Measurement of inclusive $B \rightarrow \Lambda_c X$ branching fraction and search for baryonic B meson decays with invisible particles

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Motivation

The Standard Model of Particle Physics (SM), while now tested to great precision, leaves many questions unanswered. The most striking ones:

- the quest for **dark matter** (DM): gravitationally inferred but thus far undetected component of matter which makes up roughly 26% of the energy budget of the Universe [1, 2].
- the matter-antimatter asymmetry caused by **Baryogenesis** that satisfies the three Sakharov conditions [3]; C and CP Violation (CPV), baryon number violation, and departure from thermal equilibrium.

A recent model [4] proposes a new mechanism of Baryogenesis and DM production, in which both the dark matter relic abundance and the baryon asymmetry arise from neutral B mesons oscillations and their subsequent decays, as shown in Fig.1

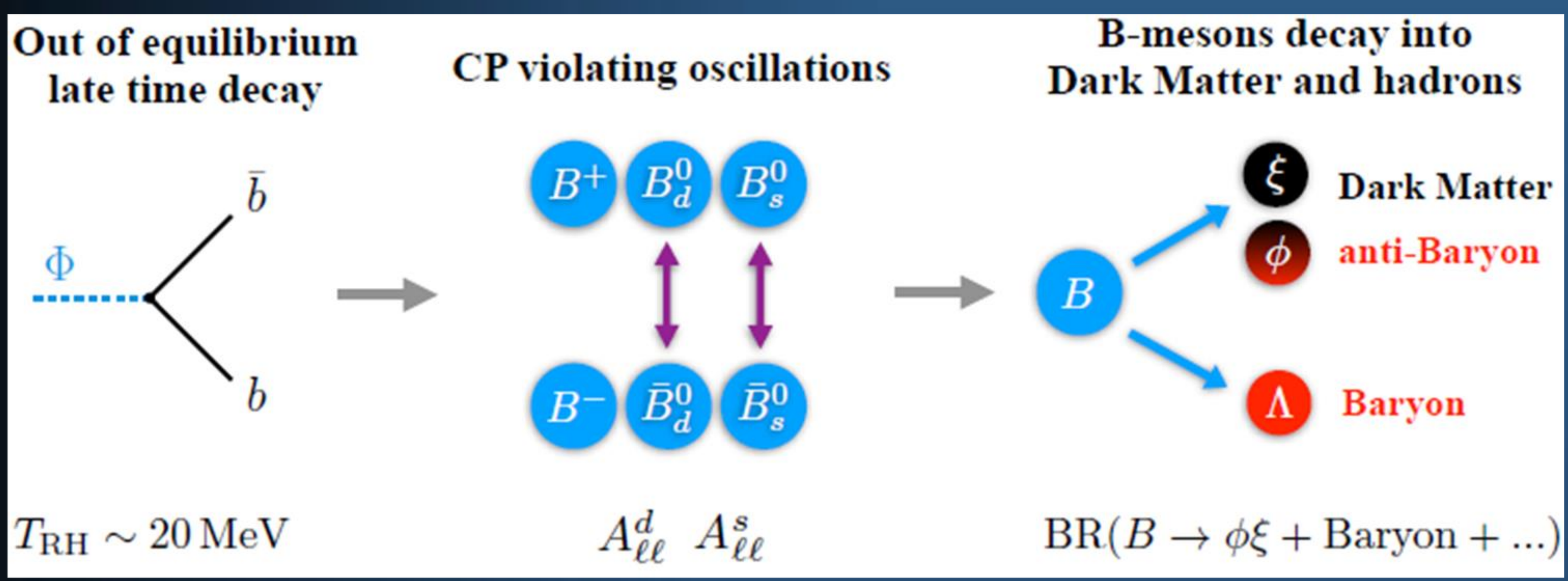


Fig.1 Summary of the mechanism generating the baryon asymmetry and DM relic abundance [4] .

Decays of *B* mesons into baryons, mesons and missing energy would be a distinct signature of this mechanism.
B meson decays with a $\boldsymbol{\Lambda_c}$ in the final state are appropriate for such a study: most abundant due to relatively large $|V_{cb}|$
$(B^0 \rightarrow \Lambda_c^- X) = (5.0^{+2.1}_{-1.5})\%$ [5].

Experimental method

B factories offer a unique capability:

- precisely known center of mass energy
- exclusive hadronic reconstruction of B_{tag}

} **reconstruction of B_{sig} with missing energy**

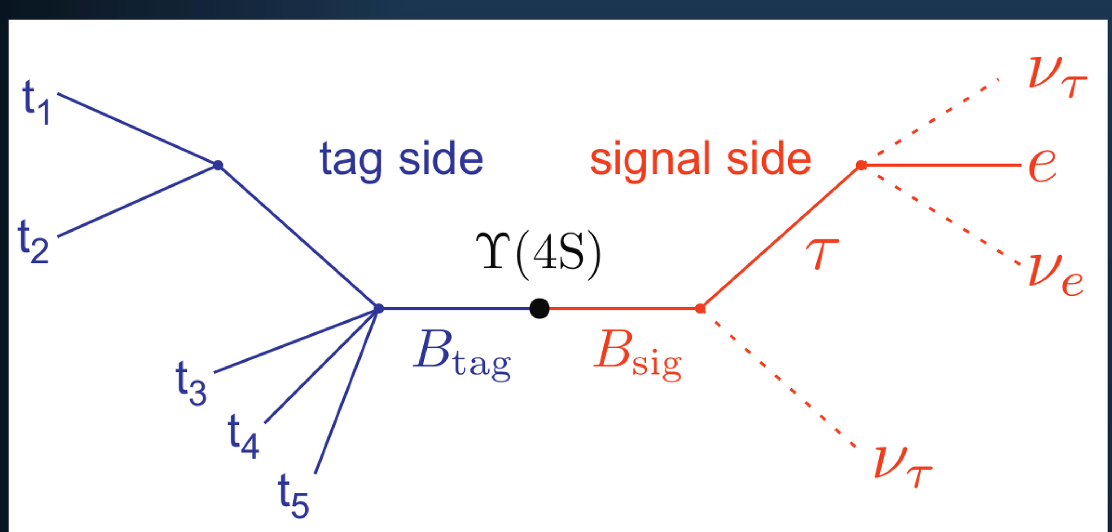


Fig. 2: Scheme of the tagging technique used to reconstruct a $B\bar{B}$ event. [8]

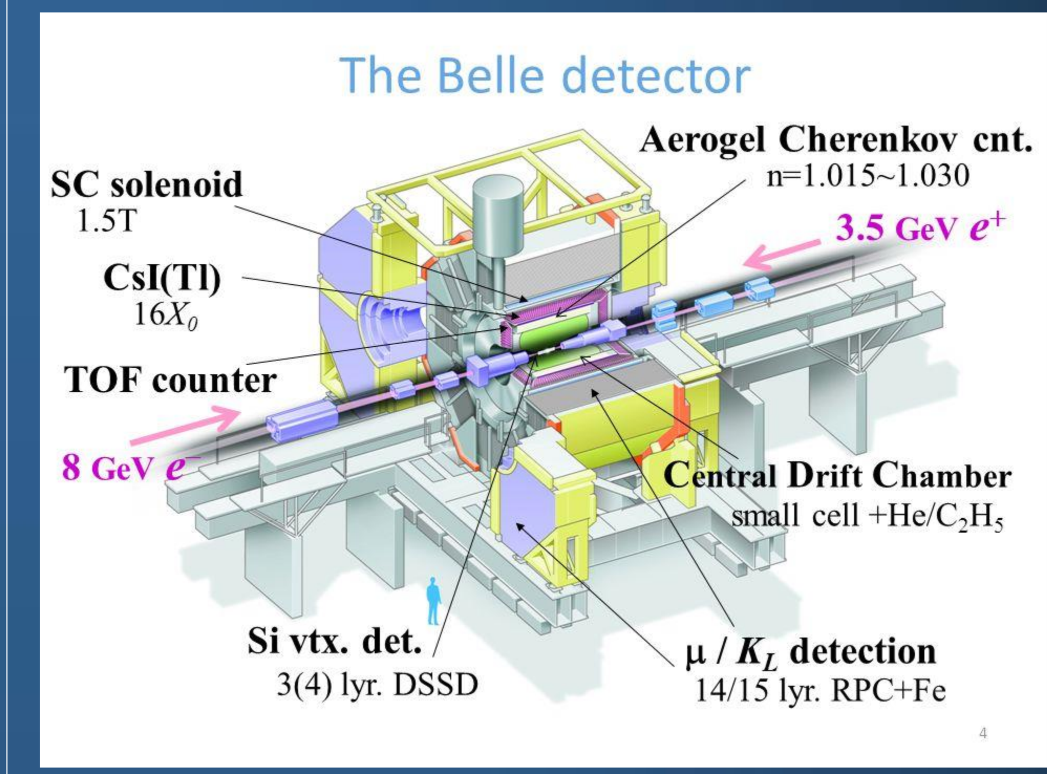
A new exclusive tagging algorithm, based on machine learning, was developed for Belle II: **Full Event Interpretation** (FEI)[8].

FEI adopts a hierarchical approach:
- first train multivariate classiers (MVCs) on Final State Particles
- reconstruct intermediate particles, build new dedicated MVC
- reconstruct a B candidate with a "*signal probability* " (represents the "goodness" of its reconstruction).

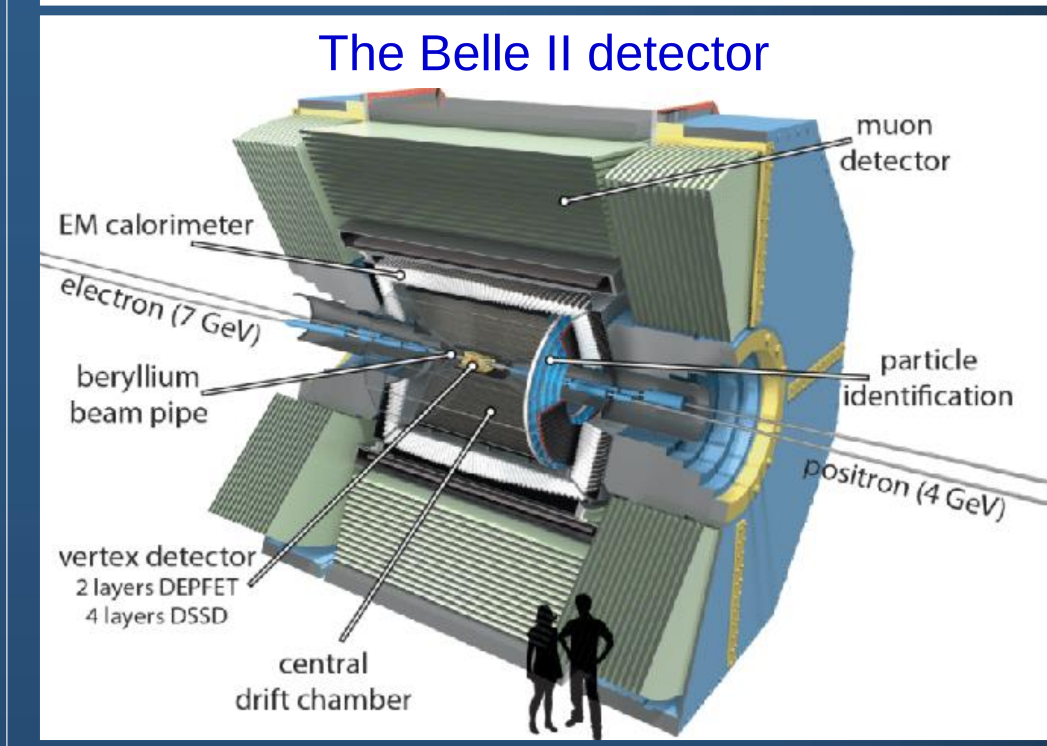
Procedure for the measurement of inclusive $B \rightarrow \Lambda_c$ decays:
- reconstruct B_{tag} with FEI
- reconstruct Λ_c in the most abundant decay mode ($\Lambda_c \rightarrow p K \pi$) in the signal side (the remaining tracks and clusters represent other hadrons produced in the B_{sig} decay)
- Calculate an invariant mass of all other B_{sig} decay products (missing mass, m_{miss})

B factory

Such decays can be studied with great precision at **B factories,** Electron-positron colliders with centre of mass energy tuned to Υ(4S) resonance (decaying ~100% into pairs of B mesons) such as Belle/Belle2:



In Tsukuba (Japan) from 1999 to 2010 Belle experiment collected an integrated luminosity ~1ab^{-1} at Υ(4S) resonance [6] .



Its upgraded version, Belle II [7], started taking data in 2018. Over its running period, Belle II is expected to collect ~ 50 times more data than its predecessor due to a factor 40 increase in luminosity.

Figures: Overview of Belle (above) and Belle II (below) detector.

Expected results

The measurement can be performed using Belle data set and eventually expanded to Belle II data set.

Estimated signal yields with Belle data:

$$N_{sig}(B^+ \rightarrow \Lambda_c^- X) = N_{BB}\, Br(B^+ \rightarrow \Lambda_c^- X)\, \varepsilon^+_{FEI} \cdot Br(\Lambda_c^- \rightarrow p\, K\, \pi)\, \varepsilon_\Lambda \sim \mathbf{8.8 \cdot 10^3}$$

ε^+_{FEI} : tag-side-efficiency of FEI for charged hadronic tagging
$N_{BB} = 772 \cdot 10^6$ total number of $B\bar{B}$ pairs in the full Belle dataset
$\varepsilon_\Lambda \sim 50\%$ for 3 tracks

In case that one finds values of $m_{miss} < m_p$ this would be a clear indication of baryon number violation.

Additionally, if also $E_{miss} \neq 0$ this would prove that some invisible particles are involved in the process.

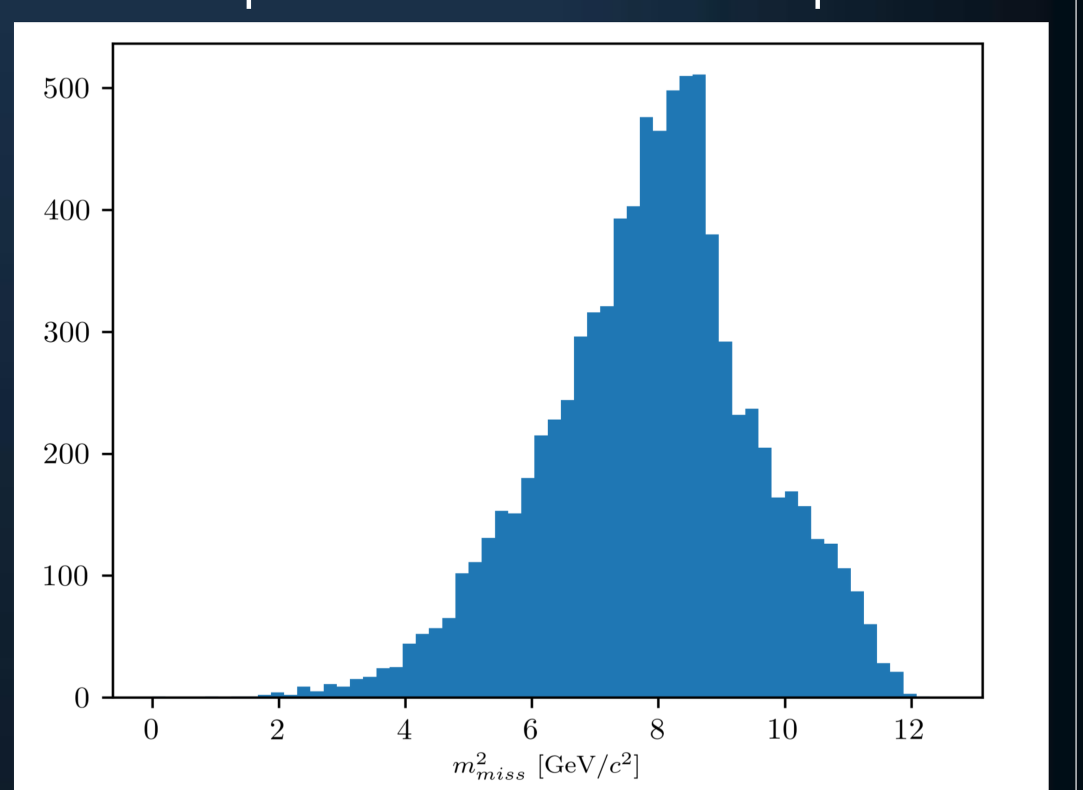


Fig. 3: Simulated distribution of m^2_{miss}

References

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