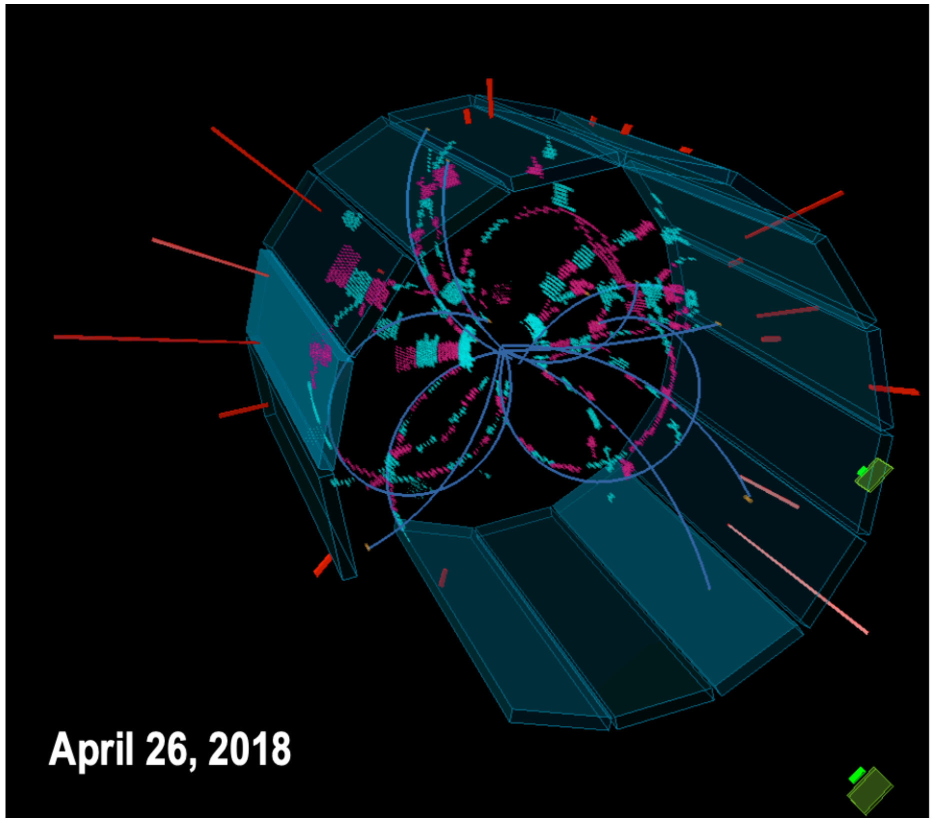
UNIVERSITÀ DEGLI STUDI DI TRIESTE

INFN Istituto Nazionale di Fisica Nucleare

Belle II

B physics rediscoveries with Belle II first data



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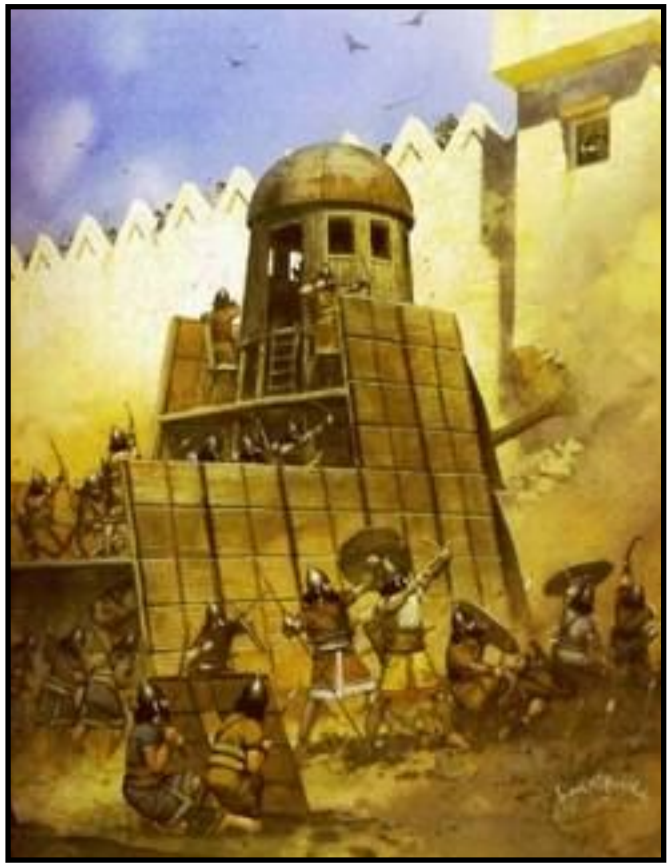
University of Trieste and INFN
On behalf of Belle II collaboration

Lake Louise Winter Institute 2019
15 February 2019

Introduction

- The standard model: successful, incomplete.



Direct approach

Indirect approach

- Weak-interactions of quarks (flavor physics): promising for indirect searches;
- Flavor physics questions:
  - ❖ are there new CP violating phases in the quark sector?
  - ❖ does nature have multiple Higgs bosons?
  - ❖ are there flavor-changing neutral currents beyond the SM?
  - ❖ are there sources of lepton flavor violation?

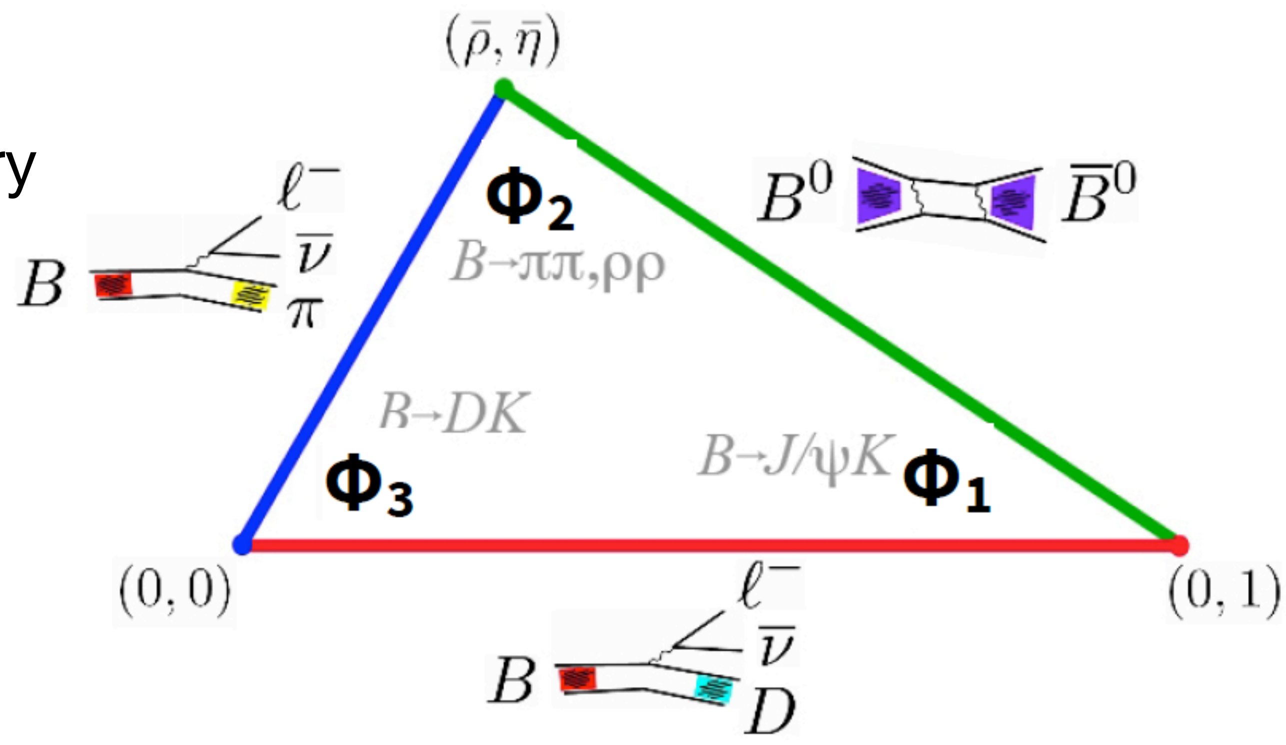
Flavor physics at Belle II

Belle II core program: metrology of CKM and CPV parameters

Quark mixing:
mass eigenstates are not equal to the weak eigenstates. Quark mixing described by unitary Cabibbo-Kobayashi-Maskawa matrix.

$$V_{\mathrm{CKM}} = \begin{pmatrix} V_{\mathrm{ud}} & V_{\mathrm{us}} & V_{\mathrm{ub}} \\ V_{\mathrm{cd}} & V_{\mathrm{cs}} & V_{\mathrm{cb}} \\ V_{\mathrm{td}} & V_{\mathrm{ts}} & V_{\mathrm{tb}} \end{pmatrix}$$

3 angles, 1 phase



$B \to \pi\pi, \rho\rho$	α / Φ_2
$B \to D^{(*)} K^{(*)}$	γ / Φ_3
$B \to J/\psi K_s$	β / Φ_1
$B_s \to J/\psi \Phi$	β_s

WA HFLAV & CKMfitter 2018

$\sin 2\Phi_1 = 0.70 \pm 0.02$

$\Phi_2 = (84.9^{+5.1}_{-4.5})°$

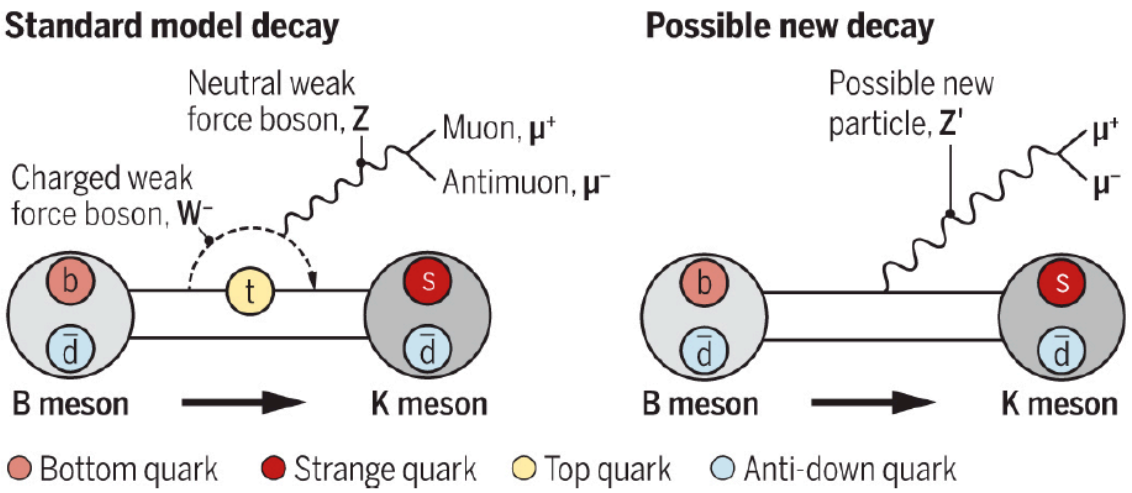
$\Phi_3 = (73.5^{+4.2}_{-5.1})°$

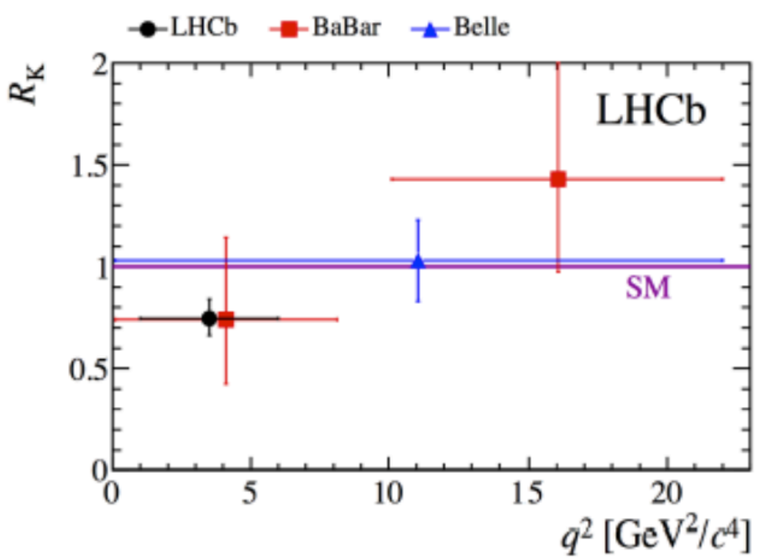
$|V_{ub}| = (3.98 \pm 0.08 \pm 0.22)\ 10^{-3}$

$|V_{cb}| = (41.8 \pm 0.4 \pm 0.6) \times 10^{-3}$

Flavor physics at Belle II

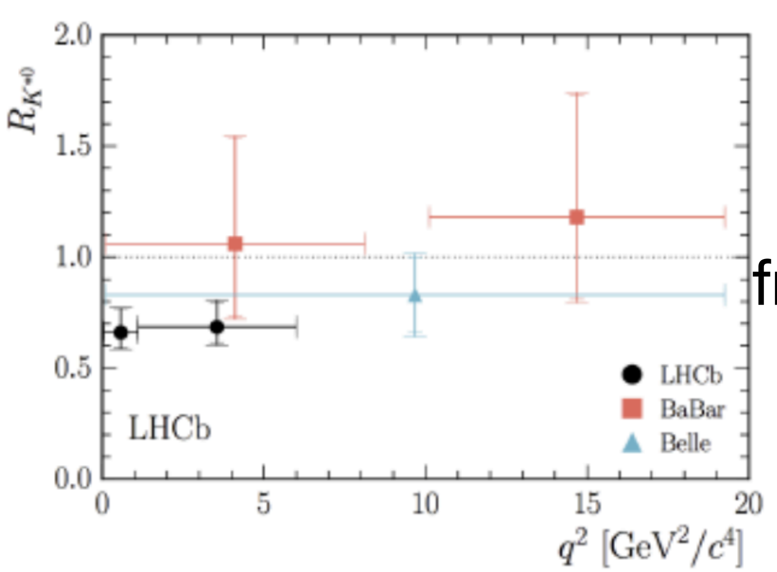
R(K*) and R(K) anomalies





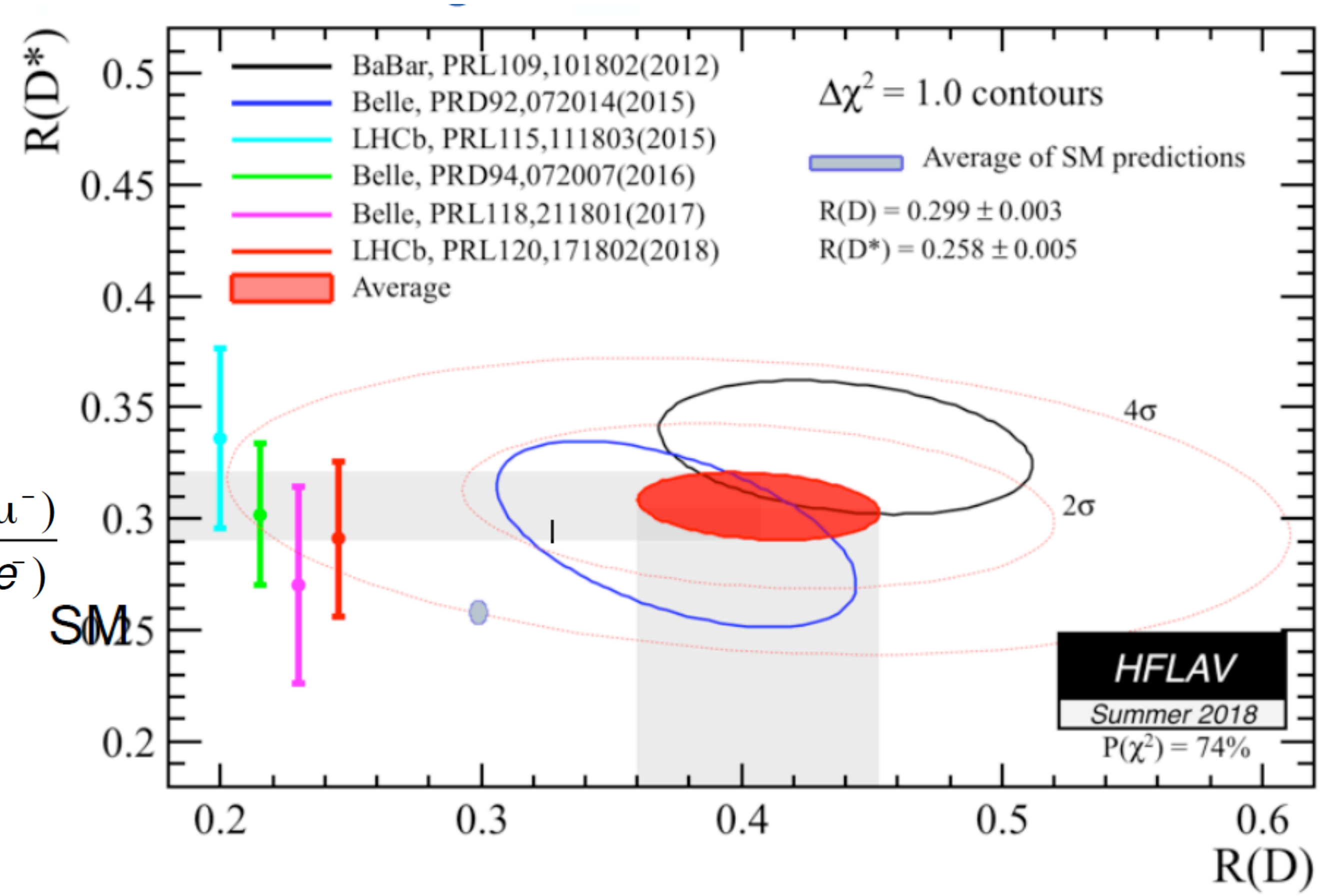
$$R_{K^{(*)}}(q^2) = \frac{BF(B \to K^{(*)}\mu^+\mu^-)}{BF(B \to K^{(*)}e^+e^-)}$$

~ 2.6σ deviation from the SM

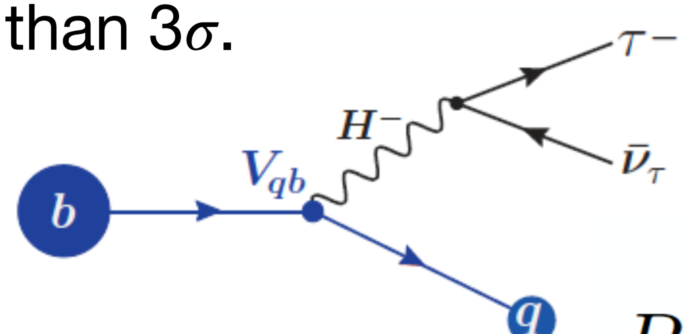


~ 2.1σ deviation from the SM (low bin)
2.5σ (central bin)

R(D*) and R(D) anomalies



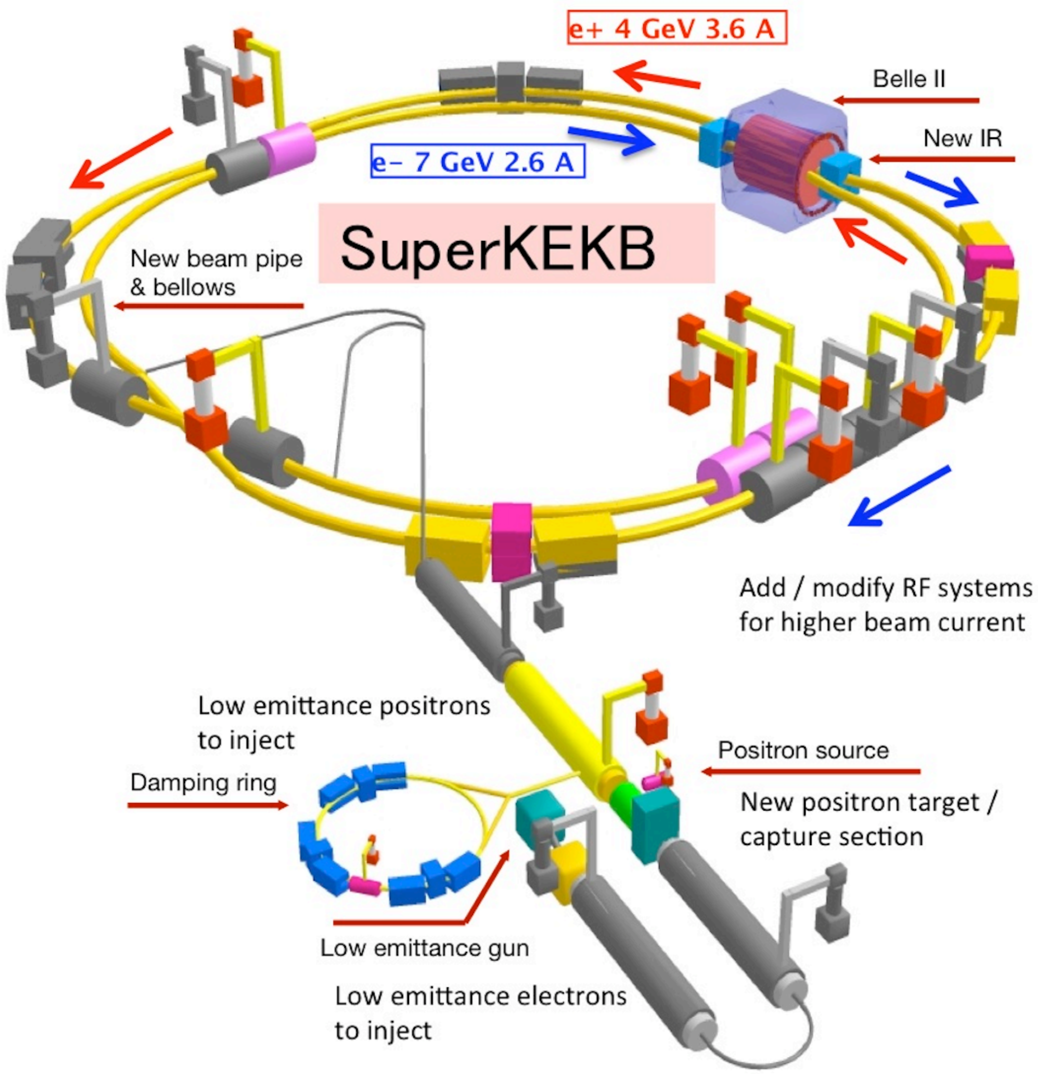
Measured R(D*) value is deviated from the predicted value with the significance more than 3σ.

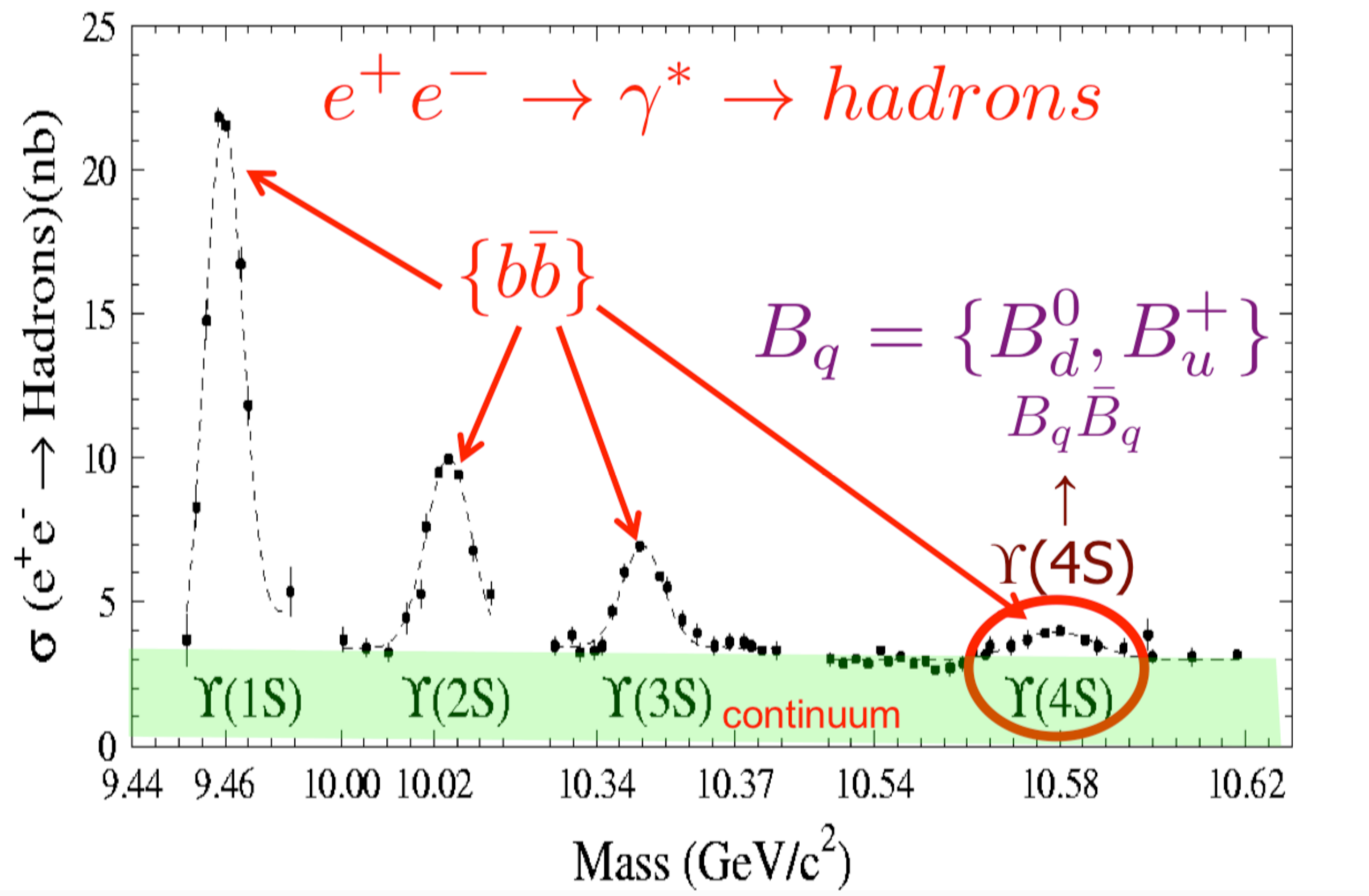


$$R = \frac{\mathcal{B}(b \to q\,\tau\,\bar{\nu}_\tau)}{\mathcal{B}(b \to q\,\ell\,\bar{\nu}_\ell)}$$

$\ell = e, \mu$

Belle II at SuperKEKB





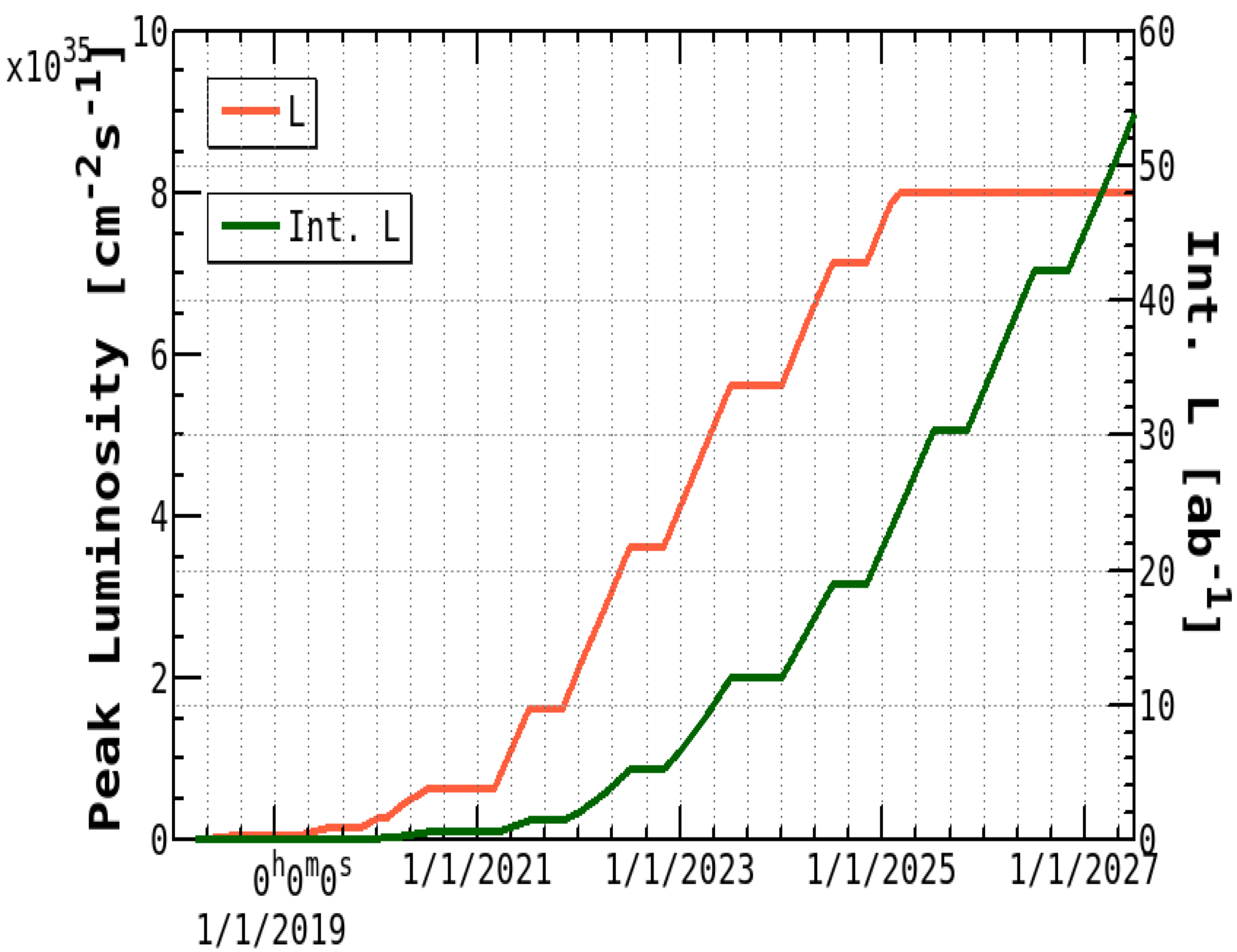
900 BB̄ pairs/second at design intensity

96% of Υ(4S) mesons decay to BB̄ pairs

- low background production of billions B̄B pairs
- precisely known collision energy
- coherent B-B̄ evolution

Belle II performance in 2018

- Operated with only one slice of silicon vertex detector
- First collisions and pilot run April 26 - July 17 2018
- Maximum luminosity $\mathscr{L} \sim 5\mathrm{x}10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ (~ 1% of design luminosity)
- Integrated luminosity $\mathscr{L} \sim 0.5\ \mathrm{fb}^{-1}$



Rediscovery strategy - back to the basics:

charged tracks and photons

↓

strange and charm particles

↓

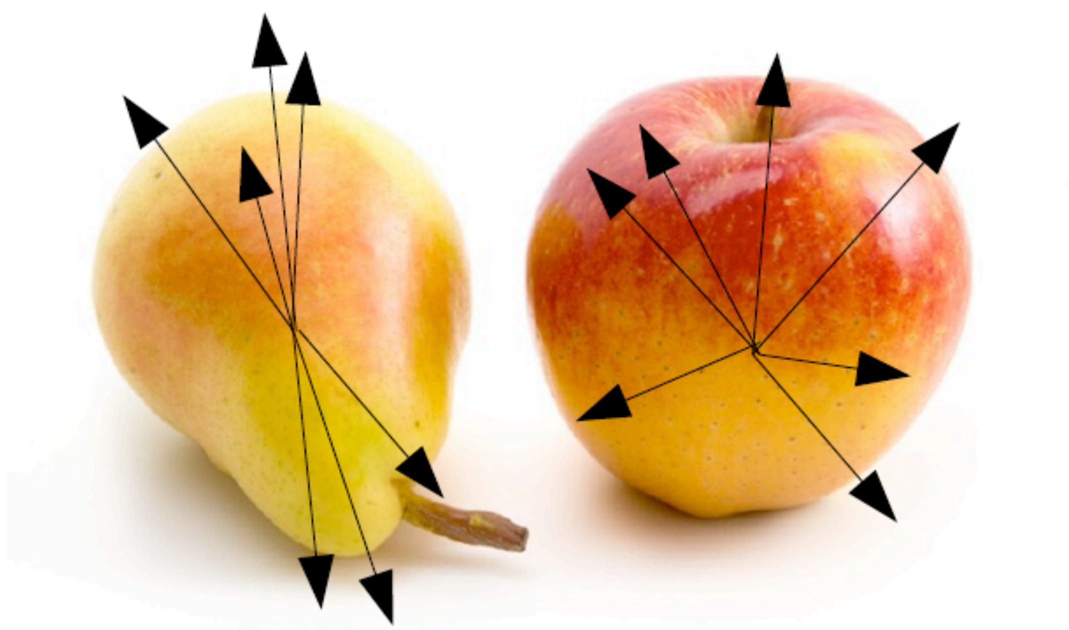
B mesons (cut-based analysis)

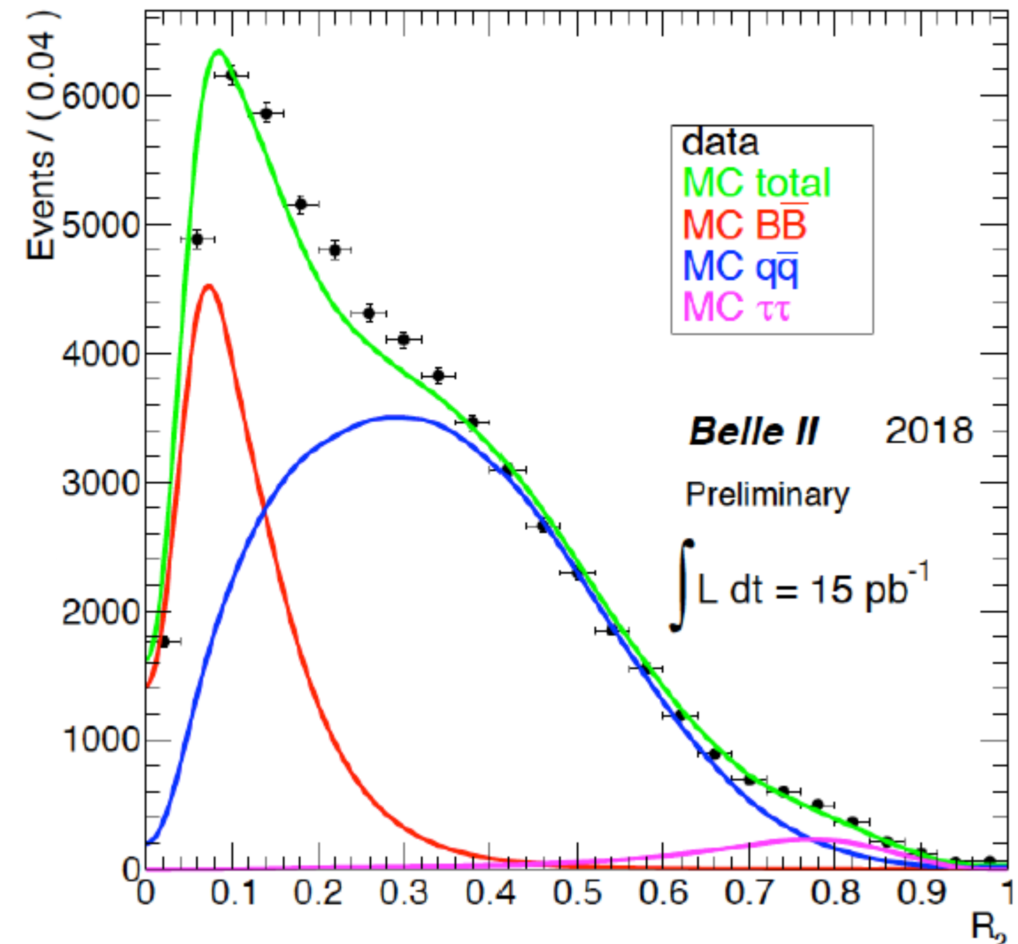
↓

B mesons (full event interpretation)

Event shape

Event topology tell us we see B's:
separate planar events from jet-like events





Spherical R$_2$ Jet-like

At Υ(4S) resonance we record BB̄ pairs with 99% efficiency and 2% retention rate.

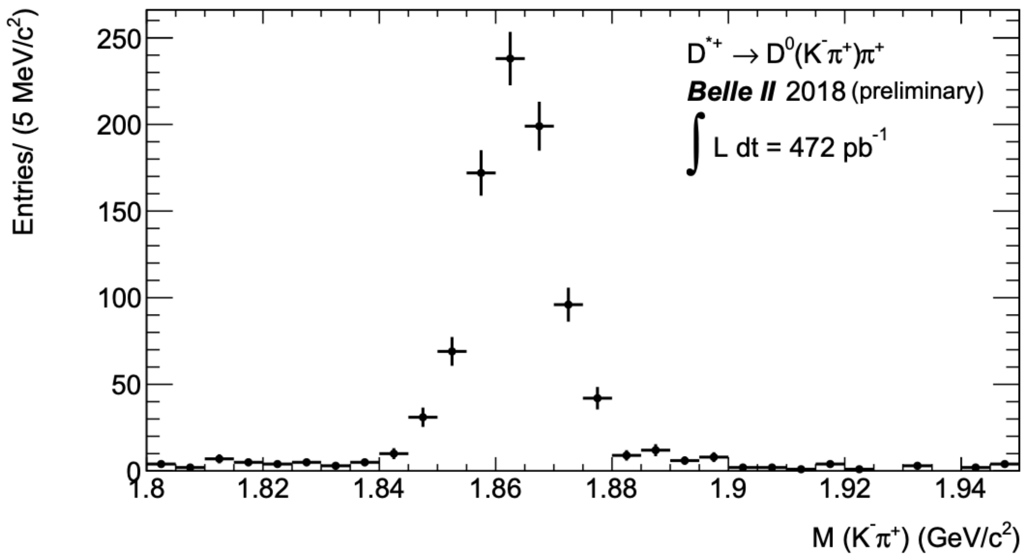
$$R_2 = H_2 / H_0$$

$$H_l = \sum_{ij} \frac{|p_i||p_j|}{E_{vis}^2} P_l(cos\theta_{ij})$$

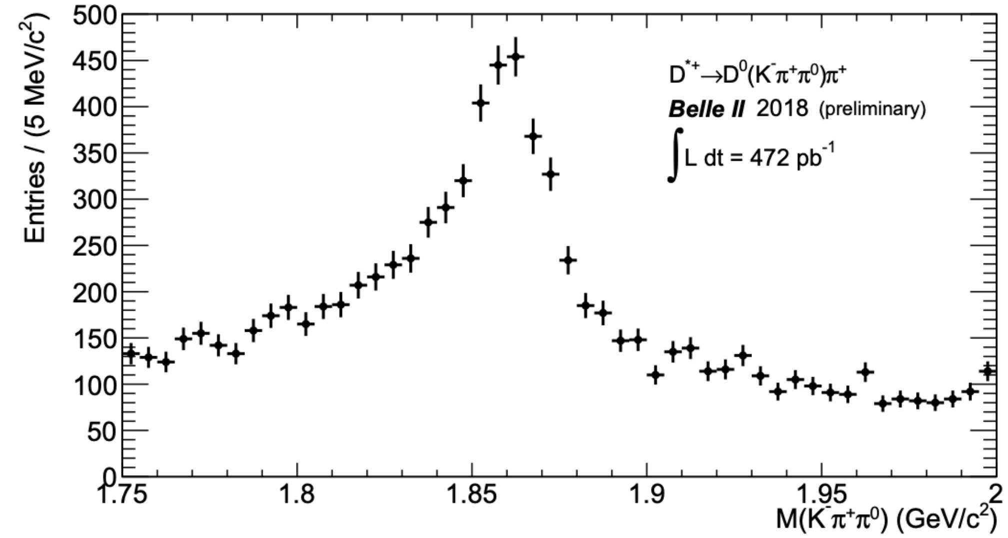
Charm rediscoveries - D* tags

Cabibbo favored D decays are observed

$D^0 \longrightarrow K^- \pi^+$

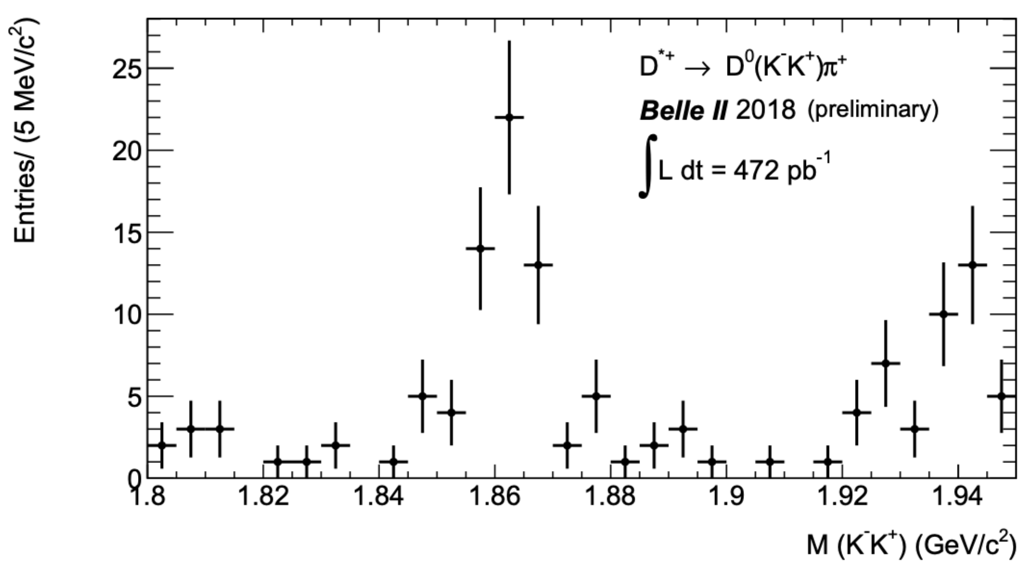


$D^0 \longrightarrow K^- \pi^+ \pi^0$

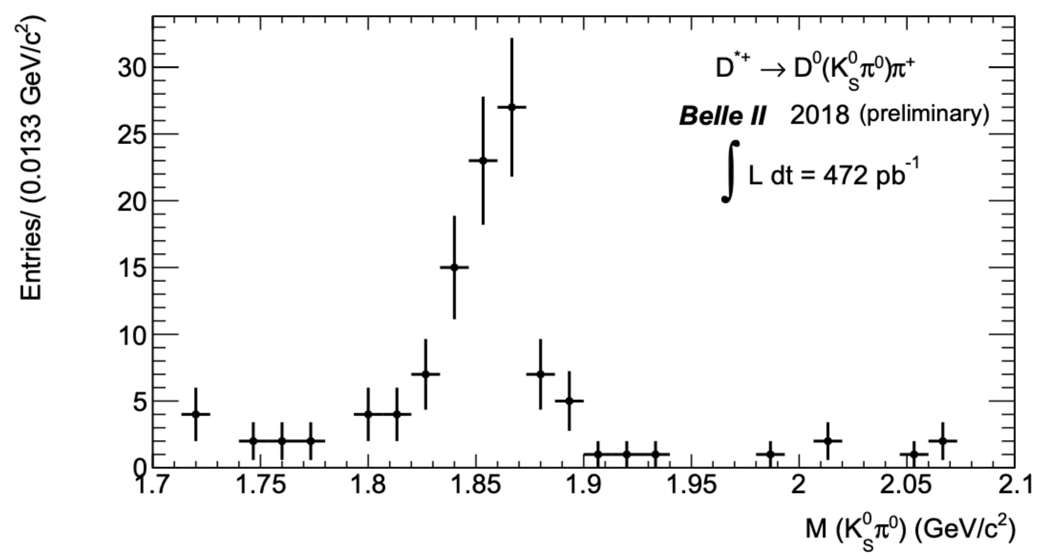


Singly Cabibbo suppressed D decays (CP eigenstates) are observed

$D^0 \longrightarrow K^- K^+$



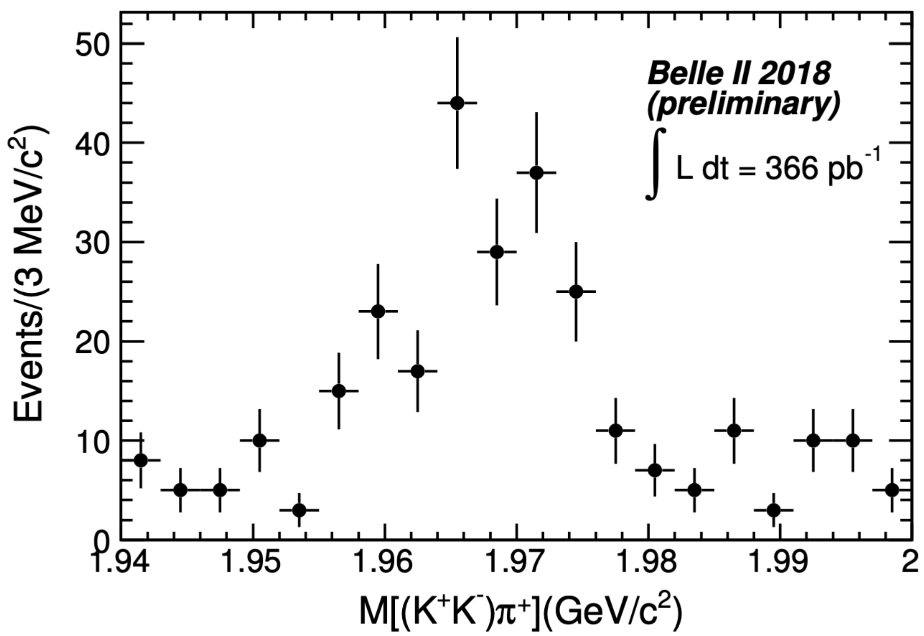
$D^0 \longrightarrow K_S \pi^0$



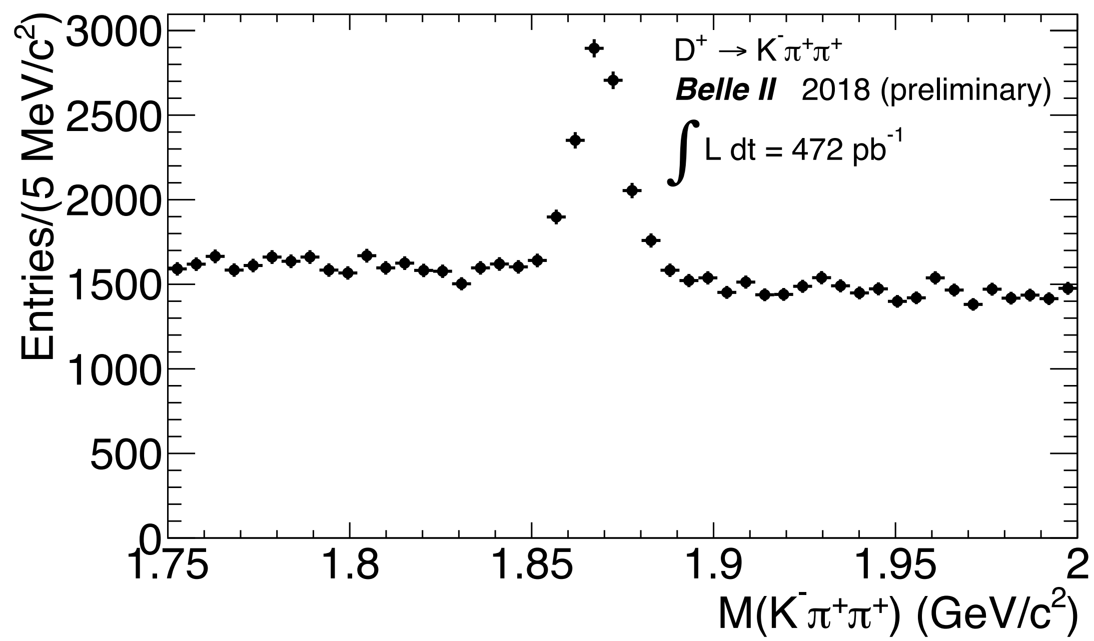
- A requirement on D* candidate, $p_{CMS} > 2.5$ GeV/c, allows to extract prominent D signal;

Without D* tagging too

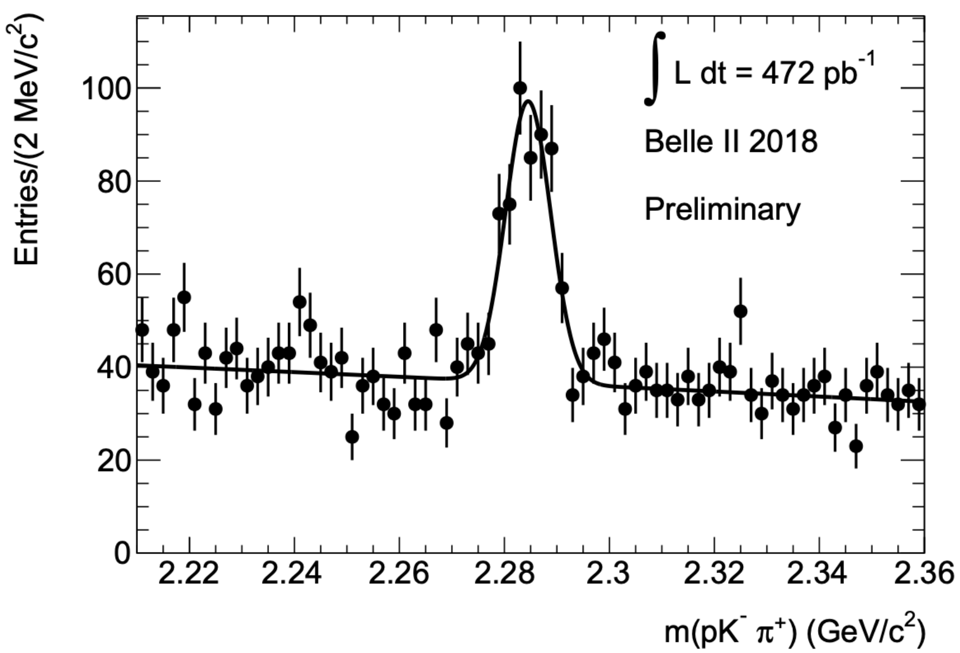
$D_s^+ \longrightarrow \phi\pi^+$



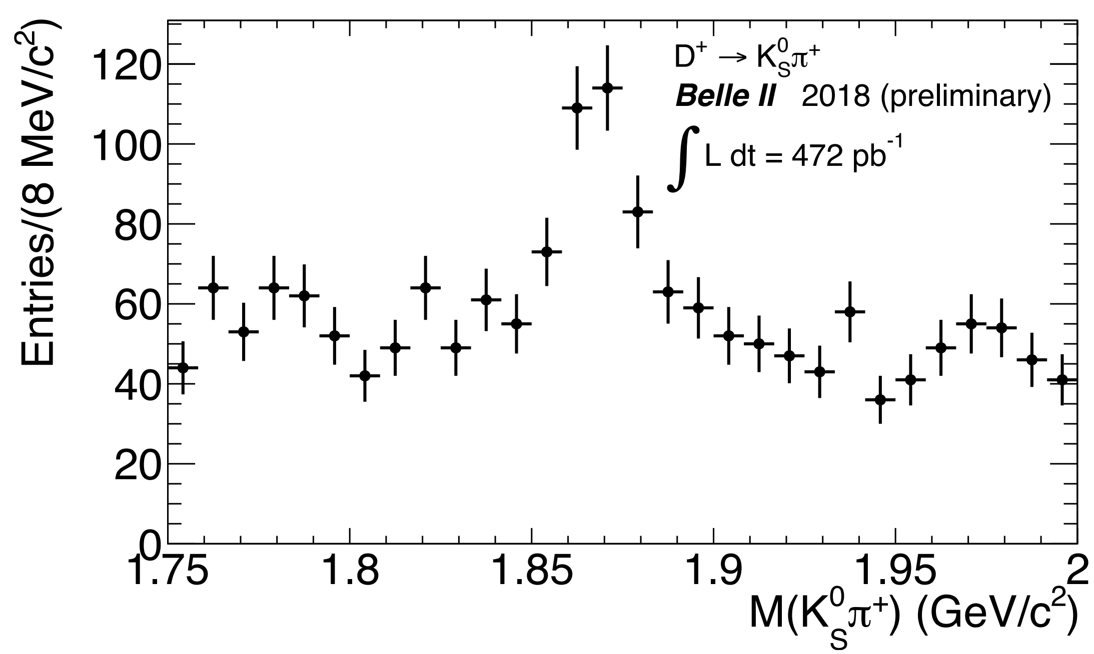
$D^+ \longrightarrow K^-\pi^+\pi^-$



$\Lambda_c^+ \longrightarrow pK^-\pi^+$



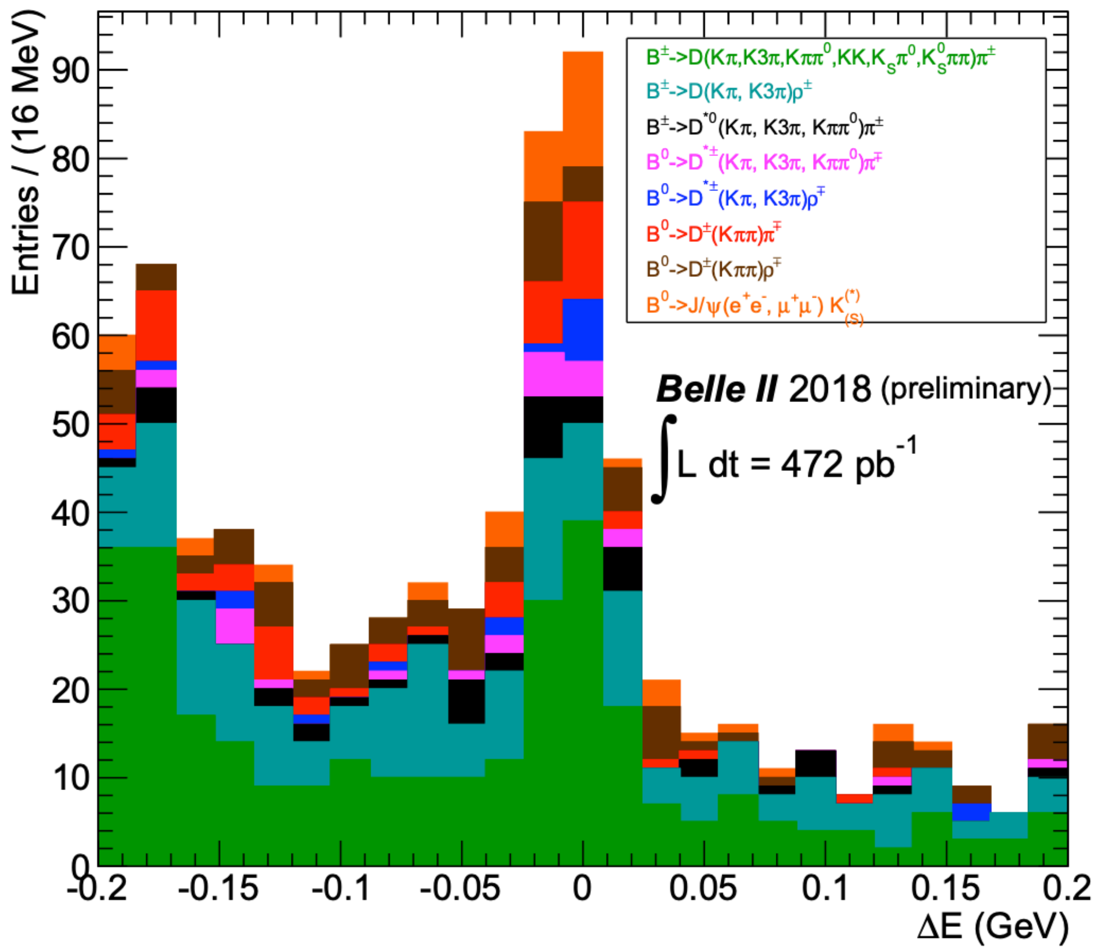
$D^+ \longrightarrow K_S\pi^+$

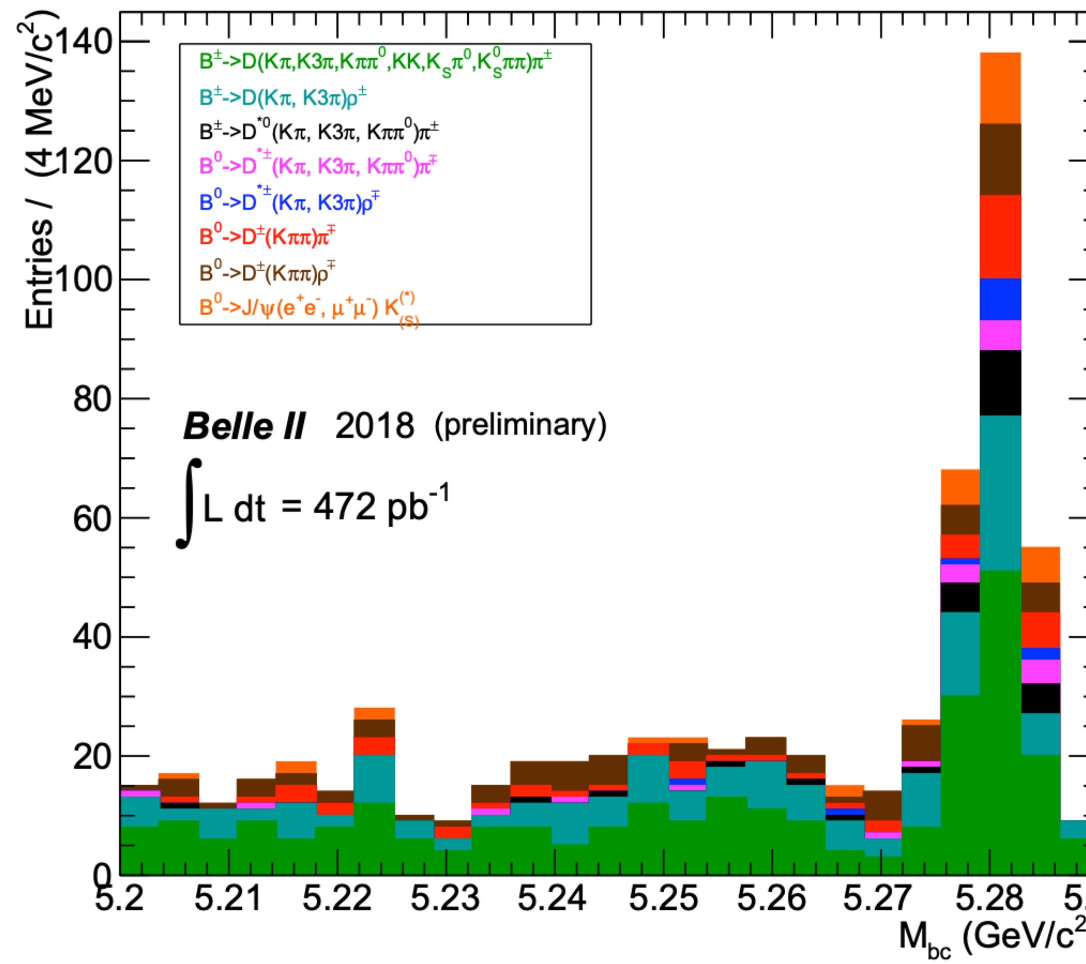


Fully reconstructed $b \longrightarrow c$

$$\Delta E = \frac{p_B \cdot p_{e^+e^-} - s/2}{\sqrt{s}}$$

$$M_{bc} = \sqrt{\frac{(s/2 + \mathbf{p}_B \cdot \mathbf{p}_{e^+e^-})^2}{E^2_{e^+e^-}} - p^2_B}$$





- > 200 B candidates in hadronic modes

Reconstruction of these signals allows for validation of tracking, vertexing and particle identification performances.

ARGUS Results on B Decays via $b \to C$ Transitions

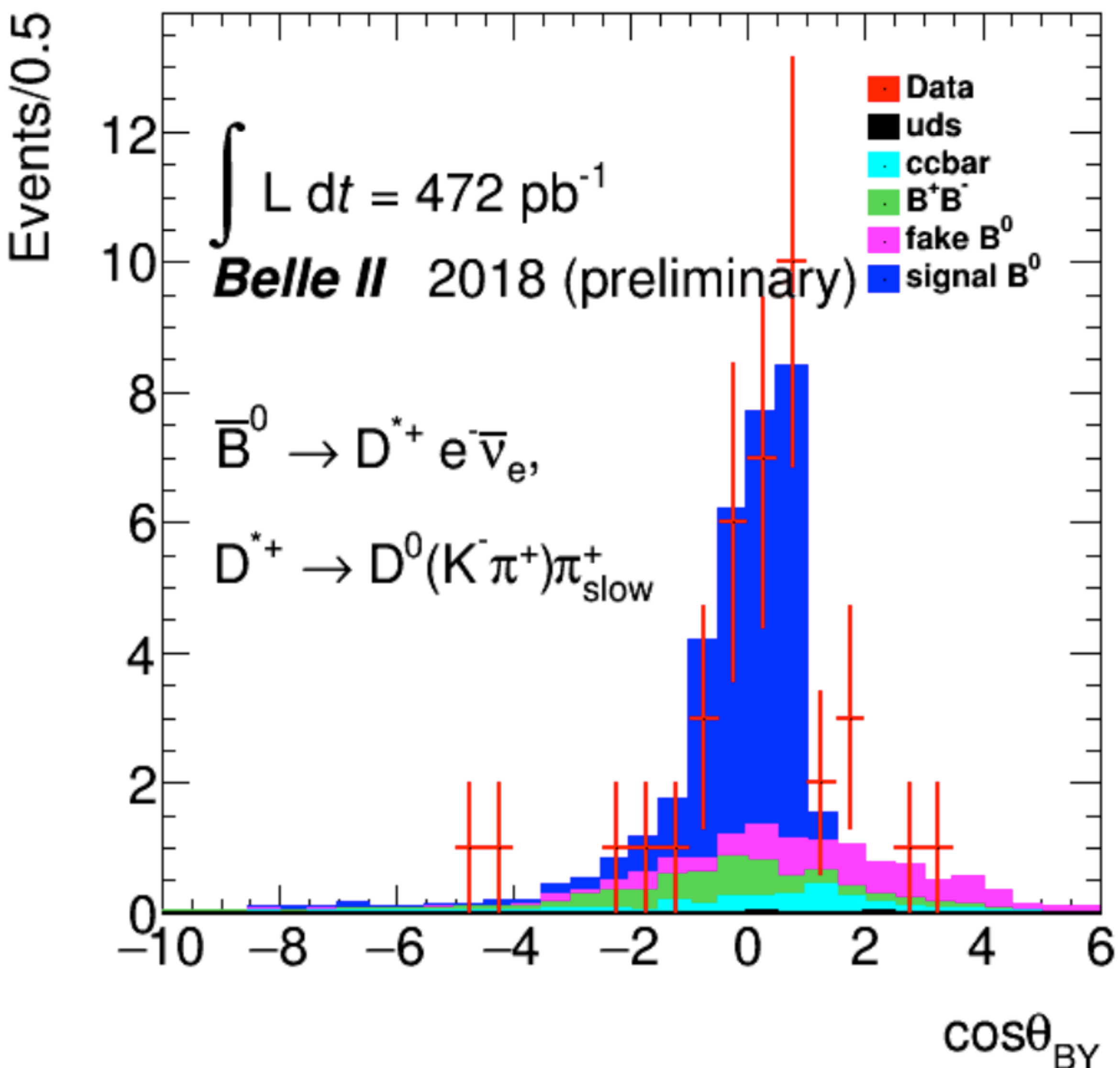
Henning Schroder
DESY, Hamburg, Germany

$\int L\,dt = 227\ pb^{-1}$

ABSTRACT

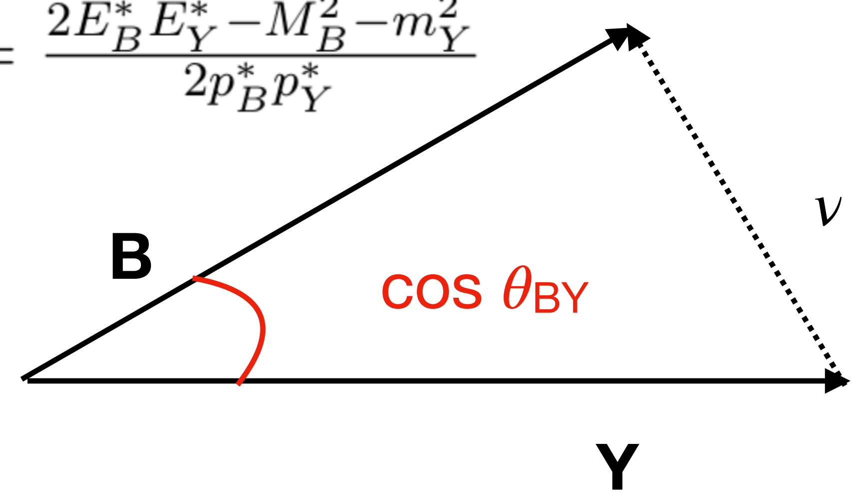
Using the ARGUS detector at the e^+e^- storage ring DORIS II at DESY new results on beauty physics have been obtained. About 280 B mesons have been reconstructed in 26 hadronic decay modes.

Partially reconstructed B decays



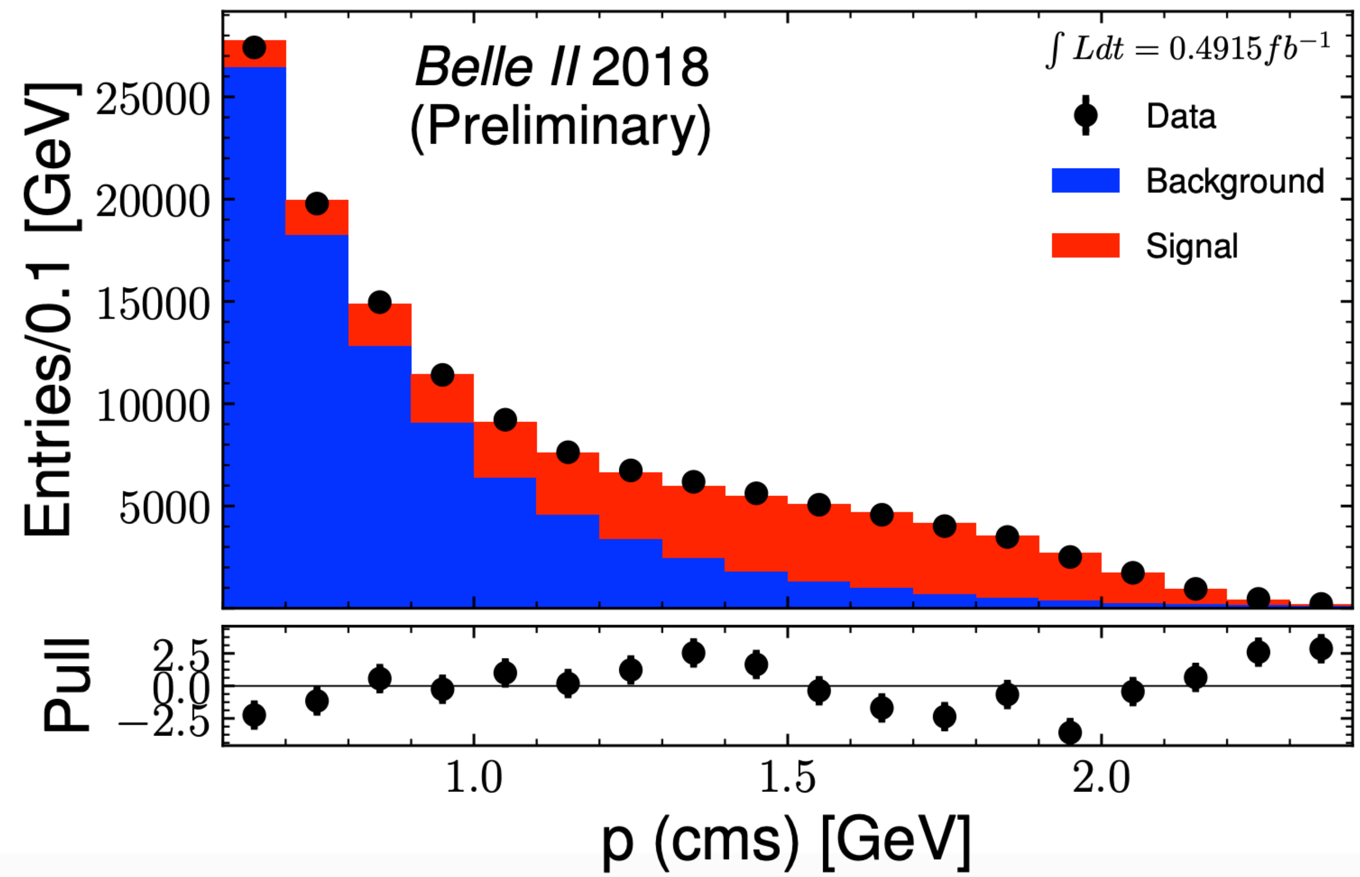
$$\cos\theta_{BY} = \frac{2E^*_B E^*_Y - M^2_B - m^2_Y}{2p^*_B p^*_Y}$$

Y = D^{*+}e$^-$



- ~ 38 $\bar{B}^0 \longrightarrow D^{*+} e \bar{\nu}_e$ found

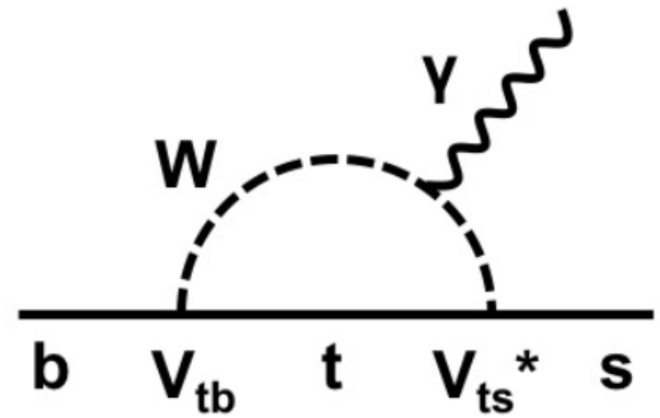
$B \to Xe\nu$

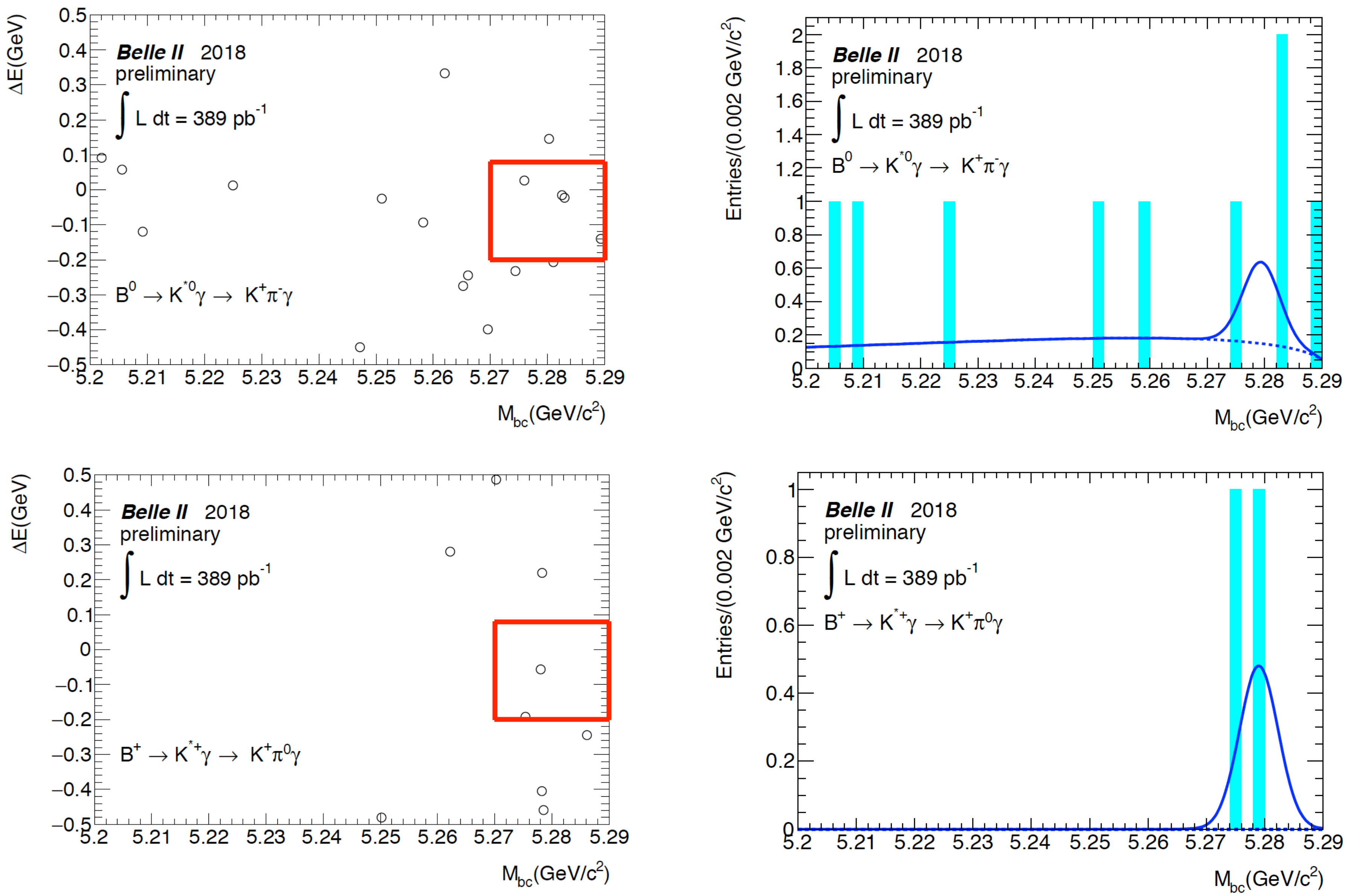


More than 40k signal events observed

Radiative b⟶s

Penguin decay b⟶sγ: BF ~ 10^{-5}

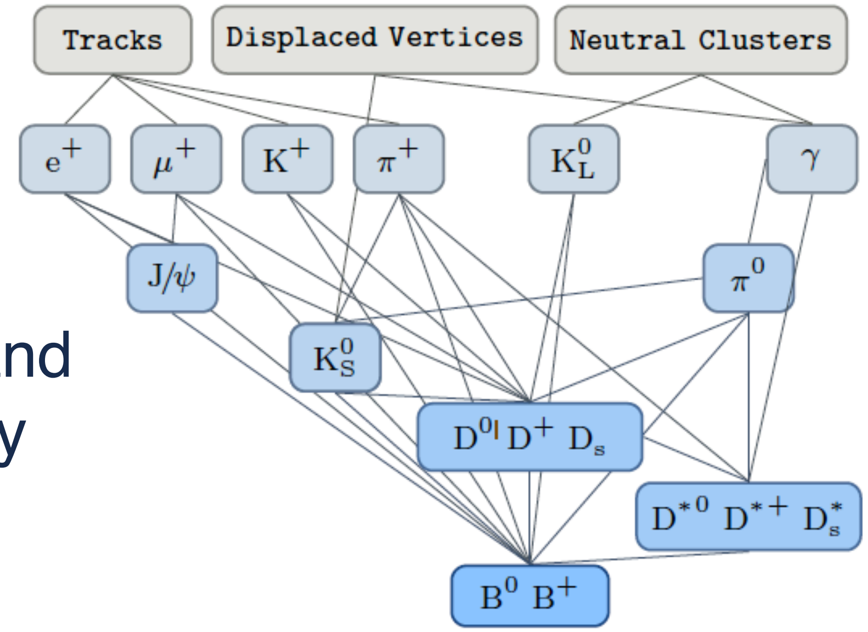




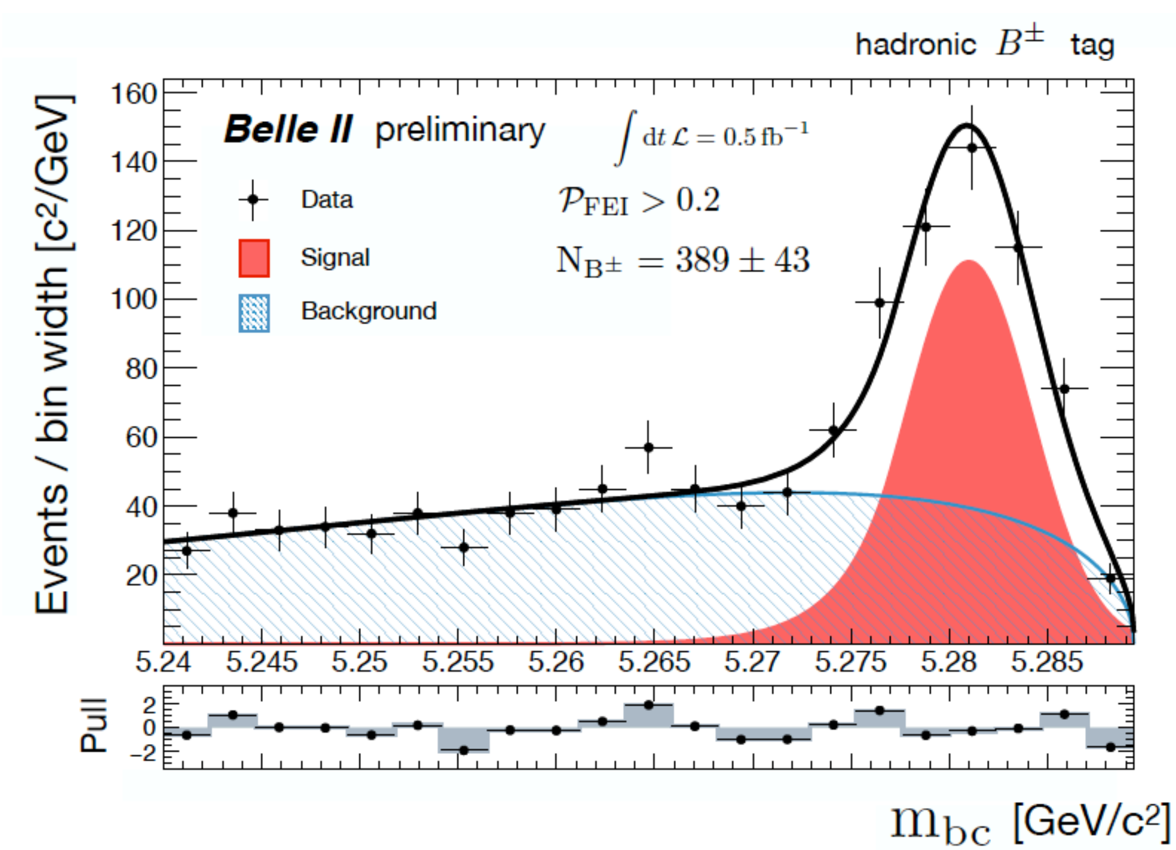
Illustrates capabilities of Belle II to study rare decays

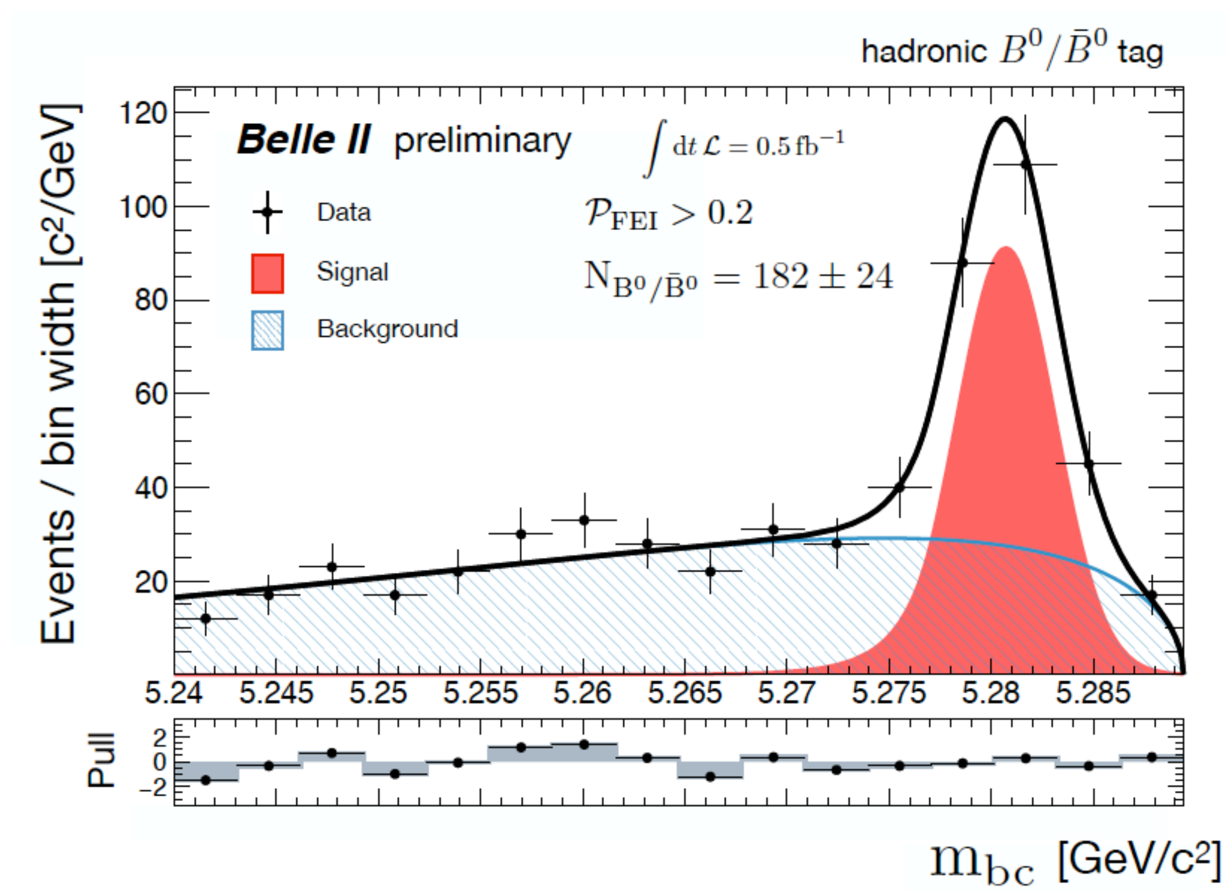
Full event reconstruction

- Recursive reconstruction algorithm (full event interpretation): > 5000 B decay modes.
- Boosted decision tree classifier.



It recovers missing kinematic information partially and infers strong constraints on the signal candidates by automatically reconstructing the rest of the event in thousands of exclusive decay channels.





Allows to increase performance in B reconstruction. That's essential for further studying of B decays with missing energy.

Summary

- Belle II came online in 2018 - “rediscovered” heavy flavour: charm, beauty.
- Essential validation information to check and optimize the Belle II performance in view of the 2019 physics run.
- Ready to start physics in Super Factory mode.