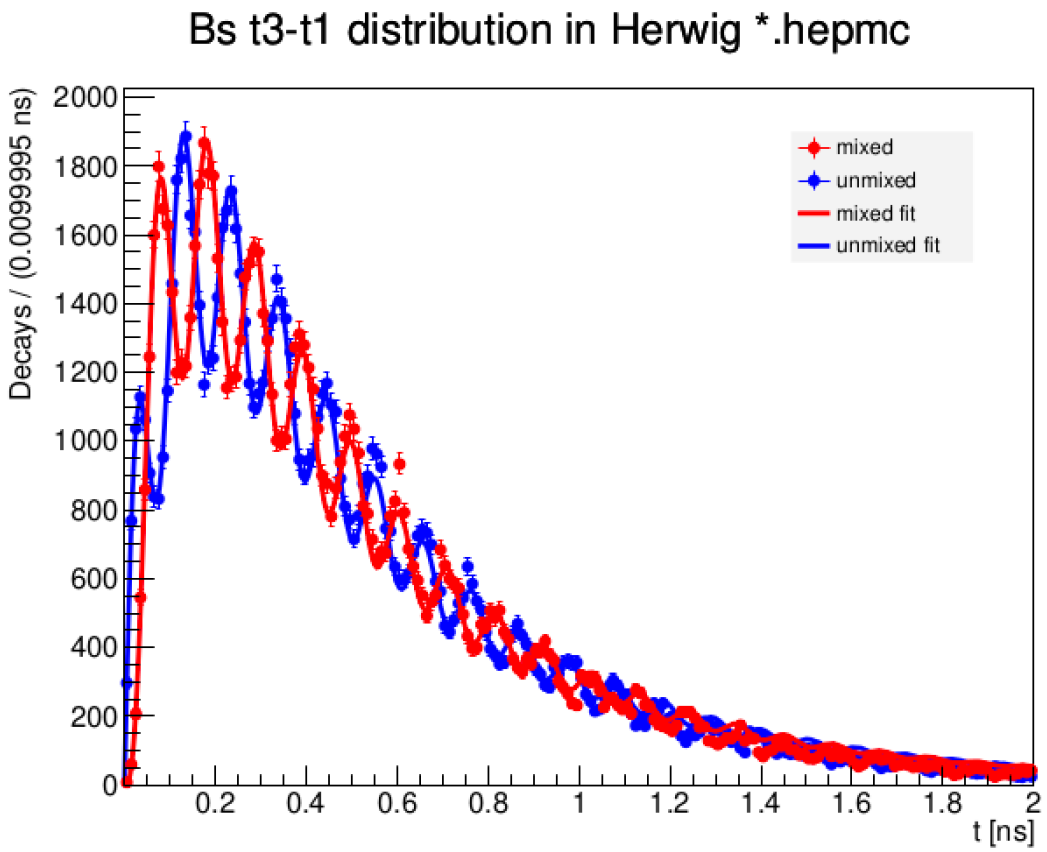
```
if((*p)->pdg_id() == 531 || (*p)->pdg_id() == -531)
{
    Bs_M = mass;
    Bs_E = energy;
    GenEvent::particle_const_iterator am = (*p)->parent_event()->particles_begin();


    cout<< "parent ID: "<< (*am)->pdg_id() <<endl;
```

```
Particle ID: 531, Flight Time-t1: 0.55037
Particle ID: -531, Flight Time-t1: 0.167168
Particle ID: -531, Flight Time-t1: 0.443375
Particle ID: -531, Flight Time-t1: 0.136498
Particle ID: -531, Flight Time-t1: 4.69707
Particle ID: -531, Flight Time-t1: 0.568665
Particle ID: 531, Flight Time-t1: 3.06571
Particle ID: -531, Flight Time-t1: 0.403697
Particle ID: -531, Flight Time-t1: 2.9745
Particle ID: 531, Flight Time-t1: 0.459158
Particle ID: -531, Flight Time-t1: 3.04256
Particle ID: -531, Flight Time-t1: 0.317022
Particle ID: 531, Flight Time-t1: 5.41378
Particle ID: -531, Flight Time-t1: 0.0542714
Particle ID: -531, Flight Time-t1: 3.08513
Particle ID: -531, Flight Time-t1: 1.63342
Particle ID: -531, Flight Time-t1: 2.82208
Particle ID: 531, Flight Time-t1: 0.145736
Particle ID: -531, Flight Time-t1: 3.1772
Particle ID: 531, Flight Time-t1: 0.652983
Particle ID: -531, Flight Time-t1: 1.0155
Number of Events10000
```

https://answers.launchpad.net/madanalysis5/+question/243656

Read Herwig output hepmc

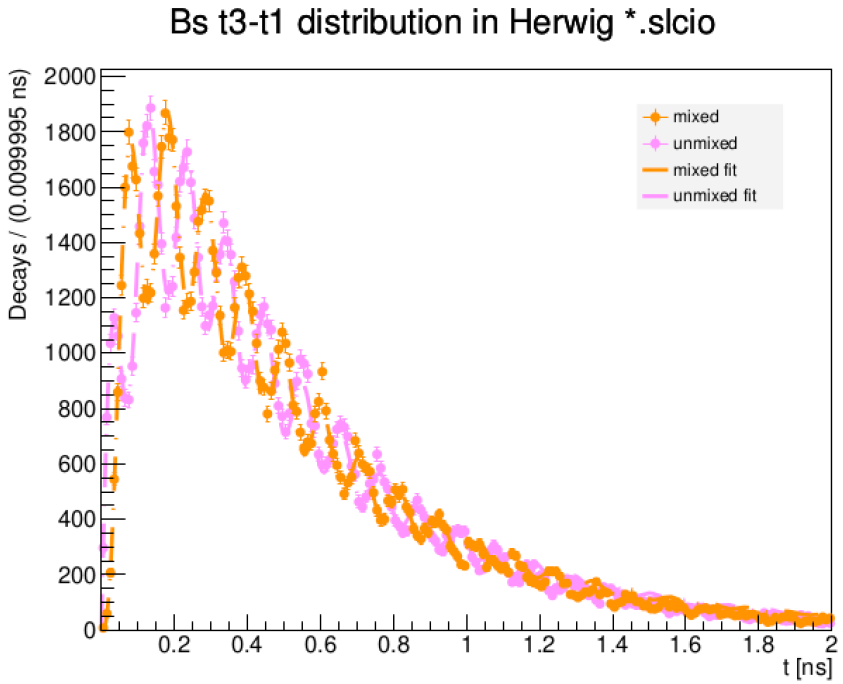
```
60: Parent PID:531, PID:531, p end-prod time:1.25879, Parent-p prod time:2.13526e-07, Parent-p end time:0.0374039, p prod time:
0.0374039, Osc:0
60: PID:531Daughter PID: -431, p prod time:0.0374039, p end time:1.29619, dau prod time:1.29619, dau end time:1.54169
60: PID:531Daughter PID: 113, p prod time:0.0374039, p end time:1.29619, dau prod time:1.29619, dau end time:1.29619
60: PID:531Daughter PID: 113, p prod time:0.0374039, p end time:1.29619, dau prod time:1.29619, dau end time:1.29619
```




```
NO.   NAME      VALUE            ERROR
 1  Delta_Gamma_s   1.78145e+00   4.60151e-02
 2  Delta_mass_s    5.92705e+01   3.41032e-02
 3  Gamma_s         2.51561e+00   2.25411e-02
 4  a               1.32990e+01   1.34385e-01
                                ERR DEF= 0.5
```

Compare Herwig output: hepmc vs slcio

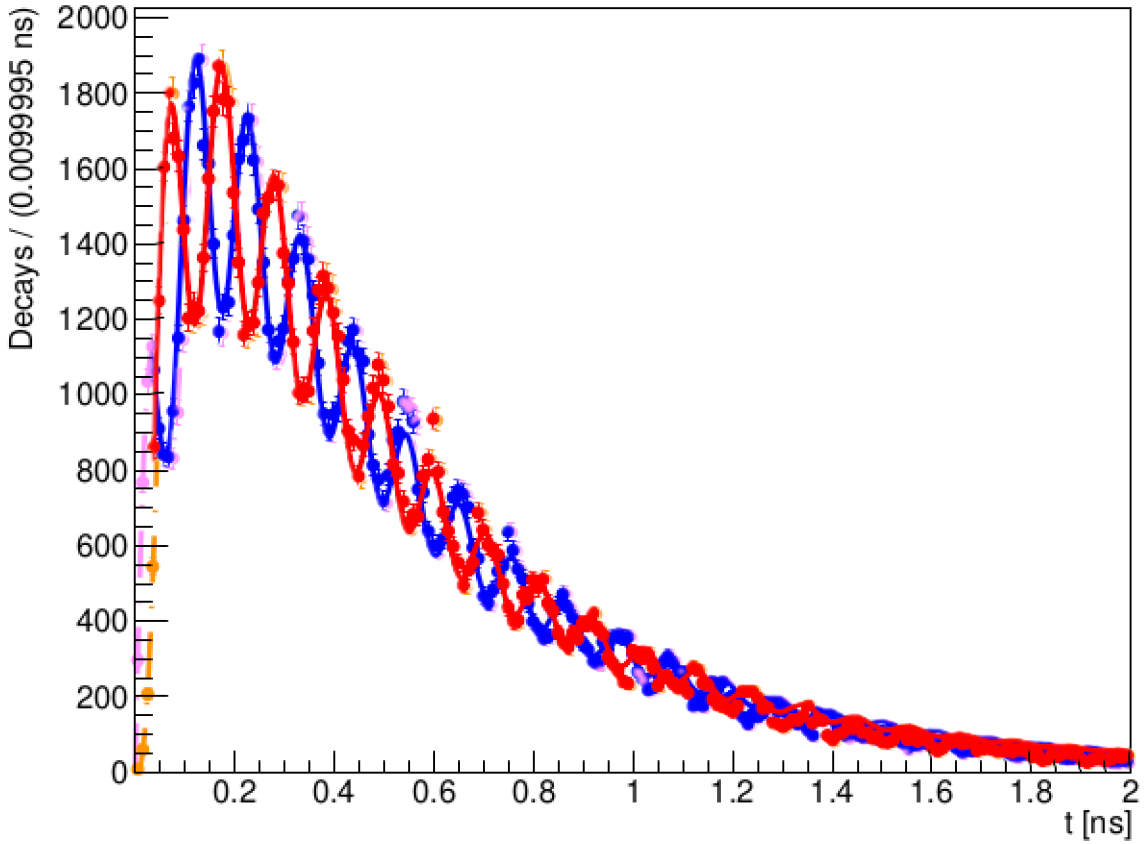
Transfer hepmc to slcio



NO.	NAME	VALUE	ERROR
1	Delta_Gamma_s	1.78150e+00	4.58359e-02
2	Delta_mass_s	5.92706e+01	3.46840e-02
3	Gamma_s	2.51566e+00	2.25175e-02
4	a	1.32984e+01	1.30137e-01
		ERR DEF= 0.5	

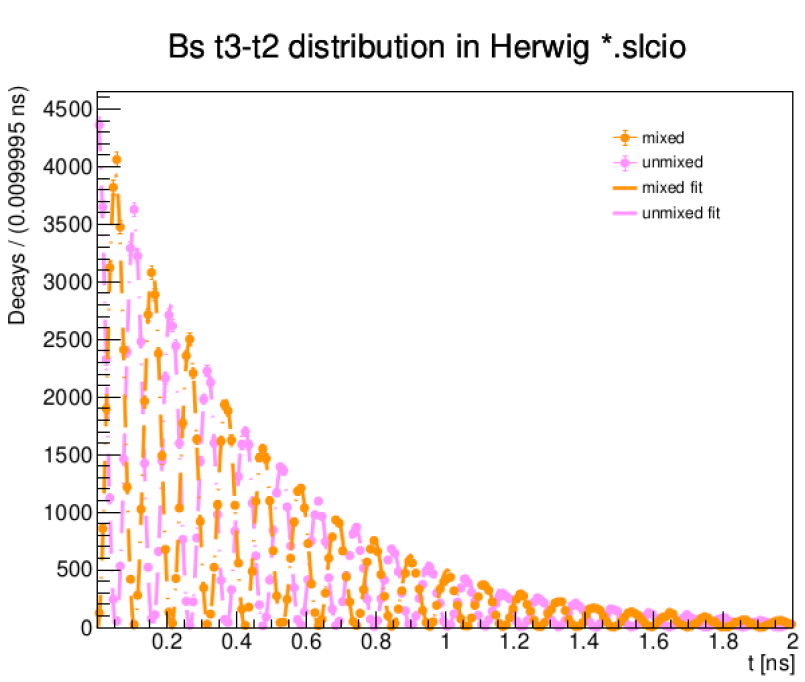
NO.	NAME	VALUE	ERROR
1	Delta_Gamma_s	1.78145e+00	4.60151e-02
2	Delta_mass_s	5.92705e+01	3.41032e-02
3	Gamma_s	2.51561e+00	2.25411e-02
4	a	1.32990e+01	1.34385e-01
		ERR DEF= 0.5	

Compare hepmc vs slcio

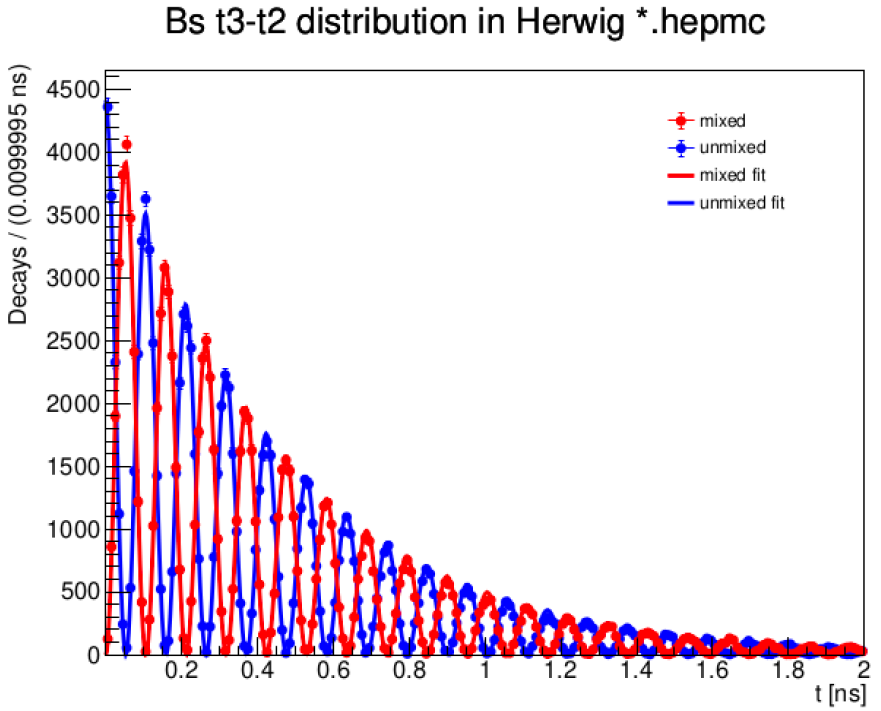


Compare Herwig output: hepmc vs slcio

Transfer hepmc to slcio




```
EXT PARAMETER
NO.   NAME      VALUE            ERROR
 1  Delta_Gamma_s   4.85941e-01   2.04320e-02
 2  Delta_mass_s    5.92801e+01   4.18679e-03
 3  Gamma_s      2.18023e+00   6.48525e-03   1
                              ERR DEF= 0.5
```




```
EXT PARAMETER
NO.   NAME      VALUE            ERROR
 1  Delta_Gamma_s   4.85990e-01   2.04320e-02
 2  Delta_mass_s    5.92802e+01   4.18716e-03
 3  Gamma_s      2.18025e+00   6.48580e-03   1
                              ERR DEF= 0.5
```

Finding in whizard samples

if the oscillation can only be proved by Bs decay products

B_s^0 DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
D_s^- anything		(93 ±25) %		–
$\ell\nu_\ell X$		(9.6 ± 0.8) %		–
$e^+\nu X^-$		(9.1 ± 0.8) %		–
$\mu^+\nu X^-$		(10.2 ± 1.0) %		–
$D_s^-\ell^+\nu_\ell$ anything	[a]	(8.1 ± 1.3) %		–
$D_s^{*-}\ell^+\nu_\ell$ anything		(5.4 ± 1.1) %		–
$D_{s1}(2536)^-\mu^+\nu_\mu$, $D_{s1}^- \to D^{*-}K_S^0$		(2.6 ± 0.7) $\times 10^{-3}$		–
$D_{s1}(2536)^- X\mu^+\nu$, $D_{s1}^- \to \overline{D}^0 K^+$		(4.4 ± 1.3) $\times 10^{-3}$		–
$D_{s2}(2573)^- X\mu^+\nu$, $D_{s2}^- \to \overline{D}^0 K^+$		(2.7 ± 1.0) $\times 10^{-3}$		–
$D_s^-\pi^+$		(3.00± 0.23) $\times 10^{-3}$		2320
$D_s^-\rho^+$		(6.9 ± 1.4) $\times 10^{-3}$		2249
$D_s^-\pi^+\pi^+\pi^-$		(6.1 ± 1.0) $\times 10^{-3}$		2301
$D_{s1}(2536)^-\pi^+$, $D_{s1}^- \to D_s^-\pi^+\pi^-$		(2.5 ± 0.8) $\times 10^{-5}$		–
$D_s^\mp K^\pm$		(2.27± 0.19) $\times 10^{-4}$		2293
$D_s^-K^+\pi^+\pi^-$		(3.2 ± 0.6) $\times 10^{-4}$		2249
$D_s^+D_s^-$		(4.4 ± 0.5) $\times 10^{-3}$		1824

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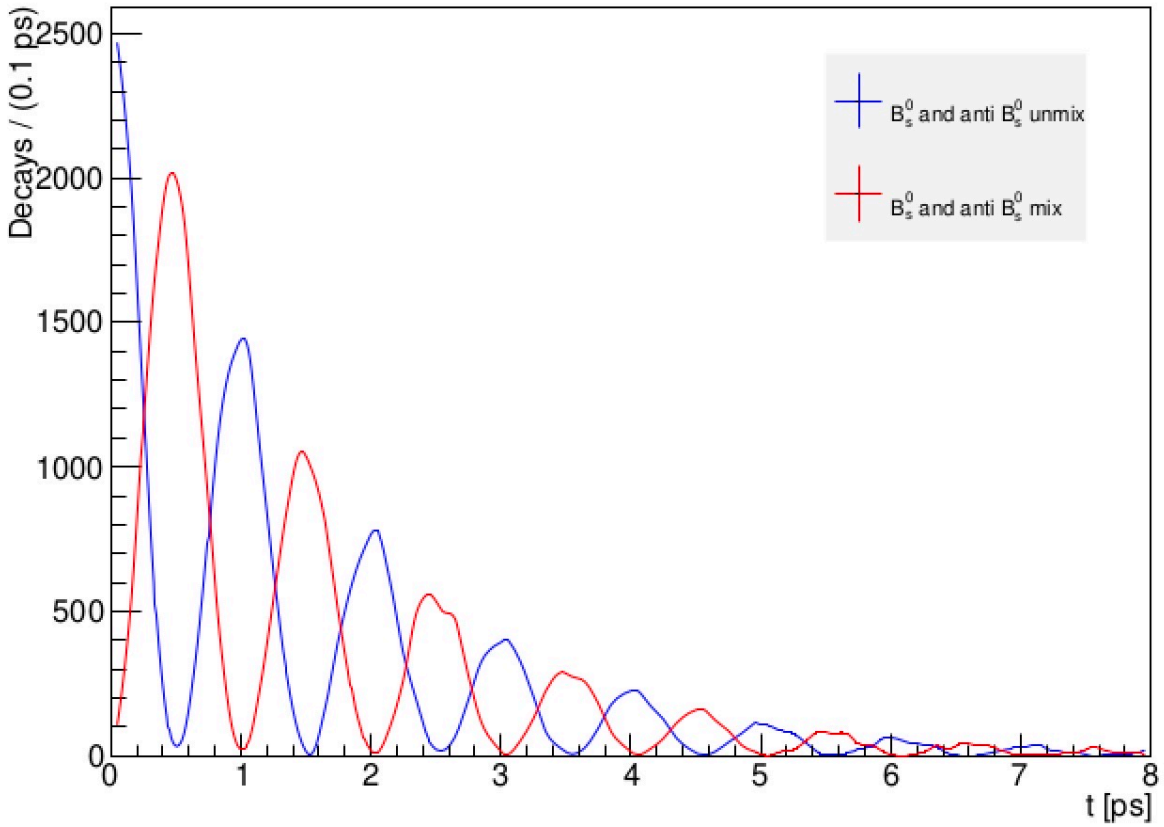


Finding in whizard samples

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Delta_Gamma_s	1.52364e-01	1.48219e-02	3.97335e-03	-5.64588e-03
2	Delta_mass_s	6.19092e+00	3.35987e-03	3.22556e-05	1.52024e+00
3	Gamma_s	6.13242e-01	5.02915e-03	2.06169e-04	-1.86212e-02

ERR DEF= 0.5

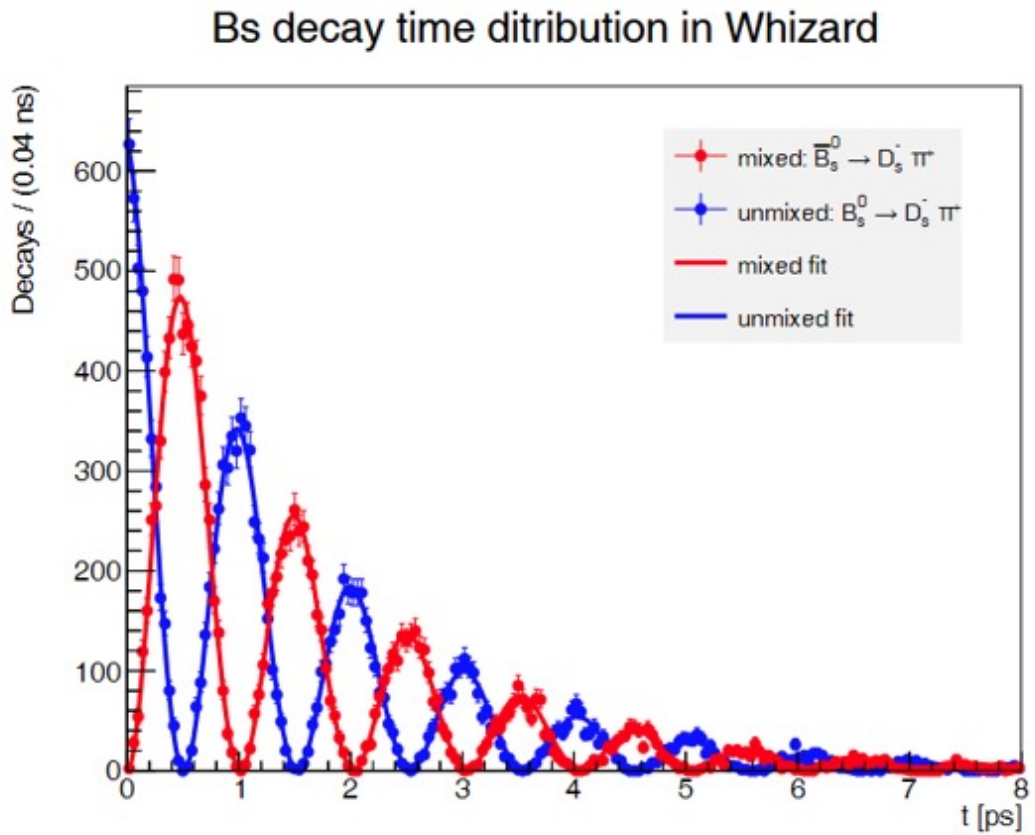
EXTERNAL ERROR MATRIX. NDIM= 25 NPAR= 3 ERR DEF=0.5

2.198e-04	1.263e-05	4.310e-05
1.263e-05	1.129e-05	2.476e-06
4.310e-05	2.476e-06	2.529e-05

PARAMETER CORRELATION COEFFICIENTS

NO.	GLOBAL	1	2	3
1	0.60270	1.000	0.254	0.578
2	0.25362	0.254	1.000	0.147
3	0.57800	0.578	0.147	1.000

y_s: 0.124228620557
x_s: 10.0953937083



Note study

Simulated samples used

Table 3: Information about the simulated samples used in the measurement. The number of events in the bookkeeping is reported separately for the magnet down (Down) and up (Up).

Decay	Event type	Year	Stripping	Sim.	Reco.	simcond	dddb	Up	Down
$B_s^0 \to D_s^- \pi^+, D_s^- \to K^- K^+ \pi^-$	11264021	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md<u,d>100	dddb-20170721-3	71736	70995
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	157586	158176
				Sim09b	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	2622617	2626915
		2017	s28r2	Sim09b	Reco17	sim-20190430-1-vc-md<u,d>100	dddb-20170721-3	3943367	3544568
		2018	s34	Sim09b	Reco18	sim-20190430-vc-md<u,d>100	dddb-20170721-3	3066830	3086560
$B_s^0 \to D_s^- \pi^+, D_s^- \to \pi^- \pi^+ \pi^-$	11164042	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md<u,d>100	dddb-20170721-3	19186	18497
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	64248	65591
				Sim09b	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	269187	218280
		2017	s28r2	Sim09b	Reco17	sim-20190430-1-vc-md<u,d>100	dddb-20170721-3	315098	227859
		2018	s34	Sim09b	Reco18	sim-20190430-vc-md<u,d>100	dddb-20170721-3	250732	250239
$B^0 \to D^- \pi^+, D^- \to K^+ \pi^- \pi^-$	11264001	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md<u,d>100	dddb-20170721-3	83833	81944
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	268712	228181
				Sim09b	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	1428458	1449190
		2017	s28r2	Sim09g	Reco17	sim-20190430-1-vc-md<u,d>100	dddb-20170721-3	229484	229516
				Sim09b	Reco17	sim-20190430-1-vc-md<u,d>100	dddb-20170721-3	1285271	1279720
		2018	s34	Sim09b	Reco18	sim-20190430-vc-md<u,d>100	dddb-20170721-3	1690508	1599539
$\overline{\Lambda}_b^0 \to \overline{\Lambda}_c^- \pi^+, \overline{\Lambda}_c^- \to \overline{p} K^+ \pi^-$	15264010	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md<u,d>100	dddb-20170721-3	44701	52025
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	77377	78138
		2017	s28r2	Sim09g	Reco17	sim-20190430-1-vc-md<u,d>100	dddb-20170721-3	154122	152044
		2018	s34	Sim09b	Reco18	sim-20190430-vc-md<u,d>100	dddb-20170721-3	156739	155560
$B_s^0 \to D_s^{*-} \pi^+, D_s^{*-} \to D_s^- \gamma / \pi^0, D_s^- \to K^- K^+ \pi^-$	13264021	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md<u,d>100	dddb-20170721-3	29214	29177
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	70254	70919
		2017	s28r2	Sim09g	Reco17	sim-20190430-1-vc-md<u,d>100	dddb-20170721-3	70245	77105
		2018	s34	Sim09b	Reco18	sim-20190430-vc-md<u,d>100	dddb-20170721-3	90744	88039
$B_s^0 \to D_s^0 K^0, D_s^- \to K^- K^+ \pi^-$	13264031	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md<u,d>100	dddb-20170721-3	26963	28280
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	75500	76537
		2018	s28r1	Sim09b	Reco16	sim-20170721-2-vc-md<u,d>100	dddb-20170721-3	1641009	1710739
		2017	s28r2	Sim09b	Reco17	sim-20190430-1-vc-md<u,d>100	dddb-20170721-3	2651221	2063816
		2018	s34	Sim09b	Reco18	sim-20190430-vc-md<u,d>100	dddb-20170721-3	2880568	3089089

```
# file /tmp/tmp.jL7AyRlWvT/DBASE/Gen/DecFiles/v30r106/options/13264021.py generated: Thu, 16 May 2024 16:58:05
#
# Event Type: 13264021
#
# ASCII decay Descriptor: {[[B_s0]nos -> (D_s- => K+ K- pi-) pi+]cc, [[B_s0]os -> (D_s+ => K- K+ pi+) pi-]cc}
#
from Configurables import Generation
Generation().EventType = 13264021
Generation().SampleGenerationTool = "SignalRepeatedHadronization"
from Configurables import SignalRepeatedHadronization
Generation().addTool( SignalRepeatedHadronization )
Generation().SignalRepeatedHadronization.ProductionTool = "Pythia8Production"
from Configurables import ToolSvc
from Configurables import EvtGenDecay
ToolSvc().addTool( EvtGenDecay )
ToolSvc().EvtGenDecay.UserDecayFile = "$DECFILESROOT/dkfiles/Bs_Dspi,KKpi=DecProdCut.dec"
Generation().SignalRepeatedHadronization.CutTool = "DaughtersInLHCb"
Generation().SignalRepeatedHadronization.SignalPIDList = [ 531,-531 ]

# Ad-hoc particle gun code

from Configurables import ParticleGun
pgun = ParticleGun("ParticleGun")
pgun.SignalPdgCode = 531
pgun.DecayTool = "EvtGenDecay"
pgun.GenCutTool = "DaughtersInLHCb"

from Configurables import FlatNParticles
pgun.NumberOfParticlesTool = "FlatNParticles"
pgun.addTool( FlatNParticles , name = "FlatNParticles" )

from Configurables import MomentumSpectrum
pgun.ParticleGunTool = "MomentumSpectrum"
pgun.addTool( MomentumSpectrum , name = "MomentumSpectrum" )
pgun.MomentumSpectrum.PdgCodes = [ 531,-531 ]
pgun.MomentumSpectrum.InputFile = "$PGUNSDATAROOT/data/Ebeam4000GeV/MomentumSpectrum_531.root"
pgun.MomentumSpectrum.BinningVariables = "pteta"
pgun.MomentumSpectrum.HistogramPath = "h_pteta"

from Configurables import BeamSpotSmearVertex
pgun.addTool(BeamSpotSmearVertex, name="BeamSpotSmearVertex")
pgun.VertexSmearingTool = "BeamSpotSmearVertex"
pgun.EventType = 13264021
```

```
# file /tmp/tmp.jL7AyRlWvT/DBASE/Gen/DecFiles/v30r106/options/13164042.py generated: Thu, 16 May 2024 16:58:05
#
# Event Type: 13164042
#
# ASCII decay Descriptor: {[[B_s0]nos -> (D_s- => pi+ pi- pi-) pi+]cc, [[B_s0]os -> (D_s+ => pi- pi+ pi+) pi-]cc}
#
from Configurables import Generation
Generation().EventType = 13164042
Generation().SampleGenerationTool = "SignalRepeatedHadronization"
from Configurables import SignalRepeatedHadronization
Generation().addTool( SignalRepeatedHadronization )
Generation().SignalRepeatedHadronization.ProductionTool = "Pythia8Production"
from Configurables import ToolSvc
from Configurables import EvtGenDecay
ToolSvc().addTool( EvtGenDecay )
ToolSvc().EvtGenDecay.UserDecayFile = "$DECFILESROOT/dkfiles/Bs_Dspi,pipipi=DDalitz,DecProdCut.dec"
Generation().SignalRepeatedHadronization.CutTool = "DaughtersInLHCb"
Generation().SignalRepeatedHadronization.SignalPIDList = [ 531,-531 ]

# Ad-hoc particle gun code

from Configurables import ParticleGun
pgun = ParticleGun("ParticleGun")
pgun.SignalPdgCode = 531
pgun.DecayTool = "EvtGenDecay"
pgun.GenCutTool = "DaughtersInLHCb"

from Configurables import FlatNParticles
pgun.NumberOfParticlesTool = "FlatNParticles"
pgun.addTool( FlatNParticles , name = "FlatNParticles" )

from Configurables import MomentumSpectrum
pgun.ParticleGunTool = "MomentumSpectrum"
pgun.addTool( MomentumSpectrum , name = "MomentumSpectrum" )
pgun.MomentumSpectrum.PdgCodes = [ 531,-531 ]
pgun.MomentumSpectrum.InputFile = "$PGUNSDATAROOT/data/Ebeam4000GeV/MomentumSpectrum_531.root"
pgun.MomentumSpectrum.BinningVariables = "pteta"
pgun.MomentumSpectrum.HistogramPath = "h_pteta"

from Configurables import BeamSpotSmearVertex
pgun.addTool(BeamSpotSmearVertex, name="BeamSpotSmearVertex")
pgun.VertexSmearingTool = "BeamSpotSmearVertex"
pgun.EventType = 13164042
```

Note study

Simulated samples used

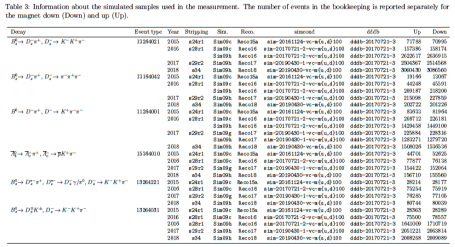


Table 3: Information about the simulated samples used in the measurement. The number of events in the bookkeeping is reported separately for the magnet down (Down) and up (Up).

Decay	Event type	Year	Stripping	Sim.	Reco.	simcond	dddb	Up	Down
$B_s^0 \to D_s^- \pi^+$, $D_s^- \to K^- K^+ \pi^-$	13264021	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md{u,d}100	ddds-20170721-3	71746	70895
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	157586	158174
				Sim09h	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	2022577	2036915
		2017	s29r2	Sim09h	Reco17	sim-20190430-1-vc-md{u,d}100	ddds-20170721-3	3282967	3314568
		2018	s34	Sim09h	Reco17	sim-20190430-vc-md{u,d}100	ddds-20170721-3	3066430	3096560
$B_s^0 \to D_s^- \pi^+$, $D_s^- \to \pi^- \pi^+ \pi^-$	13164042	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md{u,d}100	ddds-20170721-3	19180	19497
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	44248	45591
				Sim09h	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	2091497	2109506
		2017	s29r2	Sim09h	Reco17	sim-20190430-1-vc-md{u,d}100	ddds-20170721-3	2150598	2278769
		2018	s34	Sim09h	Reco17	sim-20190430-vc-md{u,d}100	ddds-20170721-3	2027121	2051220
$B^0 \to D^- \pi^+$, $D^- \to K^+ \pi^- \pi^-$	11264001	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md{u,d}100	ddds-20170721-3	83931	81994
		2016	s28r1	Sim09h	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	2097122	2201181
				Sim09h	Reco17	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	1428458	1445100
		2017	s29r2	Sim09g	Reco17	sim-20190430-1-vc-md{u,d}100	ddds-20170721-3	225854	230516
				Sim09h	Reco17	sim-20190430-1-vc-md{u,d}100	ddds-20170721-3	1283271	1279720
		2018	s34	Sim09h	Reco17	sim-20190430-vc-md{u,d}100	ddds-20170721-3	1500320	1530516
$\overline{\Lambda}_b^0 \to \overline{\Lambda}_c^- \pi^+$, $\overline{\Lambda}_c^- \to \overline{p} K^+ \pi^-$	15196010	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md{u,d}100	ddds-20170721-3	44716	32625
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	77477	76116
		2017	s29r2	Sim09h	Reco17	sim-20190430-1-vc-md{u,d}100	ddds-20170721-3	154122	152864
		2018	s34	Sim09h	Reco17	sim-20190430-vc-md{u,d}100	ddds-20170721-3	136710	135665
$B_s^0 \to D_s^{*-} \pi^+$, $D_s^{*-} \to D_s^- \gamma / \pi^0$, $D_s^- \to K^- K^+ \pi^-$	13366221	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md{u,d}100	ddds-20170721-3	39214	39177
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	75214	75919
		2017	s29r2	Sim09h	Reco17	sim-20190430-1-vc-md{u,d}100	ddds-20170721-3	76245	77105
		2018	s34	Sim09h	Reco17	sim-20190430-vc-md{u,d}100	ddds-20170721-3	66741	66520
$B_s^0 \to D_s^0 K^+$, $D_s^- \to K^- K^+ \pi^-$	13266021	2015	s24r1	Sim09c	Reco15a	sim-20161124-vc-md{u,d}100	ddds-20170721-3	28963	29289
		2016	s28r1	Sim09c	Reco16	sim-20170721-2-vc-md{u,d}100	ddds-20170721-3	72020	72157
		2017	s29r2	Sim09h	Reco17	sim-20190430-1-vc-md{u,d}100	ddds-20170721-3	1642000	1720719
		2018	s34	Sim09h	Reco17	sim-20190430-vc-md{u,d}100	ddds-20170721-3	1953232	1965814

```
# EventType: 13264021
#
# Descriptor: {[[B_s0]nos -> (D_s- => K+ K- pi-) pi+]cc, [[B_s0]os -> (D_s+ => K- K+ pi+) pi-]cc}
#
# NickName: Bs_Dspi,KKpi=DecProdCut
#
# Cuts: DaughtersInLHCb
#
# Documentation:
# B_s0 decay to D_s- (KKpi) pi+ with Dalitz decay model for D_s- decay.
# DaughtersInLHCb
# EndDocumentation
#
# PhysicsWG: B2OC
# Tested: Yes
# Responsible: Paul Szczypka
# Email: paul.szczypka@{nospam}cern.ch
# Date: 20110927
#
Alias      MyD_s-     D_s-
Alias      MyD_s+     D_s+
ChargeConj MyD_s+     MyD_s-
#
Decay B_s0sig
  1.000     MyD_s-     pi+      PHSP;
Enddecay
CDecay anti-B_s0sig
#
Decay MyD_s-
  1.000        K-        K+        pi-             D_DALITZ;
Enddecay
CDecay MyD_s+
#
End
```

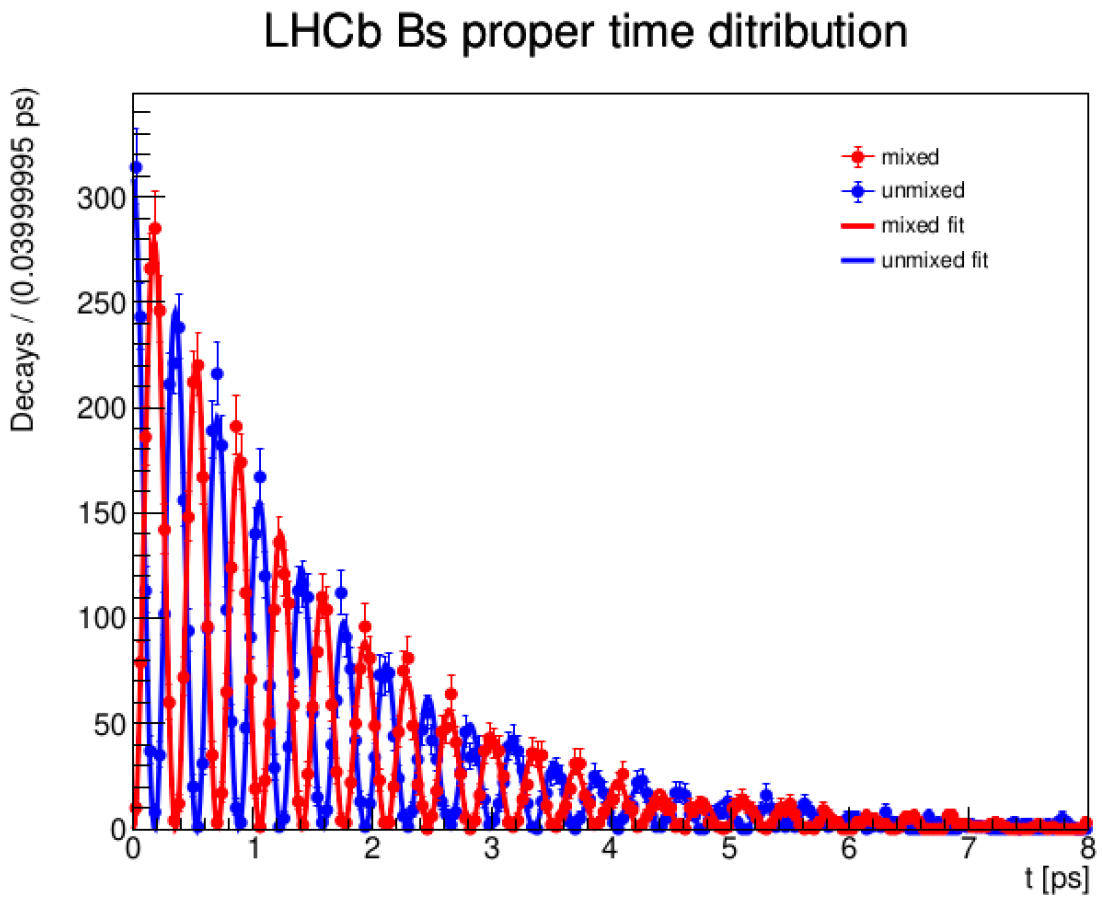
```
# EventType: 13164042
#
# Descriptor: {[[B_s0]nos -> (D_s- => pi+ pi- pi-) pi+]cc, [[B_s0]os -> (D_s+ => pi- pi+ pi+) pi-]cc}
#
# NickName: Bs_Dspi,pipipi=DDalitz,DecProdCut
#
# Cuts: DaughtersInLHCb
#
# Documentation:
# B_s0 decay to D_s- (pipipi) pi+ with Dalitz decay model for D_s- decay.
# DaughtersInLHCb
# EndDocumentation
#
# PhysicsWG: B2OC
# Tested: Yes
# Responsible: Anton Poluektov
# Email: A.O.Poluektov@warwick.ac.uk
# Date: 20120503

Alias      MyD_s-     D_s-
Alias      MyD_s+     D_s+
ChargeConj MyD_s+     MyD_s-
#
Decay B_s0sig
  1.000     MyD_s-     pi+      PHSP;
Enddecay
CDecay anti-B_s0sig
#
Decay MyD_s-
  1.000     pi+    pi-     pi-          D_DALITZ;
Enddecay
CDecay MyD_s+
#
End
```

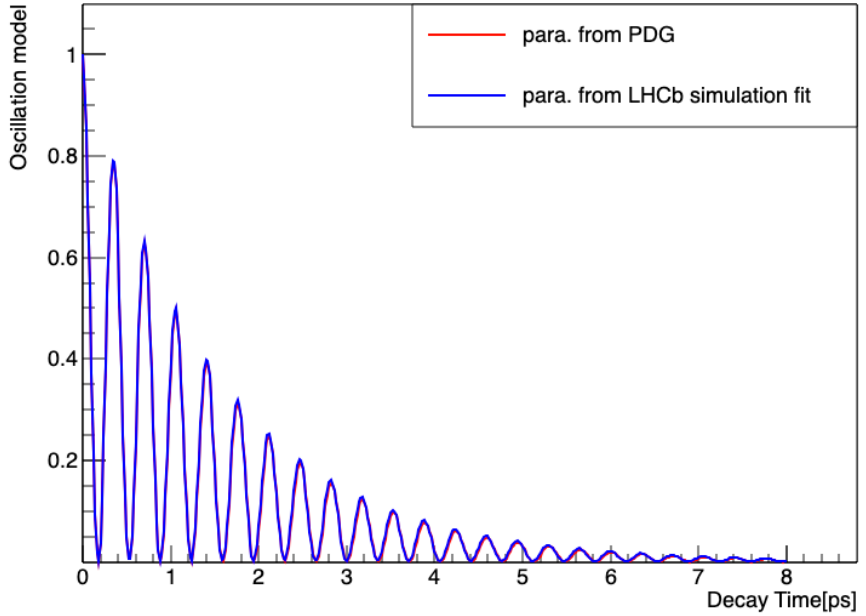
LHCb result study

Simulated samples used

Decay
$B_s^0 \to D_s^- \pi^+, D_s^- \to K^- K^+ \pi^-$




```
EXT PARAMETER
NO.   NAME      VALUE            ERROR
 1  Delta_Gamma_s   1.61628e-01   2.06497e-02
 2  Delta_mass_s    1.78065e+01   5.14595e-03
 3  Gamma_s         6.52400e-01   7.54099e-03   1
                              ERR DEF= 0.5
```



$$P(t) \approx e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + C\cos(\Delta m_s t)\right],$$

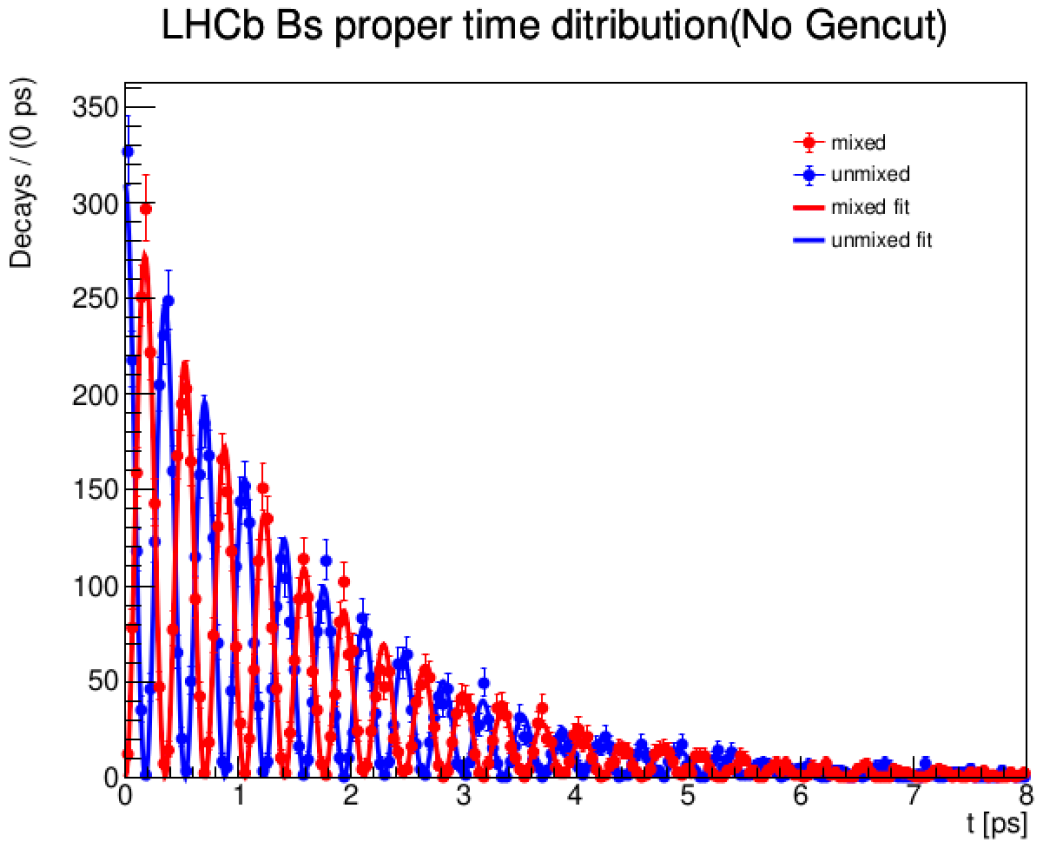
- head_TRUETAU : true propertime

..ttps://lhcb-comp.web.cern.ch/Support/Conventions/units.pdf

LHCb result study

No Gencut sample

Decay
$B_s^0 \to D_s^- \pi^+, D_s^- \to K^- K^+ \pi^-$




```
EXT PARAMETER
NO.   NAME      VALUE            ERROR
 1  Delta_Gamma_s   1.61628e-01   2.06497e-02
 2  Delta_mass_s    1.78065e+01   5.14595e-03
 3  Gamma_s         6.52400e-01   7.54099e-03   1
                              ERR DEF= 0.5
```

```
EXT PARAMETER
NO.   NAME      VALUE            ERROR
 1  Delta_Gamma_s   1.28423e-01   2.29790e-02
 2  Delta_mass_s    1.78087e+01   4.94629e-03
 3  Gamma_s         6.49562e-01   7.38862e-03   1
                              ERR DEF= 0.5
```

$$P(t) \approx \mathrm{e}^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + C\cos(\Delta m_s t)\right],$$

- head_TRUETAU : true propertime

..ttps://lhcb-comp.web.cern.ch/Support/Conventions/units.pdf

Summary and next

1. Compare with the result of LHCb and PDG, Herwig samples have different time scale and Whizard samples have different frequency.

2. It seems that the question is from Generators configurations, and maybe there is still something wrong in our code and calculation.

3. Clear oscillation shapes from generators now, so maybe we could start tagging from here.