THE SIMULATION OF POLARIZED BARYONS IN THE LHC ATLAS USING EVTGEN

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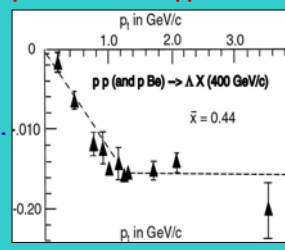
Motivation

Hyperons display large polarizations when produced at energies even up to several hundred GeV, though most models predict zero polarization. Can this effect be explained inside the S.M. or does it point to new physics?
The study of Λ_b polarization may shed light on polarized b-quarks and other quark production processes.

Hyperons Polarization

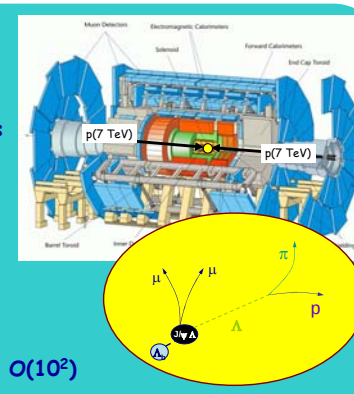
Λ polarization in pp → ΛX



Λ_b at LHC ATLAS

ATLAS is an experiment for the Large Hadron Collider (LHC) at CERN. Protons will collide at a center-of-mass energy of 14 TeV. With 0.7 mb cross section for b production, the LHC is a B-factory. The ATLAS detector allows a wide program of B-physics studies.

- At low luminosity, $O(10^{12})$ Λ_b will be produced per year
- In 3 years ATLAS can collect $O(10^5)$ $\Lambda_b \rightarrow J/\psi\,(\mu^+\mu^-)\,\Lambda\,(\pi p)$
- The world's biggest sample so far is ~ $O(10^2)$



Λ_b Production and Decay

Due to the parity conservation in the strong interactions, Λ_b can be produced with polarization orthogonal to the production plane. The considered decay is

$$\Lambda_b \rightarrow J/\psi\,\Lambda_0 \quad \Lambda_0 \rightarrow \pi p, \quad J/\psi \rightarrow \mu^+\mu^-$$

$\Lambda_b \rightarrow J/\psi\,(\mu\mu)\,\Lambda\,(p\pi)$ is characterizes by 4 helicity amplitudes a_+, a_-, b_+, b_-, and the asymmetry parameter α_b caused by the parity non conservation of the weak interactions

$$a_+ = A(1/2,0)$$
$$a_- = A(-1/2,0)$$
$$b_+ = A(-1/2,-1)$$
$$b_- = A(1/2,1)$$

$$\alpha_b = \frac{|a_+|^2 - |a_-|^2 + |b_+|^2 - |b_-|^2}{|a_+|^2 + |a_-|^2 + |b_+|^2 + |b_-|^2}$$

Implementation of Λ_b Polarization in EvtGen

EvtGen, a decay package from A. Ryd et al

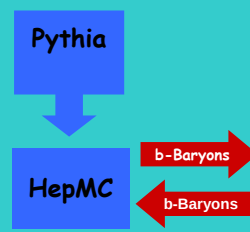
- Simulates decays using complex amplitudes, can account for interference terms
- The framework includes tools to handle sequential decays, implemented in individual nodes
- Allows users to build complicated decay chains from simple pieces
- Modules which perform the decay simulation are called models, represented by C++ classes.
- Users may add their own classes.

EvtGen uses spin density matrix formalism so it can calculate angular distributions of decay products for processes involving non-zero spin particles.

In ATLAS software, Pythia is used for the production of the primary event. EvtGen is used to decay selected particles and produce the full decay tree.

Method used to decay polarized Λ_b within EvtGen

- Get unpolarized and undecayed baryons from Pythia via HEPMC record
- Exploit the EvtGen capability to use spinor algebra and helicity amplitudes:
  - set the polarization of the particle before the particle is decayed, assigning to the Λ_b the correct polarization vector and the relative spin density matrix
  - obtain the correct angular distributions using a generic EvtGen two-body decay model, HELAMP, which is able to use the set of helicity amplitudes given by users



EvtGen

1 Set Polarization

·Calculate the polarization vector $\vec{P} = \frac{\hat{z} \times \vec{p}}{|\hat{z} \times \vec{p}|}$

·Calculate the spin density matrix

$$\rho \approx 1 + \vec{\sigma} \cdot \vec{P}$$

·Associate the density matrix to the particle

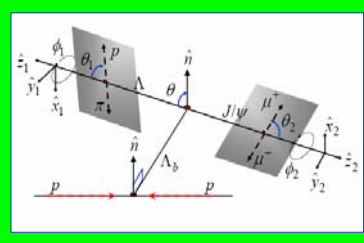
2 Decay with helicity amplitudes

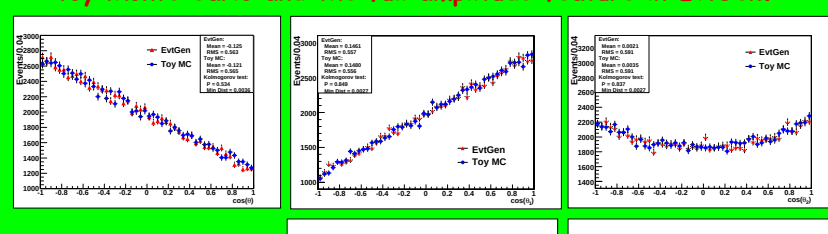
Adopt EvtGen class "HELAMP" to introduce a theoretical model for Λ_b decay

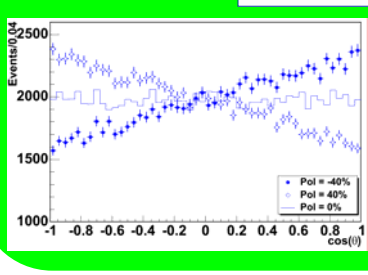
EvtGen Results

In order to validate the EvtGen method, the relevant 5 angular distributions have been generated using both a toy Monte Carlo and the full amplitude feature in EvtGen.

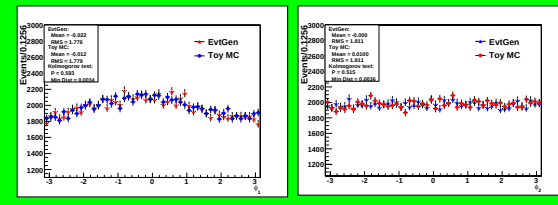
$\Lambda_b \rightarrow J/\psi(\mu\mu)\,\Lambda(\pi p)$ probability density function depends on 5 angles: $\theta, \theta_1, \phi_1, \theta_2, \phi_2$ shown in figure







Cos(θ) distribution generated with EvtGen for different values of the polarization P and a fixed value of α_b. As expected, the slope of the distribution is proportional to $P \cdot \alpha_b$



EvtGen demonstration for $P(\Lambda_b)$=80%
A good agreement is observed !