First Physics Results at the Belle II Experiment

Kobayashi-Maskawa Institute
for the Origin of Particles and the Universe

Belle II

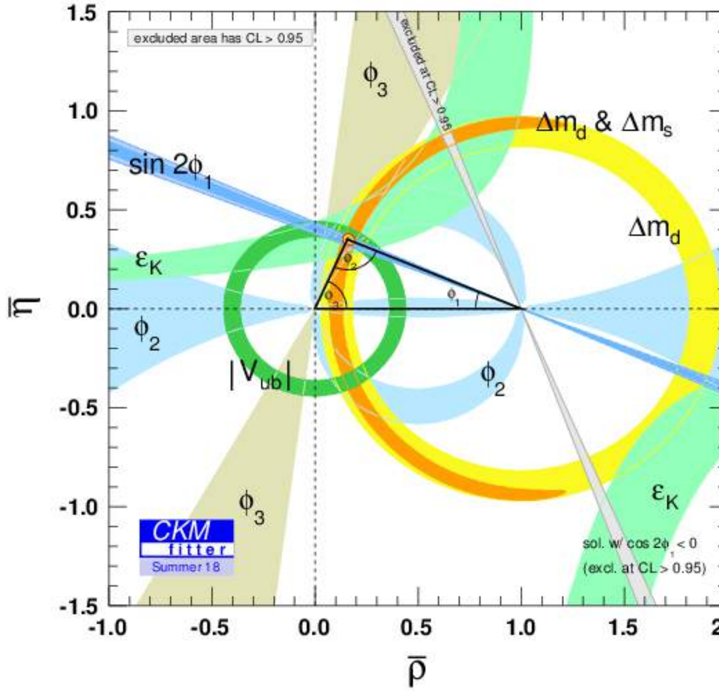
Alessandro Gaz

KMI, Nagoya University

KMI Topics, November 13th 2019

Flavor Physics Today

- Tremendous progress in Flavor Physics in the last 20 years:
  - Discovery of direct CP violation in K decays (NA48, KTEV);
  - Discovery of CP violation in B mesons (BaBar, Belle);
  - Discovery of D° oscillations (BaBar, Belle);
  - Discovery of CP violation in Charm (LHCb);
  - ...
- Some other tensions wrt the Standard Model expectations:
  - Hints for Lepton Flavor Universality violation,
  - Tension on $(g\text{-}2)_\mu$;
  - ...
- The Belle II Experiment is ready to take the next step in precision!

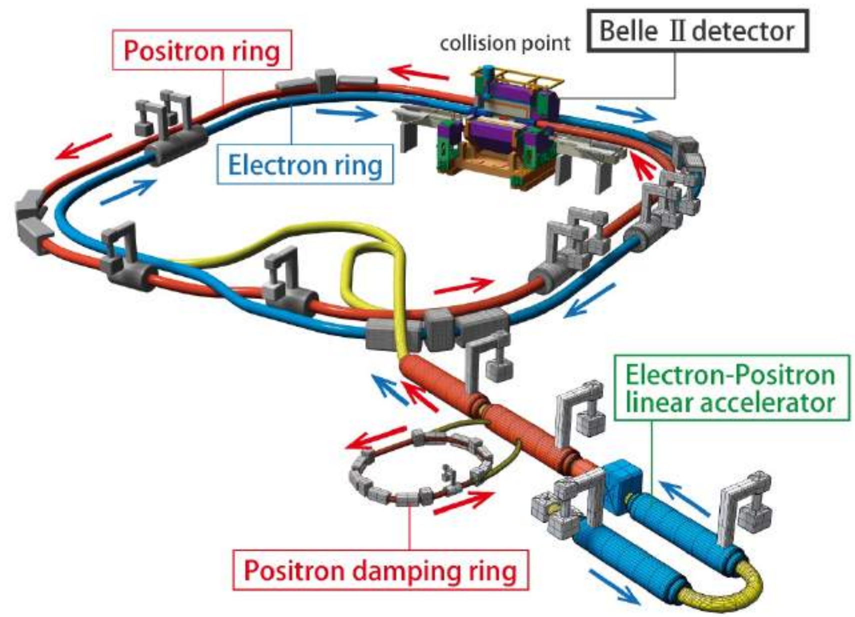


Status of the CKM Unitarity Triangle fit, as of Summer 2018: one single complex phase can explain all the CP violating phenomena we have observed today (!)

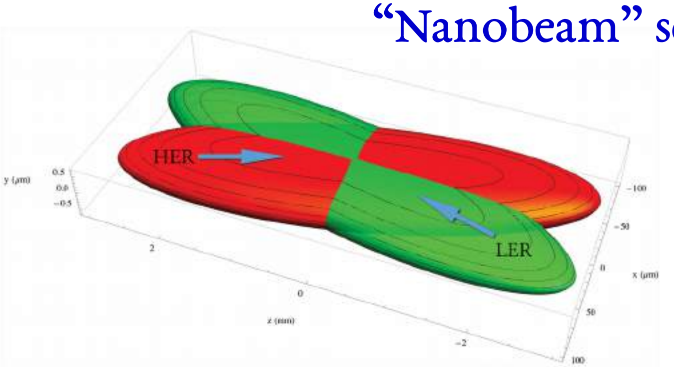
The SuperKEKB Collider

B Factory concept: asymmetric energy e^+ (4.0 GeV) e^- (7.0 GeV) Collider, running at (or close to) the center of mass energy corresponding to the Υ(4S) resonance;

Key to success: increase the instantaneous luminosity by a factor 40 compared to its predecessor KEKB;

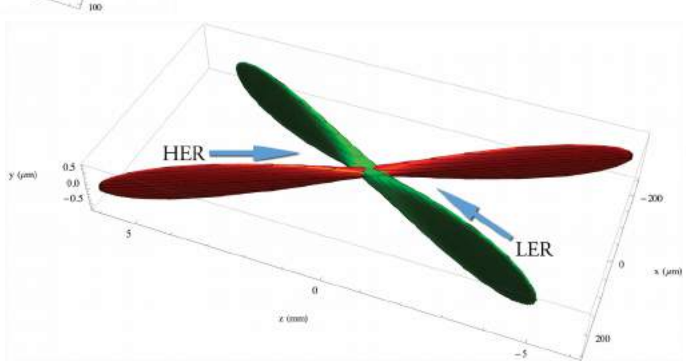


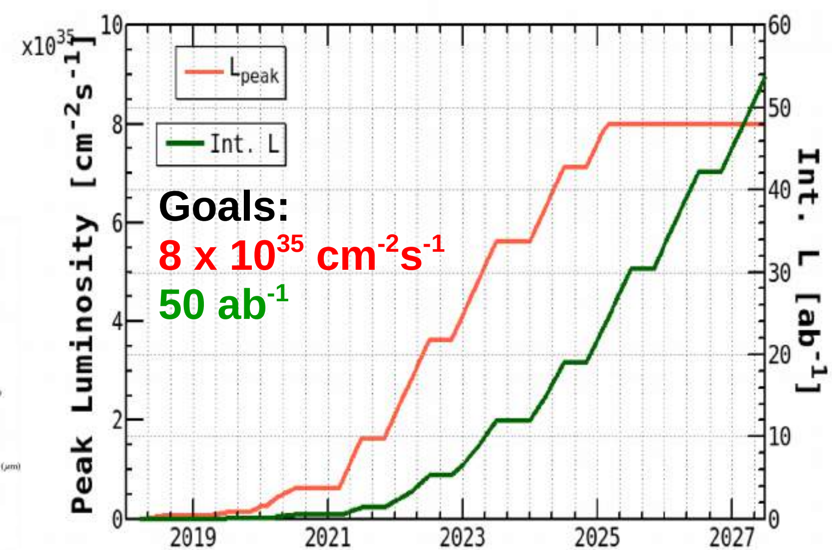
"Nanobeam" scheme:



KEKB

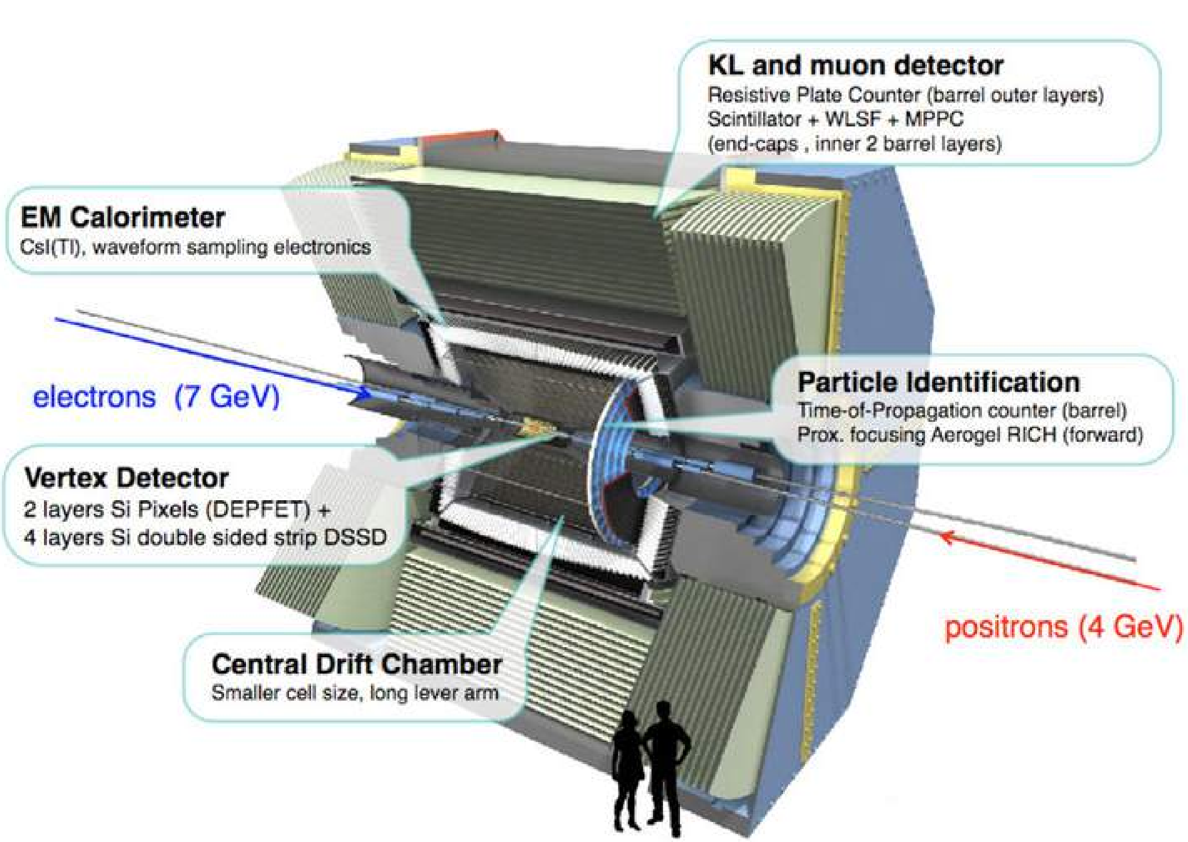
SuperKEKB





The Belle II Experiment

- In a few words: still using Belle's structure, solenoid, and calorimeter crystals;
- Everything else is new/upgraded!



Detector highlights:

- 6 layer silicon VerteX Detector (2 pixel + 4 strip). Closest layer ~1.5 cm from the Interaction Point;
- Central Drift Chamber: main tracking device, with smaller cells and longer lever arm;
- Two novel Cherenkov PID detectors: Time Of Propagation and focusing Aerogel RICH;
- Waveform sampling electromagnetic calorimeter;
- K°_{L} and μ detector upgraded with scintillators in endcaps to better cope with higher backgrounds.

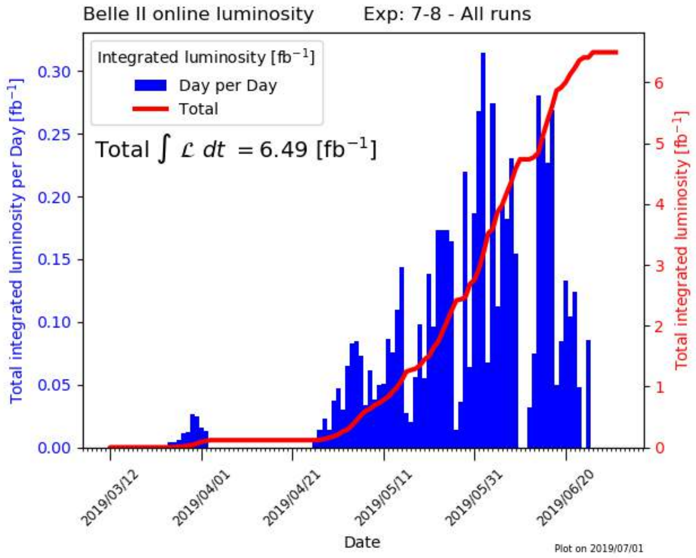
Early Datasets

Three main stages of Machine and Detector commissioning:

- Phase1 (Feb – June 2016): single beam studies, no BelleII detector, dedicated "Beast II" detector for detector studies;
- Phase2 (Apr – July 2018): Belle II detector rolled into position, but only a small fraction of the vertex detector. First collisions and first opportunity for Physics Results with ~0.5 fb^{-1} of integrated luminosity;
- Phase3 (Apr – June 2019): first Physics Run with complete Belle II detector. Integrated luminosity (good for analysis):

  5.15 fb^{-1} of Υ(4S)

  0.83 fb^{-1} of "off-resonance"



This is O(1%) of BaBar's and Belle's datasets.

Outline

- Snapshots of Detector performance;
  - Reconstruction of neutrals;
  - Beamspot and vertexing performance;
  - Particle Identification;

- Results on the Phase2 dataset;
  - $e^+e^- \to$ (light hadrons) + ISR;
  - Offline luminosity;
  - Z' searches;

- Early Phase3 "rediscoveries" presented at the Summer Conferences;
  - Quarkonia;
  - D° lifetime;
  - "Golden modes" $B \to J/\psi\ K^{(*)\circ}$;
  - $B\bar{B}$ mixing;
  - $B \to DK$;
  - $B \to K\pi$;
  - $b \to s\ \gamma$ transitions;
  - Full Event Interpretation and $B \to D^*\ l\ \nu$.

I will go through quite a few results, my apologies if I go too quickly or if I skip your favorite topic!

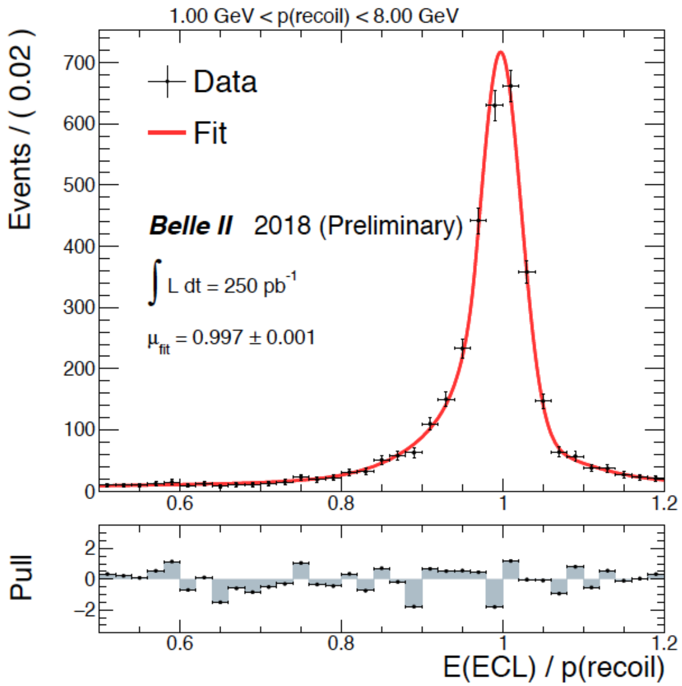
Snapshots of Detector performance

Reconstruction of neutrals

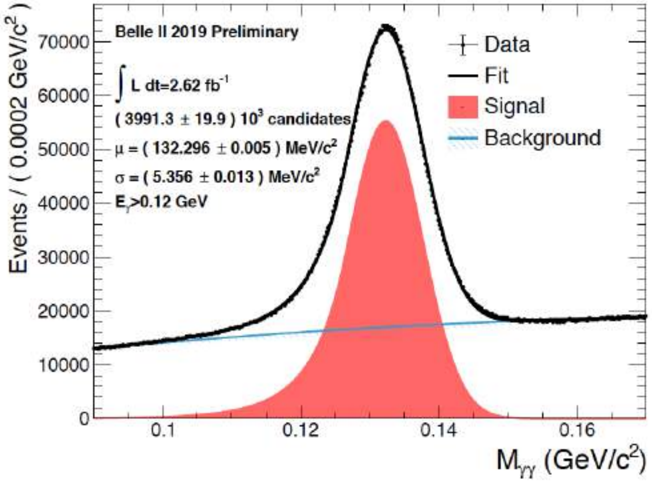
Crucial for the competition with LHCb: modes with π°, $\eta^{(')}$, K°_L, ... in the final state will be almost exclusive to Belle II;

Main mode for γ calibration:

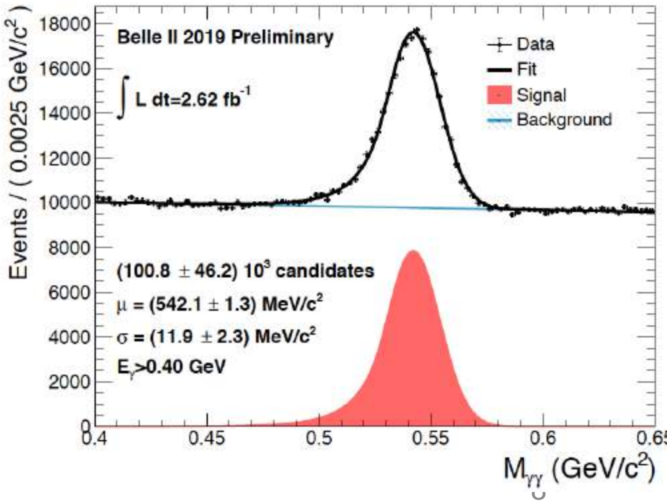
$e^+e^- \rightarrow \mu^+\mu^-\gamma$



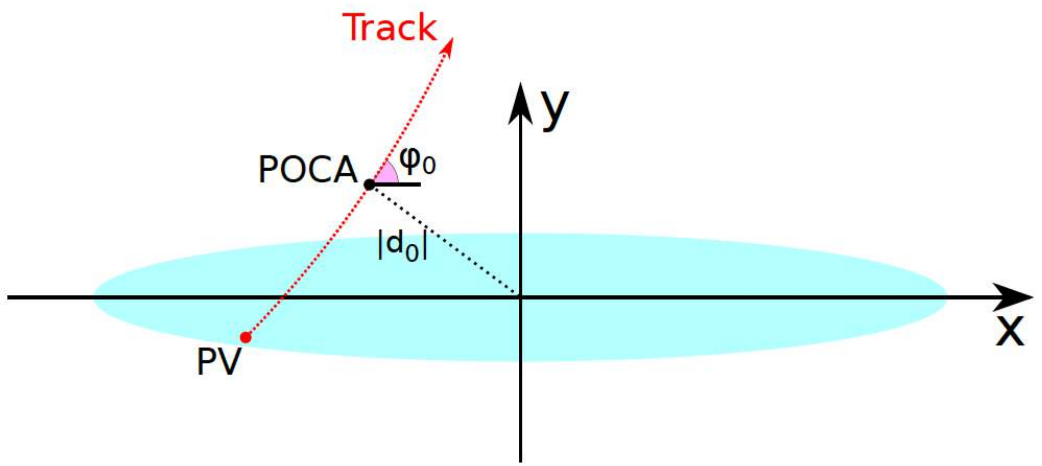
$\pi^\circ \rightarrow \gamma\gamma$

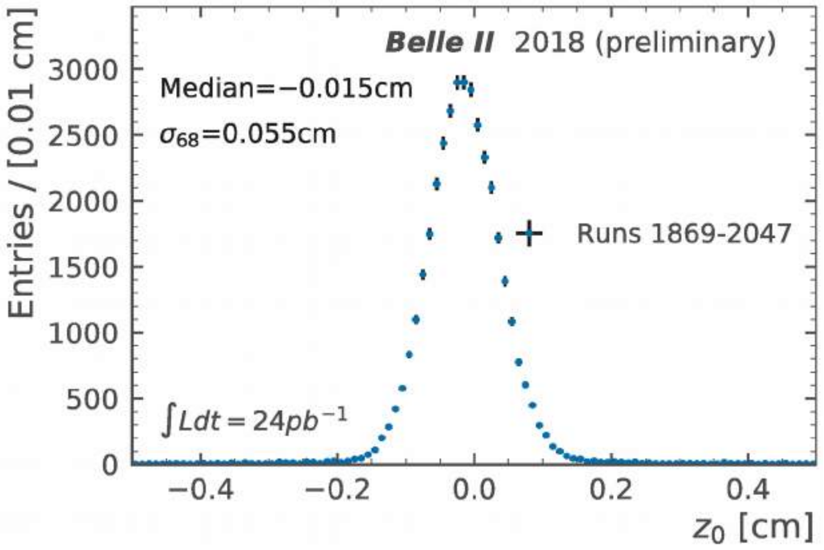


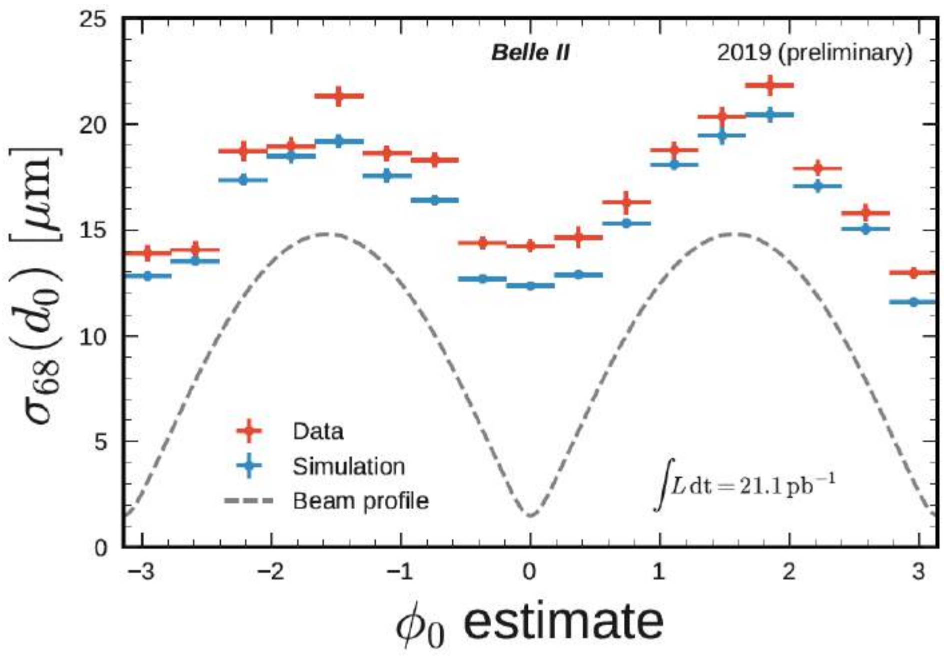
$\eta \rightarrow \gamma\gamma$



Beamspot and Vertexing





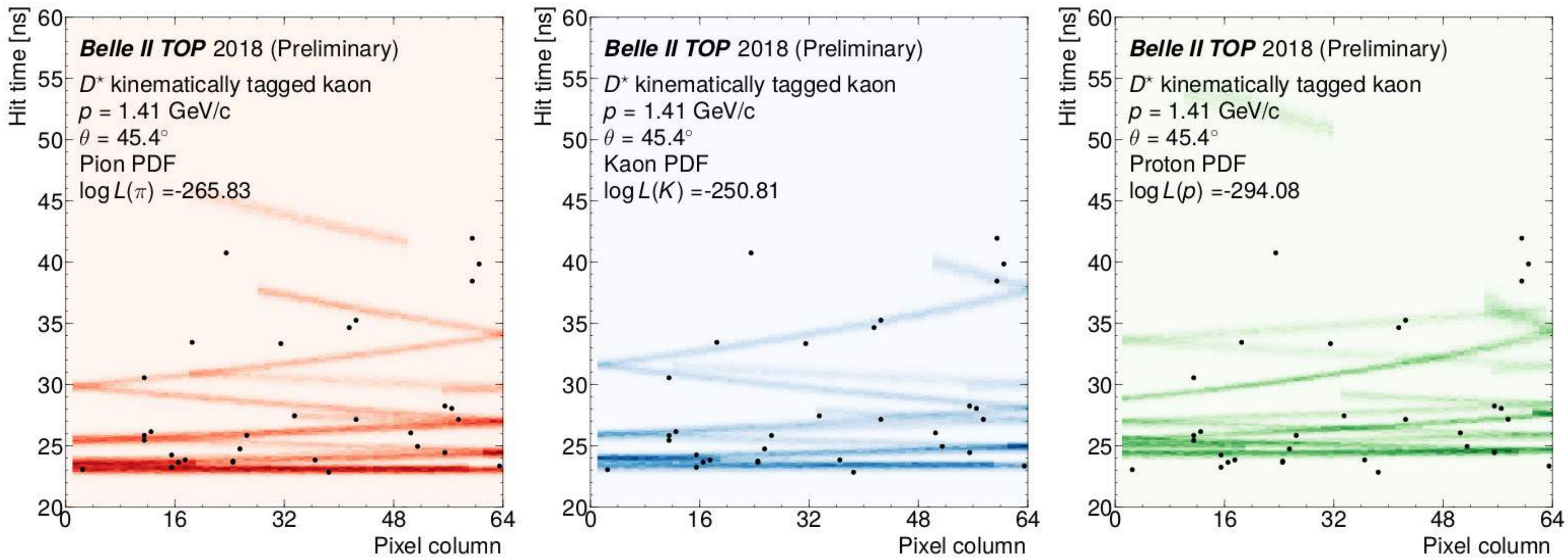


The position of the Point Of Closest Approach is consistent with the expectations based on the current beam sizes and the 41 mrad crossing angle

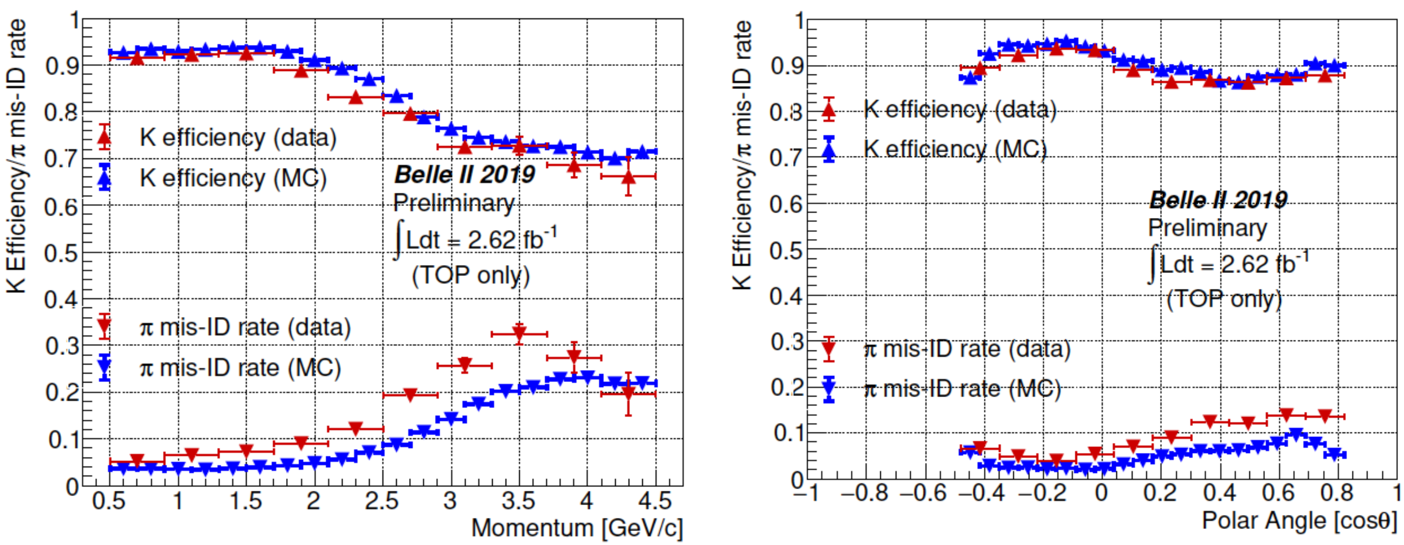
Particle Identification (Kπ separation)

Main control sample: $D^{*+} \rightarrow D^{\circ}\pi^{+}_{s}$, $D^{\circ} \rightarrow K^{-}\pi^{+}$;

Example:
a K candidate traversing a TOP module



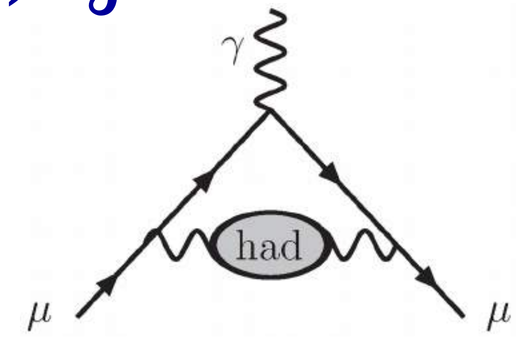
Still some work to do in order to push down the π misID probability...

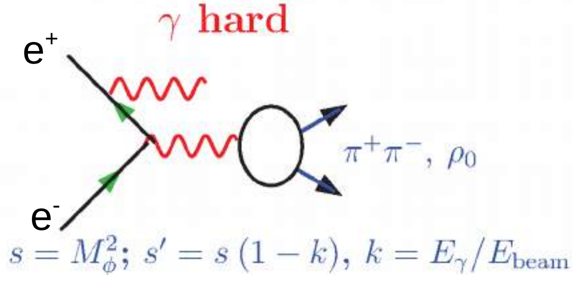


Phase2 Results

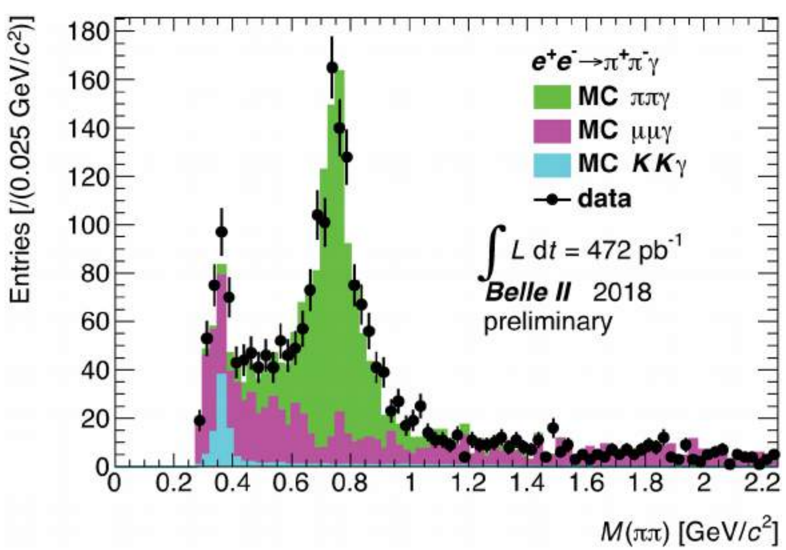
$e^+e^- \to$ (light hadrons) γ

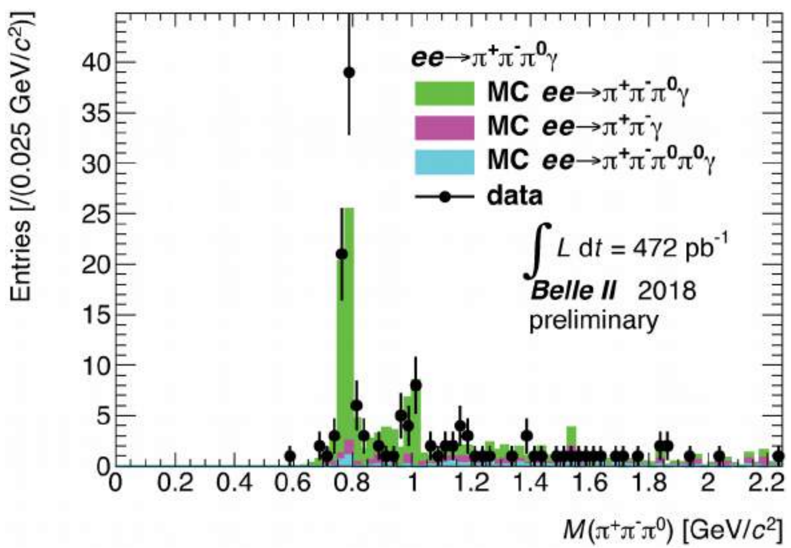
- The theoretical uncertainty on the prediction of $(g-2)_\mu$ is dominated by the "hadronic vacuum polarization";
- Improving the precision on the measurement of the $e^+e^- \to \rho/\omega/\phi$ ... cross-sections is a fundamental step to reduce the theoretical uncertainty on $(g-2)_\mu$;
- At Belle II, we can exploit the Initial State Radiation to effectively perform a scan in energy and probe masses much lower than the Y(4S);





First rediscoveries on Phase2 data!





Phase2: Offline Luminosity

- The offline luminosity of the Phase2 dataset is measured using:

  $e^+e^- \rightarrow e^+e^-$ (nominal method)

  $e^+e^- \rightarrow \gamma\gamma$ (cross-check)

Quantity	Bhabha	digamma
$N_{\rm data}^{\rm obs}$	$3\,134\,488 \pm 1\,770$	$454\,650 \pm 674$
$\epsilon_{\rm ee}$ (%)	35.93 ± 0.02	0.255 ± 0.002
$\epsilon_{\gamma\gamma}$ (%)	3.56 ± 0.02	47.74 ± 0.05
$\sigma_{\rm ee}$ (nb)	17.37	17.37
$\sigma_{\gamma\gamma}$ (nb)	1.833	1.833
$R_{\rm bkg}$ (%)	0.07	0.28
L (pb^{-1})	496.7 ± 0.3	493.1 ± 0.7

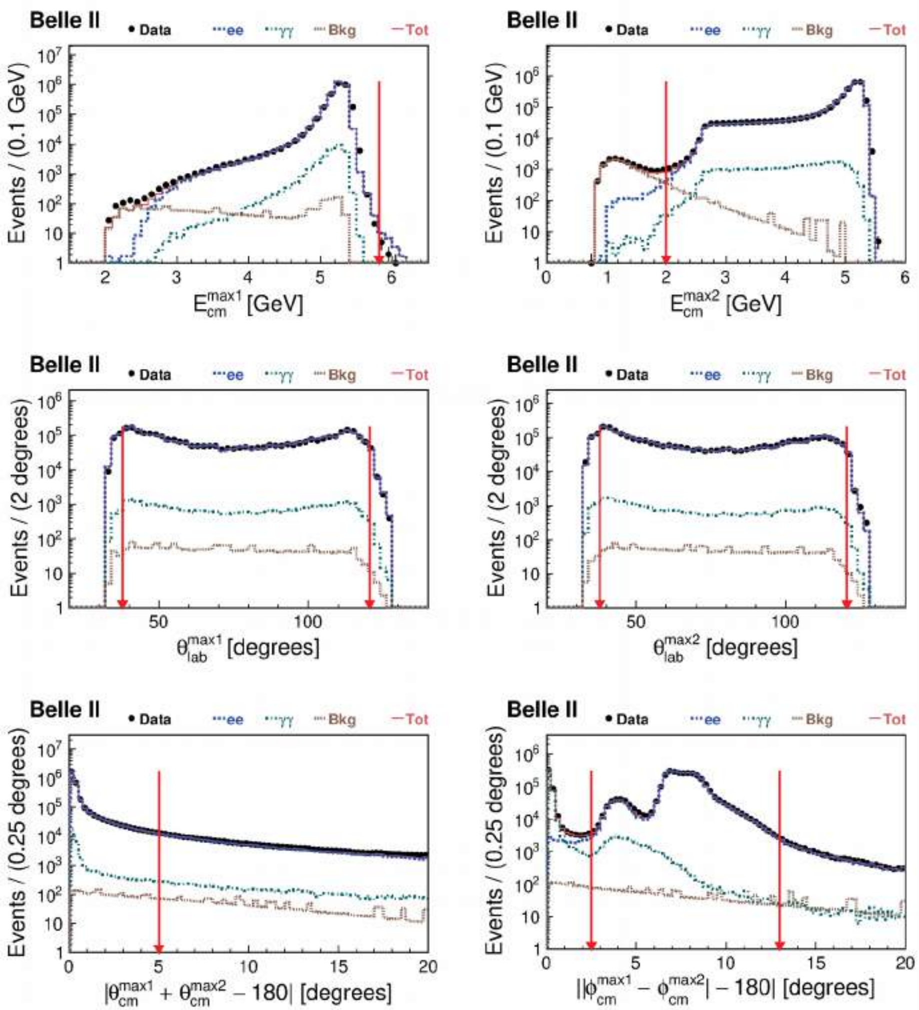
- Total systematic uncertainties:

  ±0.7% (Bhabha)

  $^{+1.2}_{-0.9}$% (digamma)

- Good agreement between the two methods.

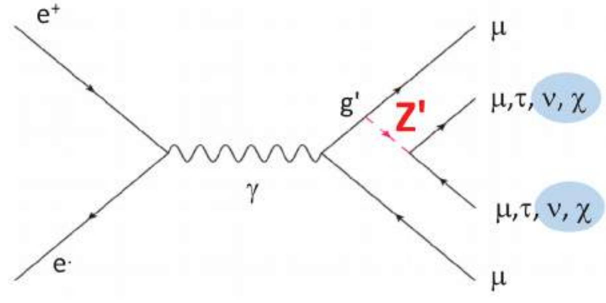
1st Belle II paper:
arXiv:1910.05365 [hep-ex]
submitted to Chinese Physics C



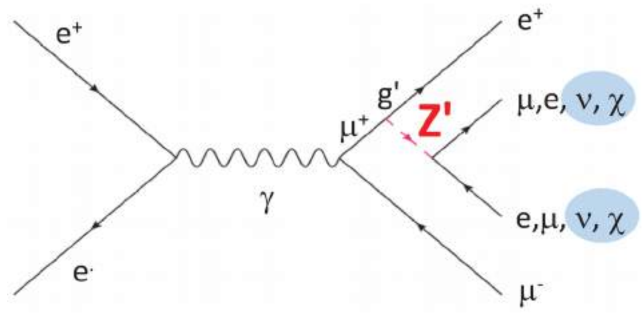
Z' searches

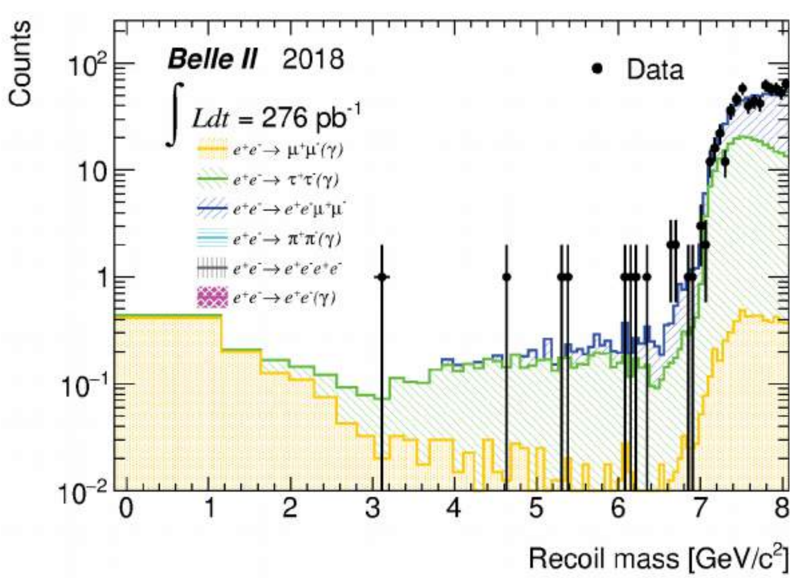
- Probing simple extensions of the SM: extra U(1)', which gives rise to a Z' boson that couples both to SM and NP (e.g. dark matter) particles;
- Searching for:

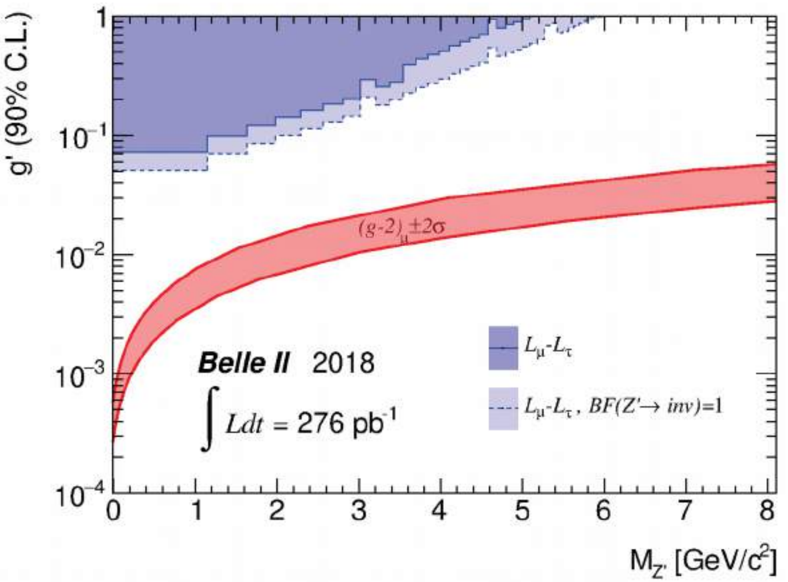
$e^+e^- \rightarrow \mu^+\mu^- Z'$, ($Z' \rightarrow$ invis.)



$e^+e^- \rightarrow e^\pm\mu^\mp Z'$, ($Z' \rightarrow$ invis.)





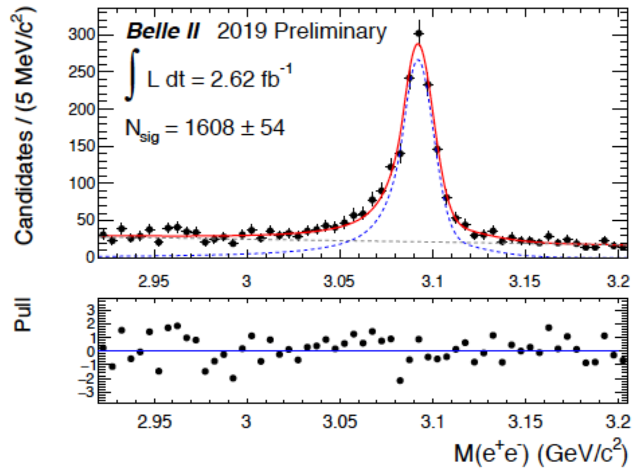


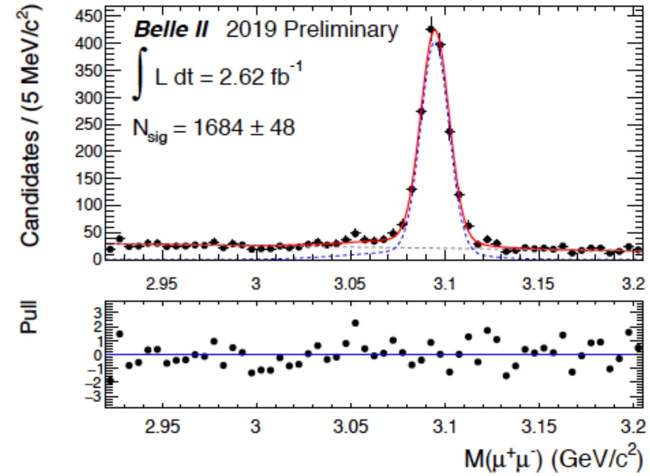
2nd paper is on the way!

Phase3 Results

Rediscovery of quarkonia

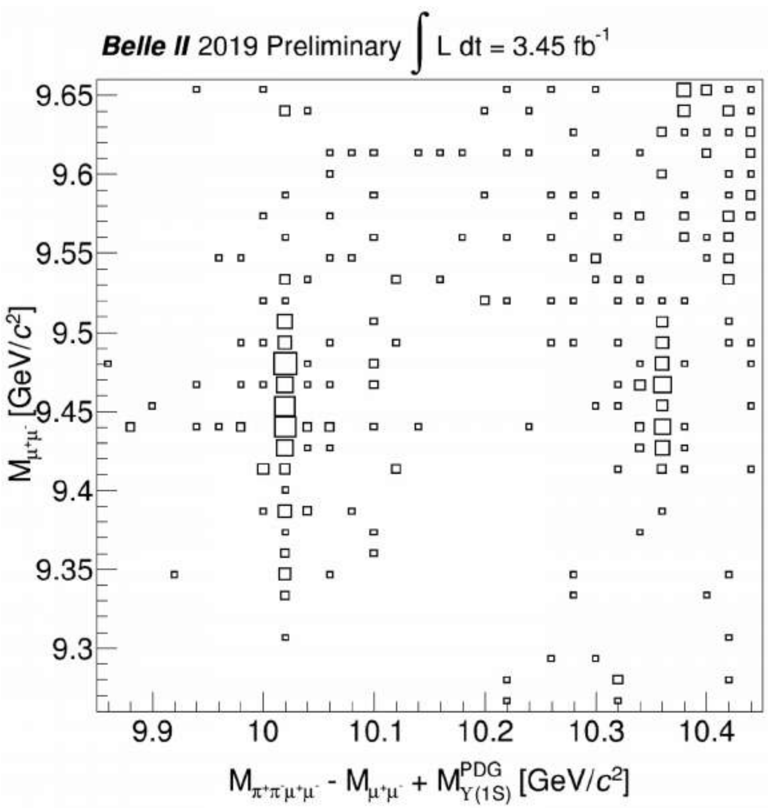
Rediscovery of $J/\psi \to l^+l^-$





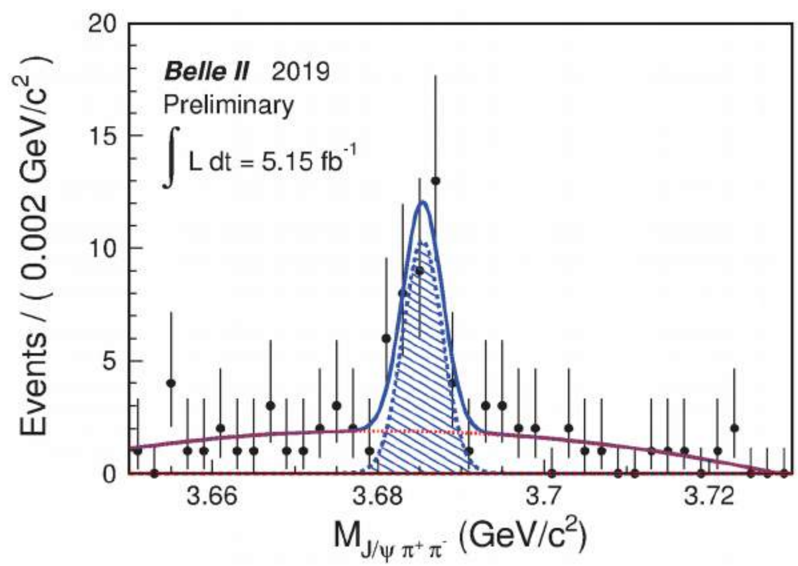
$e^+e^- \to \gamma\, \Upsilon(2S, 3S)$

$\Upsilon(2S, 3S) \to \pi^+\pi^- \Upsilon(1S)$, $\Upsilon(1S) \to \mu^+\mu^-$

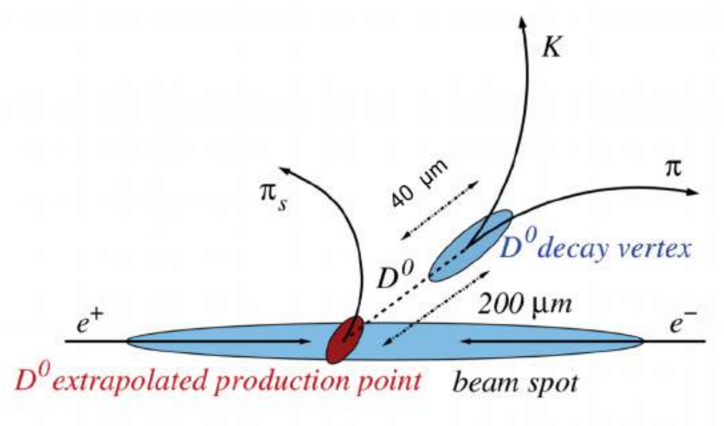


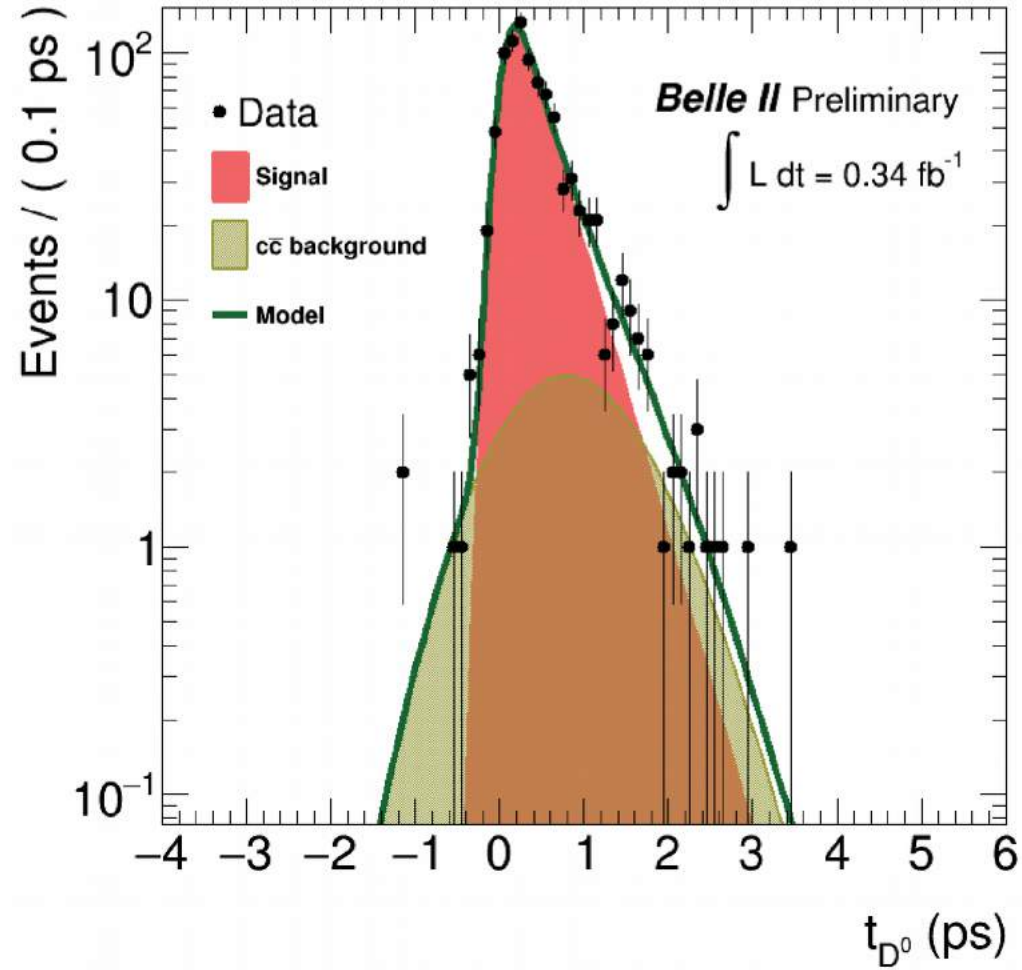
Rediscovery of $B \to \psi(2S)\, K$, $\psi(2S) \to J/\psi\, \pi^+\pi^-$

Preliminary step for rediscovering the X(3872)



D^0 lifetime





- One of our highlights of EPS:

  $N_{sig} = 860 \pm 30$

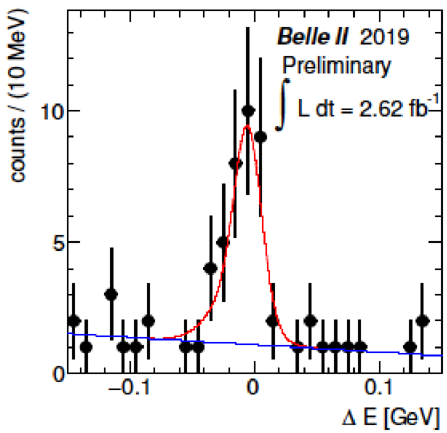
  $\tau_{D0} = 370 \pm 40$ fs (stat only)

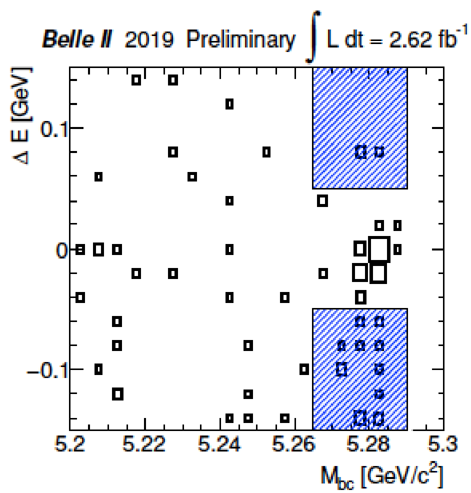
  (PDG: $\tau_{D0} = 410$ fs)

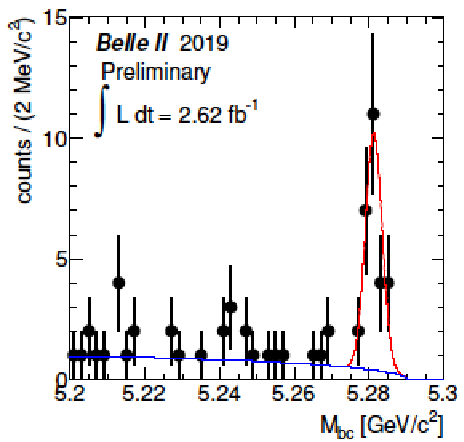
- Clear demonstration of Belle II vertexing capabilities;
- Beamspot position needs to be monitored on a run by run basis;
- Excellent benchmark to study systematics (on vertexing/VXD alignment).

Rediscovery of $B^0 \to J/\psi\, K^{(*)}$

$B^\circ \to J/\psi\, K^\circ_s,\ K^\circ_s \to \pi^+\pi^-$

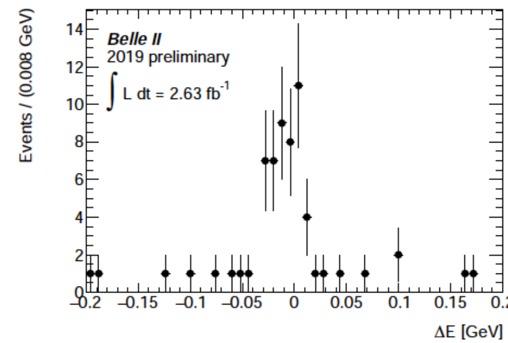


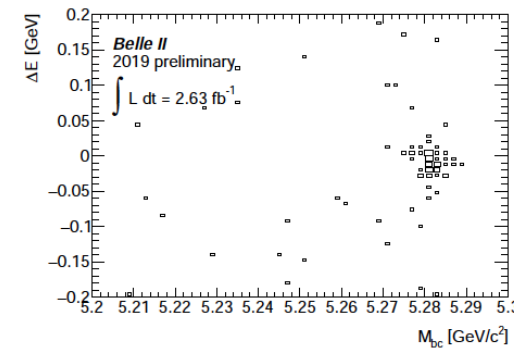




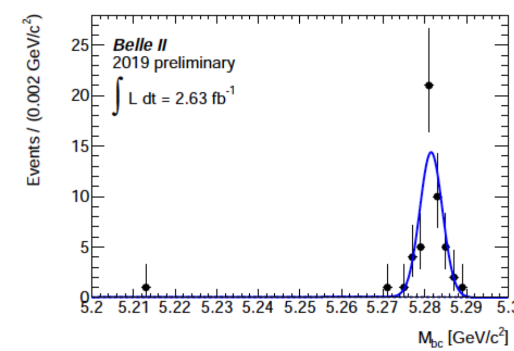
N_{sig} = 26.9 ± 5.2

$B^\circ \to J/\psi\, K^{*\circ},\ K^{*\circ} \to K^-\pi^+$





N_{sig} = 48.6 ± 7.0

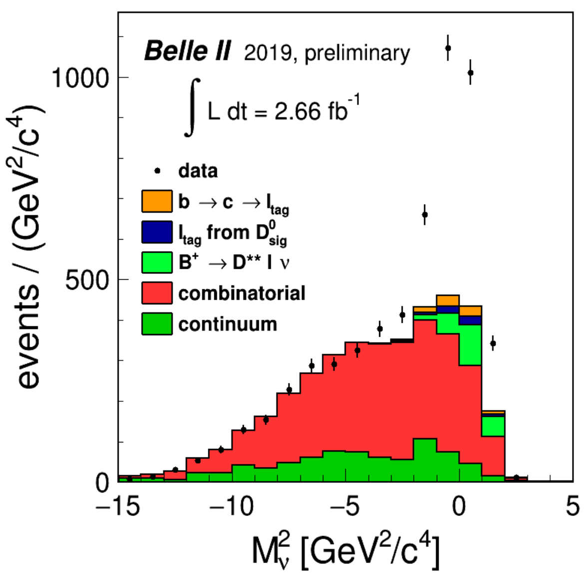


Not useful for measuring CP violation, but very useful to study vertexing resolution (comparing the J/ψ and the K* vertices)

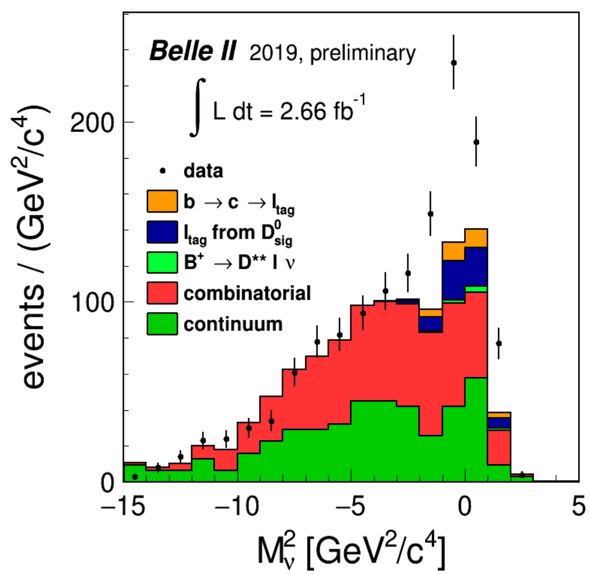
Observation of $B\bar{B}$ mixing at Belle II

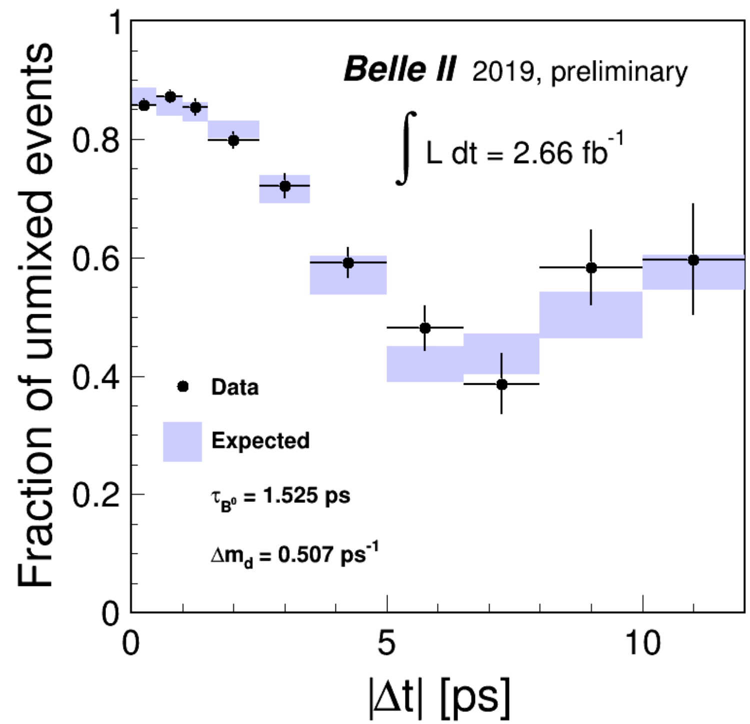
- Target: $B^{\circ} \rightarrow D^{*-} l^{+} \nu$ decays, with $D^{*-} \rightarrow D^{\circ} \pi^{-}_{soft}$;
- The charge of the leptons tag the flavor of the B's: $B^{\circ} \rightarrow l^{+} X$, $\bar{B}^{\circ} \rightarrow l^{-} \bar{X}$
- Proper decay time difference Δt estimated from displacement of the B decay vertices along the boost axis: $\Delta t = \Delta z/(\beta\gamma c)$

Unmixed ($l^{\pm}l^{\mp}$)



Mixed ($l^{\pm}l^{\pm}$)





Fraction of mixed events $\chi_d = (17.2 \pm 3.6)\%$

(World Average = 18.6%)

$|\Delta t|$ dependent behavior of the fraction of unmixed events consistent with the expectations

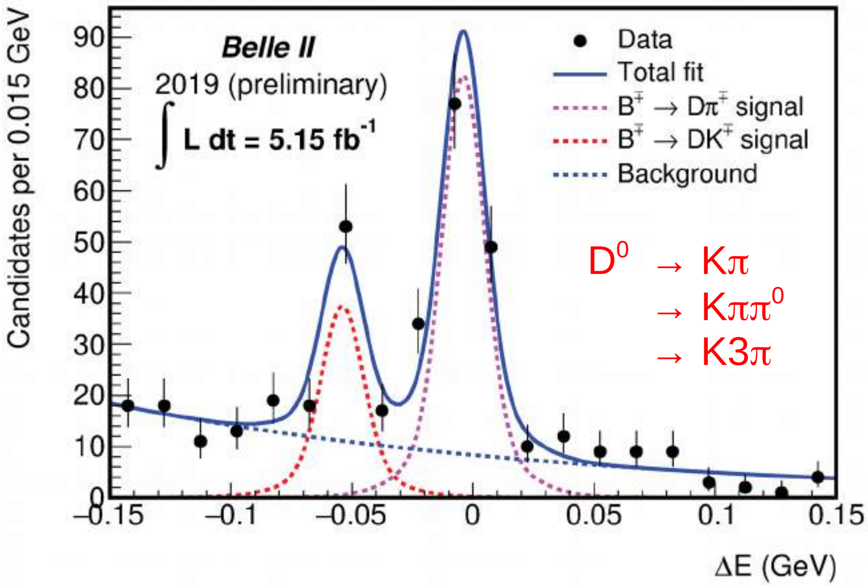
Rediscovery of B → DK at Belle II

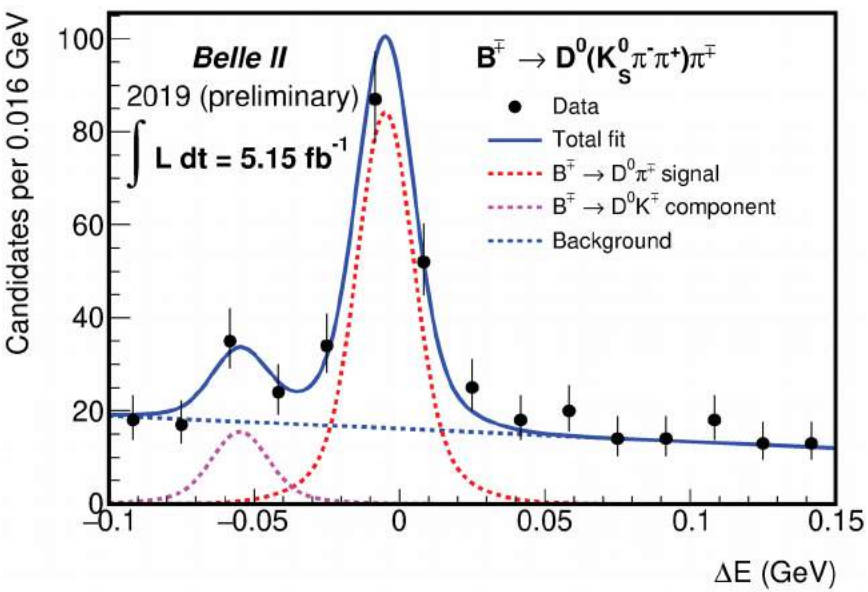
- Major milestone: rediscover the $B^+ \to D^0 K^+$ signal, next to the higher branching fraction mode $B^+ \to D^0 \pi^+$;
- Multivariate discriminator suppresses continuum background;
- Tight PID criteria for the $D^0 \to K\pi$, $K\pi\pi^0$, $K3\pi$ modes:

pionID (bachelor hadron) < 0.4

(53 ± 9 B → DK signal events)

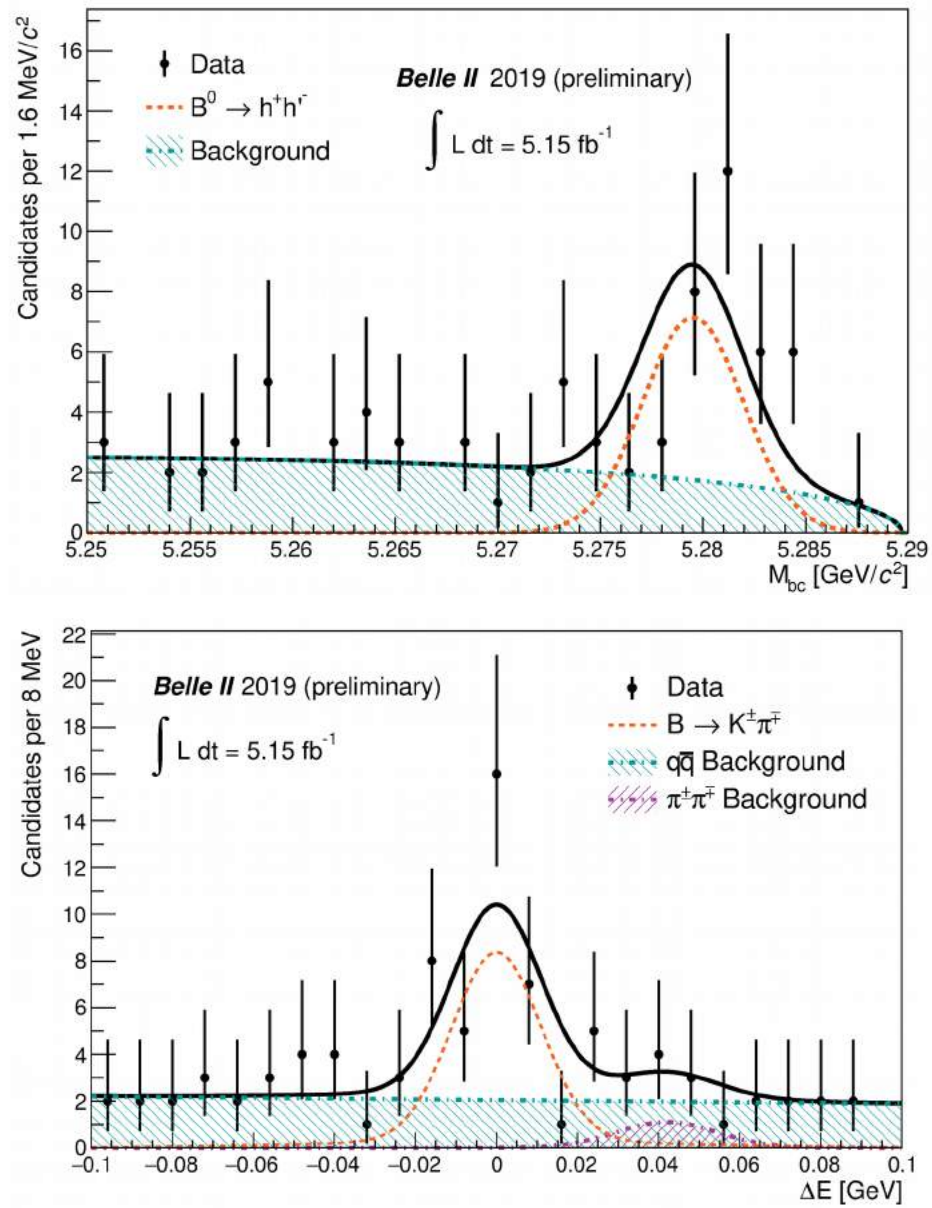
- Also the golden mode for the GGSZ analysis ($D^0 \to K_S\pi^+\pi^-$) is starting to show up.





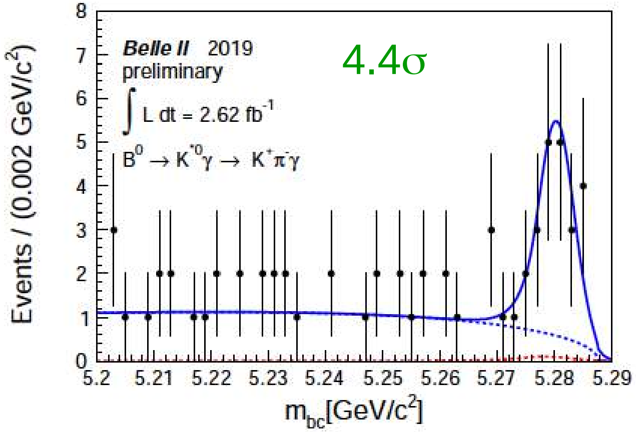
Rediscovery of B → h⁺h'⁻

- First milestone for the measurement of ϕ_2: rediscovery of the charmless $B \to h^+h'^-$ decays;
- Continuum background is suppressed using a BDT classifier utilizing variables sensitive to the event topology;
- Only very loose PID requirements on the final state particles;
- A clear signal (~25 events) is observed for the $K^+\pi^-$ mode;
- More statistics will be needed to observe the more elusive $\pi^+\pi^-$ signal.

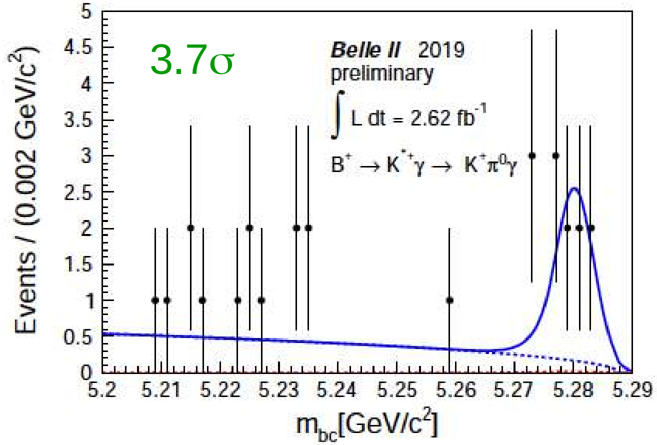


Rediscovery of $B \to K^{*}\gamma$

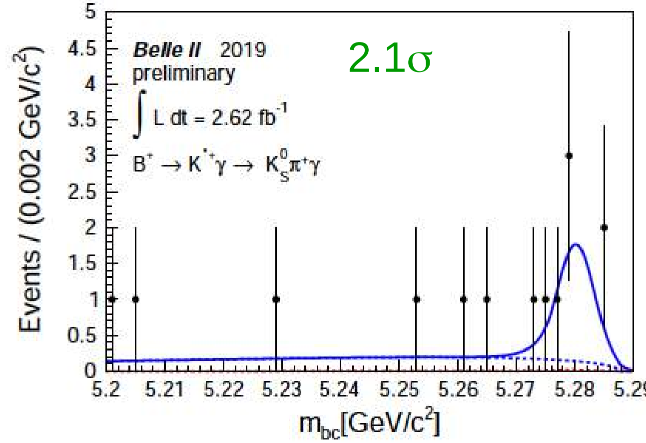
$K^{*0} \to K^{+}\pi^{-}$



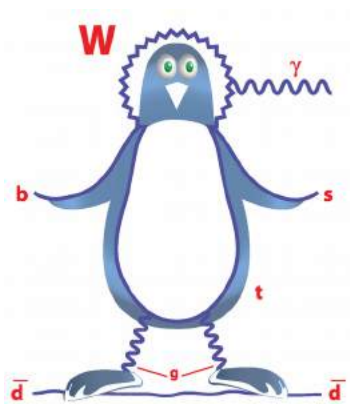
$K^{*+} \to K^{+}\pi^{0}$



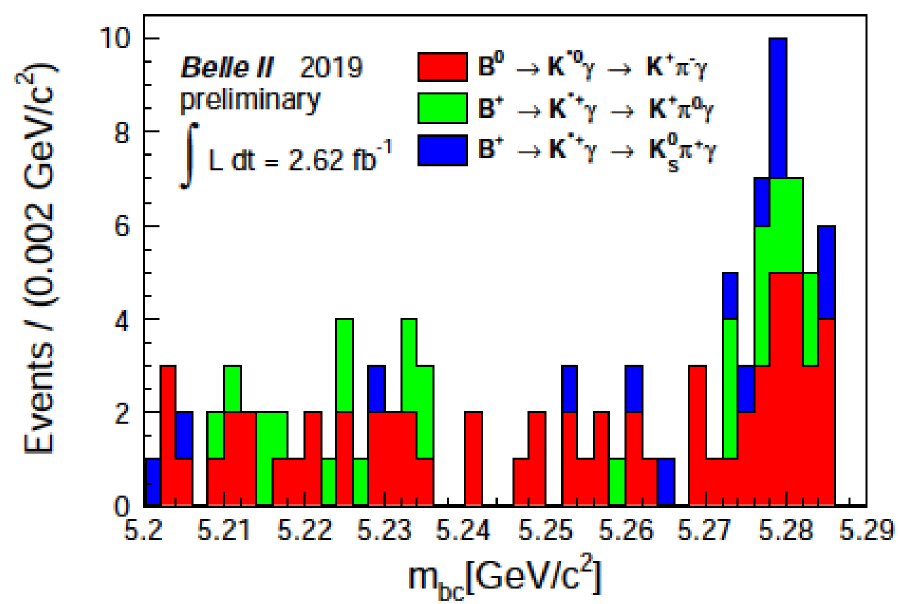
$K^{*+} \to K_S\pi^{+}$



Rediscovered $b \to s\gamma$ radiative penguins:



$N_{sig} = 35.5 \pm 6.9$

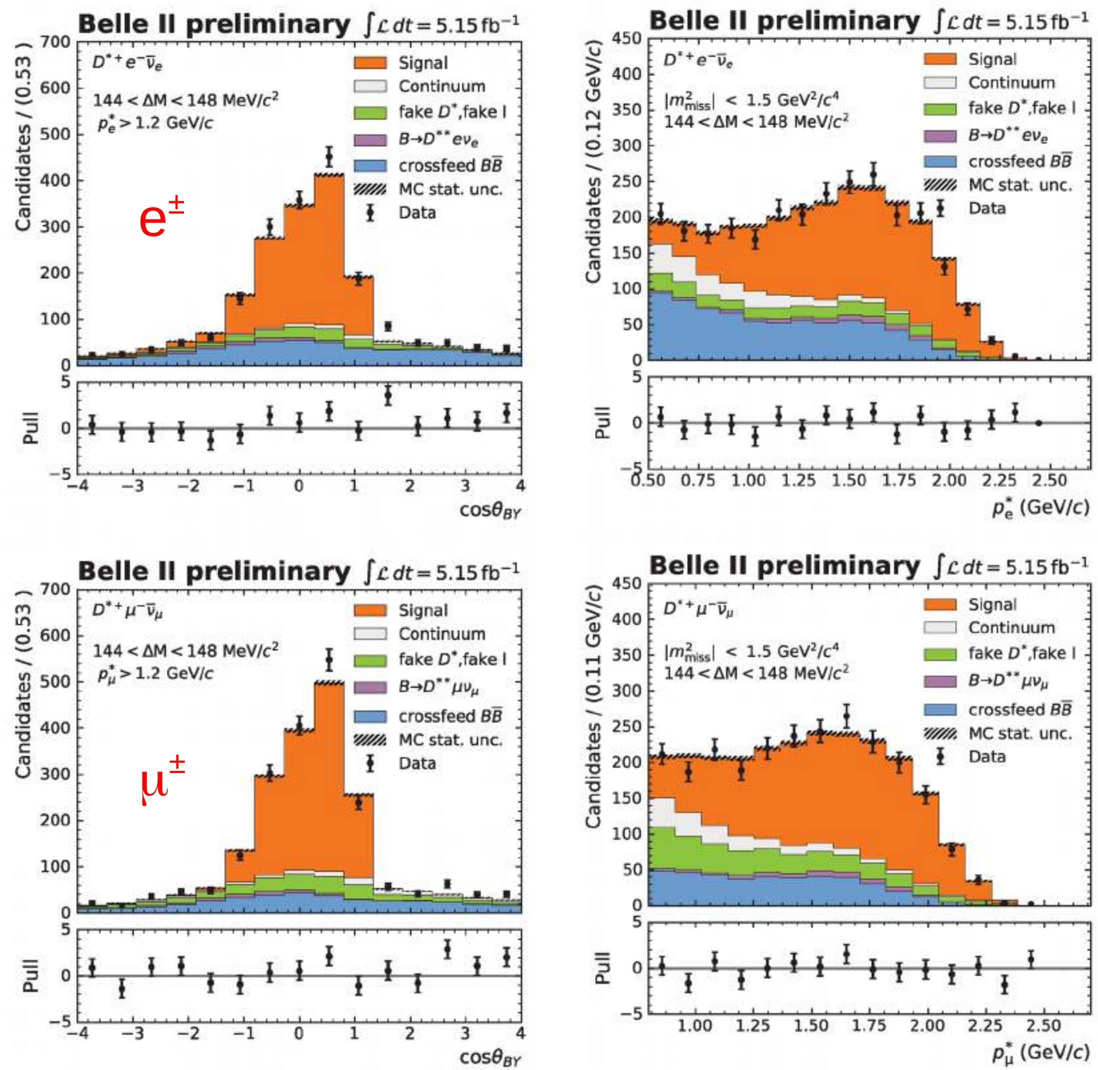


Untagged $B^0 \to D^{*-} l^+ \nu$

- Flagship decay channel for the measurement of $|V_{cb}|$;
- Fully reconstruct $D^{*-} \to D^\circ\pi^-$, with $\overline{D}^\circ \to K^+\pi^-$;
- Key variable: cosine of the angle between the B flight direction and the direction of the (D*l) system (Y):

$$\cos\theta_{BY} = \frac{2E_B^* E_Y^* - M_B^2 - m_Y^2}{2p_B^* p_Y^*}$$

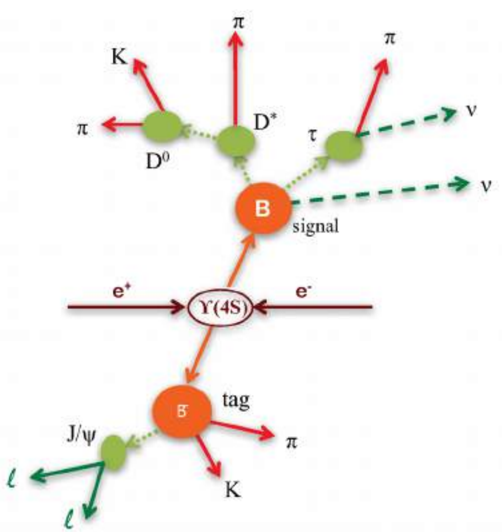
- Full scale test of Belle II's Lepton ID capabilities!

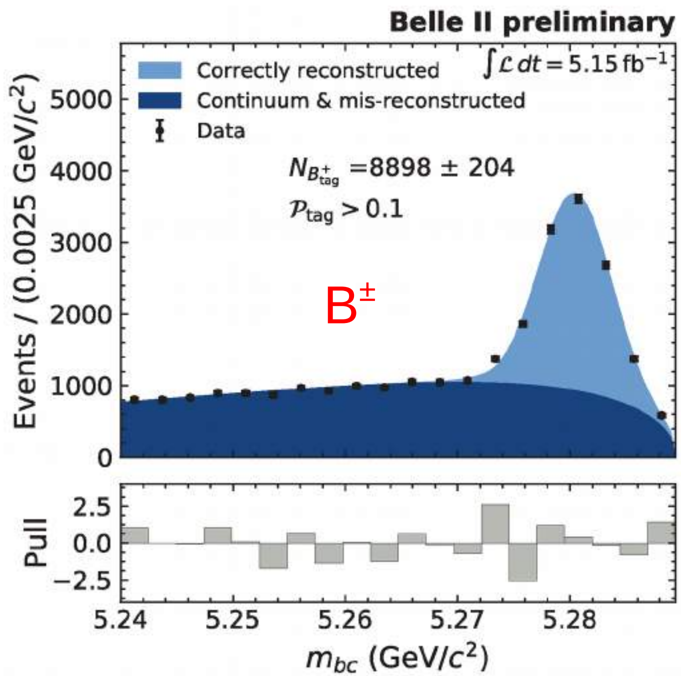


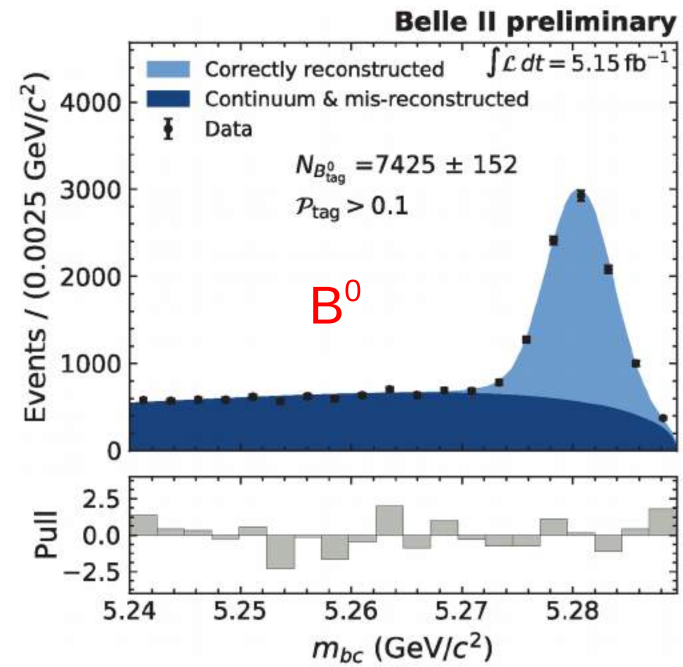
> 1000 events for both e and μ channels!

Full Event Interpretation

- Experimental challenge: SL decays involve at least one neutrino in the final state;
- In order to control the backgrounds we need good understanding of the event kinematics: great advantage of an experiment at an e^+e^- collider!
- Only at a B-factory: employ MVA's to reconstruct both B mesons (signal and tag side) in the event:







- In general: very wide range of measurements (techniques and final states) will take advantage of this technique.

arXiv: 1807.08680 [hep-ex]
Comput. Softw. Big Sci. 3 (2019) no.1, 6

The Belle II Physics Book

- The "Belle II Physics Book" has been recently accepted for publication by PTEP;
- This is the results of several years of collaboration between Belle II and the Theory Community;
- Sensititivity estimates on the golden (and silver) channels are given.

arXiv: 1808.10567
DOI: 10.1093/ptep/ptz106

200+ citations

KEK Preprint 2018-27
BELLE2-PAPER-2018-001
FERMILAB-PUB-18-398-T
JLAB-THY-18-2780
INT-PUB-18-047
UWThPh 2018-26

The Belle II Physics Book

E. Kou[74,¶,†], P. Urquijo[143,§,†], W. Altmannshofer[133,¶], F. Beaujean[78,¶], G. Bell[120,¶], M. Beneke[112,¶], I. I. Bigi[146,¶], F. Bishara[148,16,¶], M. Blanke[49,50,¶], C. Bobeth[111,112,¶], M. Bona[150,¶], N. Brambilla[112,¶], V. M. Braun[43,¶], J. Brod[110,133,¶], A. J. Buras[113,¶], H. Y. Cheng[44,¶], C. W. Chiang[91,¶], M. Ciuchini[58,¶], G. Colangelo[126,¶], H. Czyz[154,29,¶], A. Datta[144,¶], F. De Fazio[52,¶], T. Deppisch[50,¶], M. J. Dolan[143,¶], J. Evans[133,¶], S. Fajfer[107,139,¶], T. Feldmann[120,¶], S. Godfrey[7,¶], M. Gronau[61,¶], Y. Grossman[15,¶], F. K. Guo[41,132,¶], U. Haisch[148,11,¶], C. Hanhart[21,¶], S. Hashimoto[30,26,¶], S. Hirose[88,¶], J. Hisano[88,89,¶], L. Hofer[125,¶], M. Hoferichter[166,¶], W. S. Hou[91,¶], T. Huber[120,¶], S. Jaeger[157,¶], S. Jahn[82,¶], M. Jamin[124,¶], J. Jones[102,¶], M. Jung[111,¶], A. L. Kagan[133,¶], F. Kahlhoefer[1,¶], J. F. Kamenik[107,139,¶], T. Kaneko[30,26,¶], Y. Kiyo[63,¶], A. Kokulu[112,138,¶], N. Kosnik[107,139,¶], A. S. Kronfeld[20,¶], Z. Ligeti[19,¶], H. Logan[7,¶], C. D. Lu[41,¶], V. Lubicz[151,¶], F. Mahmoudi[140,¶], K. Maltman[171,¶], S. Mishima[30,¶], M. Misiak[164,¶],

Process	Observable	Theory	Sys. dom. (Discovery) [ab^{-1}]	vs LHCb	vs Belle	Anomaly	NP
$B \to \pi \ell \nu_\ell$	$\|V_{ub}\|$	⋆⋆⋆	10-20	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆
$B \to X_u \ell \nu_\ell$	$\|V_{ub}\|$	⋆⋆	2-10	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆
$B \to \tau \nu$	$Br.$	⋆⋆⋆	>50 (2)	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \mu \nu$	$Br.$	⋆⋆⋆	>50 (5)	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to D^{(*)} \ell \nu_\ell$	$\|V_{cb}\|$	⋆⋆⋆	1-10	⋆⋆⋆	⋆⋆	⋆⋆	⋆
$B \to X_c \ell \nu_\ell$	$\|V_{cb}\|$	⋆⋆⋆	1-5	⋆⋆⋆	⋆⋆	⋆⋆	⋆⋆
$B \to D^{(*)} \tau \nu_\tau$	$R(D^{(*)})$	⋆⋆⋆	5-10	⋆⋆	⋆⋆⋆	⋆⋆⋆	⋆⋆⋆
$B \to D^{(*)} \tau \nu_\tau$	P_τ	⋆⋆⋆	15-20	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆
$B \to D^{**} \ell \nu_\ell$	$Br.$	⋆	-	⋆⋆	⋆⋆⋆	⋆⋆	-

Process	Observable	Theory	Sys. dom. (Discovery) [ab^{-1}]	vs LHCb	vs Belle	Anomaly	NP
$B \to J/\psi K_S^0$	ϕ_1	⋆⋆⋆	5-10	⋆⋆	⋆⋆	⋆	⋆
$B \to \phi K_S^0$	ϕ_1	⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \eta' K_S^0$	ϕ_1	⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \rho^\pm \rho^0$	ϕ_2	⋆⋆⋆	>50	⋆	⋆⋆⋆	⋆	⋆
$B \to J/\psi \pi^0$	ϕ_1	⋆⋆⋆	>50	⋆	⋆⋆⋆	-	-
$B \to \pi^0 \pi^0$	ϕ_2	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆
$B \to \pi^0 K_S^0$	S_{CP}	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆

Conclusions

- The Belle II Experiment is at the beginning of its long journey;
- The dataset collected so far is O(1%) of the BaBar/Belle datasets: enough to establish the performance of the detector, but not yet to probe new territory (in most cases);
- The first Belle II paper was submitted for publication, the second is on its way!
- Many nice results were shown at last Summer Conferences, proving that the experiment can process, calibrate, and analyze the data in a short time;
- We are looking forward to the next Winter (~10 fb^{-1}) and Summer (~200 fb^{-1}) Conferences!

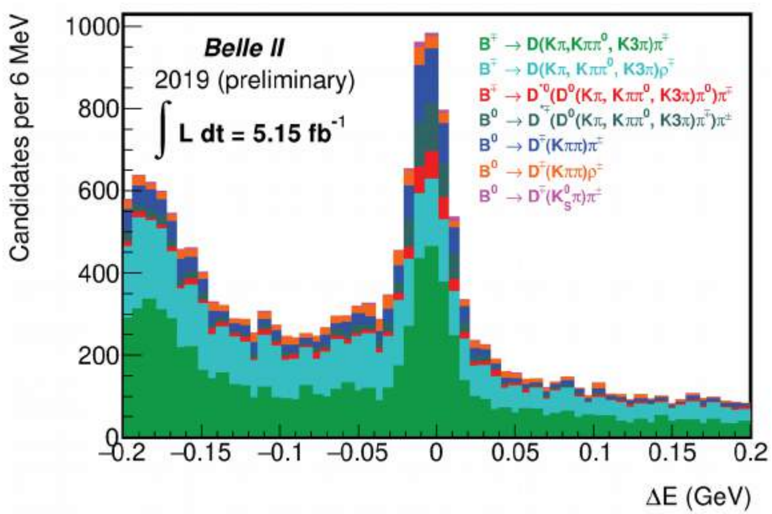
Backup Slides

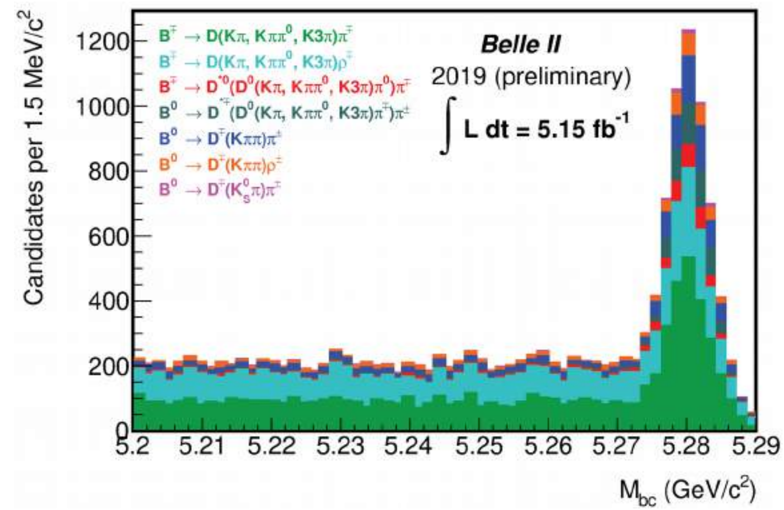
B-factory jargon

Two variables are extremely useful to discriminate against background for fully reconstructed final states:

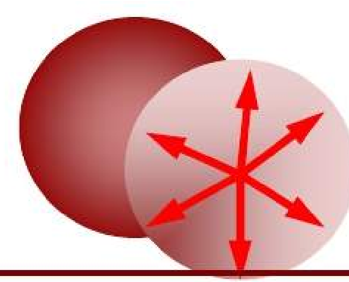
$$\Delta E = E_B^* - \frac{\sqrt{s}}{2}$$

$$M_{bc} = \sqrt{\frac{s}{4} - p_B^{*2}}$$





For many final states, the dominant source of background is the 'continuum', which is suppressed based on the different topology with respect to $B\bar{B}$ events:

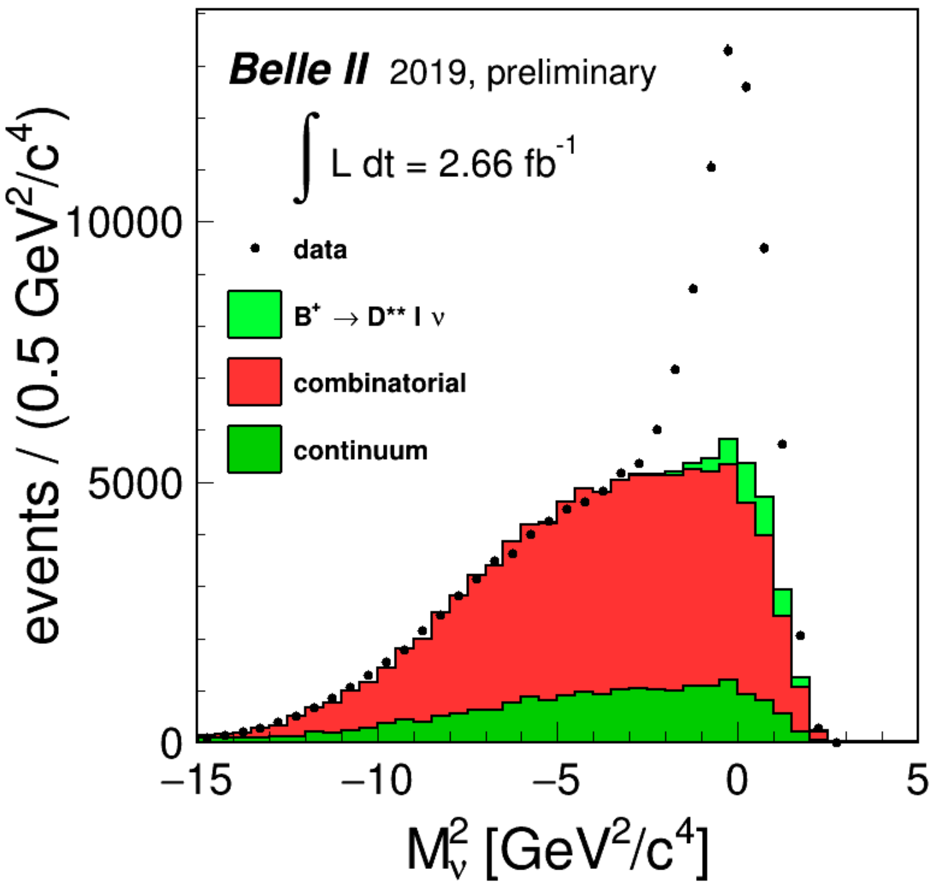


Spherical BB events

Jet-like qq events

Rediscovery of $B\bar{B}$ mixing

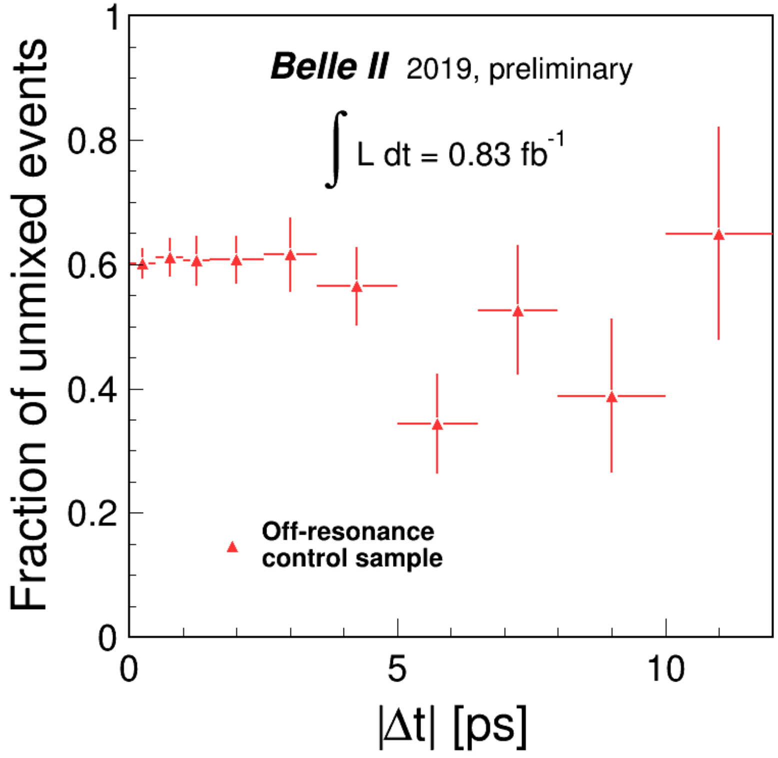
- One partially reconstructed $B^0 \rightarrow D^{*-} l^+ \nu$ candidate in the event is required;
- Major background: $B\bar{B}$ combinatorial, estimated from the data using same-sign (π_s, l) pairs, and normalizing to the $M^2_\nu < -3$ GeV^2 sideband;
- Continuum is taken from the off-resonance sample (taking into account the integrated luminosity ratio with the on-resonance);
- The fraction of peaking backgrounds within the peaking component is taken from the simulation.



~35k peaking B^0 events

Rediscovery of $B\bar{B}$ mixing

Channel	Data
Untagged e only	18514 ± 1128
Untagged μ only	16625 ± 1111
Untagged (e or μ)	35492 ± 2209
Tagged unmixed (N_U)	1642 ± 133
Tagged mixed (N_M)	253 ± 45
($\varepsilon_U/\varepsilon_M$) correction factor	1.35 ± 0.10
χ_d (fraction of mixed events)	$(17.2 \pm 3.6)\%$



Experimentally:

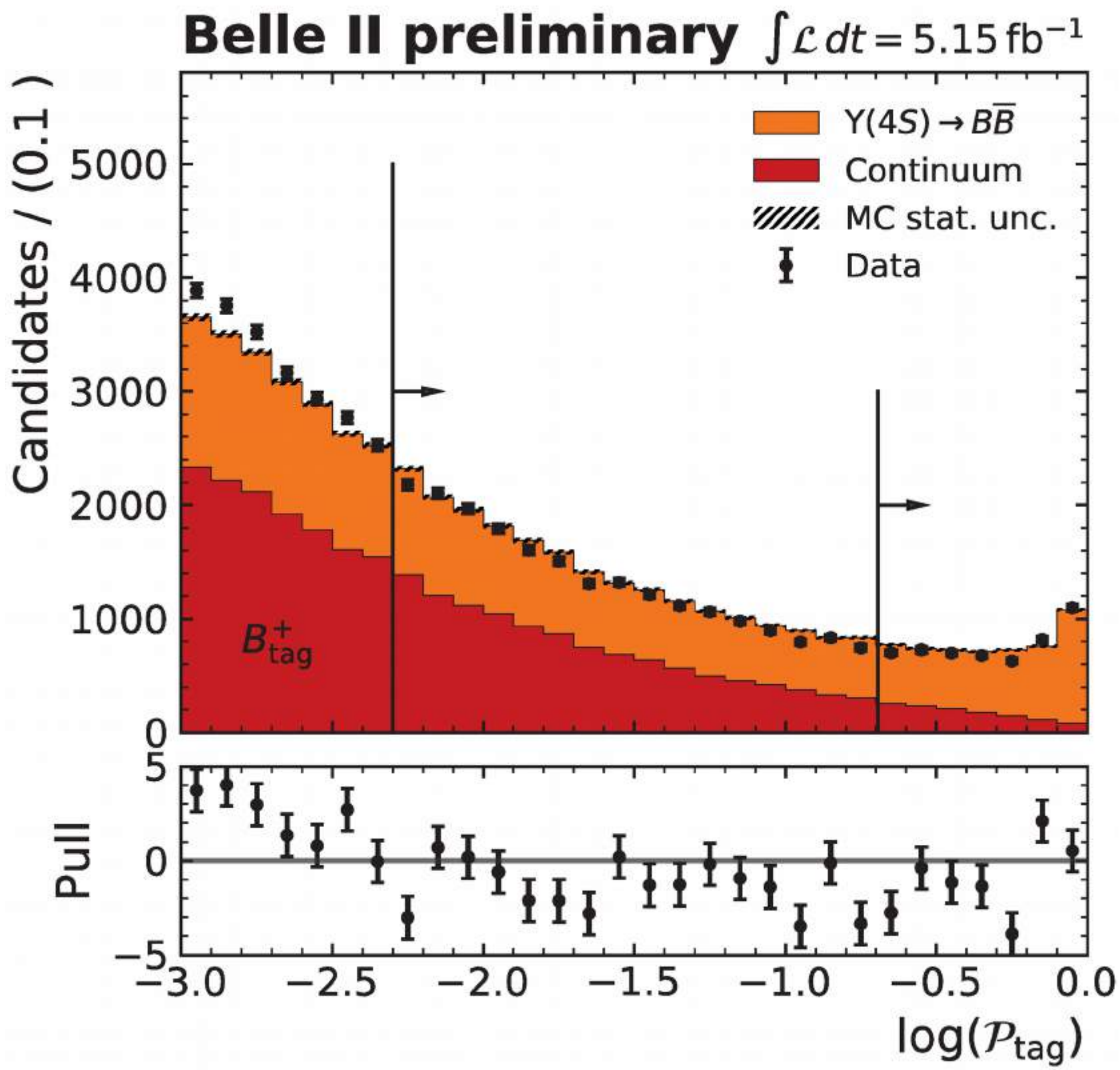
$$\chi_d = \frac{N_M/\varepsilon_M}{N_U/\varepsilon_U + N_M/\varepsilon_M} = \frac{N_M \cdot \left(\frac{\varepsilon_U}{\varepsilon_M}\right)}{N_U + N_M \cdot \left(\frac{\varepsilon_U}{\varepsilon_M}\right)}$$

χ^2 probability of a fit with a flat line: ~13%

Connection with τ_B and Δm:

$$\chi_d = \frac{\tau_{B^0}^2 \Delta m^2}{2(1 + \tau_{B^0}^2 \Delta m^2)}$$

FEI probability

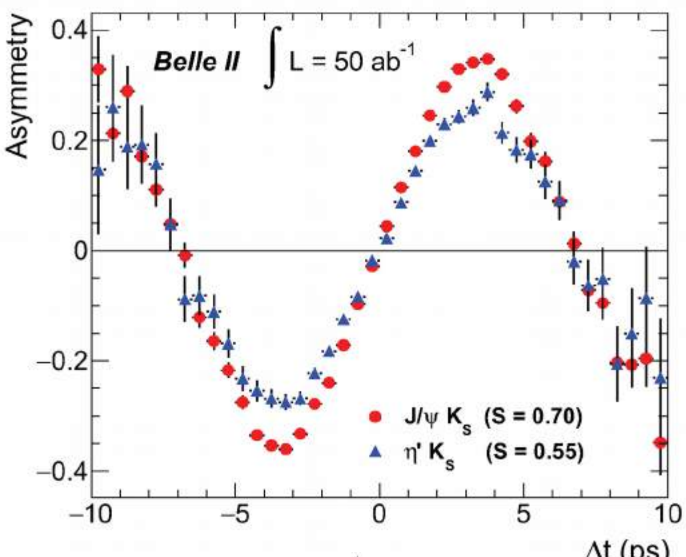


$\sin 2\phi_1$: status and motivations

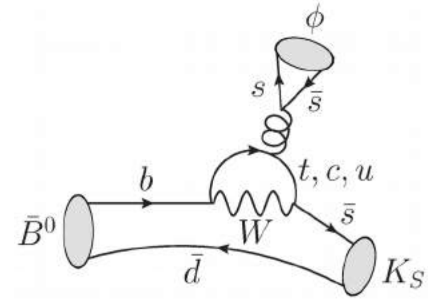
- On the golden modes ($B^\circ \to c\bar{c}\, K^\circ$) we are definitely in the precision era:

Int. lumi: 426 fb^{-1}	BaBar:	$S = 0.687 \pm 0.028 \pm 0.012$	PRD **79**, 072009 (2009)
Int. lumi: 711 fb^{-1}	Belle:	$S = 0.667 \pm 0.023 \pm 0.012$	PRL **108**, 171802 (2012)
Int. lumi: 3.0 fb^{-1}	LHCb:	$S = 0.731 \pm 0.035 \pm 0.020$	PRL **115**, 031601 (2015)

HFLAV Average: $S = 0.691 \pm 0.017$



- Challenge both for the **experiment** (the measurement will be systematics dominated) and for the **theory** (no longer possible to neglect penguin pollution);
- Additional motivation: compare the time-dependent asymmetry between tree- and loop-dominated modes, New Physics could produce a sizable shift.



$\sin 2\phi_1$: projections

- Breakdown of systematics:

		No improvement	Vertex improvement	Leptonic categories
Time-dependent CP asymmetry	$S_{c\bar{c}s}$ (50 ab^{-1})			
	stat.	0.0027	0.0027	0.0048
	syst. reducible	0.0026	0.0026	0.0026
	syst. irreducible	0.0070	0.0036	0.0035
Direct CP asymmetry	$A_{c\bar{c}s}$ (50 ab^{-1})			
	stat.	0.0019	0.0019	0.0033
	syst. reducible	0.0014	0.0014	0.0014
	syst. irreducible	0.0106	0.0087	0.0035

Two major irreducible systematics:

1) vertex detector alignment;

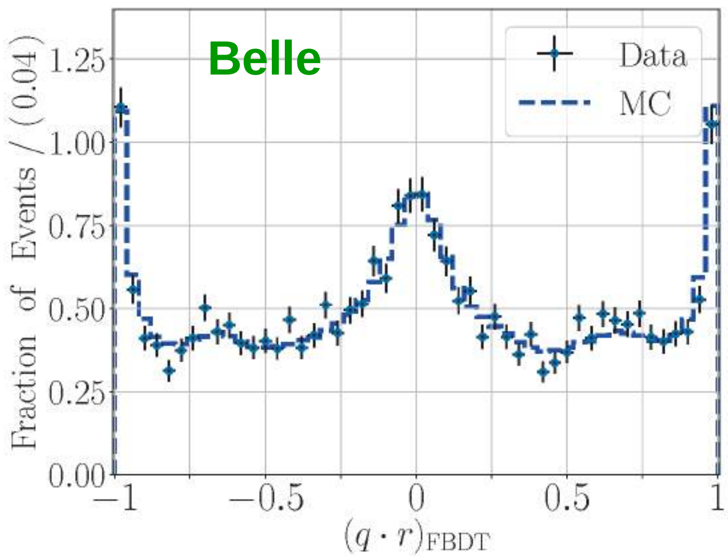
2) Doubly Cabibbo Suppressed decays on tag-side (does not affect leptonic categories)

- Prospects on the golden channels: Belle II will lead on most penguin dominated modes.

	WA (2017)		5 ab^{-1}		50 ab^{-1}	
Channel	$\sigma(S)$	$\sigma(A)$	$\sigma(S)$	$\sigma(A)$	$\sigma(S)$	$\sigma(A)$
$J/\psi K^0$	0.022	0.021	0.012	0.011	0.0052	0.0090
ϕK^0	0.12	0.14	0.048	0.035	0.020	0.011
$\eta' K^0$	0.06	0.04	0.032	0.020	0.015	0.008
ωK_S^0	0.21	0.14	0.08	0.06	0.024	0.020
$K_S^0 \pi^0 \gamma$	0.20	0.12	0.10	0.07	0.031	0.021
$K_S^0 \pi^0$	0.17	0.10	0.09	0.06	0.028	0.018

Belle II Flavor Tagger

We can test the performance of the new Flavor Tagger on Belle data converted to Belle II format:



FBDT Combiner

r- Interval	ε_i	$w_i \pm \delta w_i$	$\varepsilon_{\mathrm{eff},i} \pm \delta\varepsilon_{\mathrm{eff},i}$
0.000 − 0.100	15.49	47.61 ± 0.04	0.035 ± 0.002
0.100 − 0.250	15.81	41.42 ± 0.06	0.465 ± 0.014
0.250 − 0.500	19.88	31.57 ± 0.09	2.695 ± 0.066
0.500 − 0.625	10.68	21.87 ± 0.06	3.375 ± 0.110
0.625 − 0.750	11.52	15.68 ± 0.06	5.416 ± 0.169
0.750 − 0.875	9.68	9.39 ± 0.07	6.372 ± 0.219
0.875 − 1.000	16.77	2.32 ± 0.05	15.226 ± 0.382
Total	$\varepsilon_{\mathrm{eff}} = \sum_i \varepsilon_i \cdot \langle 1 - 2w_i \rangle^2 = 33.6 \pm 0.5$		

$$\varepsilon_{\mathrm{eff}} = \sum_i \varepsilon_i (1 - 2\, w_i)^2$$

$\varepsilon_{\mathrm{eff}}$: effective tagging efficiency

ε_i: efficiency of category i

w_i: mis-tagging probability of category i

Summary

Old FT - Belle data: $\varepsilon_{\mathrm{eff}}$ = (30.1 ± 0.4)%

New FT - Belle data: $\varepsilon_{\mathrm{eff}}$ = (33.6 ± 0.5)%

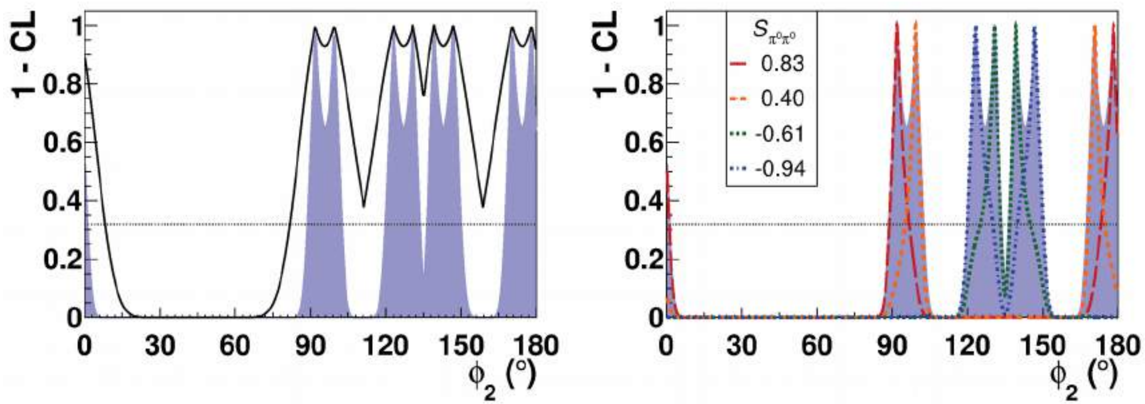
New FT - Belle MC: $\varepsilon_{\mathrm{eff}}$ = (34.18 ± 0.03)%

New FT - Belle II MC: $\varepsilon_{\mathrm{eff}}$ = (37.16 ± 0.03)%

More than 10% relative improvement on the same dataset!

TD CPV analysis of $B^0 \to \pi^0\pi^0$

- Only at Belle II: TD CPV of $B^0 \to \pi^0\pi^0$, exploiting π^0 Dalitz decays and γ conversions;
- Expect ~270 signal events with full dataset;
- Predicted error on S^{00} ~ 0.28;
- This would reduce the ambiguity on ϕ_2 by a factor 2 or 4 (depending on central value);

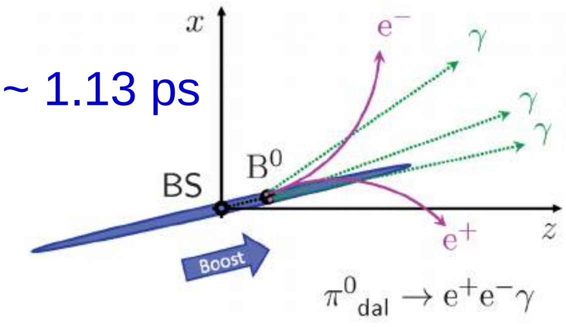


Filled area: extrapolation of Belle results to Belle II sensitivity.

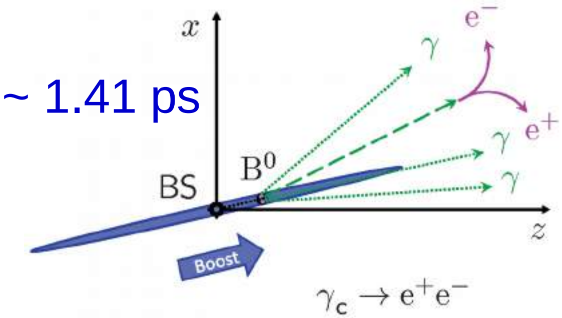
Dashed line: same as above, but adding S^{00}.

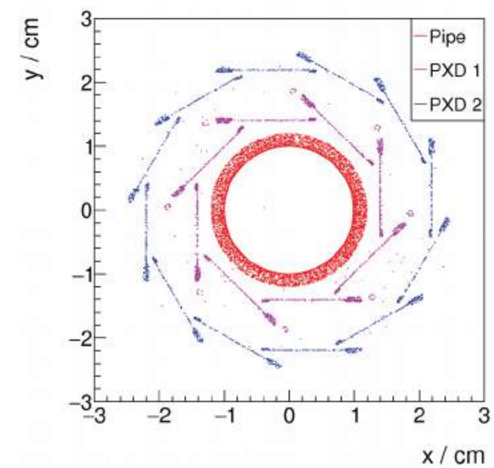
- Final precision at Belle II (50 ab^{-1}) from $B \to \pi\pi$ and $B \to \rho\rho$: $\sigma(\phi_2)$ ~ 0.6°.

Δt_{res} ~ 1.13 ps



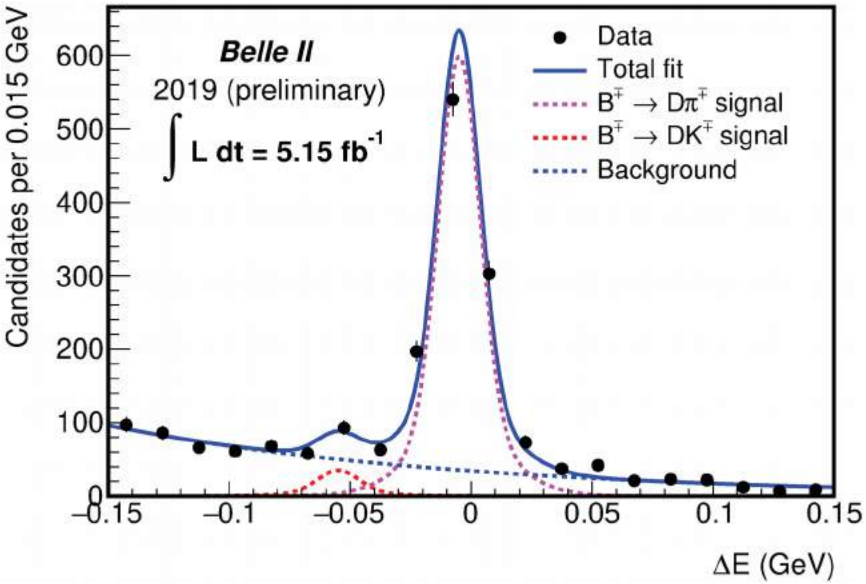
Δt_{res} ~ 1.41 ps

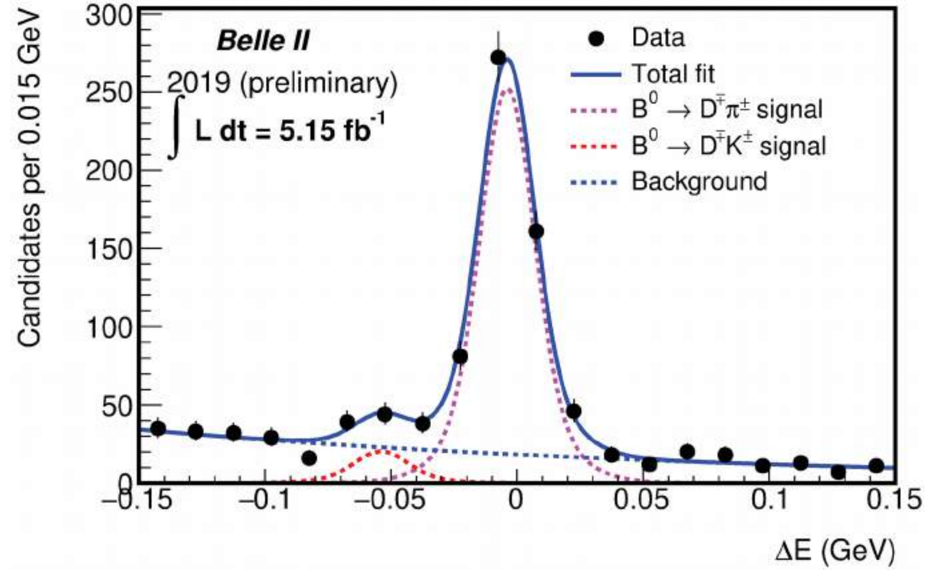




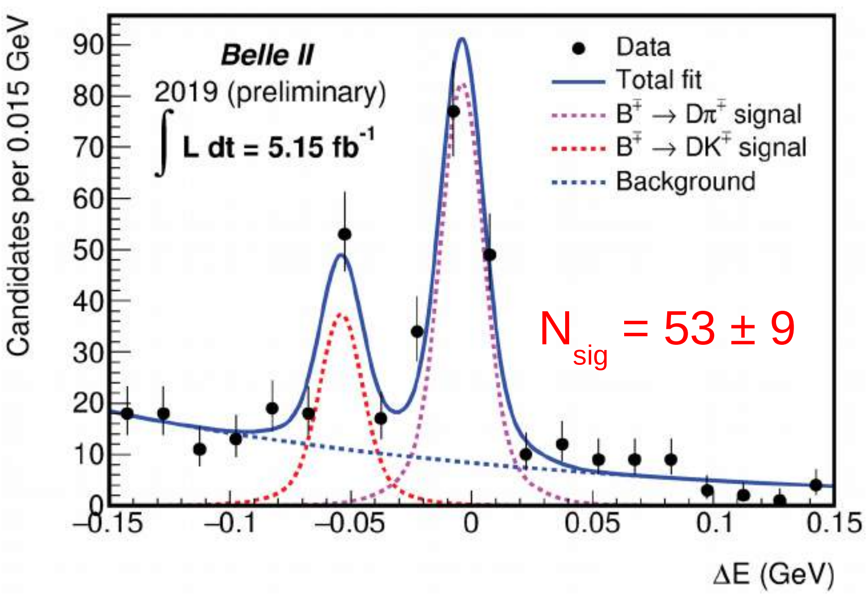
Rediscovery of B → DK

No PID on bachelor hadron

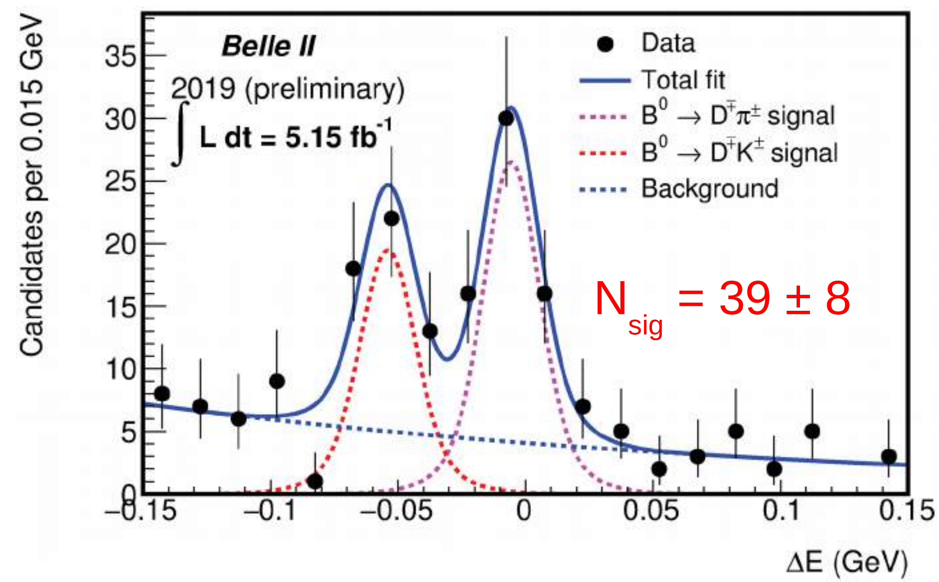




PID requirement on bachelor hadron



A. Gaz



Beam Energy Spread