Overview of the Genova analyses

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Outline

Physics topics Three and four-body charmless baryonic B decays allow to study different aspects of the Standard Model:

- Measurements of CP asymmetry
- Searches for intermediate exotic states
- Measurements of baryonic decay branching fractions

Ongoing analyses Three and four-body charmless baryonic B decays

- Study of $B_s^0 \to \eta_c(\to p\bar{p})h^+h^-$ where $h^\pm = K^\pm, \pi^\pm$
- Search for exotic Z^--like states in the $\eta_c\pi^-$ invariant mass in $B^0 \to \eta_c(\to p\bar{p})K^+\pi^-$
- Search for new charmonium and charmonium-like states in $B^+ \to p\bar{p}K^+$ decays

Study of $B_s^0 \to \eta_c(\to p\bar{p})h^+h^-$

Original physics motivations

- Measure **CP-violating phase** ϕ_s through a time-dependent measurement of mixing-induced CP violation
- ϕ_s is expected to be small in the Standard Model and is therefore sensitive to **new physics** contributions
- Differences w.r.t. $B_s^0 \to J/\psi h^+h^-$:
  - **no** CP angular analysis is required
  - statistical **limitation** $\mathcal{B}(\eta_c \to p\bar{p}) = 1.5 \times 10^{-3}$
  - **lower** trigger efficiency w.r.t $J/\psi \to \mu^+\mu^-$

Selection and fit strategy

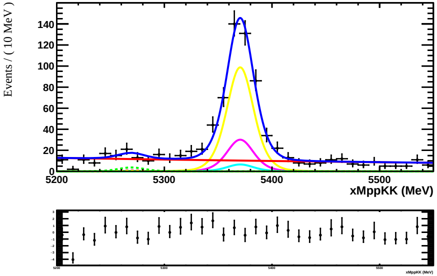
- Developed a **dedicated stripping line** in order to study $B^0_{(s)} \to p\bar{p}h^+h^-$
  $\to$ no requirements on $p\bar{p}$ and h^+h^- invariant masses
- Optimize MVA selection for a discrete set of PID criteria
  $\to$ choose the combination that provides the **best performance**
  $\to$ **separate** offline and PID selection makes life easier for systematics
- MVA trained and tested using topological and kinematical variables

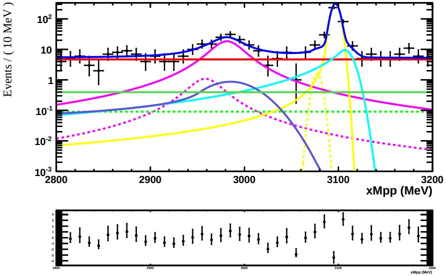
signal	MC2011 and MC2012 samples merged
background	right sideband defined in order to avoid partially reconstructed background

- **Common fit strategy** with other modes $B_s^0 \to \eta_c(\to 4h)\phi(\to K^+K^-)$
  $\to$ bidimensional fit to $M_{p\bar{p}h^+h^-}$ and $M_{p\bar{p}}$ spectra
  $\to$ 3D fit under investigation in order to separate S-wave component in the KK invariant mass

S. Akar, J. He, O. Leroy, M. Martin - CPPM,
Aix-Marseille Université CNRS/IN2P3 - CERN

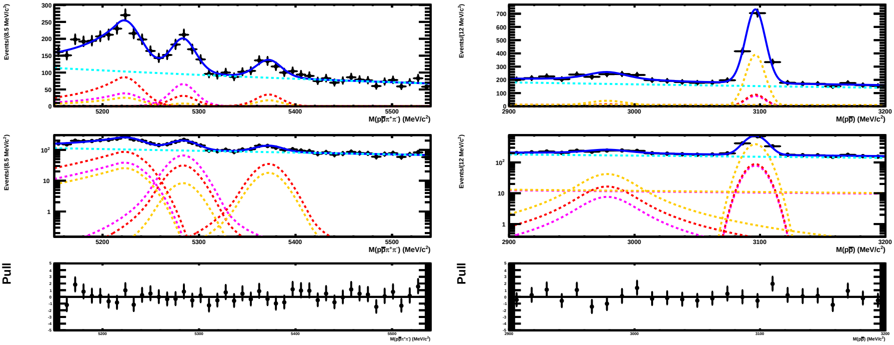
$B_s^0 \to \eta_c(\to p\bar{p})\phi(\to K^+K^-)$: bidimensional fit





$$N(B_s^0 \to J/\psi(\to p\bar{p})\phi) = 314 \pm 19$$
$$N(B_s^0 \to \eta_c(\to p\bar{p})\phi) = 96 \pm 12$$

$B_s^0 \to \eta_c(\to p\bar{p})\pi^+\pi^-$: bidimensional fit

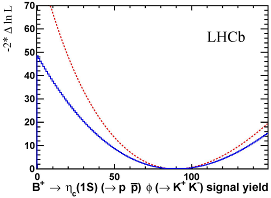


$$N(B_s^0 \to J/\psi(\to p\bar{p})\pi^+\pi^-) = 146 \pm 16$$
$$N(B_s^0 \to \eta_c(\to p\bar{p})\pi^+\pi^-) = 75 \pm 18$$

Current status

$B_s^0 \to \eta_c(\to p\bar{p})\phi(\to K^+K^-)$

- Evaluation of the efficiencies and the systematic uncertainties: done
- Preliminary measurement with statistical significance of 7.0σ
  $\frac{\mathcal{B}(B_s^0 \to \eta_c(\to p\bar{p})\phi(\to K^+K^-))}{\mathcal{B}(B_s^0 \to J/\psi(\to p\bar{p})\phi(\to K^+K^-))} = 0.312 \pm 0.044 \pm 0.015$
- Analysis note ready for WG circulation: twiki



$B_s^0 \to \eta_c(\to p\bar{p})\pi^+\pi^-$

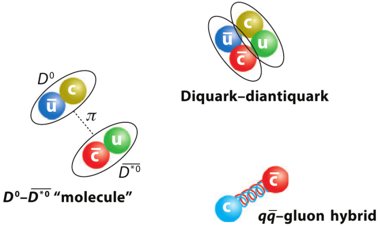
- Optimization of the offline selection and fit procedure: done
- Evaluation of the efficiencies and the systematic uncertainties: ongoing
- First measurement of the $\frac{\mathcal{B}(B_s^0 \to \eta_c(\to p\bar{p})\pi^+\pi^-)}{\mathcal{B}(B_s^0 \to J/\psi(\to p\bar{p})\pi^+\pi^-)}$ ongoing
- We started to write the analysis note

Search for exotic Z^--like states in $B^0 \to \eta_c(1S)(\to p\bar{p})K^+\pi^-$

Exotic states

- A number of charmonium-like mesons (X, Y, Z) have been recently observed
  - many **different production mechanisms**: ISR, e^+e^-, $\gamma\gamma$ and B decays
  - the measured masses and properties **do not fit** the quarkonia picture

- Many theoretical interpretations
  - conventional quarkonia
  - tetra-quarks states
  - meson-molecules
  - hybrid mesons
  - threshold effects



Physics motivations

- B decays constitutes the principal environment for the study of **exotic states**
- Several **charged** charmonium-like states (minimal quark content $c\bar{c}u\bar{d}$) have been observed in spectra $(c\bar{c})\pi^+$ ($c\bar{c} = \psi(2S)$, χ_{c1}, J/ψ)
- LHCb confirmed the existence of the tetraquark $Z^+(4430)(\to \psi(2S)\pi^+)$ and recently observed the first evidence of a pentaquark: $P_c^+(4450)(\to J/\psi p)$
- It is important to search for other charged charmonium-like states in other $B^0 \to (c\bar{c})K^+\pi^-$ decays
- States have been predicted to decay to $\eta_c(1S)\pi^+$ with mass $\sim 3800\ MeV/c^2$ arXiv: 1304.0380, arXiv:1305.6905

Considerations and plans

- The search of exotic states in this channel is **experimentally difficult**
  - statistical **limitation**
  - **lower** trigger efficiency of $p\bar{p}$ w.r.t $\mu^+\mu^-$

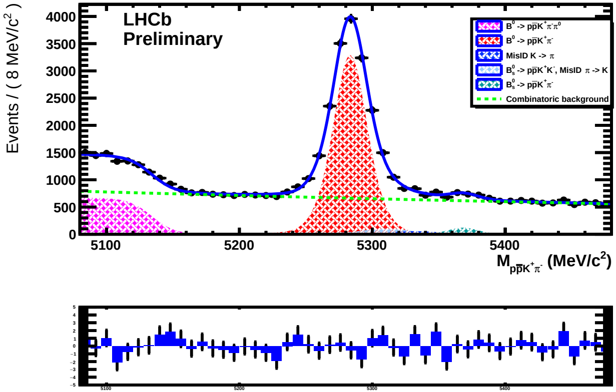
But...

- Having three pseudoscalars in the final state, the decay is fully parametrized by **two independent variables** $\to$ easier angular distribution
- 4 different particles $\to$ no swapping between $\pi^\pm/K^\pm$ from B^0 or $\eta_c(1S)$

Plans:

- Study the Dalitz plot with **Laura++** package in order to perform an amplitude analysis of the decay with the aim to search for exotic resonances
- Study the $K^+\pi^-$ dynamics and angular structure using Legendre polynomial moments
- Measure branching fractions of other charmonium decays to $p\bar{p}$, as $\eta_c(2S) \to p\bar{p}$

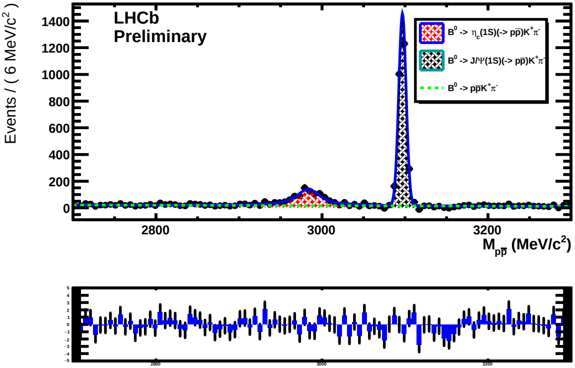
Fit to the $B^0 \to p\bar{p}K^+\pi^-$ spectrum



$$N(B^0 \to p\bar{p}K^+\pi^-) = 14349 \pm 194$$
$$N(B_s^0 \to p\bar{p}K^+\pi^-) = 463 \pm 77$$

Fit to the $p\bar{p}$ spectrum: $\eta_c(1S)$ and J/ψ range

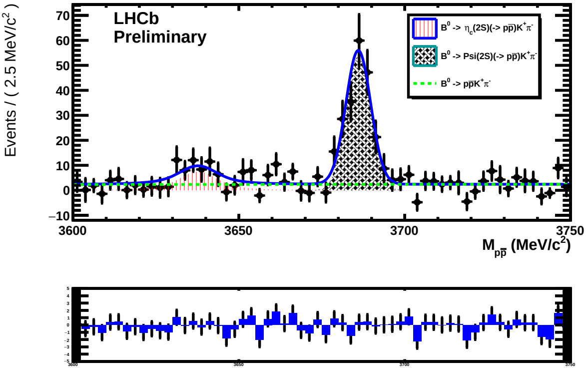
${}_s\mathcal{P}lot$ technique used to extract signal events in the decay



$$N(B^0 \to J/\psi(\to p\bar{p})K^+\pi^-) = 2645 \pm 75$$
$$N(B^0 \to \eta_c(1S)(\to p\bar{p})K^+\pi^-) = 1017 \pm 59$$

Fit to the $p\bar{p}$ spectrum: $\eta_c(2S)$ and $\psi(2S)$ range

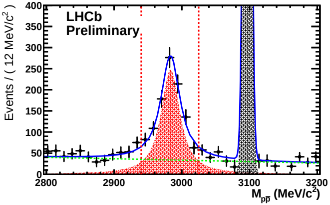
Confirmation of $\eta_c(2S) \to p\bar{p}$ observation

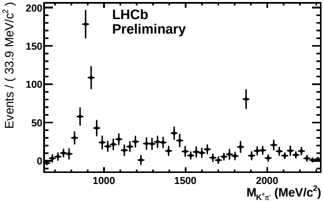


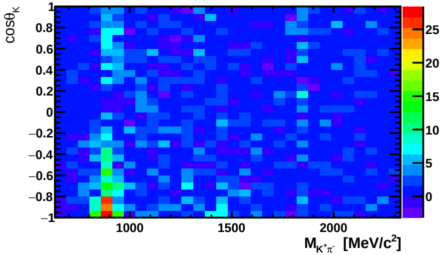
$$N(B^0 \to \psi(2S)(\to p\bar{p})K^+\pi^-) = 200 \pm 23$$
$$N(B^0 \to \eta_c(2S)(\to p\bar{p})K^+\pi^-) = 54 \pm 16$$

$B^0 \to \eta_c(1S)K^+\pi^-$ squared Dalitz Plot

$\eta_c(1S)$ events selected as the events in the $[2940, 3025]$ MeV/c^2 $p\bar{p}$ range



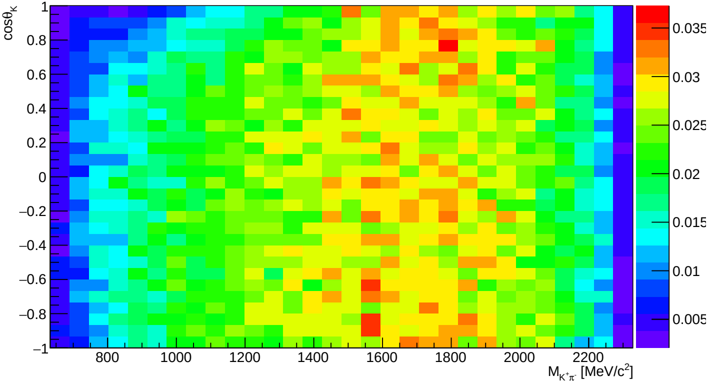




Need to subtract not resonant $p\bar{p}$ contribution and to correct for efficiency variations

$B^0 \to \eta_c(1S)K^+\pi^-$ efficiencies

MC11+MC12 phase space $B^0 \to \eta_c(1S)K^+\pi^-$ used to parametrize the efficiencies of reconstruction and trigger, stripping, BDT cuts over the squared Dalitz plot



Determination of PID cuts efficiencies using PIDcalib package on-going: twiki

Study of $B^+ \to p\bar{p}K^+$

Physics motivations and current status

- Charmonium physics $\to p\bar{p}$ can be produced through a $c\bar{c}$ intermediate resonance
- Hadronic spectroscopy $\to$ search for exotic intermediate states
- First observation of the decay $\eta_c(2S) \to p\bar{p}$
- Upper limit on $X(3872) \to p\bar{p}$
- Upper limit on $\psi(3770) \to p\bar{p}$

Under RC review: twiki

Backup slides

Stripping I

- requirements on final state kaons (StdNoPIDsKaons):
  - PT $>$ 300*MeV
  - MIPCHI2DV(PRIMARY) $>$ 4.0
  - TRCHI2DOF $<$ 3.0
  - P $>$ 1500*MeV
  - TRGHP $<$ 0.35
  - PROBNNk $>$ 0.05
- requirements on final state protons (StdNoPIDsProtons):
  - PT $>$ 300*MeV
  - MIPCHI2DV(PRIMARY) $>$ 2.0
  - TRCHI2DOF $<$ 3.0
  - P $>$ 1500*MeV
  - TRGHP $<$ 0.35
  - PROBNNp $>$ 0.05
- requirements on final state pions (StdNoPIDsPions):
  - PT $>$ 300*MeV
  - MIPCHI2DV(PRIMARY) $>$ 6.0
  - TRCHI2DOF $<$ 3.0
  - P $>$ 1500*MeV
  - TRGHP $<$ 0.35
  - PROBNNpi $>$ 0.05
- Global Event cut:
  - nLongTracks $<$ 200

Stripping II

- Using new N_4BodyDecays algorithm by Vanya in order to possibly save time
- Combination12Cut
  - AM < 4700 (5000) (5350) MeV
  - pPTSUM > 750 MeV
  - pPSUM > 7000 MeV
  - pPTMIN > 400 MeV
  - pPMIN > 4.0 GeV
  - pPROBNNpPROD> 0.05
  - ACHI2DOCA(1,2) < 20
- Combination123Cut
  - AM < 5600 MeV
  - ACHI2DOCA (1,3) < 20.
  - ACHI2DOCA (2,3) < 20.
- PreVertexCuts
  - AMAXDOCA < 0.3
  - 5.0 GeV < AM < 5.6 GeV
  - ACHI2DOCA (1,4) < 20.
  - ACHI2DOCA (2,4) < 20.
  - ACHI2DOCA (3,4) < 20.
- PostVertexCuts
  - BPVDIRA > 0.9999
  - VCHI2 < 30
  - PTsum > 3000 MeV
  - PT(B) > 1000 MeV
  - MIPDV(B) < 0.2 mm
  - 5.05 GeV < M < 5.55 GeV