Search for CP and T Violations in the Weak Semileptonic Λ_b and Λ_c^+ Decays with the LHCb Detector

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Outline

motivation

- measure the polarization of the Λ_b^0 and Λ_c^+ .
- Test the TRV and the CPV in weak semileptonic decays.
- measure directly some important parameters for particle physics.
- full anguar distribution studies for different decay channels.
- New startegy for searching for TRV or CPV.

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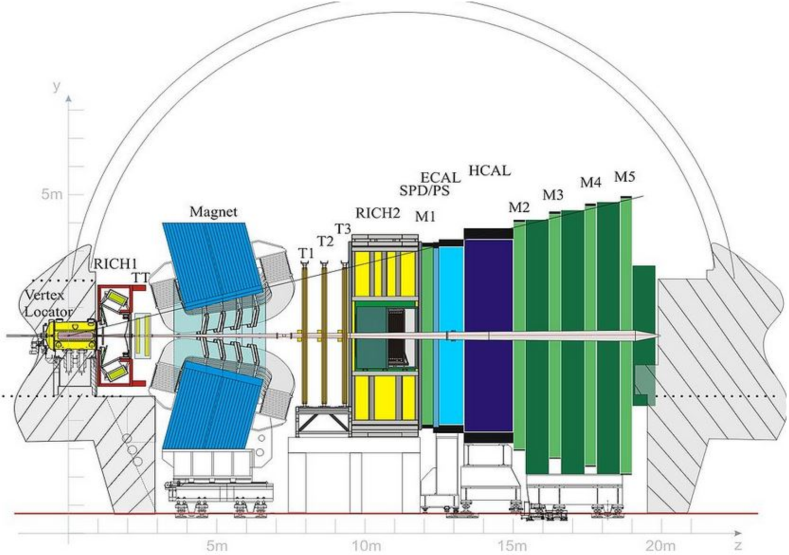

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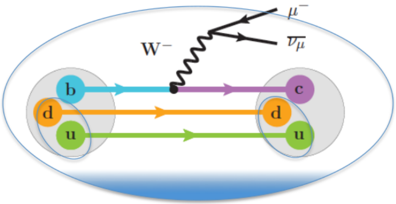

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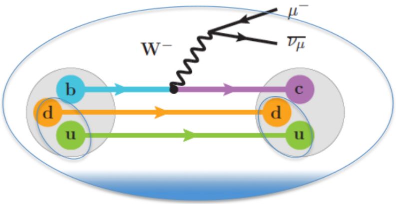

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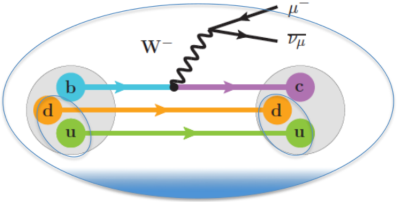

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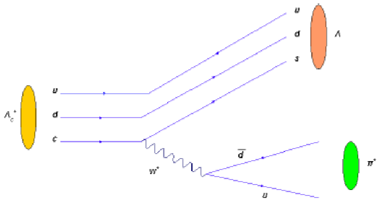

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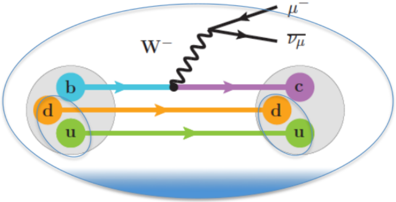

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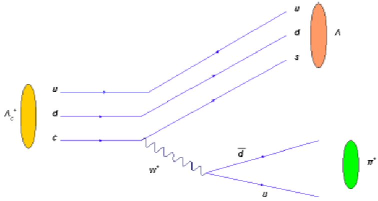

- Note that these particles decay via weak interactions due to the presence of the W-boson.

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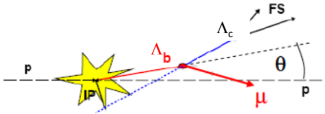

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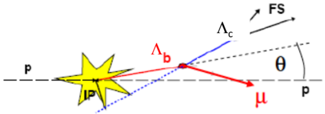

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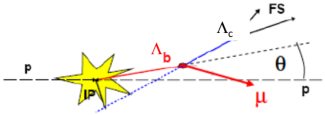

- The Λ_b momentum up to a two-fold ambiguity is given by:

$$\left[\left(\frac{\hat{p}[\Lambda_b]\cdot\vec{p}[\Lambda_c\mu]}{E[\Lambda_c\mu]}\right)^2 - 1\right] p[\Lambda_b]^2 + \left[(m[\Lambda_b]^2 + m[\Lambda_c\mu]^2)\frac{\hat{p}[\Lambda_b]\cdot\vec{p}[\Lambda_c\mu]}{E^2[\Lambda_c\mu]}\right] p[\Lambda_b] + \left[\left(\frac{(m[\Lambda_b]^2 + m[\Lambda_c\mu]^2)}{2E[\Lambda_c\mu]}\right)^2 - m[\Lambda_b]^2\right] = 0$$

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$\longrightarrow$ 4 posibilties of testing TRV in one event.

Definition of the Observable:The Special Angles

As illustrated in the figure below, consider the normal vectors to the production plane of Λ_c^+ and the W-boson :

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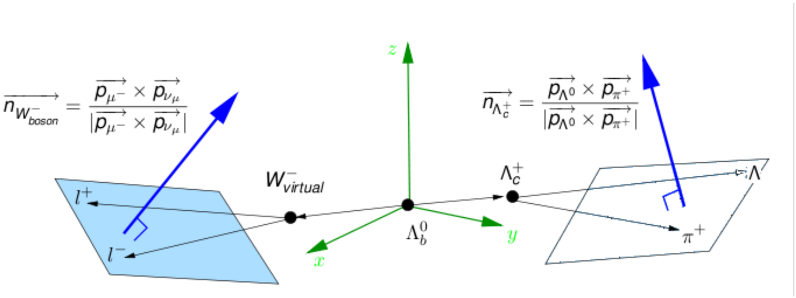

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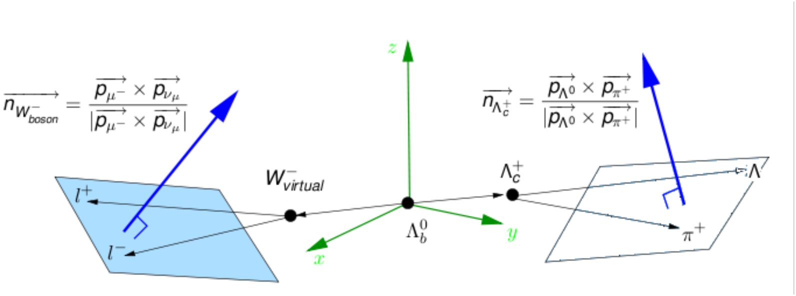

$$\overrightarrow{n_{\Lambda_c^+}} = \frac{\overrightarrow{p_{\Lambda^0}} \times \overrightarrow{p_{\pi^+}}}{|\overrightarrow{p_{\Lambda^0}} \times \overrightarrow{p_{\pi^+}}|}, \quad \overrightarrow{n_{W^-_{boson}}} = \frac{\overrightarrow{p_{\mu^-}} \times \overrightarrow{p_{\nu_\mu}}}{|\overrightarrow{p_{\mu^-}} \times \overrightarrow{p_{\nu_\mu}}|} \tag{1}$$

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These two quantities will be denoted as the Special angles. The relation 3 recalls the transformation by T of the vector base of the Transversity frame used in this decay.

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$$\overrightarrow{e_Z} = \frac{\overrightarrow{e_{p1}} \times \overrightarrow{p_{\Lambda_c^+}}}{|\overrightarrow{e_{p1}} \times \overrightarrow{p_{\Lambda_c^+}}|} \rightarrow +\overrightarrow{e_Z}, \overrightarrow{e_X} = \frac{\overrightarrow{p_{p1}}}{|\overrightarrow{p_{p1}}|} \rightarrow -\overrightarrow{e_X}, \overrightarrow{e_Y} = \overrightarrow{e_z} \times \overrightarrow{e_x} \rightarrow -\overrightarrow{e_Y} \tag{3}$$

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Remark: the quantities $\cos\phi_{(n_{\Lambda_c^+})}$ and $\sin\phi_{(n_{\Lambda_c^+})}$ are constructed from the momentums. Since the momentums are odd by T and P, the special angles therefore change sign under these two symmetries.

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Decompose the polarization vector of these resonances,$\longrightarrow$ construct the helicity frames: $(\Lambda_c^+, \overrightarrow{e_{L1}}, \overrightarrow{e_{T1}}, \overrightarrow{e_{N1}})$ and $(W_{virtual}^-, \overrightarrow{e_{L2}}, \overrightarrow{e_{T2}}, \overrightarrow{e_{N2}})$.
Figure below, shows frames constructed starting from the Λ_b^0 transversity frame. Their vector bases are defined as follows:

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$$\overrightarrow{e_{L1}} = \frac{\overrightarrow{p_{\Lambda_c^+}}}{|\overrightarrow{p_{\Lambda_c^+}}|}, \quad \overrightarrow{e_{N1}} = \frac{\overrightarrow{e_Z} \times \overrightarrow{e_{L1}}}{|\overrightarrow{e_Z} \times \overrightarrow{e_{L1}}|}, \quad \overrightarrow{e_{T1}} = \overrightarrow{e_{N1}} \times \overrightarrow{e_{L1}} \qquad (4)$$

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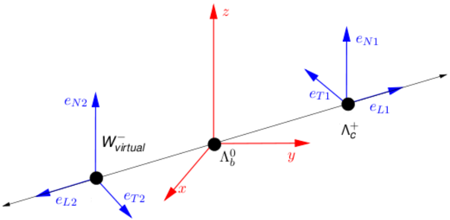

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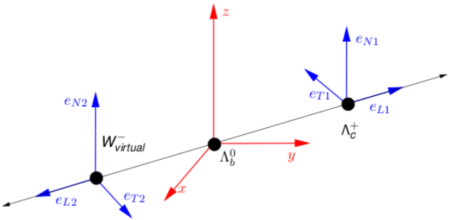

$$\overrightarrow{e_{L2}} = \frac{\overrightarrow{p_{W^-_{virtual}}}}{|\overrightarrow{p_{W^-_{virtual}}}|}, \quad \overrightarrow{e_{N2}} = \frac{\overrightarrow{e_Z} \times \overrightarrow{e_{L2}}}{|\overrightarrow{e_Z} \times \overrightarrow{e_{L2}}|}, \quad \overrightarrow{e_{T2}} = \overrightarrow{e_{N2}} \times \overrightarrow{e_{L2}} \qquad (5)$$

LHCB frame of the Λ_c^+

* Transversity frame from the Standard Laboratory frame.
  $\mathbf{e}_Z = \frac{\mathbf{e}_z \times \mathbf{p}_{\Lambda_c^+}}{|\mathbf{e}_z \times \mathbf{p}_{\Lambda_c^+}|}$
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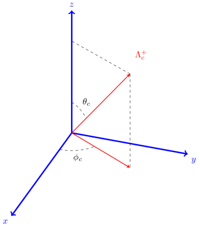

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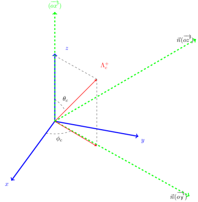
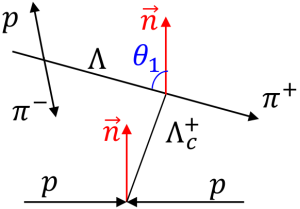
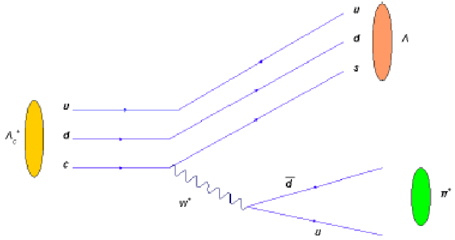


Phenomenological Study of the weak Λ_c^+ Decays

- Cascade decay $\Lambda_c^+ \rightarrow \Lambda^0\pi^+$ and $\Lambda^0 \longrightarrow p\pi^-$





- Final states are p pi- pi+ mu nu, why ?
- It is a new channel to be studied.
- 2 pseudo scalar particles (spin 0) necessary for the angular equations.
- Λ_b comes from strong interactions$\longrightarrow$ deduce its polarisation.

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- $\frac{d\sigma}{d\cos\theta_\Lambda} \propto 1 + \alpha_{AS}^{\Lambda_c^+} P_Z^{\Lambda_c^+} \cos\theta_\Lambda$
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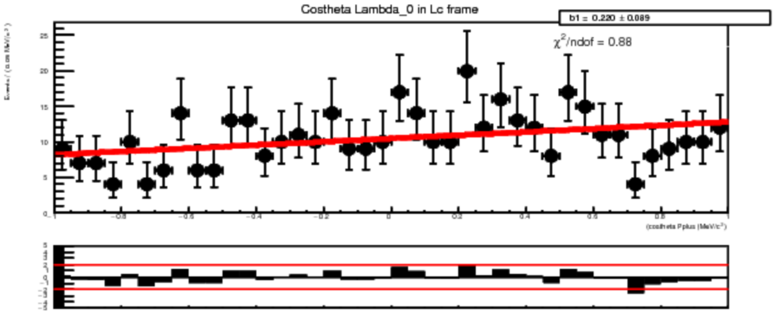

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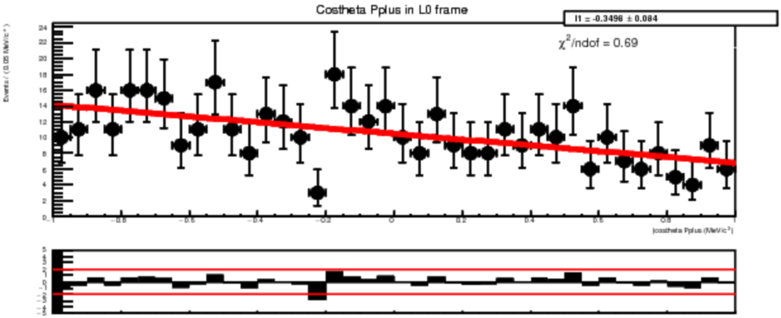

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Note: each particle is characterized by a specific parameter called the $\alpha_{asymmetry}$.

DataSet

- Data samples :2011 and 2012
- MC Simulation :2011 and 2012

PID Cuts

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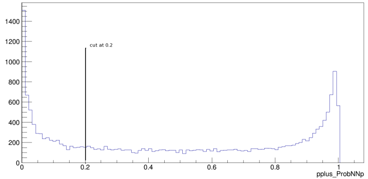

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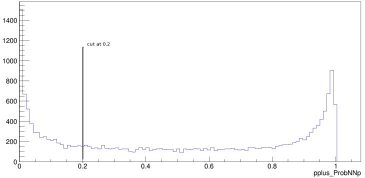

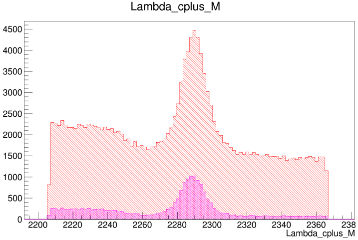

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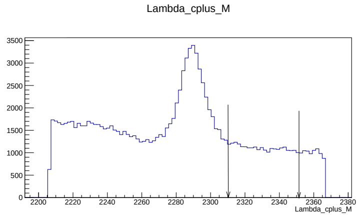

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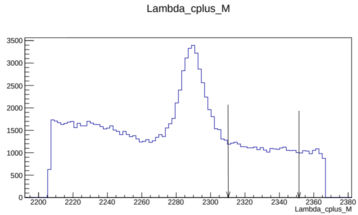

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we take the region btw two arrows to be a pure combinatoral bkg and we use BDT cuts to eliminate it.

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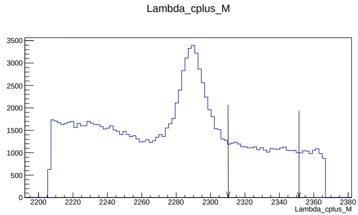
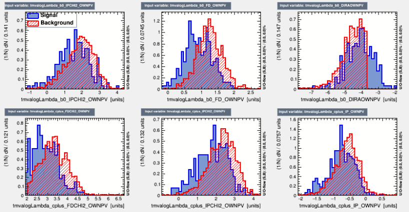
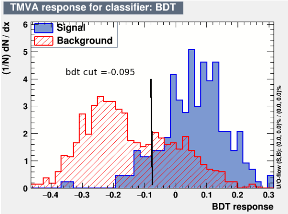
4) Lb Direction Angle

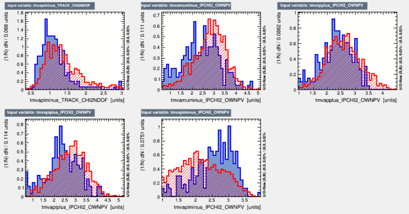


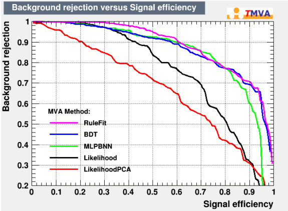
we take the region btw two arrows to be a pure combinatoral bkg and we use BDT cuts to eliminate it.

BDT and TMVA studies



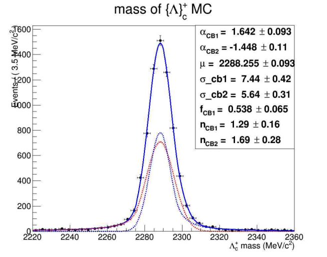






MC Model

MC Model



we used a double crystal ball function to model the MC signal

▸ CB Model

final Results

After the cuts above, we come to the Λ_c^+ mass spectrum:

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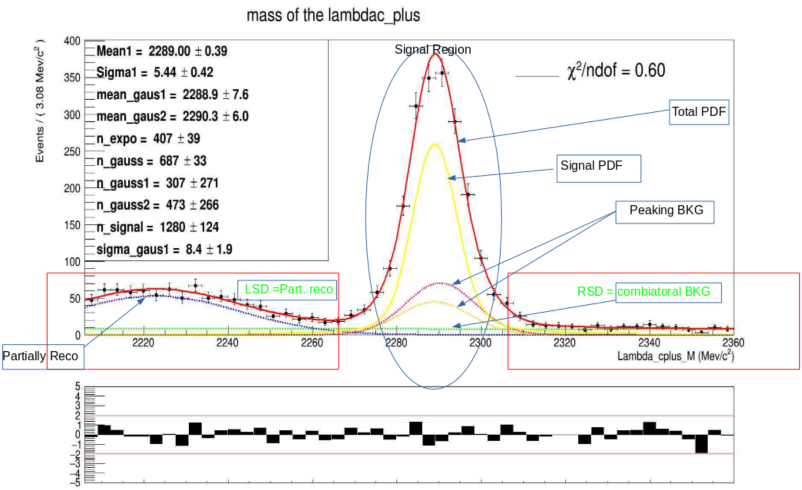

Conclusion

- Phenomenological Study of the weak Λ_b^0 and Λ_c^+ Decays
  - Direct test of TRV from Λ_b^0 decay
  - Direct test of CPV from Λ_c^+ decay
- Angular analysis of the above decays.
- extraction of some important particle parameters.

Thank you for your attention.