The Belle II experiment: status and first results

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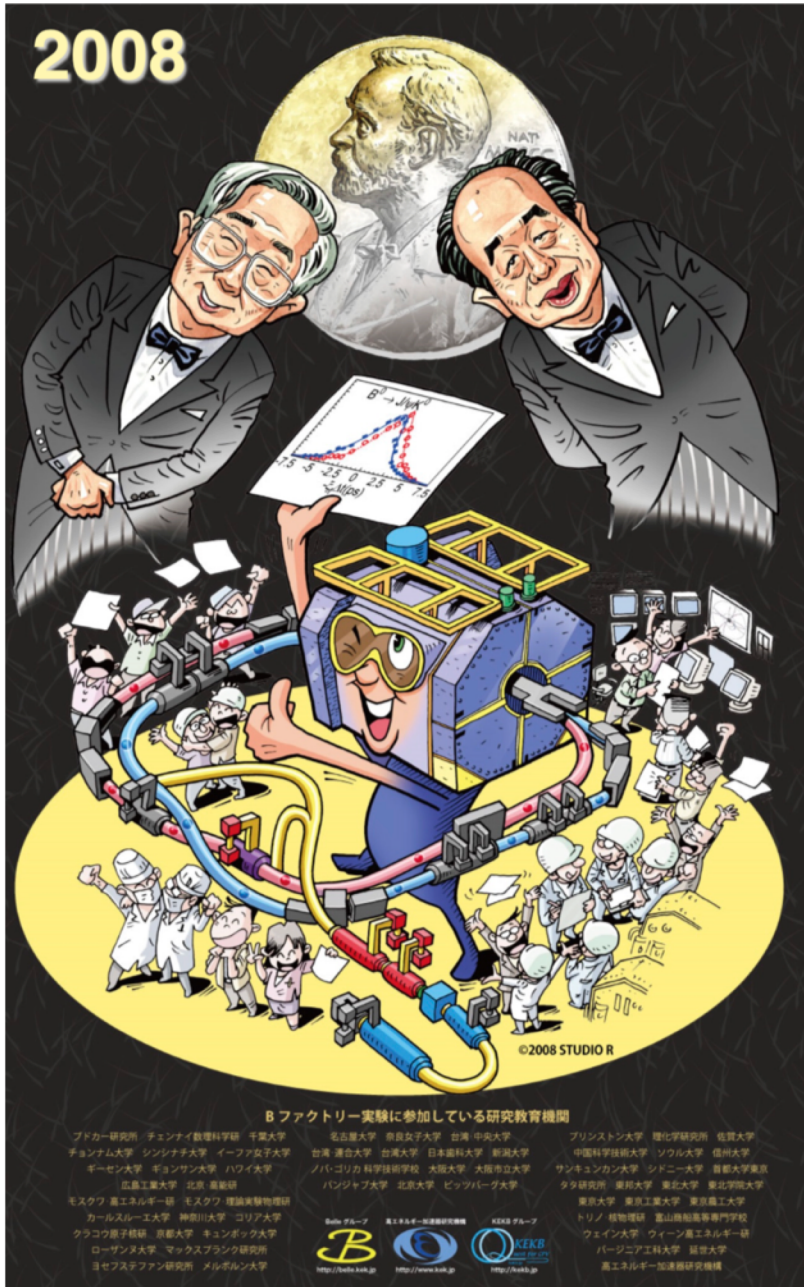
QFTHEP, September 25, 2019

Belle/BaBar era – confirming the Standard model (SM)

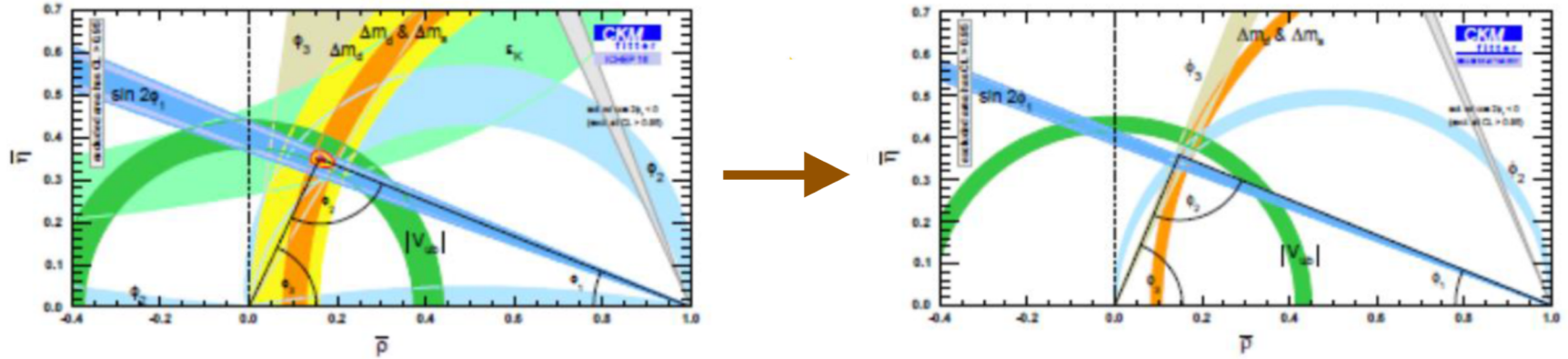
- Data collection period: 1999-2010
- The main goal of these experiments was:
  - observation and precise measurements of *CP*-violation in *B*-decays
    - sin2β is still the most precise measurement in the World
- Also many other results were obtained:
  - precise measurements of all CKM parameters
  - study of heavy flavor spectroscopy, including many unexpected results:
    - exotic states observations, starting from *X(3872)*
    - new bottomonium states
  - studies of τ, $\gamma\gamma$ and rare decays
  - etc.
- More than 1000 papers were published by Belle & BaBar

The success of these experiments led to the Nobel prize for Kobayashi and Maskawa in 2008



Belle II: new experiment – new goal: search for New Physics

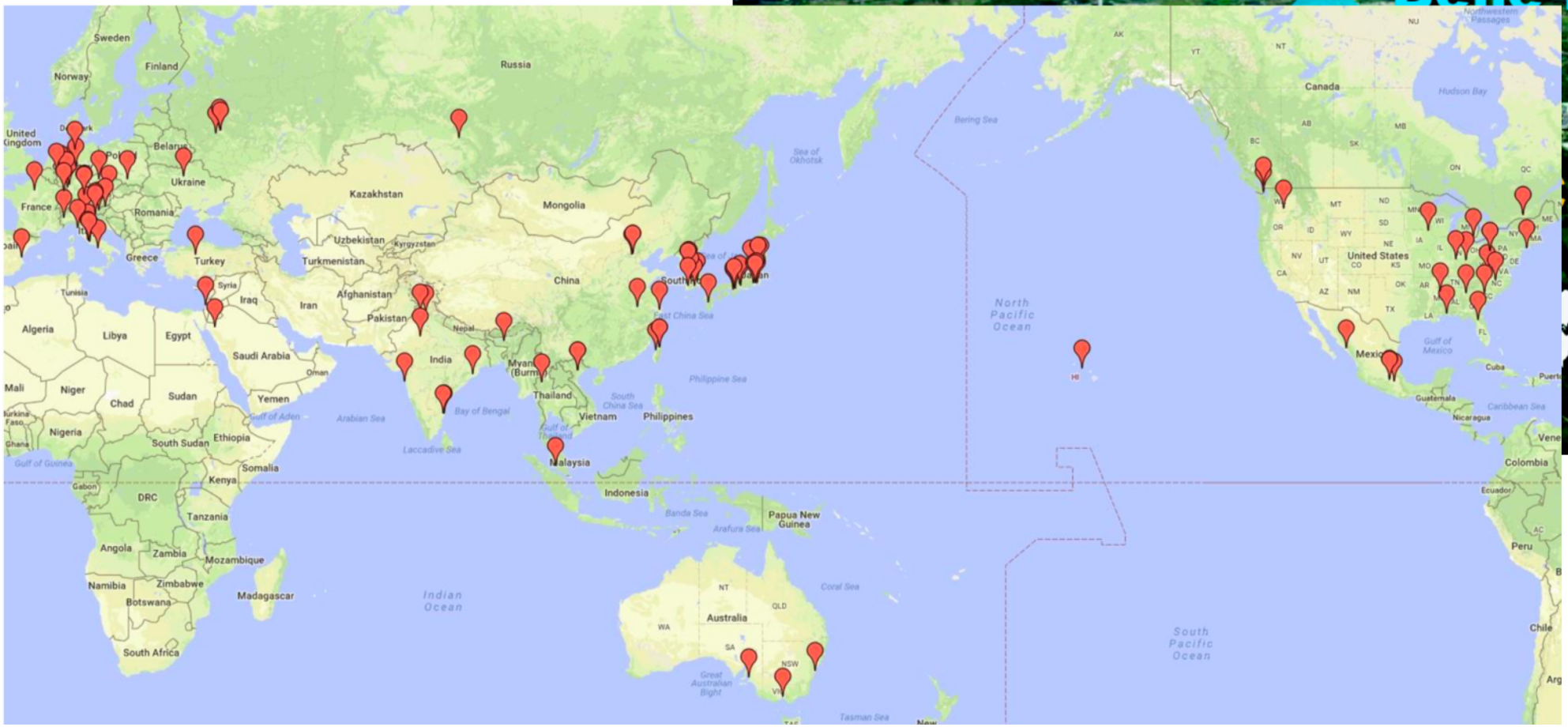
- With total statistics of ≈1.5 ab^{-1} accumulated by Belle & BaBar no significant deviations from Standard model were observed
- Belle II will test SM on the next level using 50 ab^{-1} data (x 50 of Belle data)
  - *CP*V in $b \to s$ – search for new *CP*V phase to explain a large matter-antimatter asymmetry in the Universe
  - precise measurements of CKM – search for NP in the Unitarity triangle inconsistency



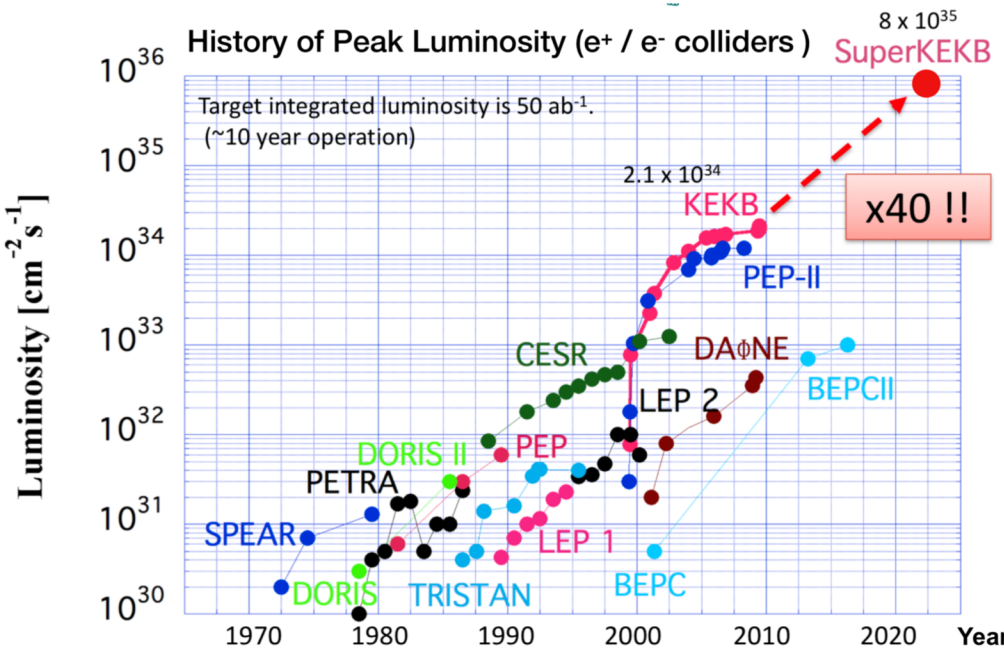
  - BR of $B^+ \to l^+ \nu$ and $B \to D^{(*)} \tau \nu$ – search for charged Higgs
  - *CP*V in $B \to K^{*0} \gamma$ – search for left-right asymmetry
  - $b \to s\, l^+ l^-$, $s \nu \nu$ – search for New Physics (NP) in FCNC transitions
  - search for exotics states, like tetraquakrs, pentaquarks and hybrid QCD states
  - study of τ decays – search for LFV
  - direct searches for new light states, dark sector

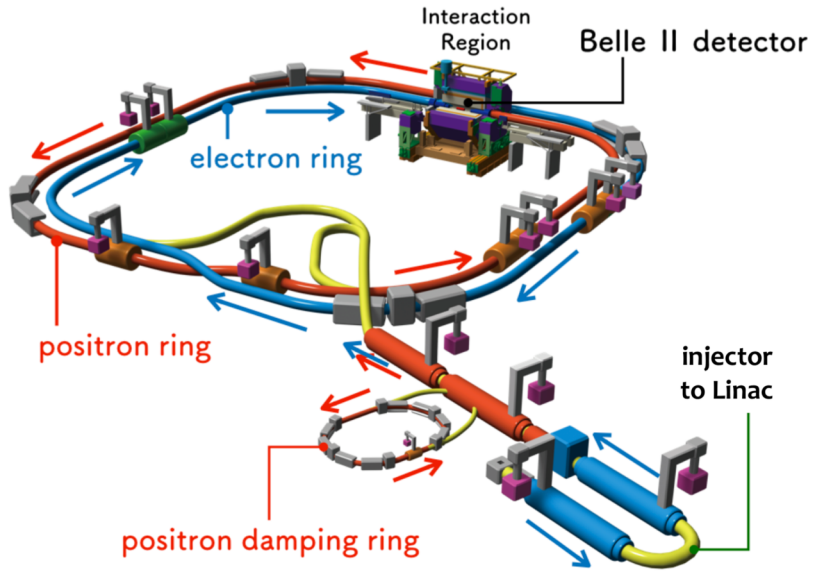
Belle II experiment

Belle II Collaboration contains over 900 members from 26 countries and is actively growing

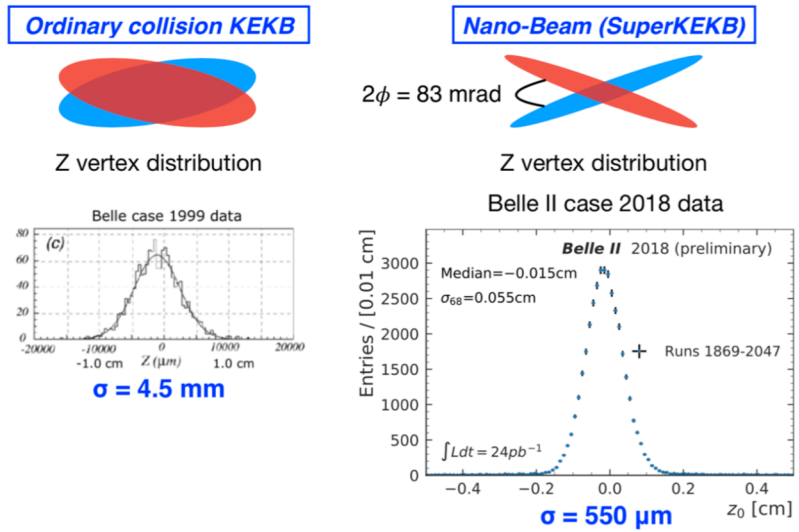


Upgrade of KEKB accelerator to SuperKEKB





$$e^- \xrightarrow{7\ \text{GeV}} (\star) \xleftarrow{4\ \text{GeV}} e^+$$

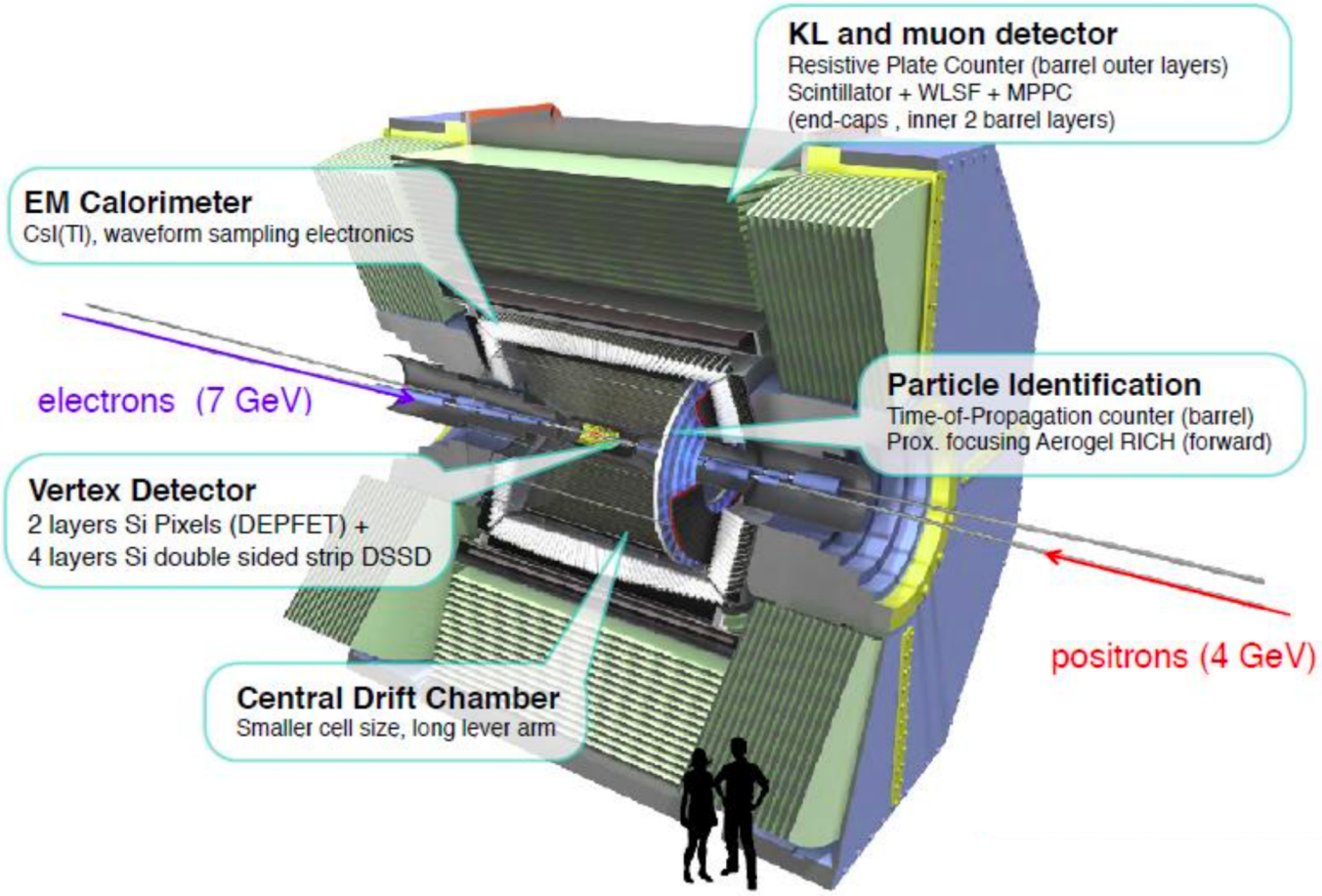


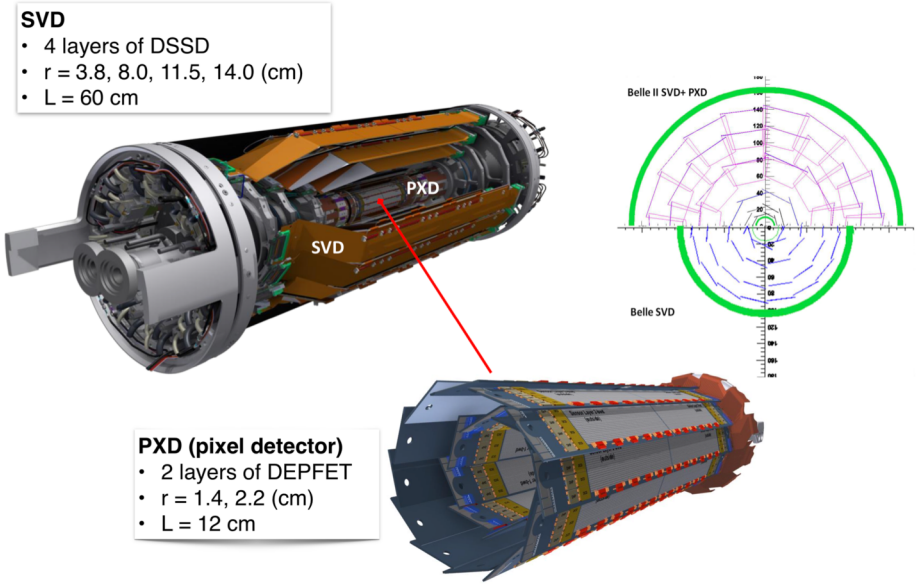
$$\mathcal{L} = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_{\mathcal{L}}}{R_{\xi_y}}\right)$$

- Doubling the beam current
- Reducing the beam size by factor 20 at IP

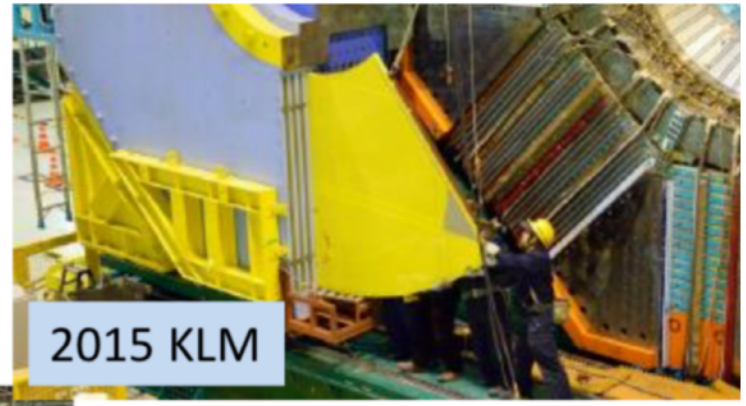
Upgrade from Belle detector to Belle II

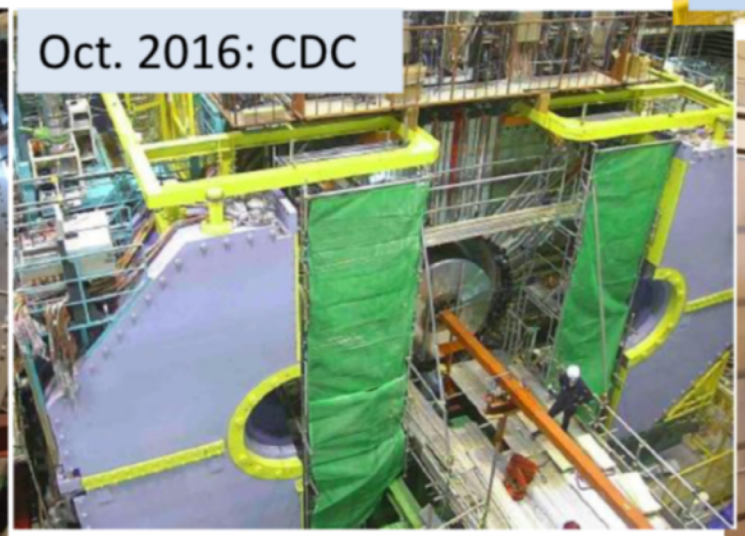
- Higher luminosity → higher occupancy & background level
- Upgrade of all Belle detector subsystems was done

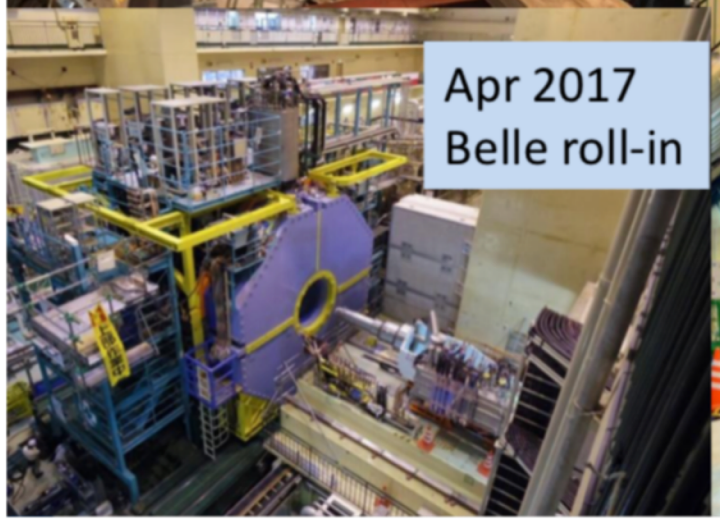


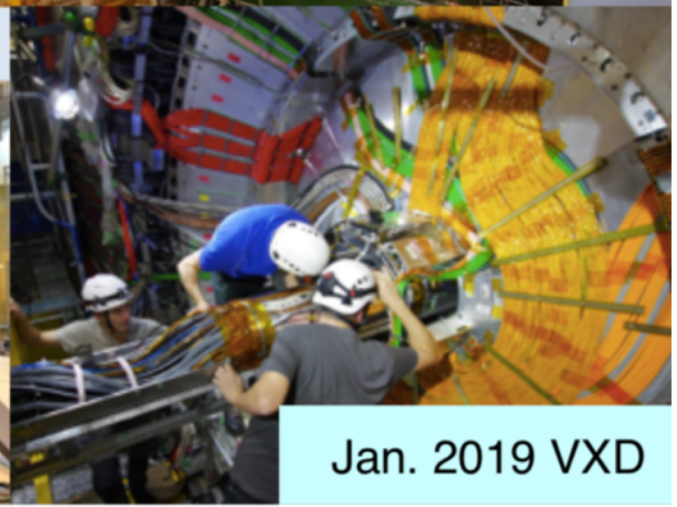


Belle II detector commissioning

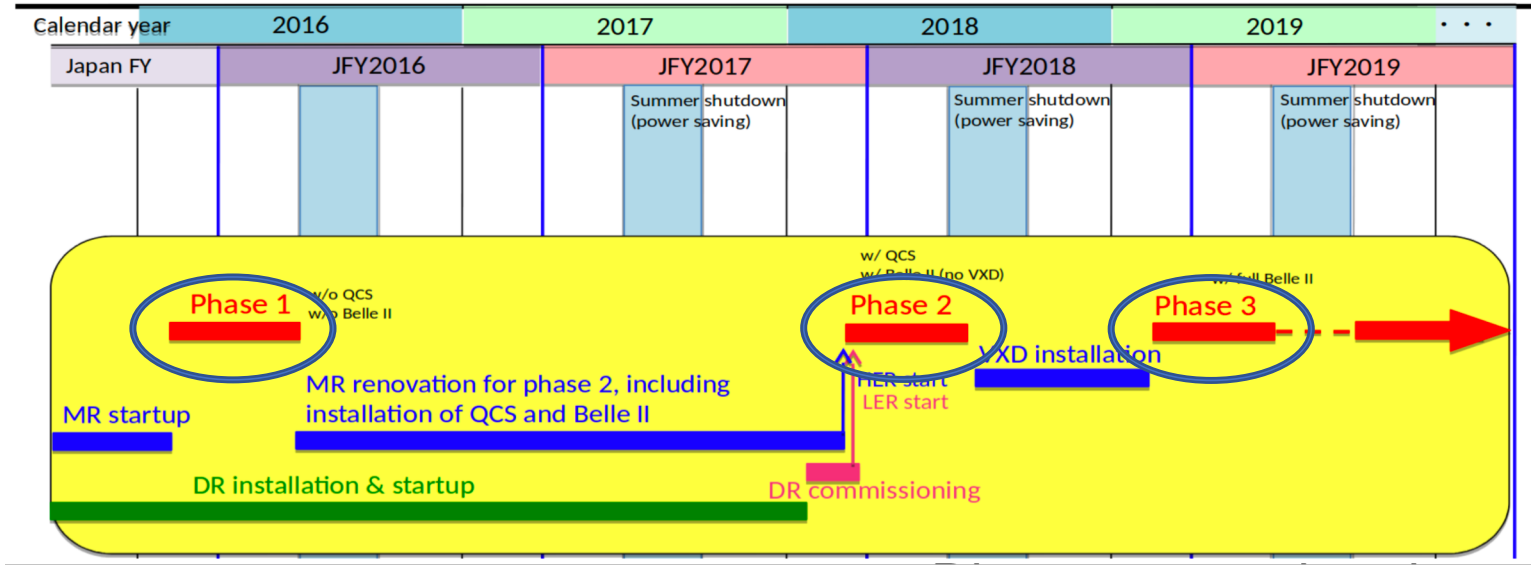


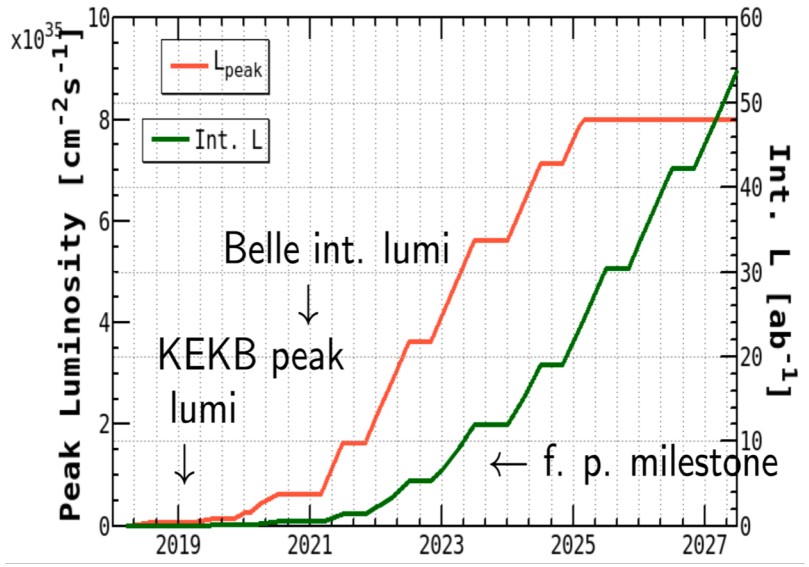




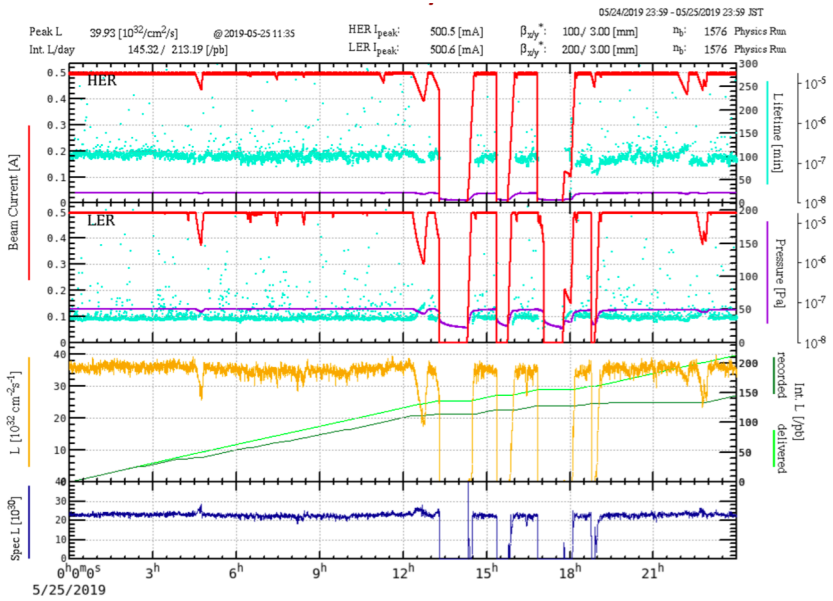


SuperKEKB & Belle II schedule





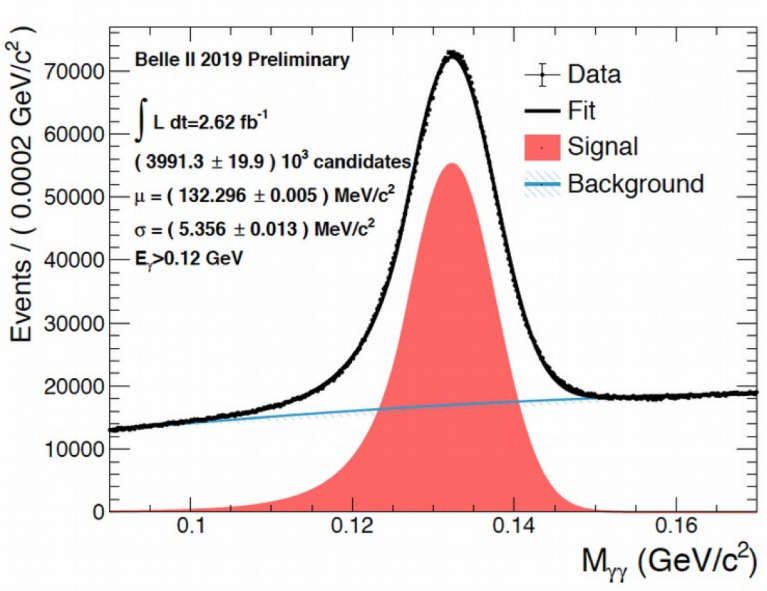
- Phase 1: SuperKEKB commissioning w/o final focus w/o Belle II
- Phase 2: collision w/ final focus w/ Belle II w/o VXD **(500 pb^{-1} recorded)**
- Phase 3: collision w/ full Belle II (March 25 – June, 2019) **(6.49 fb^{-1} recorded)**

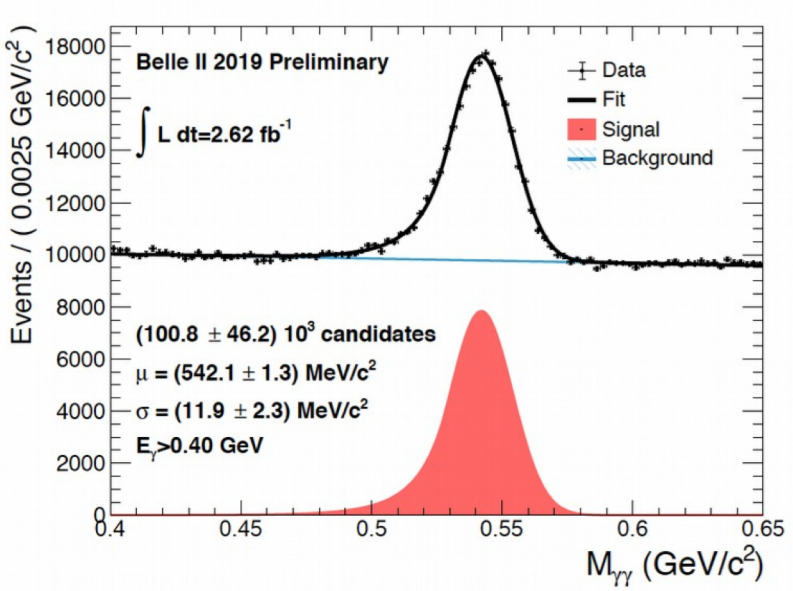


Continuous injection is operating (May 25, 2019)

Checking detector performance

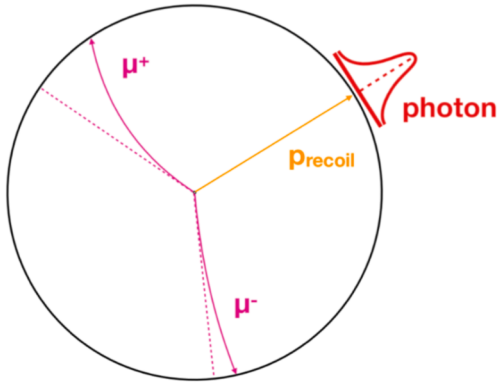
Electro-magnetic calorimeter

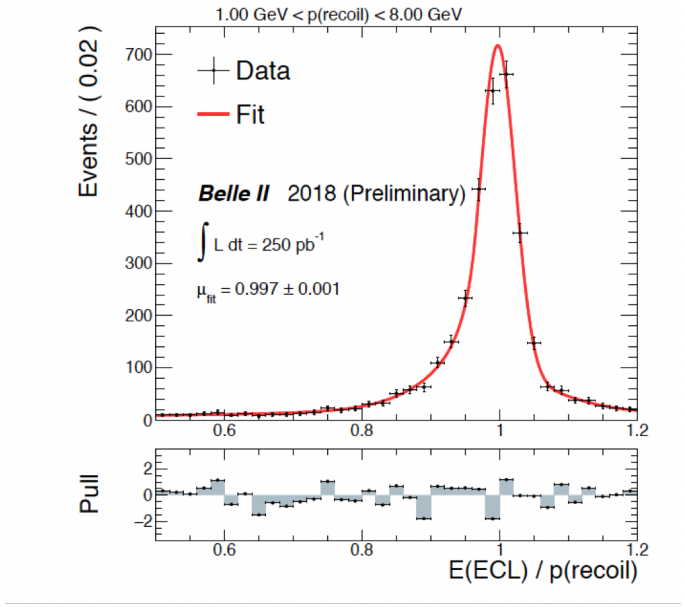




Proper π^0 & η masses –
good EM calorimeter calibration

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





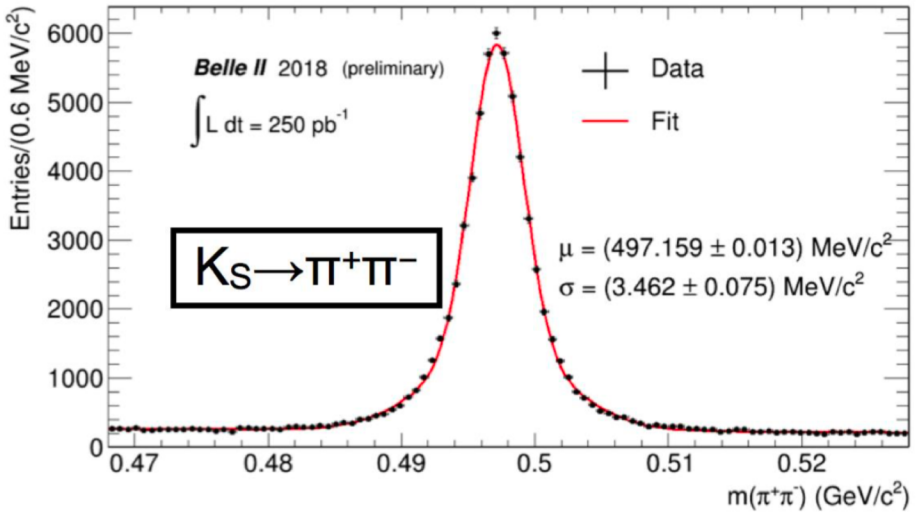
Important for dark matter search with single / triple photon triggers:

$e^+e^- \to \gamma\, X$

$e^+e^- \to \gamma\, (\gamma\, \gamma)$

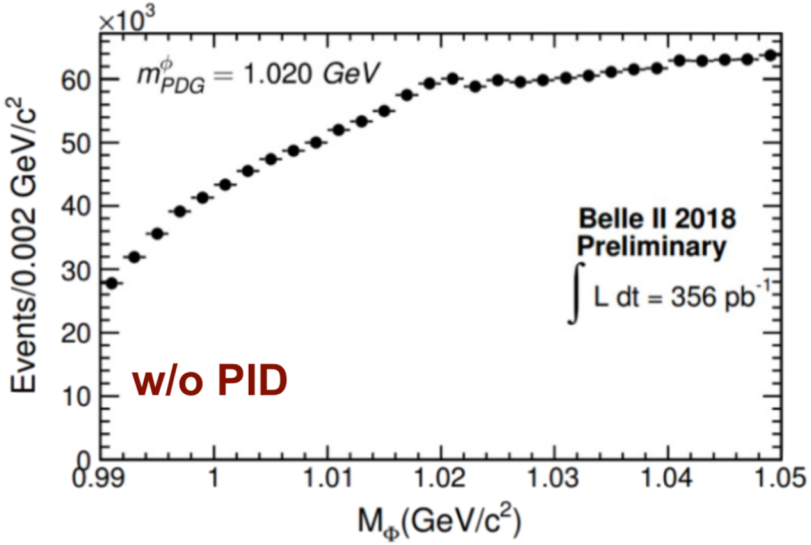
Tracking and particle identification

$K_S \rightarrow \pi^+\pi^-$

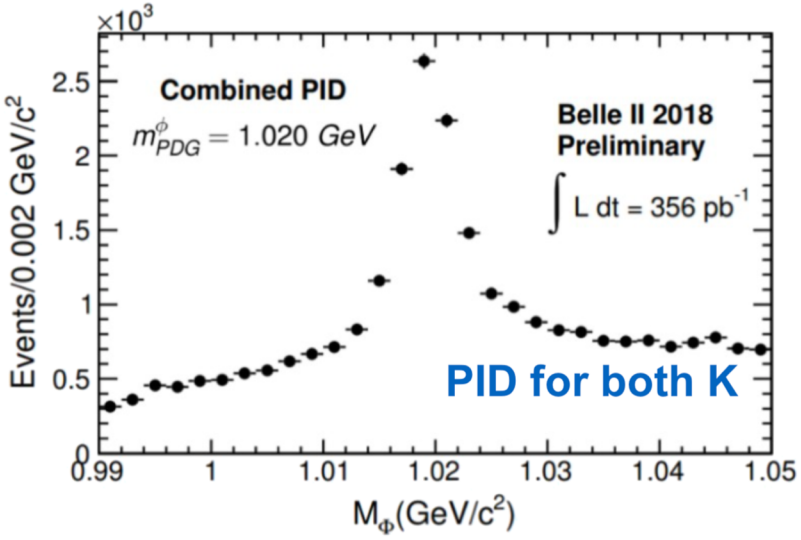


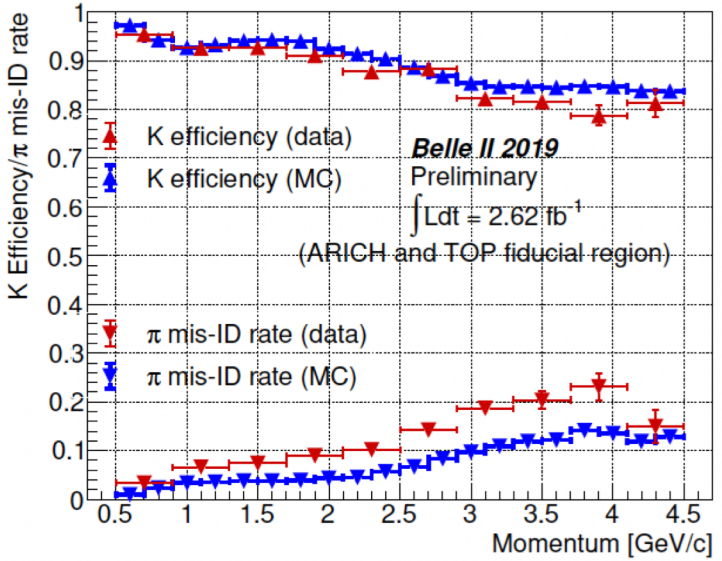
Good charged track's momentum resolution

$\phi \rightarrow K^+K^-$ w/o PID



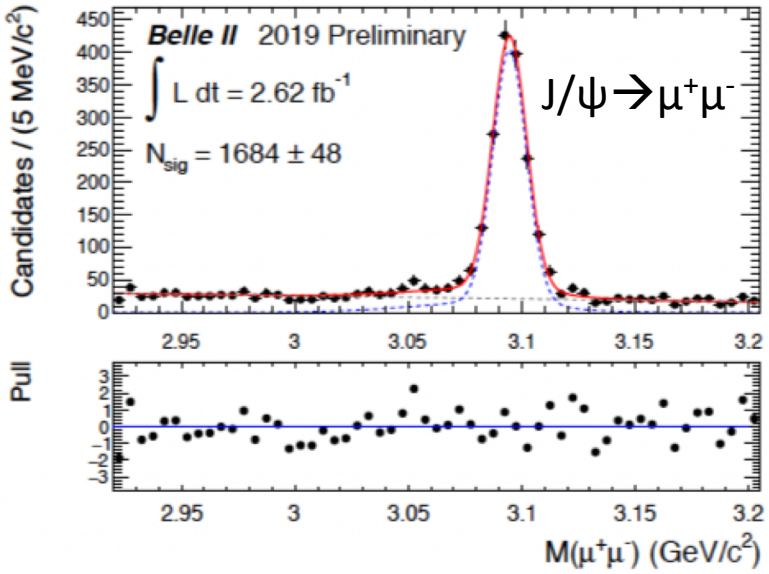
$\phi \rightarrow K^+K^-$ w/ PID

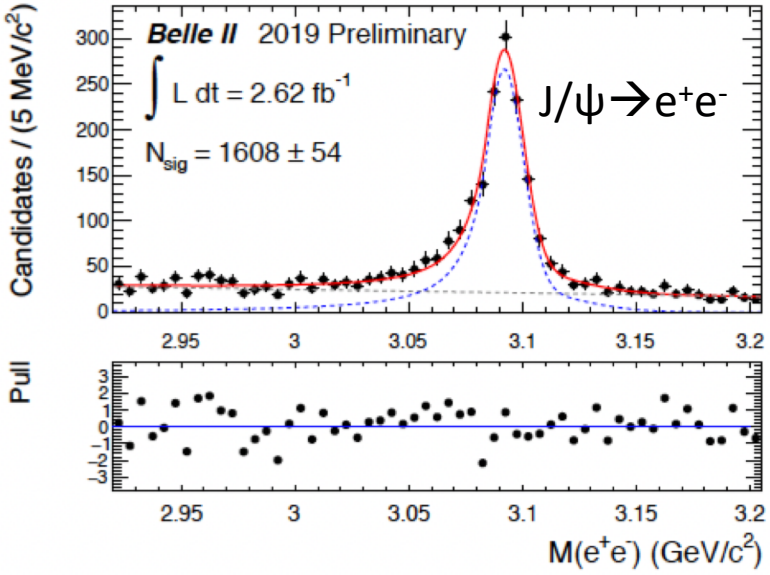


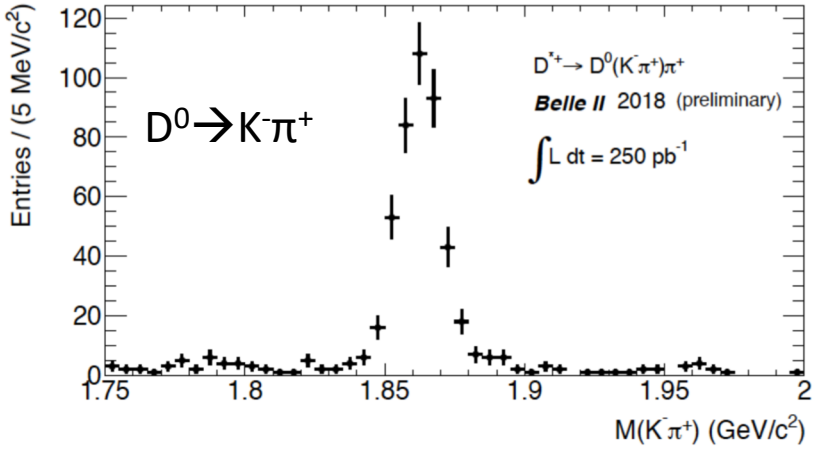


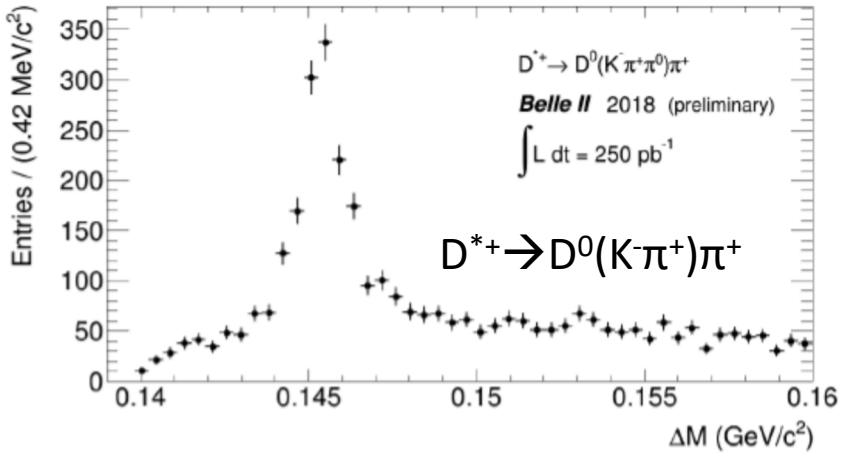
High PID performance

Complex particles reconstruction

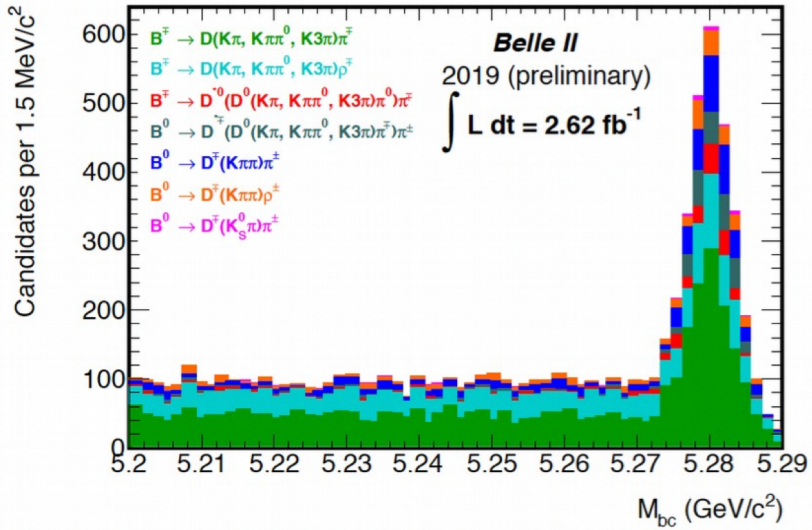


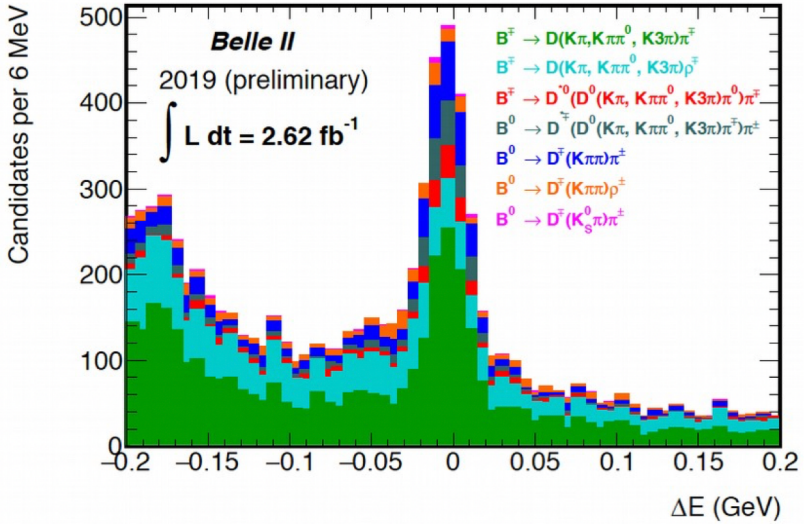




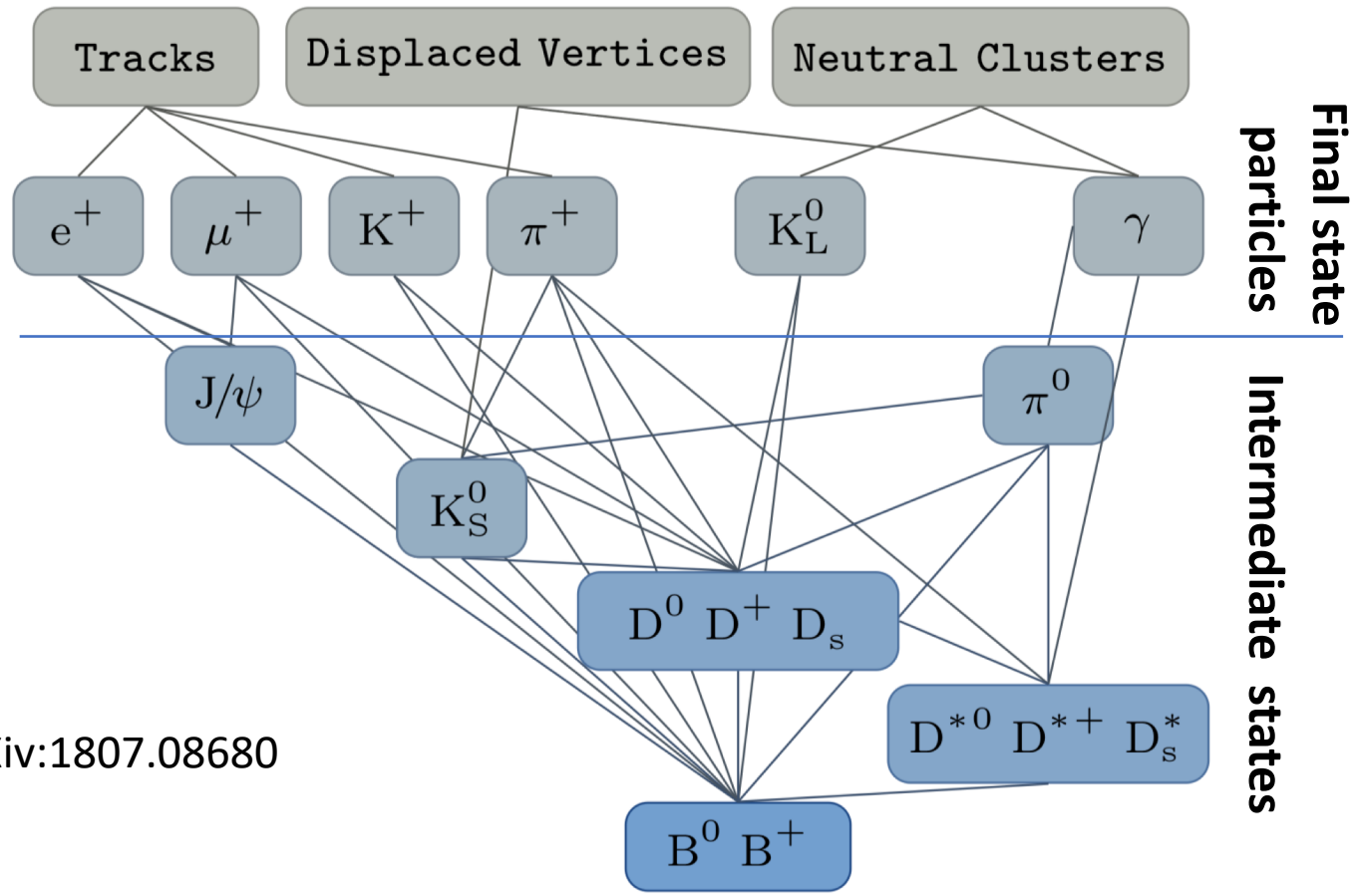


All masses on the proper places – good magnetic field calibration

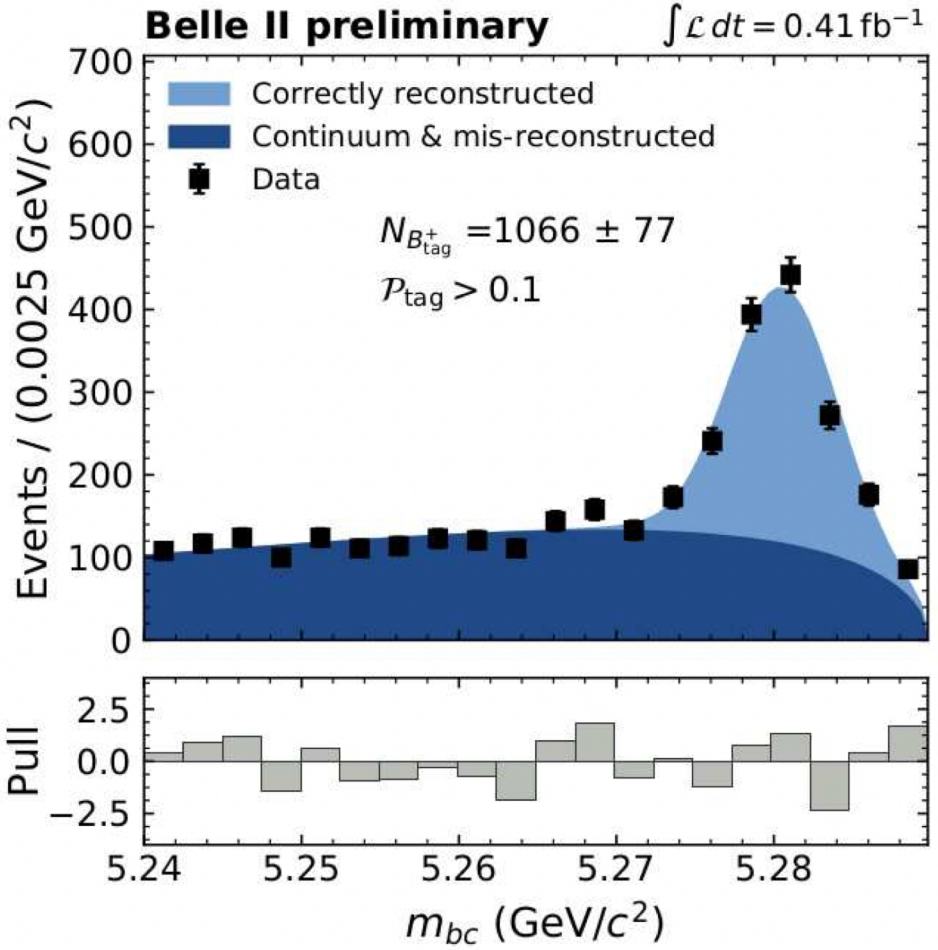




Full event interpretation (FEI)



arXiv:1807.08680



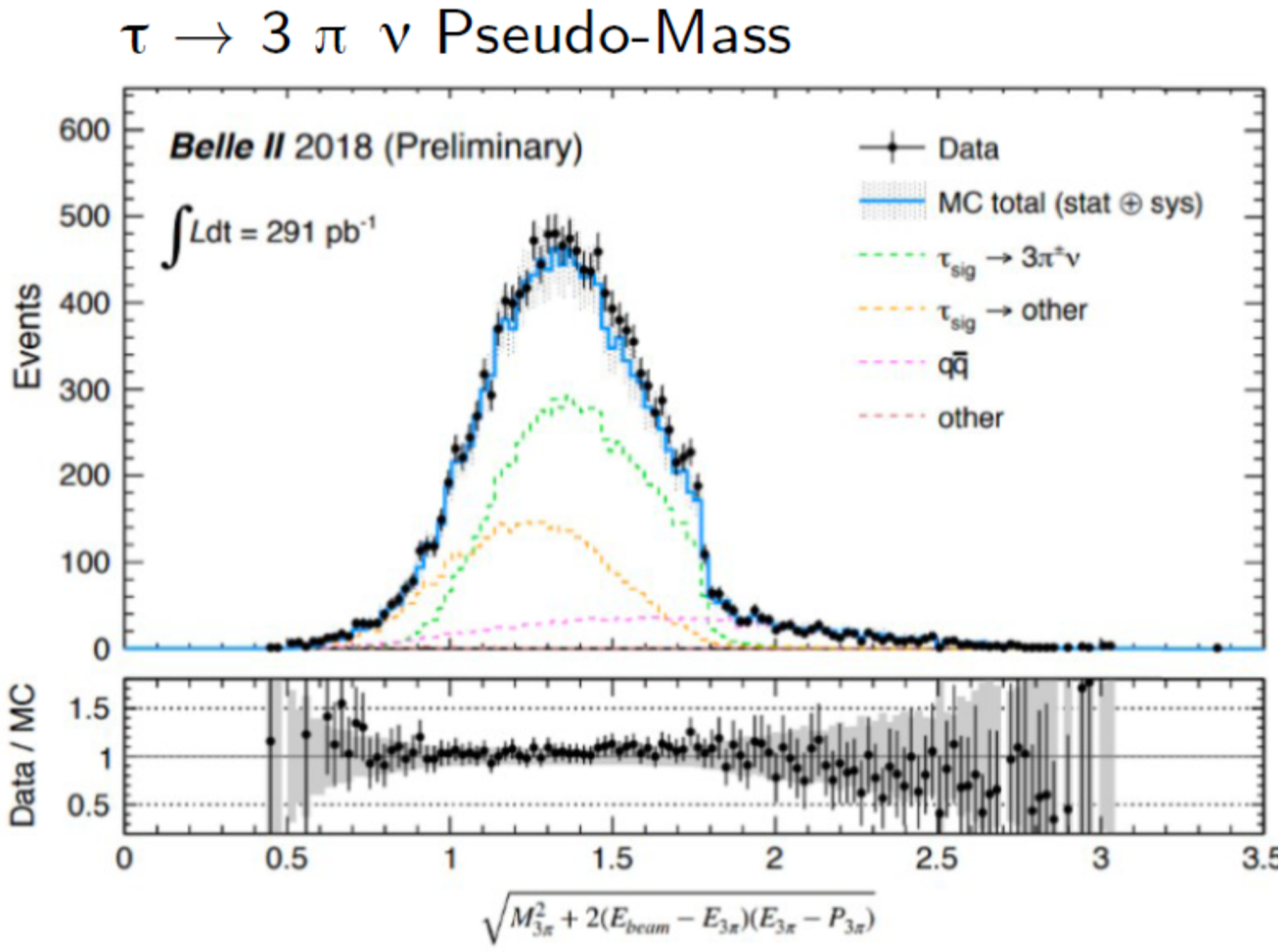
FEI:
– enhances by a factor of 2 the event tagging efficiency
– important tool for the analyses with neutrino,
like $B^+ \to l^+ \nu$, $D^{(*)}l\nu$, $K^{(*)}l\nu$, ect.

Small portion of data is presented on the plot

Number of fully rec. B events per pb^{-1} depends on the signal purity cut on NN output

First physics results

τ reconstruction (Phase 2 data)

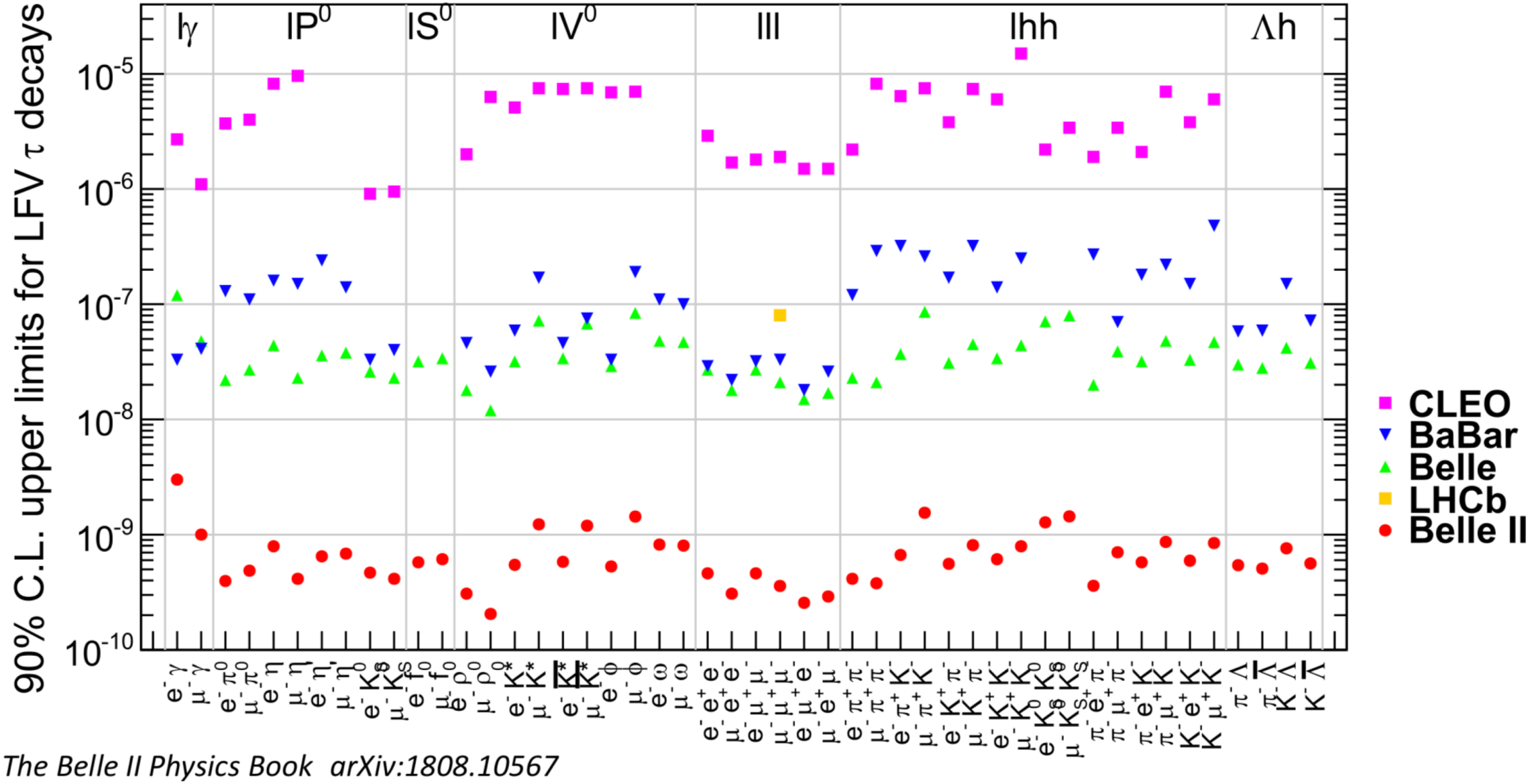


Preliminary τ mass measurement:

$m_\tau = (1776.4 \pm 4.8(\text{stat}))\ \text{MeV}/c^2$

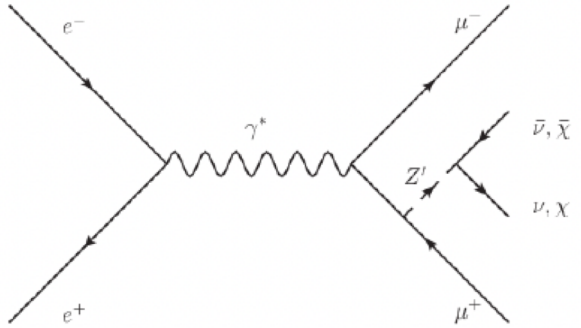
consistent with previous results

Upper limits for LFV τ decays at B factories



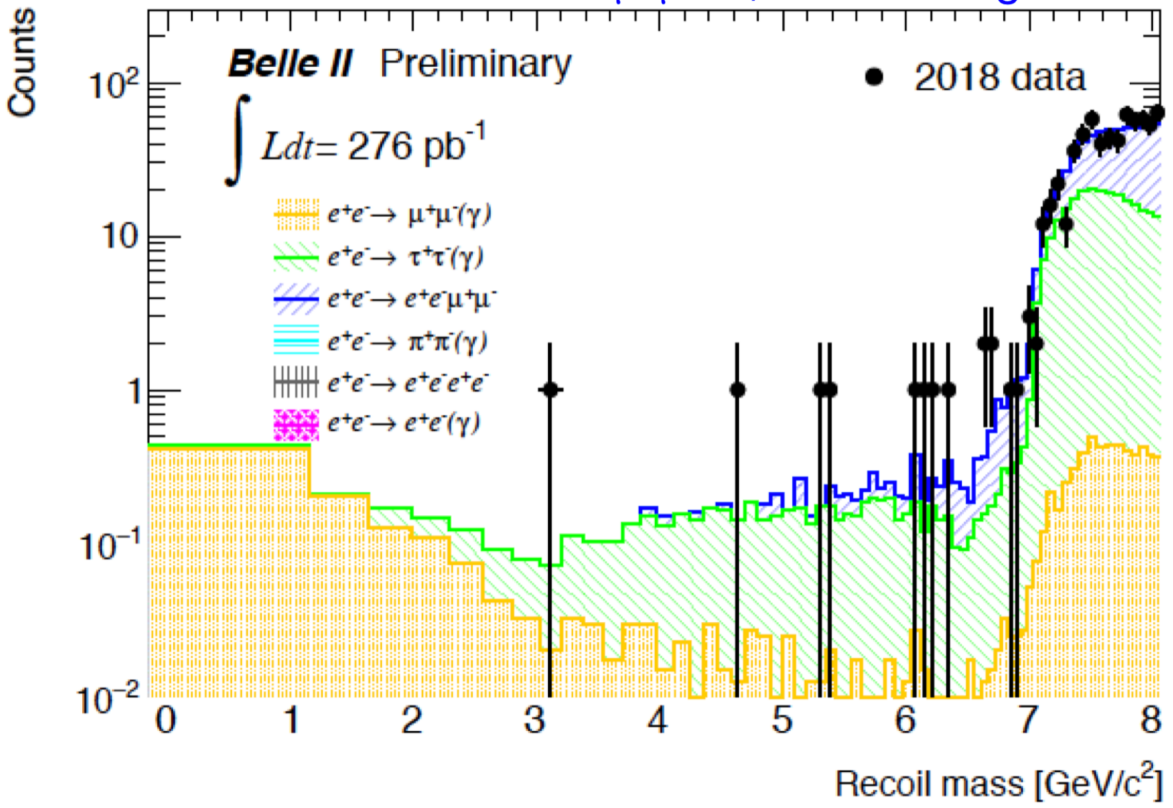
The Belle II Physics Book arXiv:1808.10567

Dark sector searches (Phase 2 data)

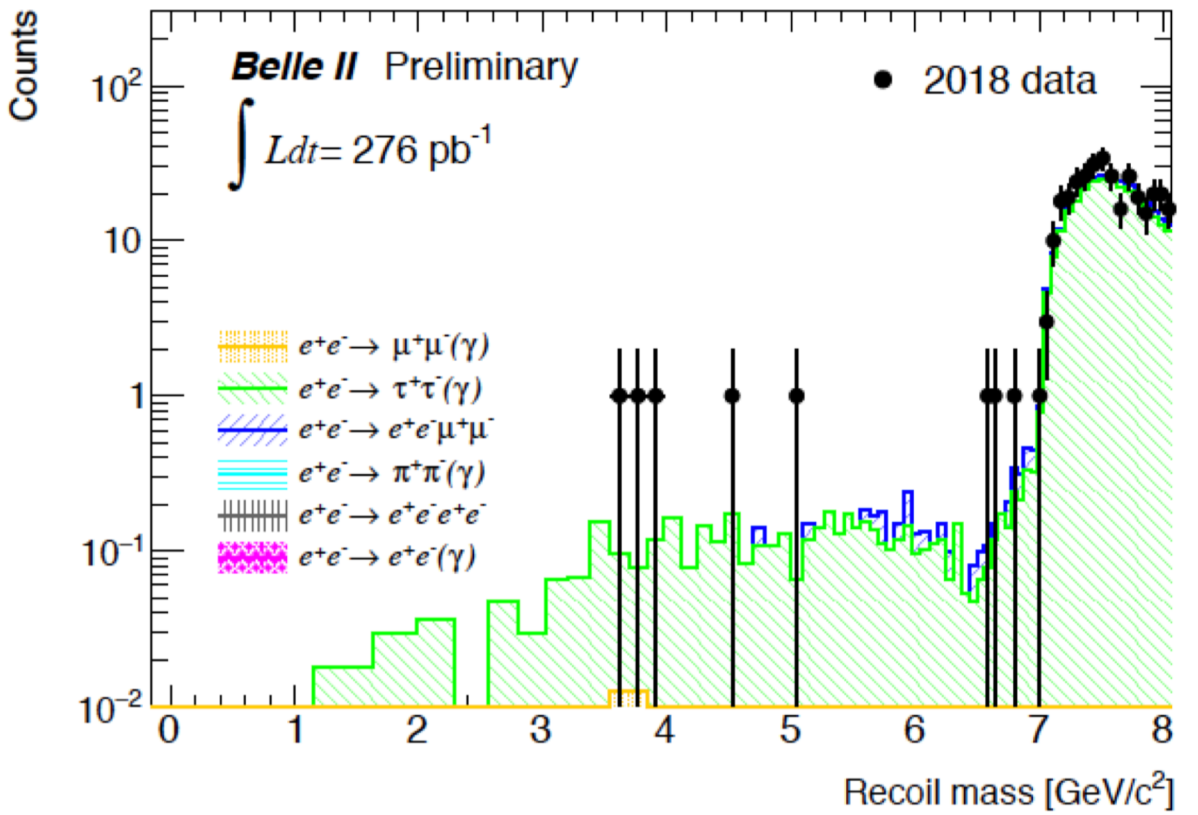


Belle II trigger is optimized to search for such processes

Search for $e^+e^- \to \mu^+\mu^- Z'$, $Z' \to$ nothing



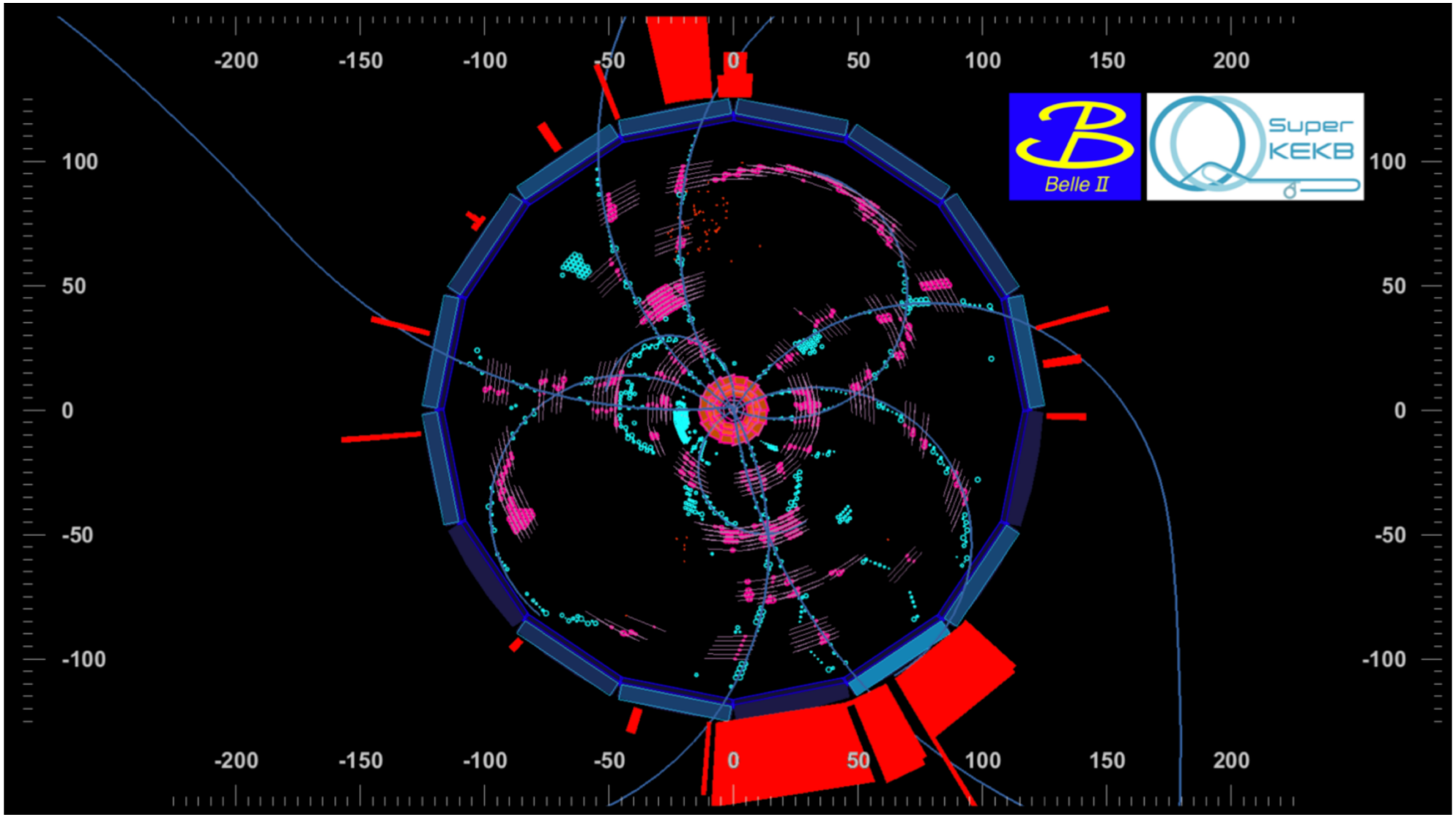
Search for $e^+e^- \to e^\pm\mu^\mp Z'_{LFV}$, $Z'_{LFV} \to$ nothing



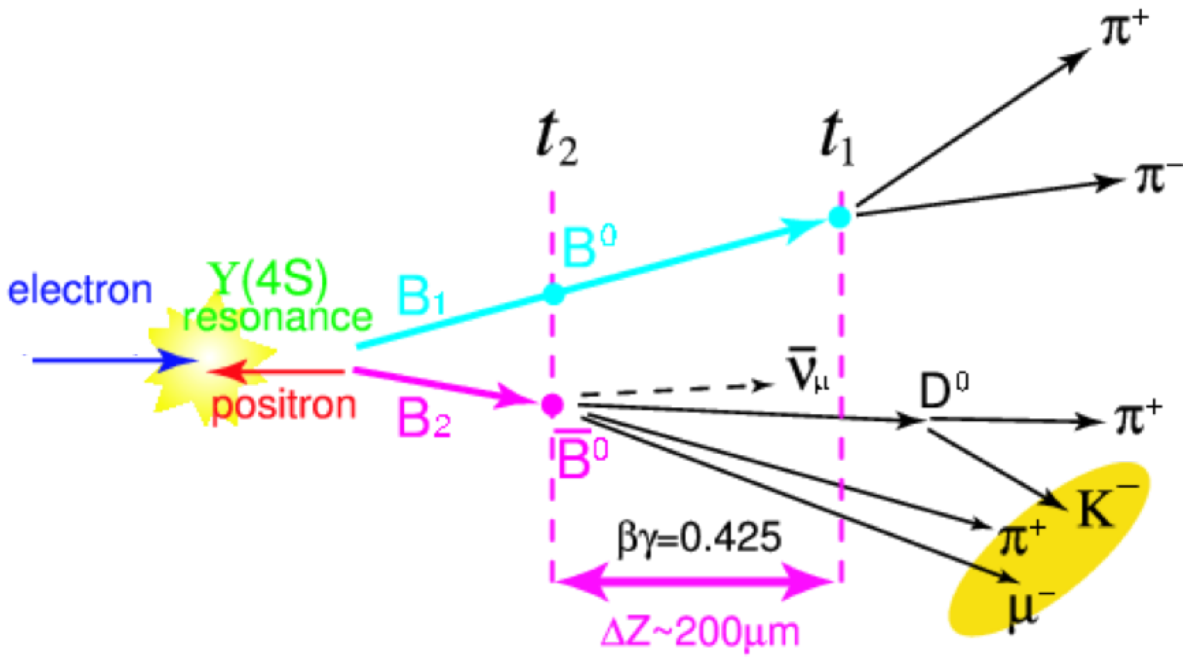
Results are compatible with backgrounds

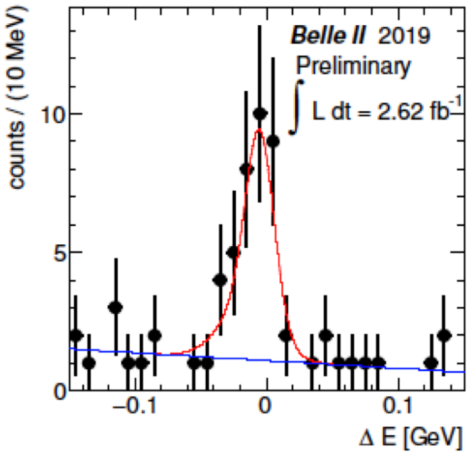
Phase 3 run with VXD installed

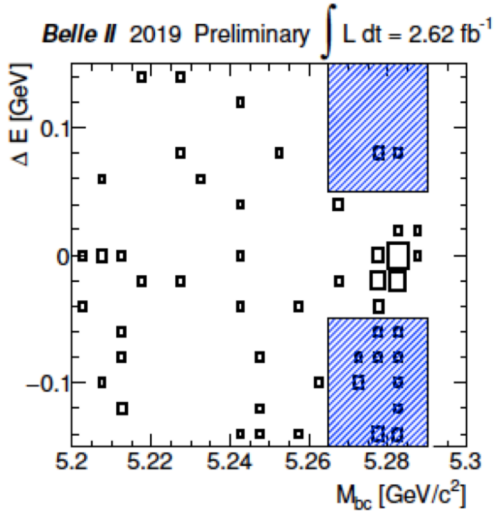
First B-like event in the Belle II Phase 3 run

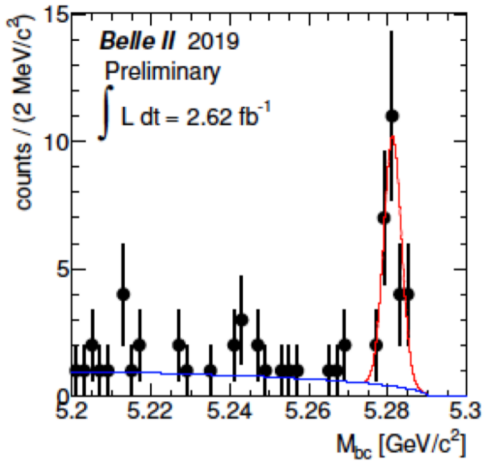


Time-dependent analyses: CPV in $B^0 \rightarrow J/\psi\ K_S$









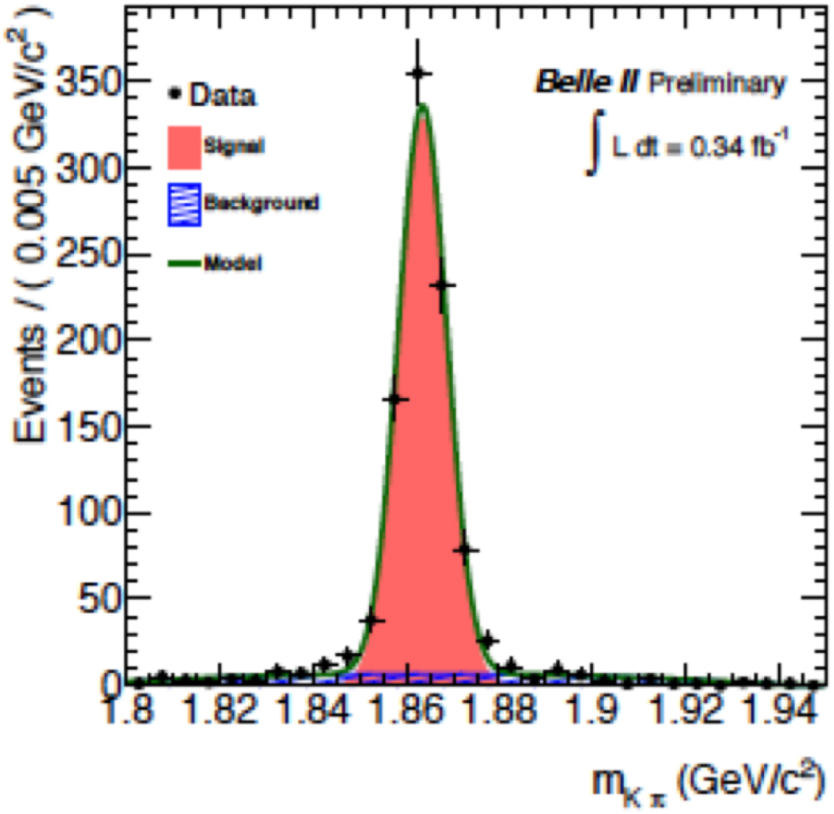
Vertexes are reconstructed using vertex detector

Lifetime is determined by the distance between two vertexes

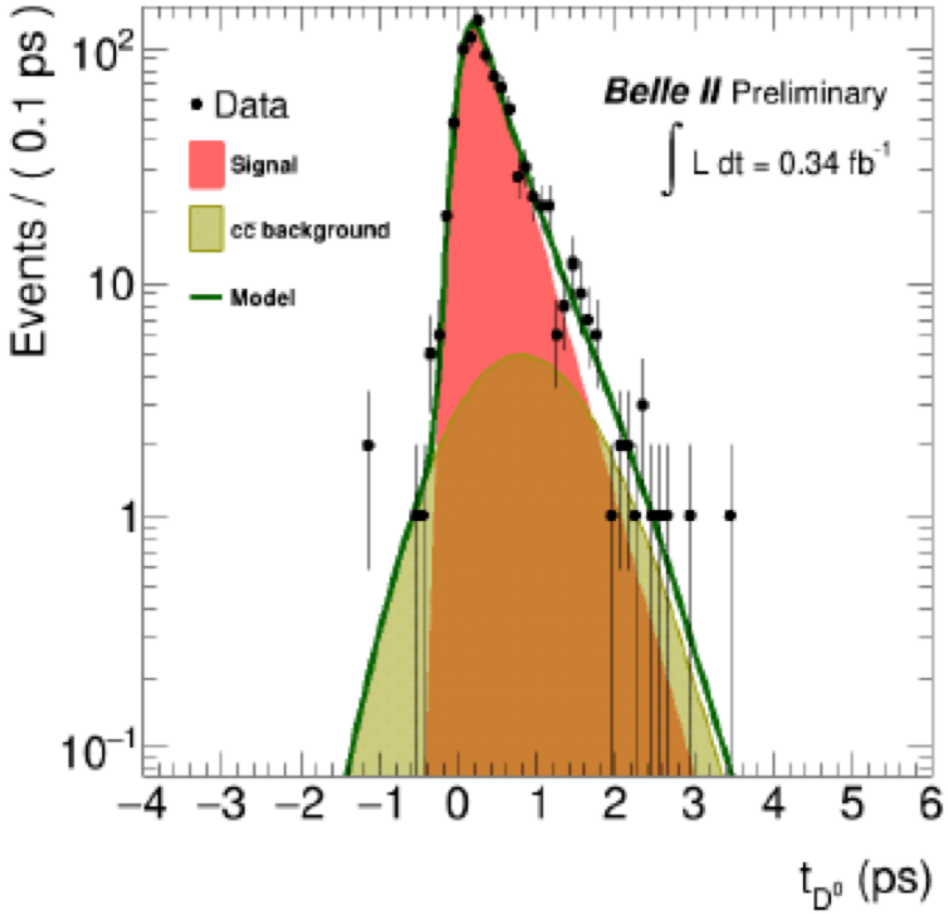
$N(B \rightarrow J/\psi\ K_S) = 26.7 \pm 5.2$

Time-dependent measurements: D^0 life-time

$N(D^0) = 860 \pm 30$

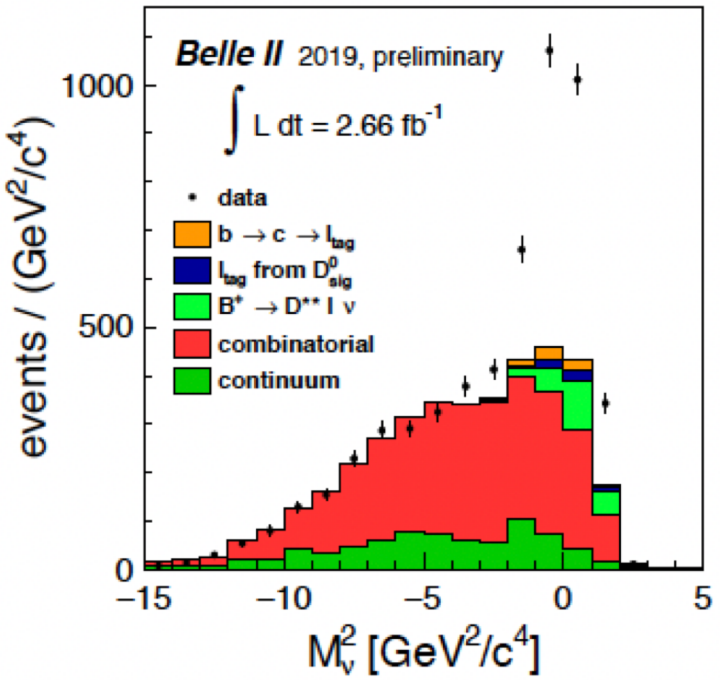


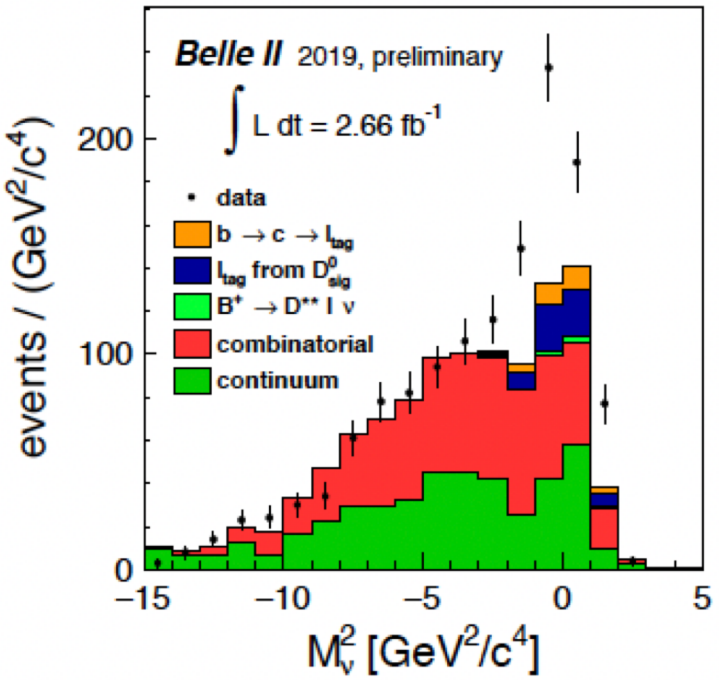
$\tau(D^0) = 370 \pm 40$ (stat) fs

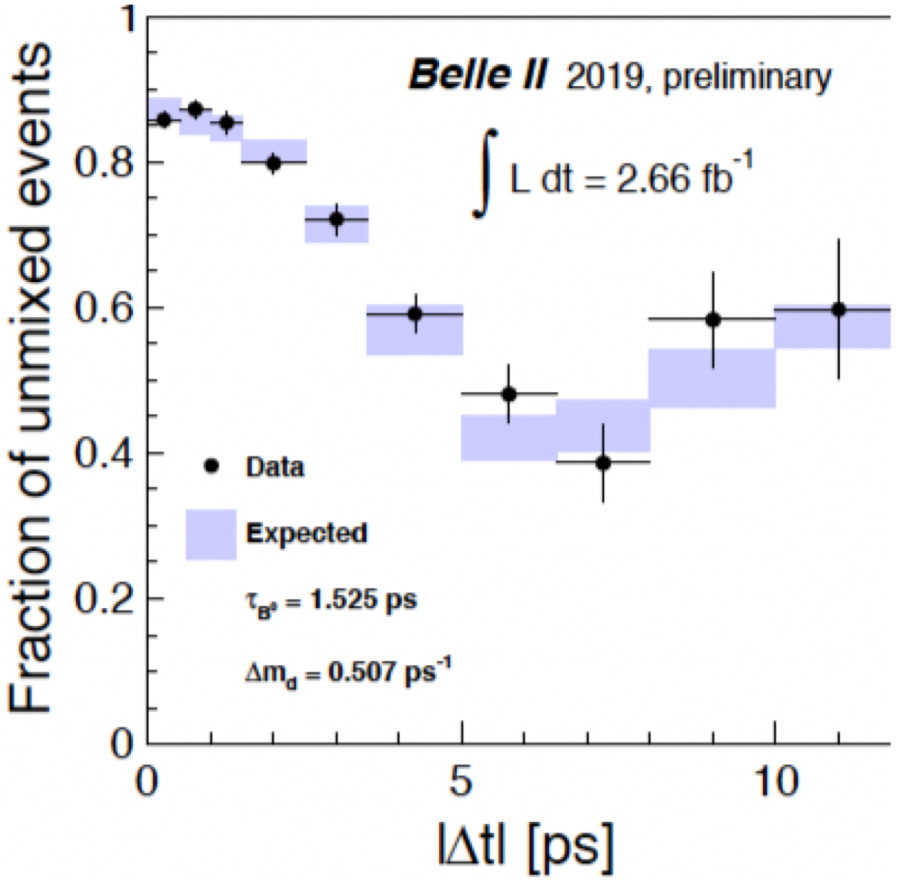


- Uses ~1/15 of the Phase 3 dataset
- Demonstrates the combined performance of the PXD and SVD

Time-dependent analyses: B^0-B^0bar mixing



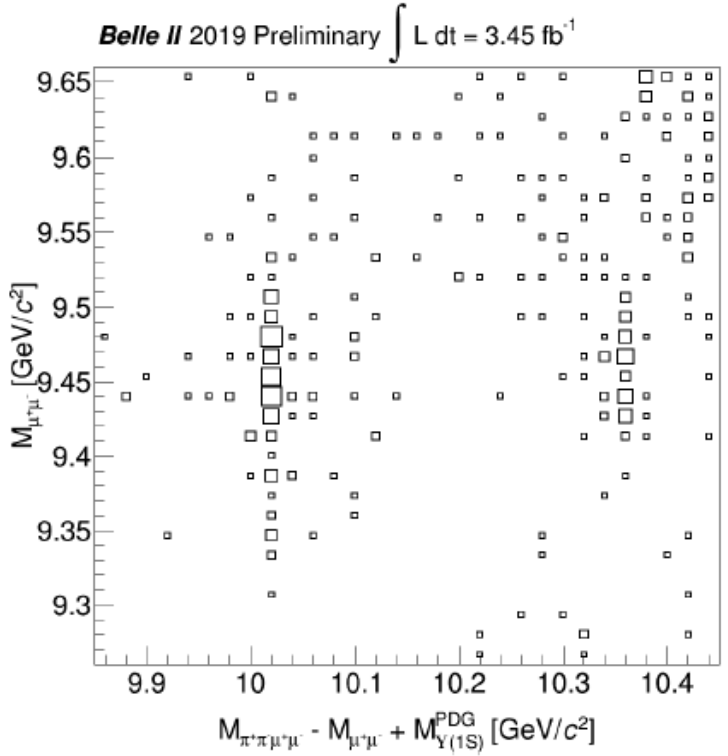


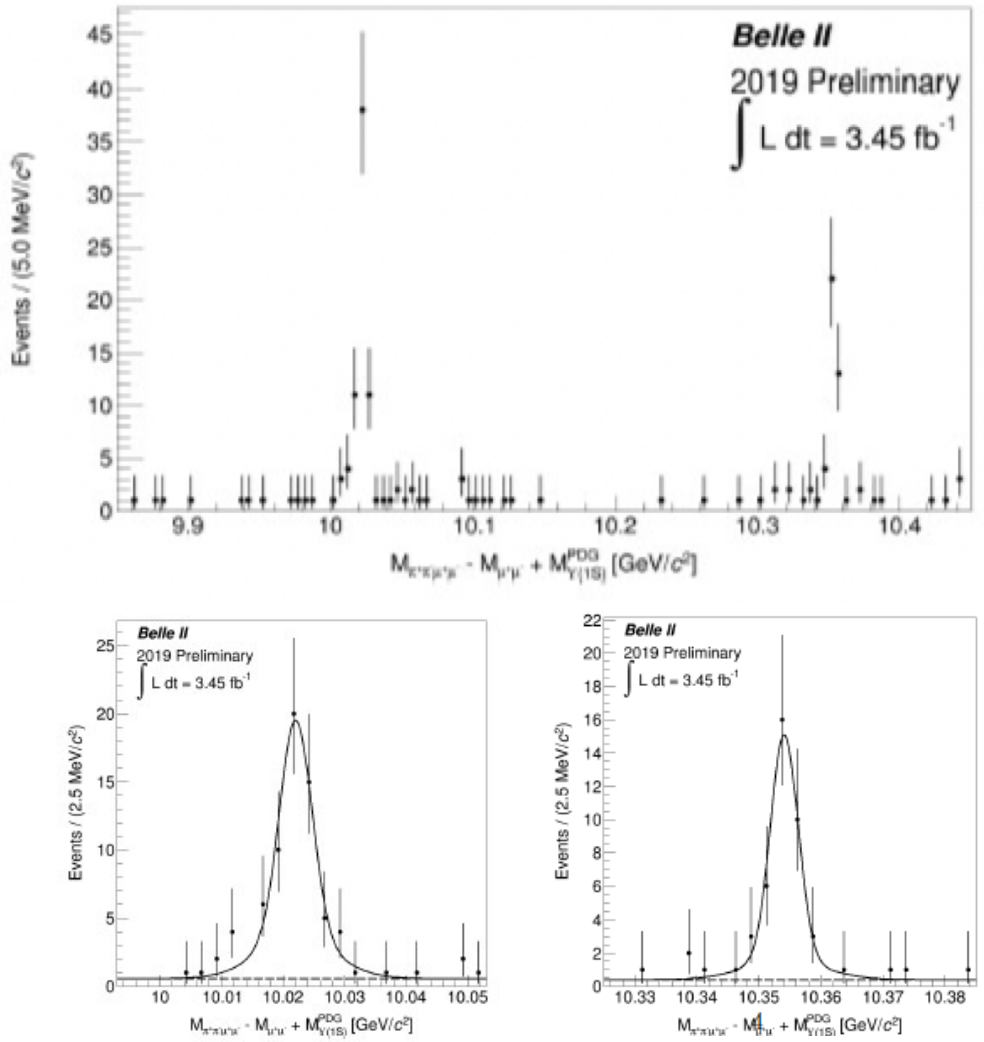


- Partial reconstruction and time determination uses only lepton tagging
- Use flavor specific final states but requires tagging
- Verifies Belle II VXD capabilities for CP violation measurements

Initial state radiation measurements

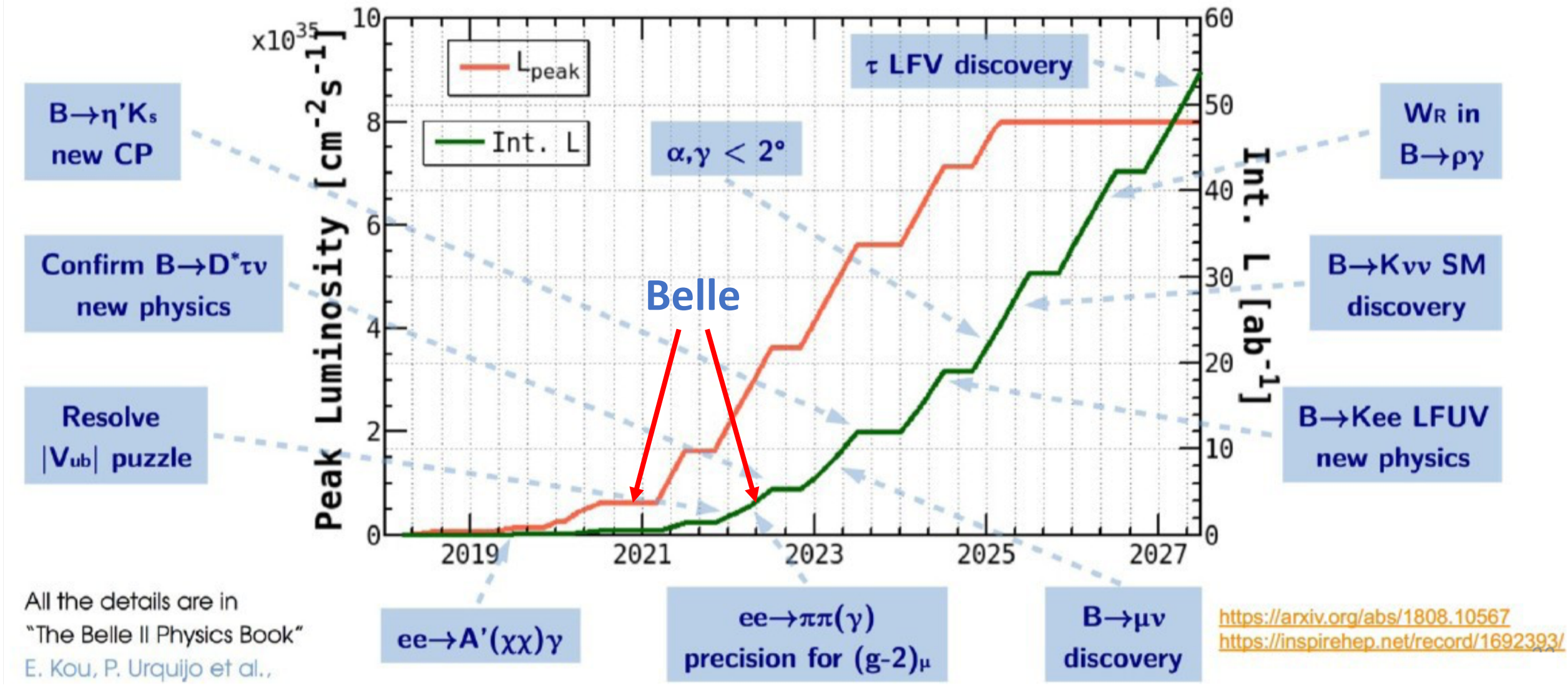
$e^+e^- \rightarrow \Upsilon(2S, 3S)\,\gamma$,
$\Upsilon(2S, 3S) \rightarrow \pi^+\pi^-\Upsilon(1S)$,
$\Upsilon(1S) \rightarrow \mu^+\mu^-$





With the larger statistics possible to search for new resonances in bb system

Belle II prospects (based on The Belle II Physics Book, arxiv:1808.10567)



All the details are in
"The Belle II Physics Book"
E. Kou, P. Urquijo et al.,

https://arxiv.org/abs/1808.10567
https://inspirehep.net/record/1692393/

Conclusion

- SuperKEKB accelerator has been commissioned
- First 500 pb-1 data were collected during Phase 2 Belle II commissioning w/o vertex detector
- Phase 3 in March-June 2019: L_{int}= 6.49 fb^{-1} data is collected
- Some of the first results are presented in this talk
- Operation will resume in October 2019 and continue till July 2020

Thank you!