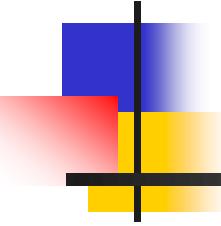


# EvtGen

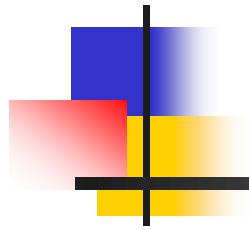
## implementation/usage in the ALICE analysis framework

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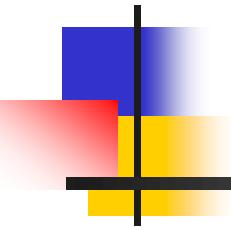


# Motivations for EvtGen in ALICE

- ALICE is not really sensitive to all theoretical refinements of B decay dynamics (i.e. CP-violation, CKM matrix elements, ...). We are principally interested (for the moment) in:
  - ✓ simulation of correct fractions and kinematics of final state products of a (beauty) decay chain
  - ✓ simulation of polarization for final states products
  - ✓ simulation of Final State Radiation (FSR) with **PHOTOS**
- It can be used by our collaboration:
  - ✓ in the procedure to deconvolute the spectrum of beauty particles studied in their inclusive decays (e.g.  $B \rightarrow e + X$ ,  $B \rightarrow J/\psi + X$ ) in order to extract  $p_T(B)$  spectrum from  $p_T(J/\psi)$  (or  $p_T(e)$ ) spectrum
  - ✓ polarization studies of  $J/\psi$
  - ✓ to compute sistematicas on secondary  $J/\psi$  ( $\leftarrow B$ ) extraction
  - ✓ We expect that it will be used more in future when our beauty and charm measurements would become more precise



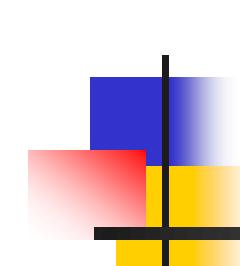
# Implementation of EvtGen and simulation scheme in the ALICE official analysis framework



# Summary

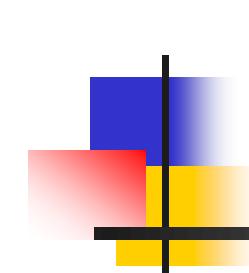
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- ✓ Motivations for EvtGen in ALICE
- ✓ Implementation in ALICE analysis framework
- ✓ Few checks
- ✓ Few issues
- ✓ Conclusions



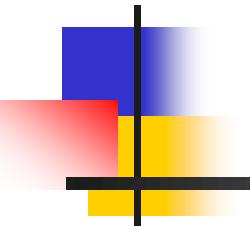
# Implementation in ALIROOT

- It was introduced in the official ALICE code (AliRoot) quite recently (less than 1 year ago)
  - ✓ source code was taken from:  
<http://www.lepp.cornell.edu/~ryd/EvtGen.tar> and the manual suggested for ALICE users is @  
<http://robbep.home.cern.ch/robbep/EvtGen/GuideEvtGen.pdf>
- The original code was almost unchanged w.r.t. the official release, except for:
  - ✓ slightly different rearrangement of directories
  - ✓ very few lines changed in order to removed dependence from CLHEP (not used in AliROOT) → in place of HepLorentzVector we use TLorentzVector of ROOT
  - ✓ displacement of friend methods declarations outside from the class scope, in order to fix some errors that happen during the compilation with newer compilers (as gcc v4.4 and newer)



# Generation scheme in ALIROOT

- We use a **Cocktail** of generators (generators are put in parallel):
  1. (AliGen)PYTHIA
    - ✓ to be the first
    - ✓ beauty decays (or particles that should be decayed by EvtGen) have to be switched-off
  2. (AliGen)EVTGEN
    - ✓ it would be used to perform beauty decay
- Interface classes to use EvtGen are easily implemented → the package is “user-friendly”
  - ✓ EvtGen works as a generator in our scheme but it is used only to perfome particle decays
- Decay cases implemented (and tested) to force beauty:  
 $B \rightarrow J/\Psi + X$  -  $B \rightarrow e + X$   
 $B \rightarrow J/\Psi + X, J/\Psi \rightarrow e^+e^-$  -  $B \rightarrow J/\Psi + X, J/\Psi \rightarrow \mu^+\mu^-$



# Few checks...

...we try to compare EvtGen  
with our standard decayer  
(Pythia)

# BR Pythia-EvtGen-PDG<sub>2008</sub>

B-hadron	J/ $\psi$ -channel	BR (AliDecayerPYTHIA)	BR (EVTGEN)	BR (PDG 2008)
$B^0$	$J/\psi K^0$	$8 \cdot 10^{-4}$	$8,72 \cdot 10^{-4}$	$(8,71 \pm 0,32) \cdot 10^{-4}$
	$J/\psi K^*(892)^0$	$1,4 \cdot 10^{-3}$	$1,33 \cdot 10^{-3}$	$(1,33 \pm 0,06) \cdot 10^{-3}$
	$J/\psi \pi^0$	--	$2,05 \cdot 10^{-5}$	$(2,05 \pm 0,24) \cdot 10^{-5}$
	$J/\psi \rho^0$	--	$1,6 \cdot 10^{-5}$	$(2,7 \pm 0,4) \cdot 10^{-5}$
	$J/\psi K^*(1430)^0$	--	$5 \cdot 10^{-4}$	--
	$J/\psi K(1400)^0$	--	$1 \cdot 10^{-4}$	--
	$J/\psi K(1270)^0$	--	$1,3 \cdot 10^{-3}$	$(1,3 \pm 0,5) \cdot 10^{-3}$
	$J/\psi K^0 \pi^+ \pi^-$	--	--	$(1 \pm 0,4) \cdot 10^{-3}$
	$J/\psi \omega$	--	$3 \cdot 10^{-4}$	$< 2,7 \cdot 10^{-4}$
	$J/\psi K^\pm \pi^\pm$	--	$1,2 \cdot 10^{-3}$	$(1,2 \pm 0,6) \cdot 10^{-3}$
	$J/\psi K^0 \pi^0$	--	$1 \cdot 10^{-4}$	--
	$J/\psi \rho^\pm \pi^0$	--	$9,4 \cdot 10^{-5}$	$(9,4 \pm 0,26) \cdot 10^{-5}$
	$J/\psi K^*(892)^+ \pi^-$	--	--	$(8 \pm 4) \cdot 10^{-4}$
	$J/\psi K^*(892)^0 \pi^+ \pi^-$	--	--	$(6,6 \pm 2,2) \cdot 10^{-4}$
$B^\pm$	$J/\psi K^\pm$	$8 \cdot 10^{-4}$	$1,007 \cdot 10^{-3}$	$(1,007 \pm 0,035) \cdot 10^{-3}$
	$J/\psi K^\pm \pi^+ \pi^-$	--	--	$(1,07 \pm 0,19) \cdot 10^{-3}$
	$J/\psi \pi^\pm$	--	$4,9 \cdot 10^{-5}$	$(4,9 \pm 0,6) \cdot 10^{-5}$
	$J/\psi \rho^\pm$	--	$6 \cdot 10^{-5}$	$(5 \pm 0,8) \cdot 10^{-5}$
	$J/\psi K^*(892)^\pm$	$1,4 \cdot 10^{-3}$	$1,41 \cdot 10^{-3}$	$(1,43 \pm 0,08) \cdot 10^{-3}$
	$J/\psi K(1270)^\pm$	--	$1,8 \cdot 10^{-3}$	$(1,8 \pm 0,5) \cdot 10^{-3}$
	$J/\psi K(1400)^\pm$	--	$1 \cdot 10^{-4}$	$< 5 \cdot 10^{-4}$
	$J/\psi \Phi k^\pm$	--	$5,2 \cdot 10^{-5}$	$(5,2 \pm 1,7) \cdot 10^{-5}$
	$J/\psi K^*(1430)^\pm$	--	$5 \cdot 10^{-4}$	--
	$J/\psi \eta K^\pm$	--	--	$(1,08 \pm 0,33) \cdot 10^{-4}$
$B_s^0$	$J/\psi \Phi$	$1,4 \cdot 10^{-3}$	$1,35 \cdot 10^{-3}$	$(9,3 \pm 3,3) \cdot 10^{-4}$
	$J/\psi \eta$	$4 \cdot 10^{-4}$	$3,2 \cdot 10^{-4}$	$< 3,8 \cdot 10^{-3}$
	$J/\psi \eta'$	$4 \cdot 10^{-4}$	$6,4 \cdot 10^{-4}$	--
	$J/\psi \pi^0$	--	--	$< 1,2 \cdot 10^{-3}$
$\Lambda_B^0$	$J/\psi \Lambda$	$2,2 \cdot 10^{-3}$	$4,7 \cdot 10^{-4}$	$(4,7 \pm 2,8) \cdot 10^{-4}$

$B \rightarrow J/\psi + X$

Comparison of decay channels and BR for Pythia (in AliRoot)-EvtGen-PDG2008

# BR Pythia-EvtGen-PDG<sub>2008</sub>

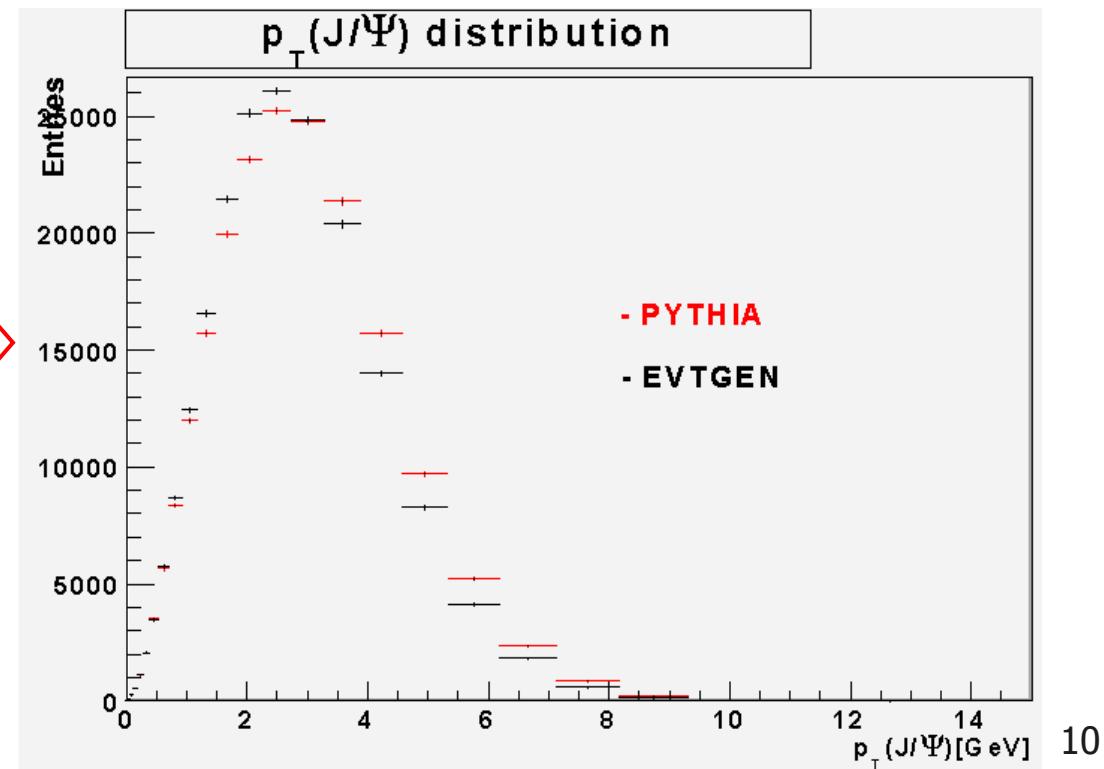
B-hadron	channel B --> e+X	BR (AliDecayerPYTHIA)	BR (EVTGEN)	BR (PDG 2008)
<b>B<sup>+</sup></b>	anti-D <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	0.02	0,0215	0,0227
	anti-D <sup>0*</sup> e <sup>+</sup> ν <sub>e</sub>	0,055	0,065	0,0607
	D <sup>*</sup> - π <sup>+</sup> e <sup>+</sup> ν <sub>e</sub> (NOT RESONANT)	-	6,3 · 10 <sup>-3</sup>	6,1 · 10 <sup>-3</sup>
	D <sup>*</sup> - π <sup>+</sup> e <sup>+</sup> ν <sub>e</sub> (RESONANT)	10,5 · 10 <sup>-3</sup>	0,95 · 10 <sup>-3</sup>	0,65 · 10 <sup>-3</sup>
	anti-D <sup>0*</sup> π <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	0,3 · 10 <sup>-3</sup>	-
	D <sup>-</sup> π <sup>+</sup> e <sup>+</sup> ν <sub>e</sub> (NOT RESONANT)	-	5,2 · 10 <sup>-3</sup>	-
	D <sup>-</sup> π <sup>+</sup> e <sup>+</sup> ν <sub>e</sub> (RESONANT)	6,53 · 10 <sup>-3</sup>	4,57 · 10 <sup>-3</sup>	4,6 · 10 <sup>-3</sup>
	anti-D <sup>0</sup> π <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	1 · 10 <sup>-3</sup>	-
	π <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	7,7 · 10 <sup>-5</sup>	7,7 · 10 <sup>-5</sup>
	η e <sup>+</sup> ν <sub>e</sub>	-	0,8 · 10 <sup>-4</sup>	< 1,01 · 10 <sup>-4</sup>
	η' e <sup>+</sup> ν <sub>e</sub>	-	0,84 · 10 <sup>-4</sup>	2,7 · 10 <sup>-4</sup>
	ω e <sup>+</sup> ν <sub>e</sub>	-	1,3 · 10 <sup>-4</sup>	1,3 · 10 <sup>-4</sup>
	ρ <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	1,28 · 10 <sup>-4</sup>	1,28 · 10 <sup>-4</sup>
	a <sub>0/1/2</sub> <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	0,96 · 10 <sup>-4</sup>	-
	b <sub>1</sub> <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	0,48 · 10 <sup>-4</sup>	-
	f <sub>0/1/2</sub> e <sup>+</sup> ν <sub>e</sub> (f <sub>0/1/2</sub> ' e <sup>+</sup> ν <sub>e</sub> )	-	0,49 · 10 <sup>-4</sup>	-
	h <sub>1</sub> e <sup>+</sup> ν <sub>e</sub> (h <sub>1</sub> ' e <sup>+</sup> ν <sub>e</sub> )	-	0,24 · 10 <sup>-4</sup>	-
<b>B<sup>0</sup></b>	D <sup>-</sup> e <sup>+</sup> ν <sub>e</sub>	0.02	0,0208	0,00217
	D*- e <sup>+</sup> ν <sub>e</sub>	0,055	0,0529	0,0516
	anti-D <sup>*0</sup> π <sup>-</sup> e <sup>+</sup> ν <sub>e</sub> (NOT RESONANT)	-	6,5 · 10 <sup>-3</sup>	4,9 · 10 <sup>-3</sup>
	anti-D <sup>*0</sup> π <sup>-</sup> e <sup>+</sup> ν <sub>e</sub> (RESONANT)	10,5 · 10 <sup>-3</sup>	8,77 · 10 <sup>-3</sup>	13,4 · 10 <sup>-3</sup>
	D <sup>-</sup> π <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	0,3 · 10 <sup>-3</sup>	-
	anti-D <sup>0</sup> π <sup>-</sup> e <sup>+</sup> ν <sub>e</sub> (NOT RESONANT)	-	3,2 · 10 <sup>-3</sup>	-
	anti-D <sup>0</sup> π <sup>-</sup> e <sup>+</sup> ν <sub>e</sub> (RESONANT)	6,9 · 10 <sup>-3</sup>	4,05 · 10 <sup>-3</sup>	4,2 · 10 <sup>-3</sup>
	D <sup>-</sup> π <sup>0</sup> e <sup>+</sup> ν <sub>e</sub>	-	1 · 10 <sup>-3</sup>	-
	π <sup>-</sup> e <sup>+</sup> ν <sub>e</sub>	-	1,36 · 10 <sup>-4</sup>	1,36 · 10 <sup>-4</sup>
	ρ <sup>-</sup> e <sup>+</sup> ν <sub>e</sub>	-	2,2 · 10 <sup>-4</sup>	2,47 · 10 <sup>-4</sup>
	a <sub>0/1/2</sub> <sup>-</sup> e <sup>+</sup> ν <sub>e</sub>	-	1,93 · 10 <sup>-4</sup>	-
	b <sub>1</sub> <sup>-</sup> e <sup>+</sup> ν <sub>e</sub>	-	1,65 · 10 <sup>-4</sup>	-

**B → e+X**

# Differences between decayers

- 100K events generated by Pythia with one bb-bar pair/event (only kinematic)
  - ✓ The B-hadrons are forced to decay by either **Pythia** or **EvtGen** (in the allowed channels  $B \rightarrow J/\Psi + X$ ,  $J/\Psi \rightarrow e+e-$ )

Same  $p_T(B)$  spectrum;  
either Pythia or  
EvtGen as decayer

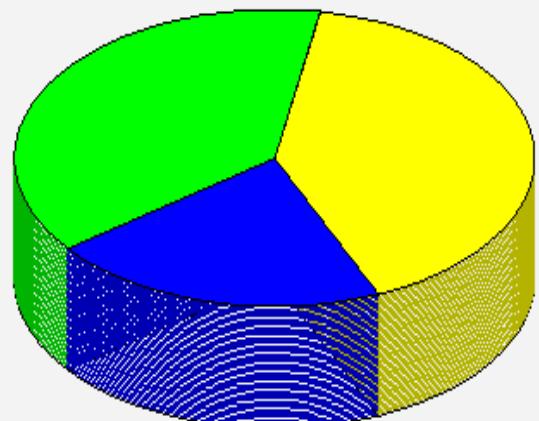


# Fractions of final hadrons in beauty decay chains

- Fractions of final hadrons that have a beauty hadron in their “parents” → evaluated on 20K events

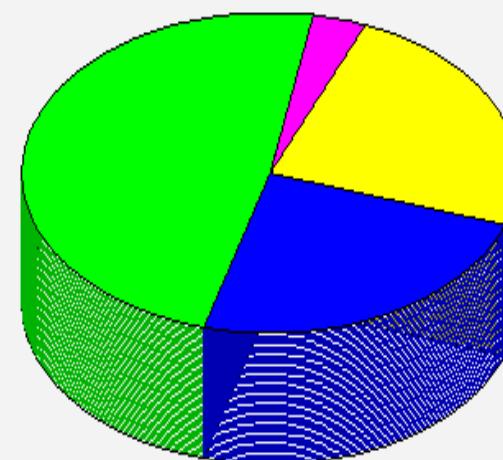
$B \rightarrow J/\Psi + X, J/\Psi \rightarrow e^+e^-$

PYTHIA



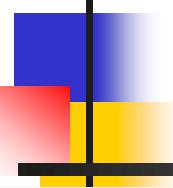
$\pi^\pm$	(38.2 $\pm$ 0.5 %)
$\pi^0$	(21.1 $\pm$ 0.5 %)
$K^\pm$	(40.6 $\pm$ 0.5 %)
(n+p)	(~0 %)

PYTHIA + EVTGEN

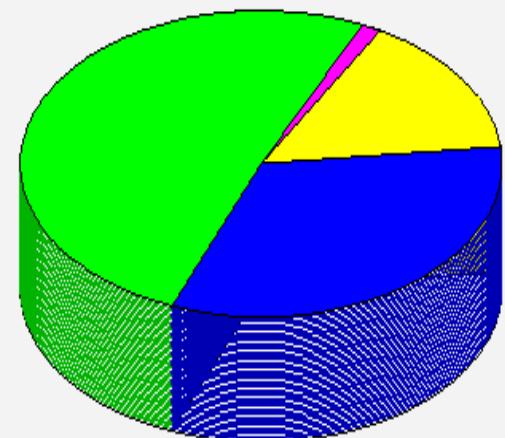


$\pi^\pm$	(48.4 $\pm$ 0.4 %)
$\pi^0$	(24.0 $\pm$ 0.3 %)
$K^\pm$	(23.9 $\pm$ 0.3 %)
(n+p)	(3.5 $\pm$ 0.3 %)

$B \rightarrow e + X$



PYTHIA



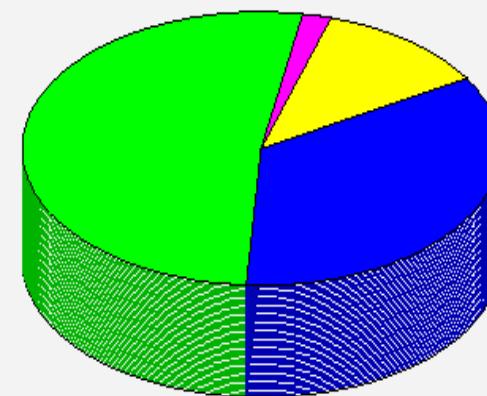
$\pi^{\pm}(50.8 \pm 0.3\%)$

$\pi^0(32.7 \pm 0.2\%)$

$K^{\pm}(14.9 \pm 0.2\%)$

$(n+p)(1.3 \pm 0.2\%)$

PYTHIA + EVTGEN



$\pi^{\pm}(51.7 \pm 0.3\%)$

$\pi^0(34.5 \pm 0.2\%)$

$K^{\pm}(11.7 \pm 0.2\%)$

$(n+p)(1.9 \pm 0.2\%)$

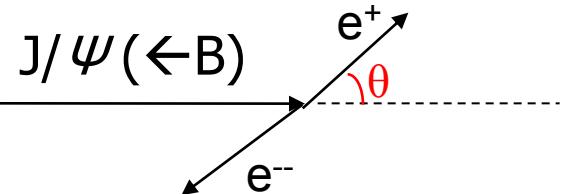
➤ Ratio  $\gamma/\pi^0 \sim 2$  ( $\pi^0 \rightarrow 2\gamma$ )

	$B \rightarrow J/\Psi + X$ , $J/\Psi \rightarrow e^+e^-$	$B \rightarrow e + X$
PYTHIA	2.15	2.17
EVTGEN	2.58	2.28

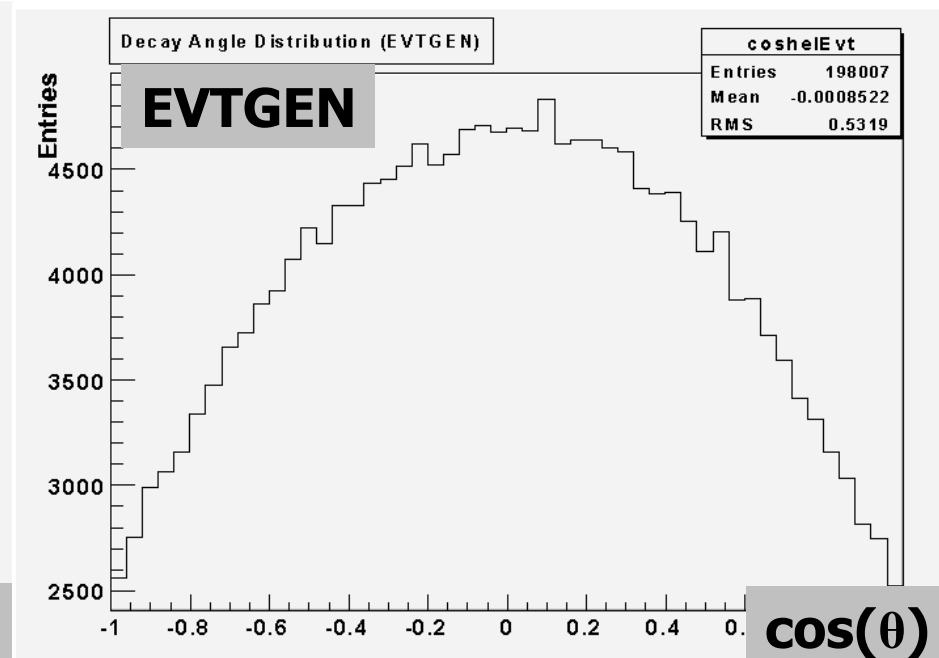
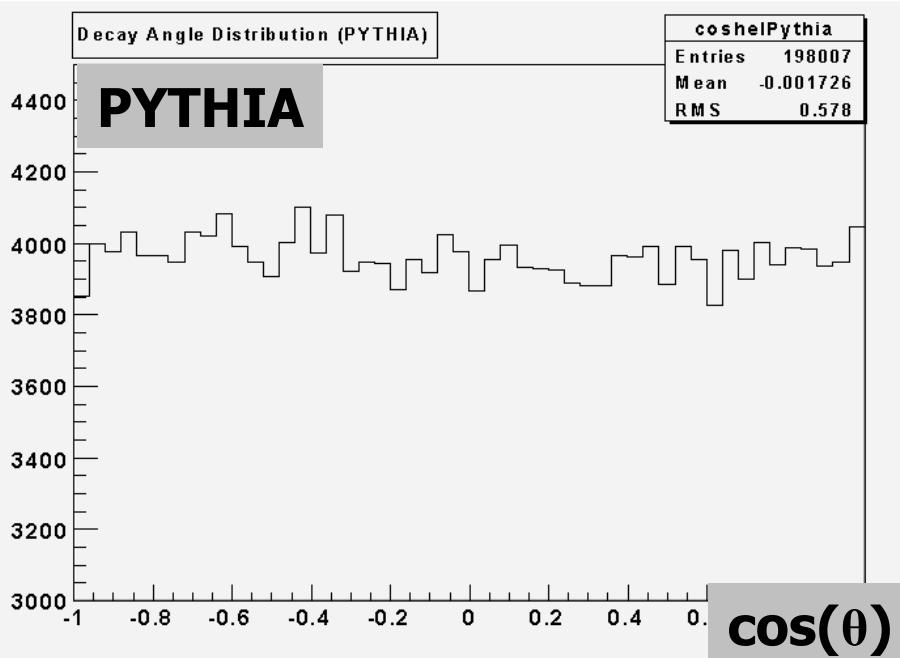
$R_{EVTGEN} > R_{PYTHIA}$  :  
photons generated from  
Final State Radiation  
(es. process of “internal”  
bremsstrahlung  
 $J/\Psi \rightarrow e^+e^-\gamma$ )

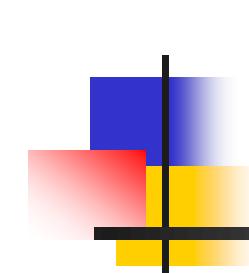
# Polarisation angle, e.g. $B \rightarrow J/\Psi + X$ , $J/\Psi \rightarrow e^+e^-$

$\theta \equiv$  angle between the flight direction of the  $e^+$ , in the rest frame of  $J/\Psi(\leftarrow B)$ , respect to the  $J/\Psi$ 's flight direction in the rest frame of beauty particle



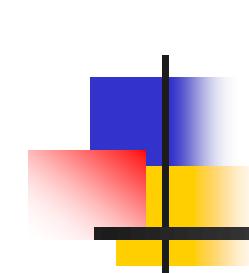
[Evaluated by  $\text{EvtDecayAngle}(p_B^\mu, p_{J/\Psi}^\mu, p_{e^+}^\mu)$ ]





# Some issues

- We experience the same problem as others LHC experiments: the interference between EvtGen initialization of Pythia with the Pythia used as “hard” generator:
  - ✓ We try to solve this problem without initialize Pythia in EvtGen (in EvtPythia the method pythiaInit() is not executed) → particles decayed by Pythia (in DECAY.DEC) are decayed with the same Pythia configuration that we set in the first Pythia (AliDecayerPythia)
  - ✓ We test this only for our specific cases ( $B \rightarrow J/\psi + X$ ,  $B \rightarrow e + X$ ) implemented in AliRoot
- We would have better documentation about updates to the code and about the location where it is possible to find the several (and the most updated) EvtGen versions



# Conclusions

- ✓ EvtGen is in the ALICE official analysis framework from less than one year ago
- ✓ It is used so far only for a few cases; we expect that it will be used more intensely when our charm and beauty measurements would become more precise
- ✓ We are interested in the future of EvtGen and we would appreciate if you would keep us updated