B_c^+ meson production, decays and properties at LHCb

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Abstract

We report the first study of the $B_c^+ \to K^+K^-\pi^+$ decay and an update of the measurement of the ratio of branching fractions $R_{K/\pi} \equiv \mathcal{B}(B_c^+ \to J/\psi K^+)/\mathcal{B}(B_c^+ \to J/\psi \pi^+)$.

Both results use an **integrated luminosity of 3.0 fb^{-1} collected by the LHCb experiment in *pp* collisions at centre-of-mass energies of 7 and 8 TeV.**

We measure $\boldsymbol{B_c^+ \to \chi_{c0}(\to K^+K^-)\pi^+}$ with **4.0σ significance** and $\frac{\sigma(B_c^+)}{\sigma(B^+)} \times \mathcal{B}(B_c^+ \to \chi_{c0}\pi^+)$ to be $(9.8^{+3.4}_{-3.0}(\text{stat}) \pm 0.8(\text{syst})) \times 10^{-6}$.

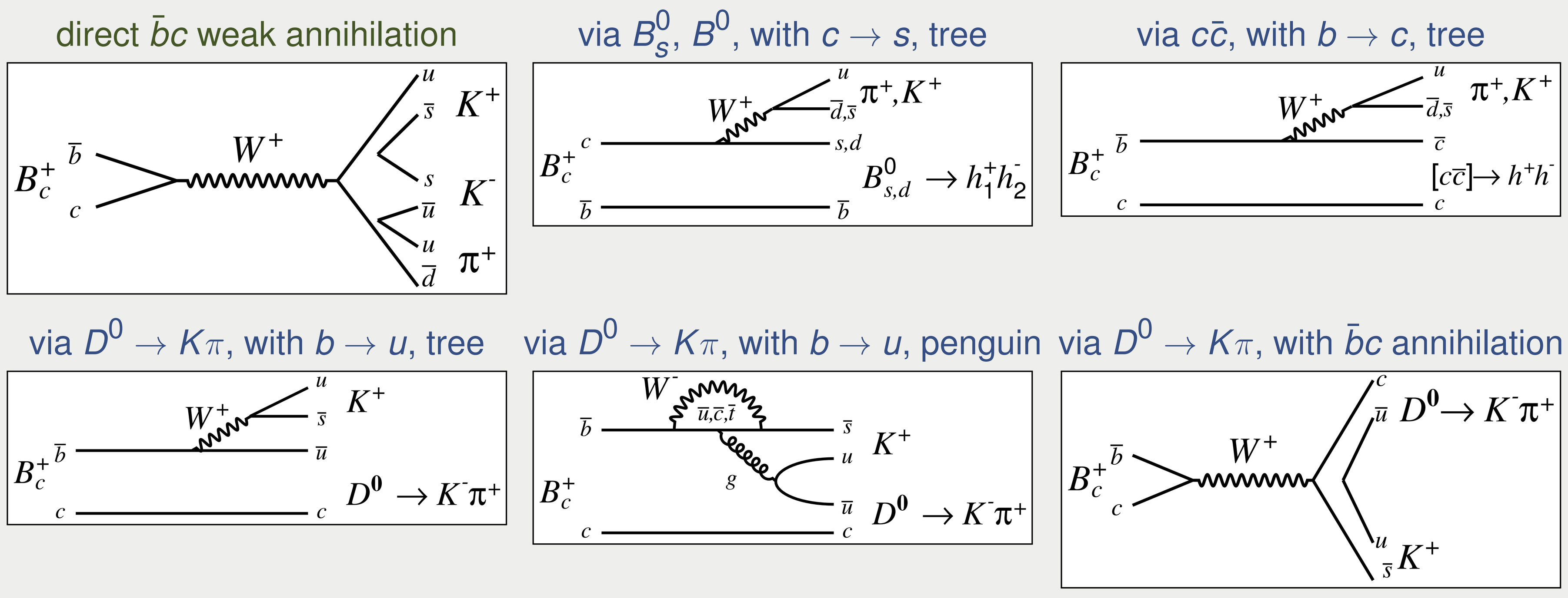
The contribution of $\boldsymbol{B_c^+ \to K^+K^-\pi^+}$ **via $\bar{b}c$ weak annihilation** for $m(K^-\pi^+) < 1.834$ GeV is measured with **2.4σ significance**.

The ratio of branching fractions $\boldsymbol{R_{K/\pi} \equiv \mathcal{B}(B_c^+ \to J/\psi K^+)/\mathcal{B}(B_c^+ \to J/\psi\pi^+)}$ is measured to be $\boldsymbol{R_{K/\pi} = 0.079 \pm 0.007(\text{stat}) \pm 0.003(\text{syst})}$. This result significantly improves the previous LHCb measurement..

Study of the $B_c^+ \to K^+K^-\pi^+$ decay arXiv:1607.06134[hep-ex]

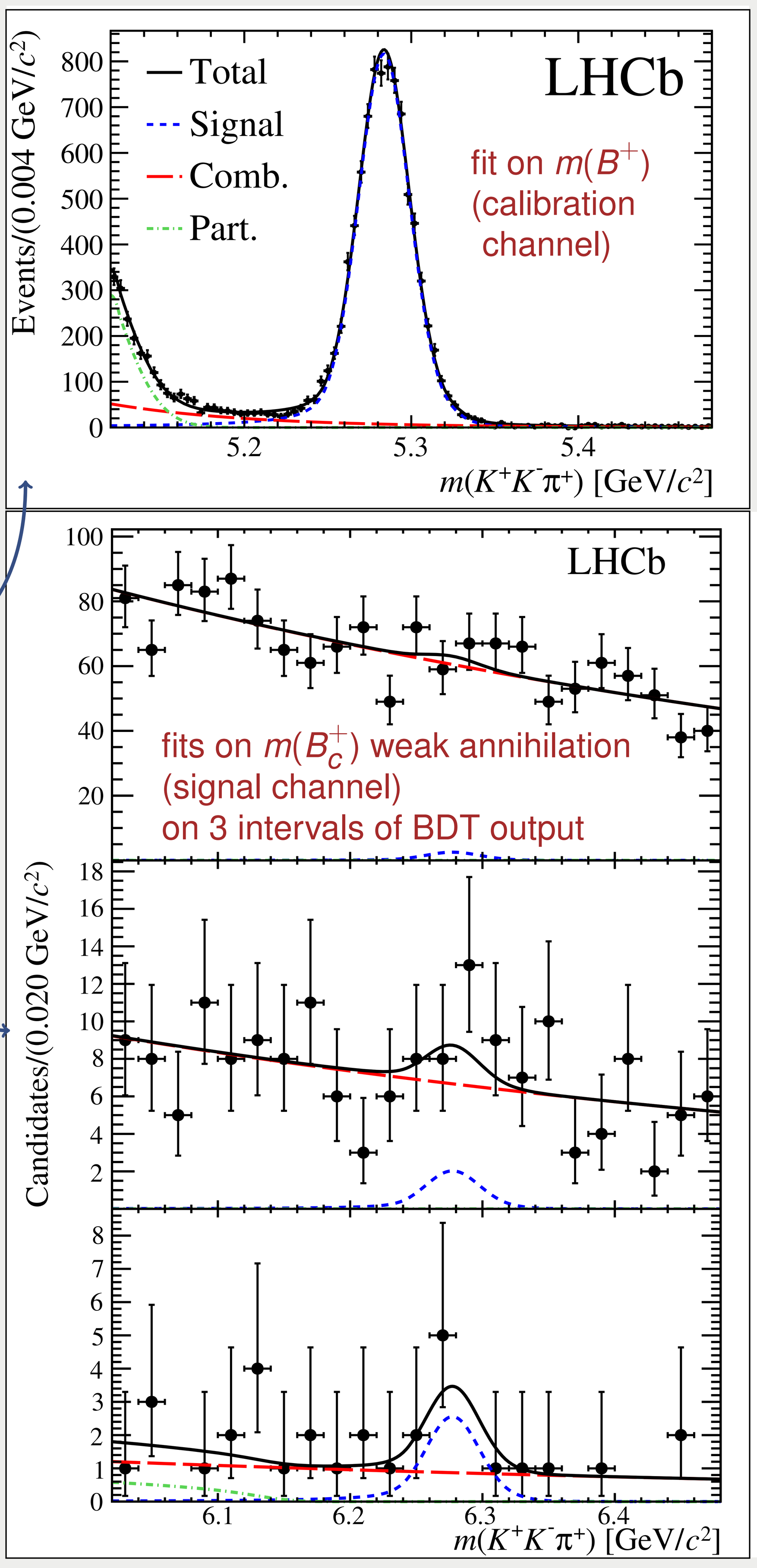
- $\mathcal{B}(B_c^+ \to$ via weak annihilation $\to$ 2-body) expected by theory models at 10^{-8}–10^{-6} [1, 2, 3]
  presently below experimental sensitivity
- study 3-body decays, expected to have larger branching fractions
- if found, excess of signal can point to $\bar{b}c$ annihilations mediated by New Physics particles

Diagrams contributing to $B_c^+ \to K^+K^-\pi^+$



Selection, fits, signal efficiencies

- fiducial region $p_T(B)$<20 GeV, 2.0<$y(B)$<4.5
- **event selection**
  - signal $B_c^+ \to K^+K^-\pi^+$
    $m(B_c^+)$ in [6.0, 6.5] GeV
  - normalization $B^+ \to \overline{D}^0(\to K^+K^-)\pi^+$
    $m(B^+)$ in [5.1, 5.5] GeV
- jointly optimize PID & a BDT for B_c^+ sensitivity
- BDT trained on
  - signal from simulated events
  - background from $m(B)$ sideband
- **unbinned maximum likelihood fits on $m(B)$**
  - signal = sum of two Crystal Ball function
  - combinatorial background
  - background from $B \to KK\pi\pi^0$ with undetected π^0
- **B^+ fit, shown on top right plot**
- **B_c^+ direct weak annihilation fits**
  - done in 3 intervals of BDT output with comparable yield but different background levels
  - shown on 3 bottom plots on right
  - cuts on $m(K^-\pi^-)$ & $m(K^+K^-)$ remove $D^0 \to K^-\pi^+$, $\chi_{c0} \to K^+K^-$, $B_s^0 \to K^-K^+$
  - yield $N_c = 20.8^{+11.4}_{-9.9}$, **2.5$\sigma$ significance**
- **$B_c^+ \to \chi_{c0}(\to K^+K^-)\pi^+$ fits**
  - done in 3 intervals of BDT output with comparable yield but different background levels
  - simultaneous fit to $m(K^+K^-\pi^+)$ *vs.* $m(K^+K^-)$
  - yield $N_{\chi_{c0}} = 20.8^{+7.2}_{-6.4}$, **4.1$\sigma$ significance**
- **no significant signal on D^0 and B_s^0 regions**
- **signal efficiencies from simulation, corrected with studies on data control samples**



Results

$$R_{\text{an},KK\pi} = \frac{N_c}{N_u} \times \frac{\epsilon_u}{\epsilon_c(\text{an}, KK\pi)} \times \mathcal{B}(B^\pm \to D^0\pi^\pm) \times \mathcal{B}(D^0 \to K^+K^-)$$

$$R_{\chi_{c0}\pi} = \frac{\sigma(B_c^+)}{\sigma(B^+)} \times \mathcal{B}(B_c^+ \to \chi_{c0}\pi^+) = \frac{N_{\chi c0}}{N_u} \times \frac{\epsilon_u}{\epsilon_c(\chi_{c0})} \times \frac{\mathcal{B}(B^\pm \to D^0\pi^\pm) \times \mathcal{B}(D^0 \to K^+K^-)}{\mathcal{B}(\chi_{c0} \to K^+K^-)}$$

- N_c, N_u = fit yields for B_c^+ and B^+
- $\sigma(B_c^+)$, $\sigma(B^+)$ = production cross-sections
- ϵ_c, ϵ_u = efficiencies

$$\boldsymbol{R_{\text{an},KK\pi} = (8.0^{+4.4}_{-3.8}(\text{stat}) \pm 0.6(\text{syst})) \times 10^{-8}}$$
$$\boldsymbol{R_{\chi_{c0}\pi} = (9.8^{+3.4}_{-3.0}(\text{stat}) \pm 0.8(\text{syst})) \times 10^{-6}}$$

LHCb, arXiv:1607.06134[hep-ex]

Relative systematic uncertainties

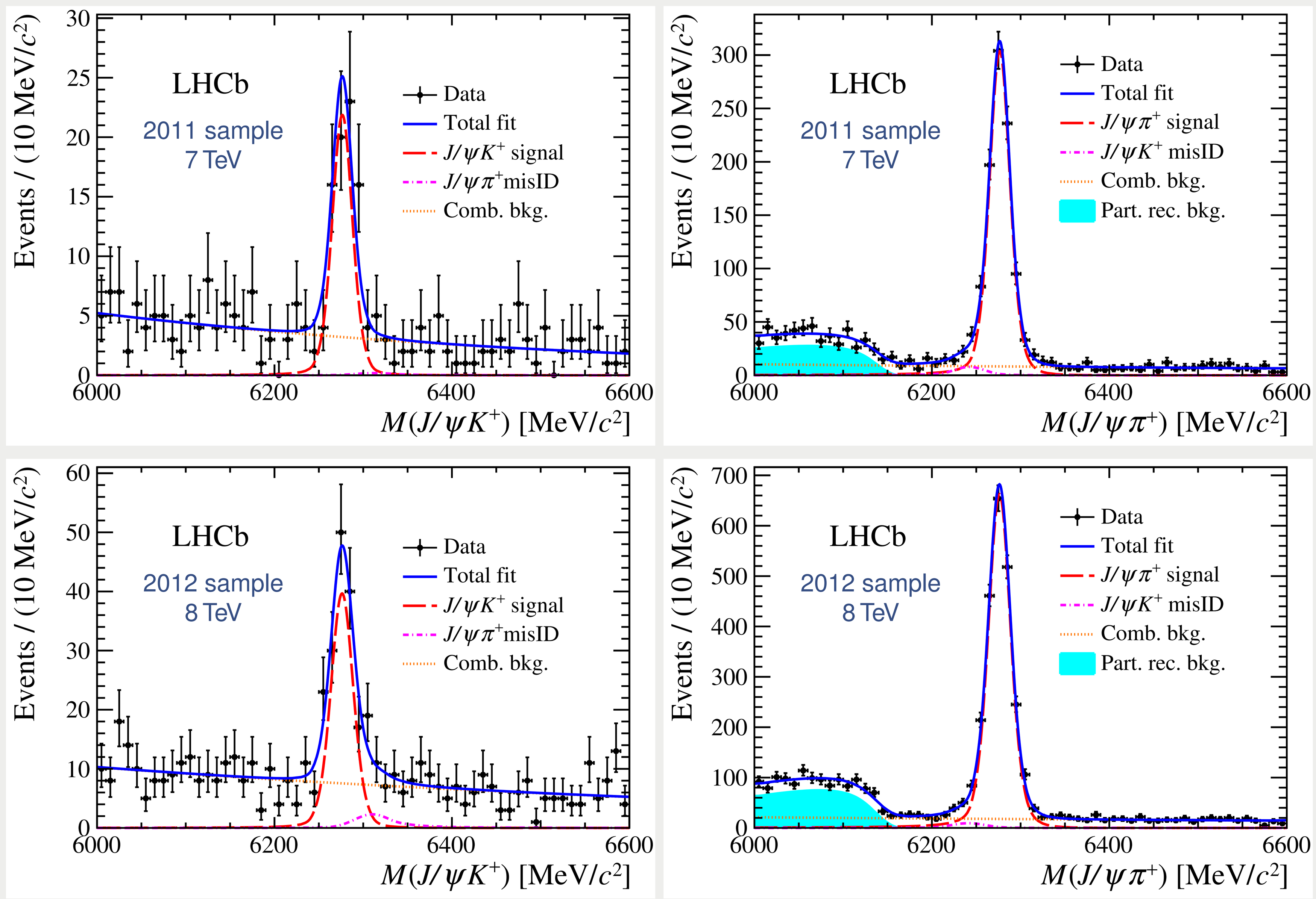
Source	$R_{\text{an},KK\pi}$	$R_{\chi_{c0}\pi}$
Normalisation yield	1.3%	1.3%
Event distribution	1.6%	–
Fit model	2.4%	2.3%
BDT shape	5.0%	2.9%
PID	1.0%	1.0%
Simulation	0.8%	0.8%
Detector acceptance	0.4%	0.3%
B_c^+ lifetime	2.0%	2.0%
Hardware trigger	1.5%	1.4%
Fiducial cut	0.1%	0.1%
Branching fractions	3.6%	6.2%
Total	7.5%	7.8%

Measurement of the ratio $\mathcal{B}(B_c^+ \to J/\psi K^+)/\mathcal{B}(B_c^+ \to J/\psi\pi^+)$ arXiv:1607.06823[hep-ex]

- $B_c^+ \to J/\psi K^+$ ($\bar{b} \to \bar{c}u\bar{s}$) is CKM-suppressed by $|V_{us}/V_{ud}|^2 \sim 0.05$ w.r.t. $B_c^+ \to J/\psi\pi^+$ ($\bar{b} \to \bar{c}u\bar{d}$)
- $R_{K/\pi} \equiv \mathcal{B}(B_c^+ \to J/\psi K^+)/\mathcal{B}(B_c^+ \to J/\psi\pi^+)$ theory predictions exist [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]
- LHCb 2013: $R_{K/\pi} = 0.069 \pm 0.019 \pm 0.005$ [16], not precise enough to discriminate theory models

Selection, fit, signal efficiencies

- **select candidate $B_c^+ \to J/\psi(\to \mu^+\mu^-)h^+$ decays, $h^+ = K^+, \pi^+$**
- J/ψ from well-reconstructed muon tracks with $p_T > 550$ MeV originating from common vertex
- h^+ from well-reconstructed tracks with $p_T > 500$ MeV, displaced from primary vertex
- $m(B_c^+)$ within 500 MeV of the known B_c^+ mass
- particle identification and a BDT jointly optimized for $B_c^+ \to J/\psi(\to \mu^+\mu^-)K^+$ significance
- BDT using 12 variables, suppresses combinatorial background
  - training signal from simulation
  - training background from data upper mass sideband of the $B_c^+ \to J/\psi\pi^+$ candidates
- **simultaneous unbinned maximum likelihood fit to $m(B_c^+)$ in range [6.0, 6.6] GeV**
  - signal = sum of two Crystal Ball functions
  - combinatorial background = exponential function
  - background from mis-identified $B_c^+ \to J/\psi\pi^+$ vs. $B_c^+ \to J/\psi K^+$ = double Crystal Ball function
  - partially reconstructed B_c^+ decays with a missing π^0 = ARGUS function



- **signal efficiencies from simulation, corrected for different track multiplicity in data**

Results

$$R_{K/\pi} \equiv \frac{\mathcal{B}(B_c^+ \to J/\psi K^+)}{\mathcal{B}(B_c^+ \to J/\psi\pi^+)} = \frac{\text{yield}(B_c^+ \to J/\psi K^+)}{\text{yield}(B_c^+ \to J/\psi\pi^+)} \times \frac{\text{efficiency}(B_c^+ \to J/\psi\pi^+)}{\text{efficiency}(B_c^+ \to J/\psi K^+)}$$

$$\boldsymbol{R_{K/\pi} = 0.079 \pm 0.007(\text{stat}) \pm 0.003(\text{syst})}$$

(uncertainty now ~2.6 smaller than 2013 result)

LHCb, arXiv:1607.06823[hep-ex]

Relative systematic uncertainties

	7 TeV	8 TeV
Signal model	0.5%	0.8%
Combinatorial background	1.1%	0.5%
Partially reconstructed background	3.3%	3.2%
Misidentification background	0.2%	0.0%
Particle identification efficiency	0.2%	0.1%
Detector material	0.3%	0.3%
Total	3.5%	3.4%

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