Performance of High Level Reconstruction at Belle II

BEAUTY 2019

18th INTERNATIONAL CONFERENCE ON B-PHYSICS AT FRONTIER MACHINES

Ljubljana, Slovenia

September 30 - October 4, 2019

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Oct 3th, 2019

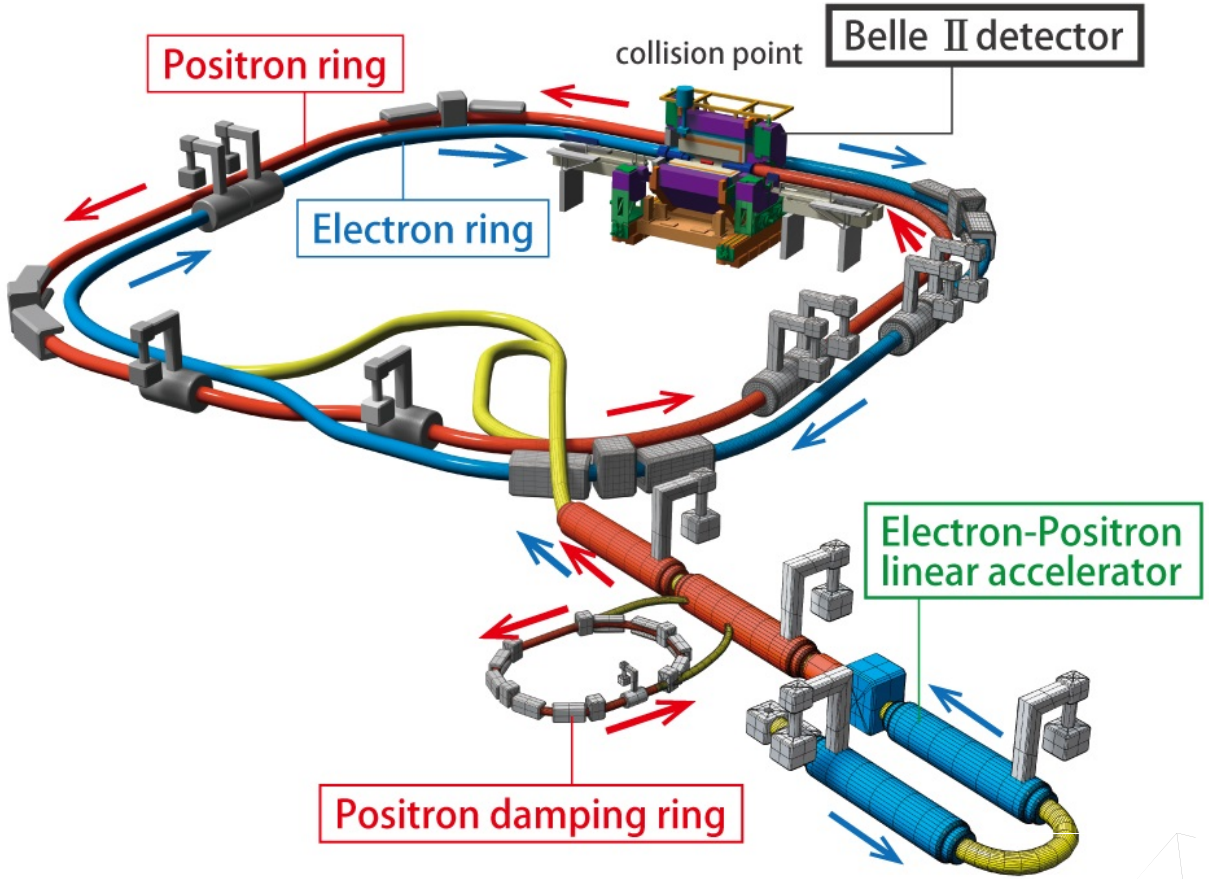
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Super KEKB

Belle II

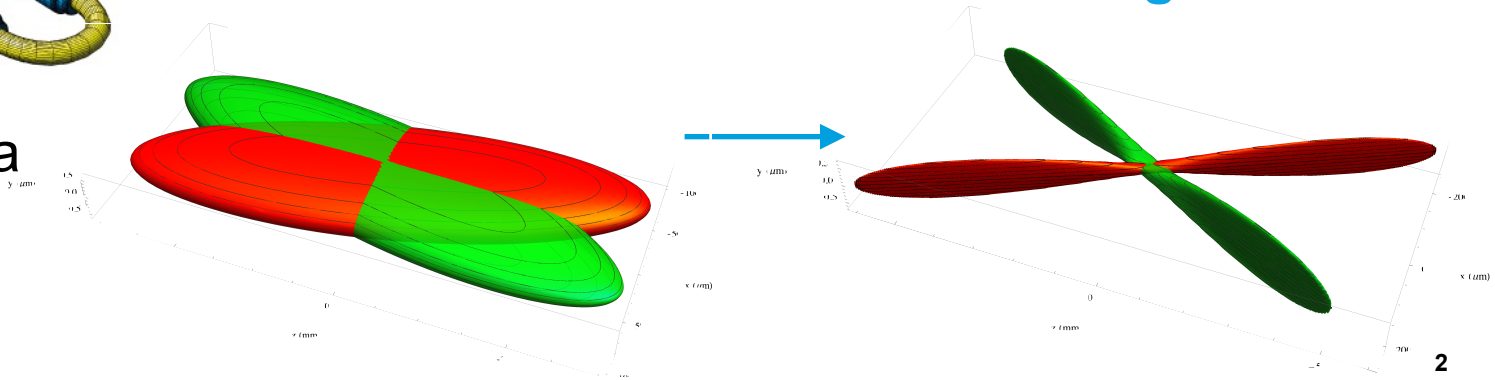
DESY

SuperKEKB @KEK, Tsukuba

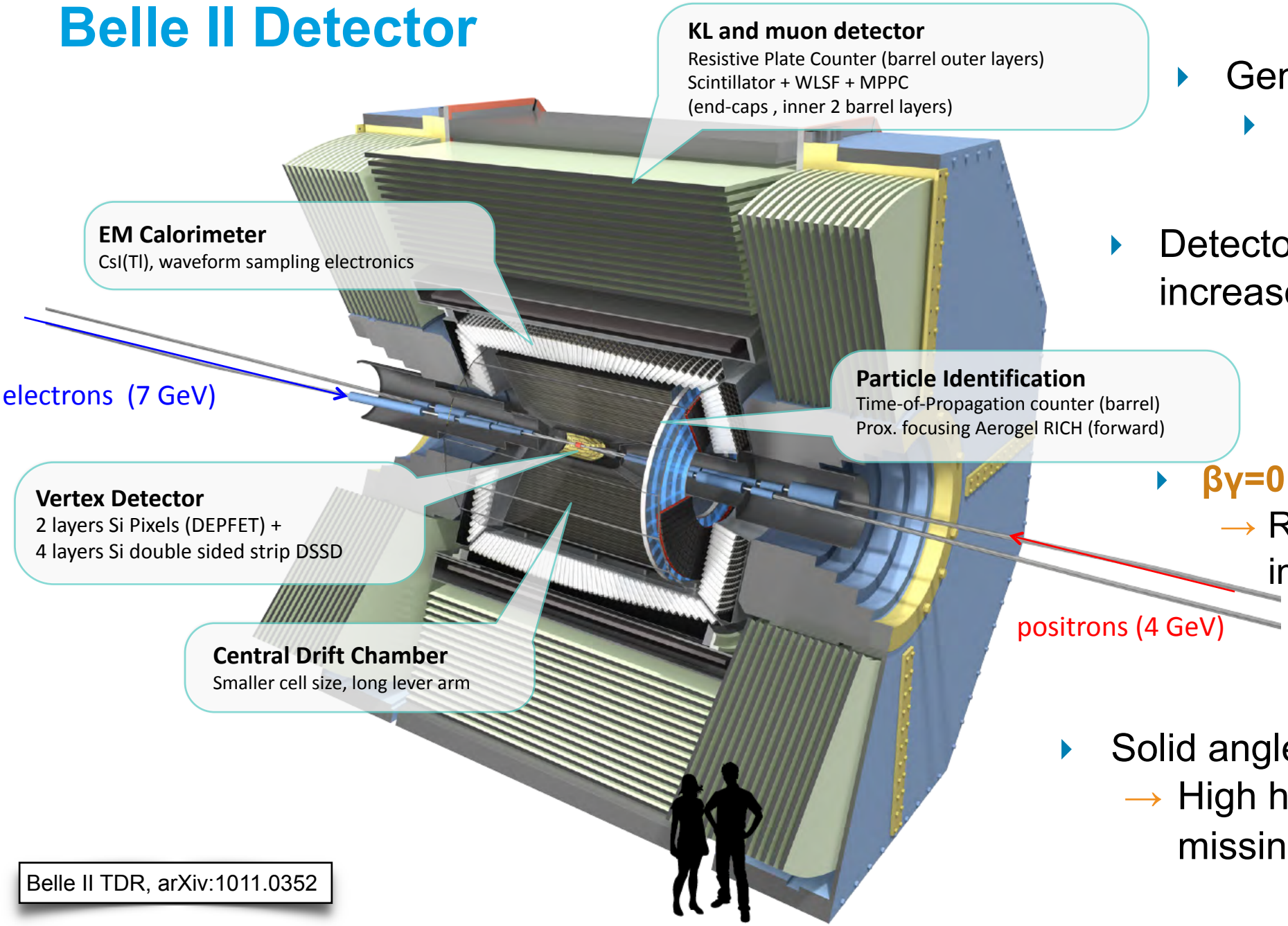


- **New facility** to search for BSM physics by studying B, D and τ decays.
- Asymmetric electron-positron collider.
- Major upgrade to the KEKB accelerator with **x40 the design luminosity (8×10^{35} $cm^{-2}s^{-1}$)**.
  - **x2** raw beam current.
  - **x20** smaller beam spot (σ_y^*=50 nm) with new nano-beam collision scheme
- **First beams and commissioning in 2016**

- Aim to collect **50 ab^{-1}** of collision data (vs ~1ab^{-1} of Belle)



Belle II Detector

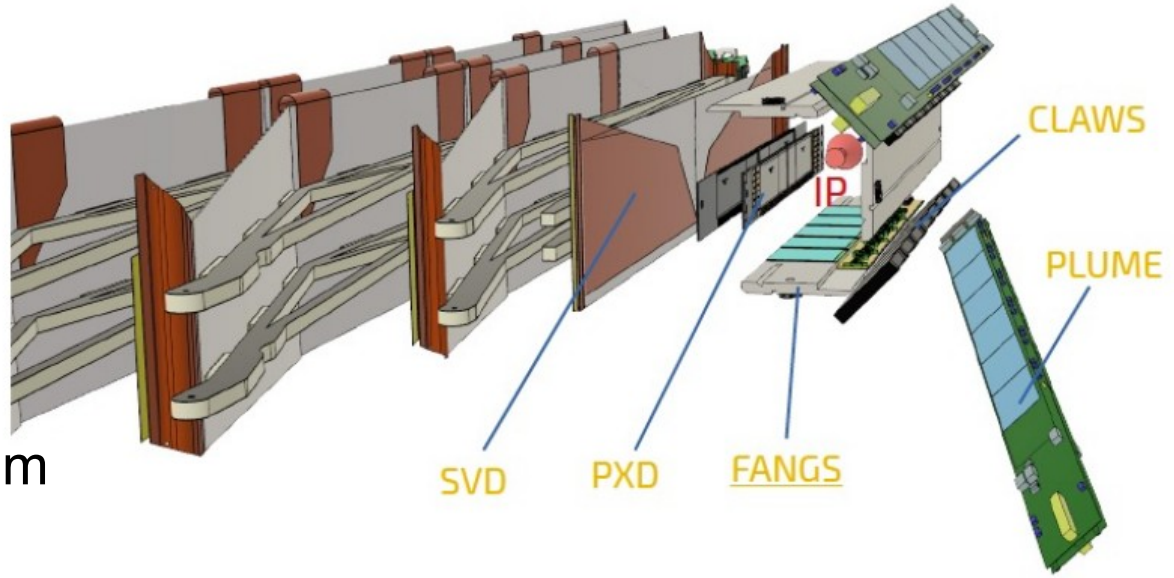


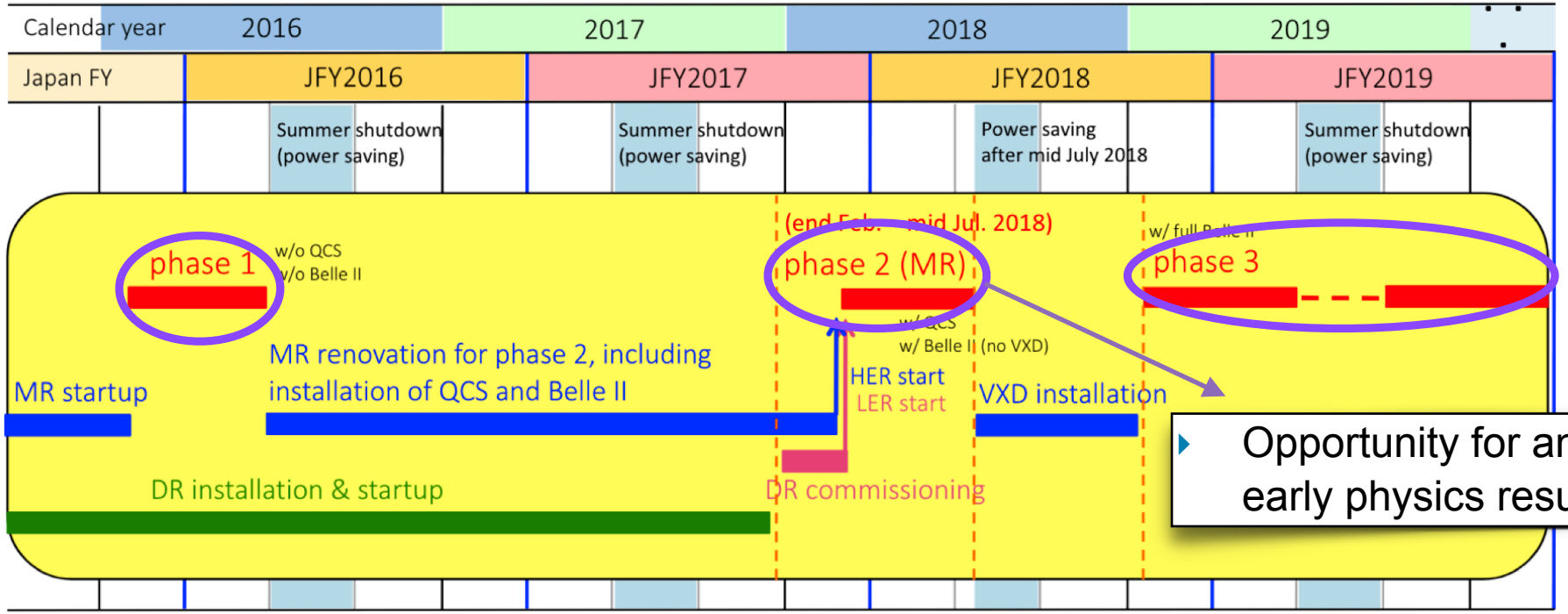
- General purpose spectrometer
  - **Roll-in: April 2017**
- Detector upgrade to mitigate increased beam background
- **βγ=0.28** (vs **0.42** @KEKB)
  → Reduced boost requiring improved vertex reconstruction
- Solid angle coverage >90%
  → High hermeticity for missing particle decays

Belle II TDR, arXiv:1011.0352

Phase 2

- Follows from Phase 1 (accelerator commissioning)
- Pilot run to test nano-beam scheme
  - Single VXD octant (2 PXD + 4 SVD modules)
  - BEAST II: commissioning detector to study beam and background conditions



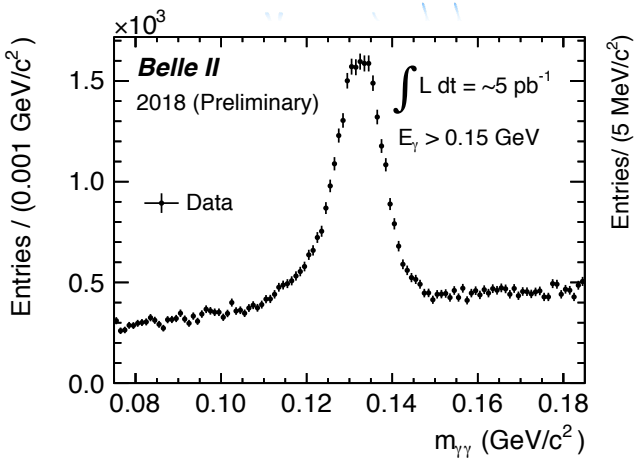


- Opportunity for analysis preparation and early physics results

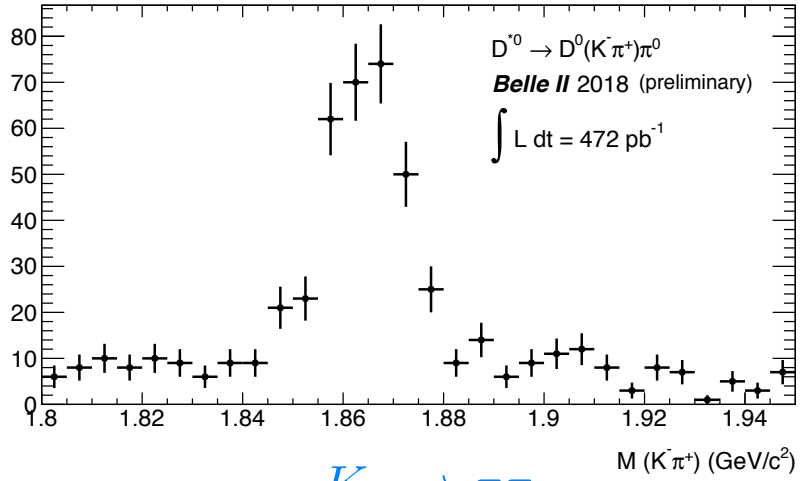
Physics Rediscovery

- **472 pb^{-1}** → first rediscoveries of known processes and physics measurements

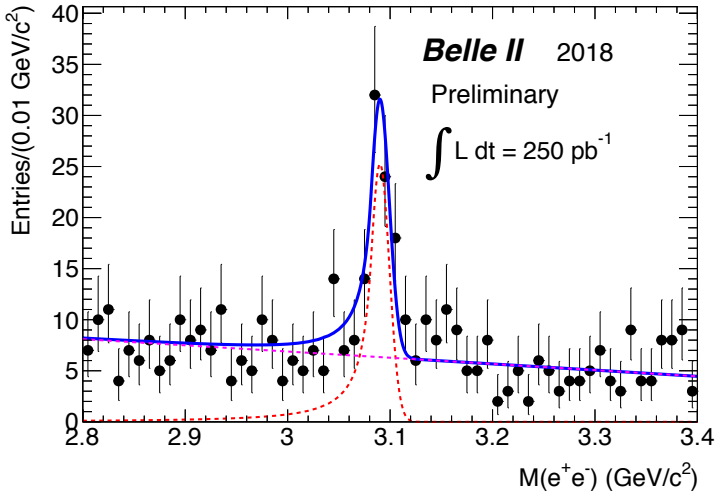
$\pi^0 \to \gamma\gamma$



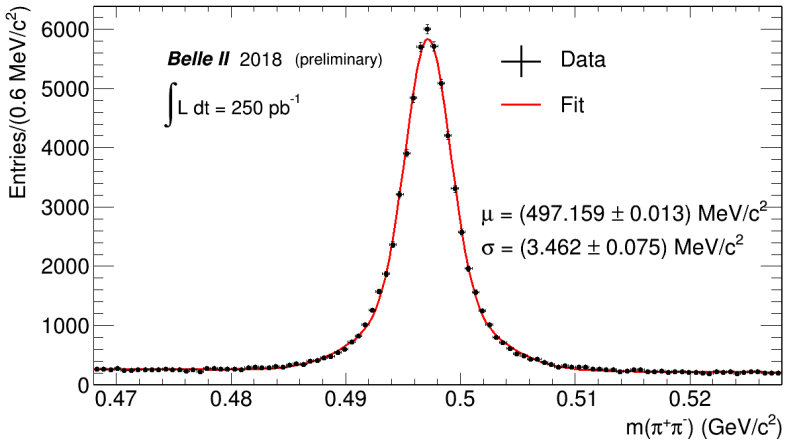
$D \to K\pi$



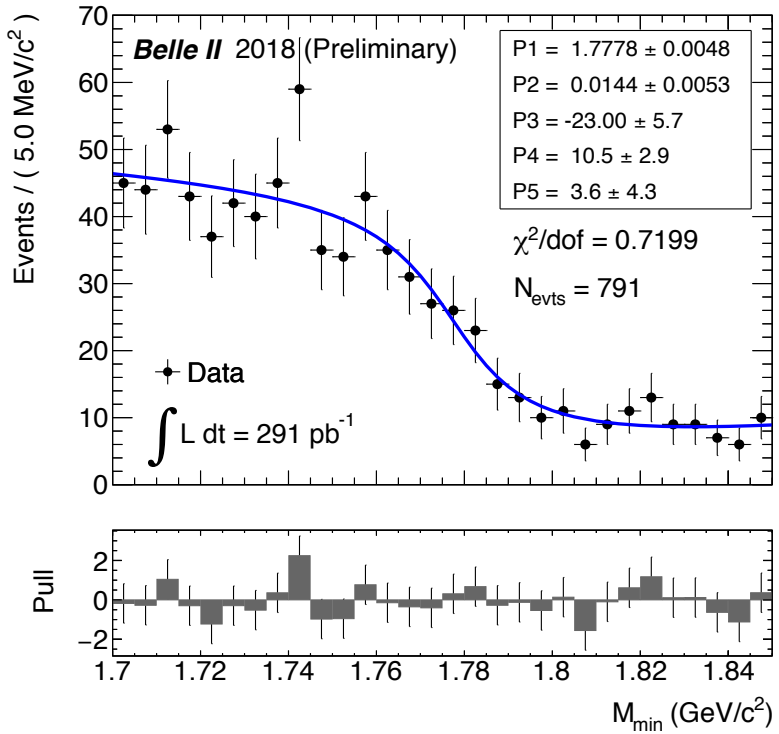
$J/\Psi \to ee$



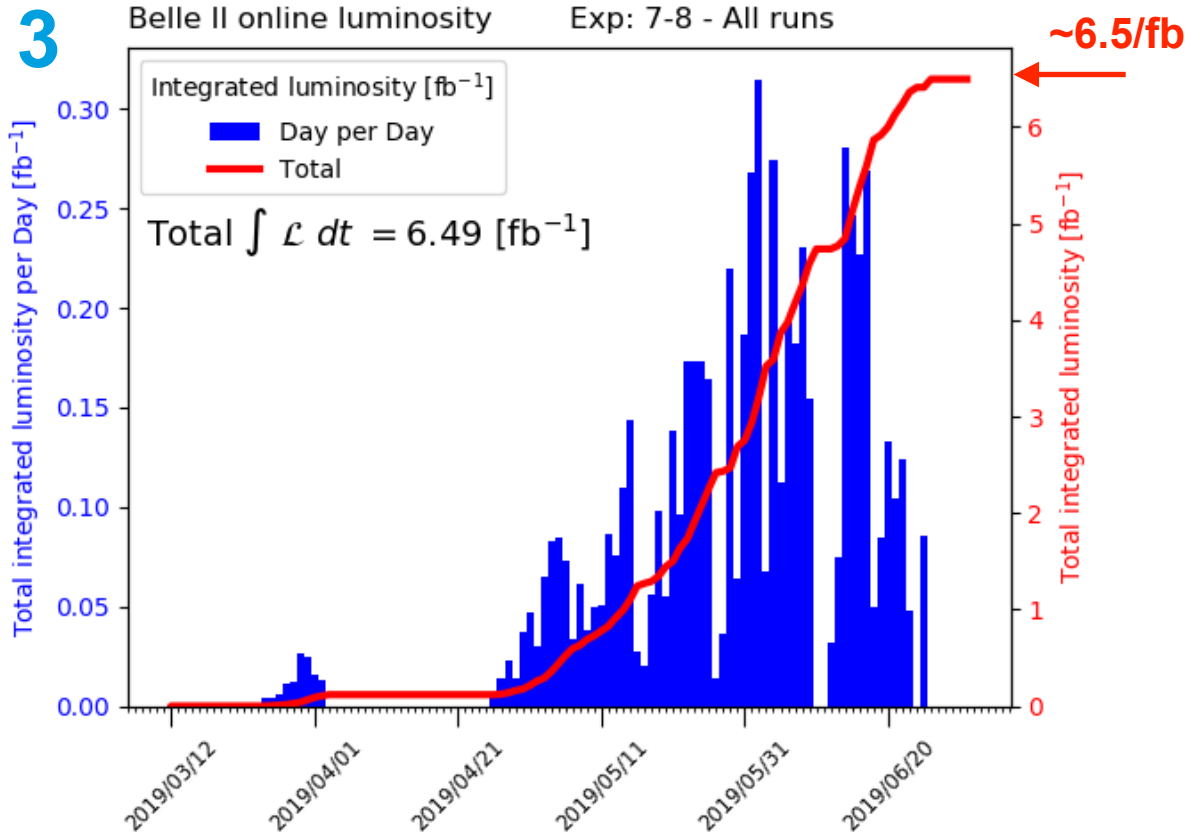
$K_S \to \pi\pi$

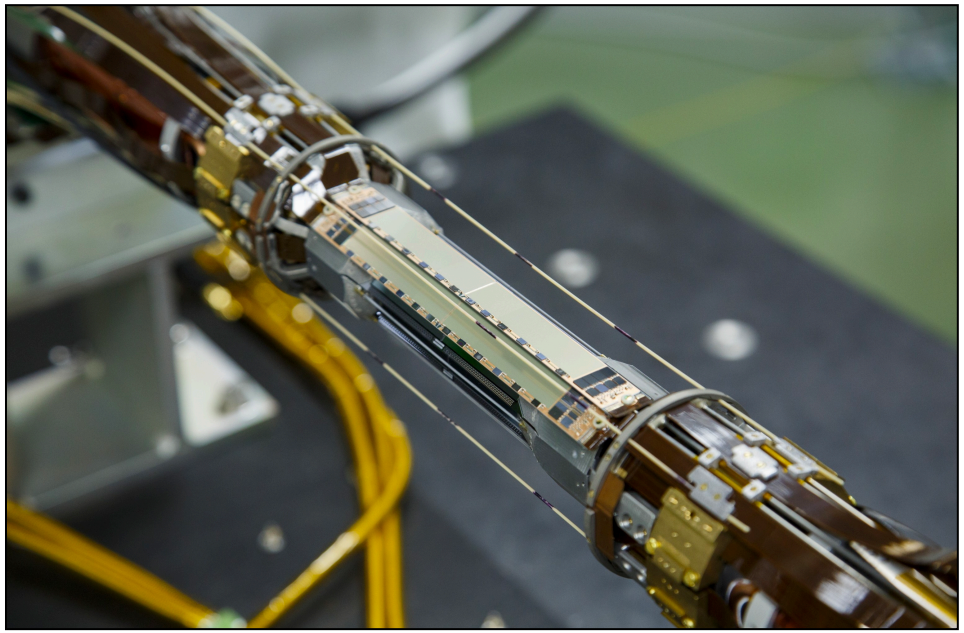


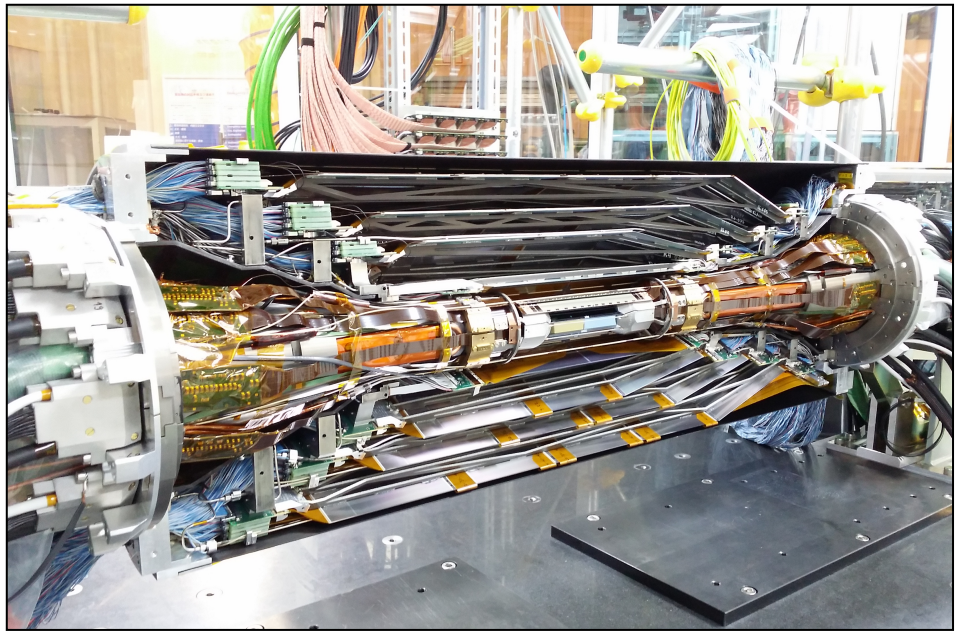
$M(\tau)$



Phase 3

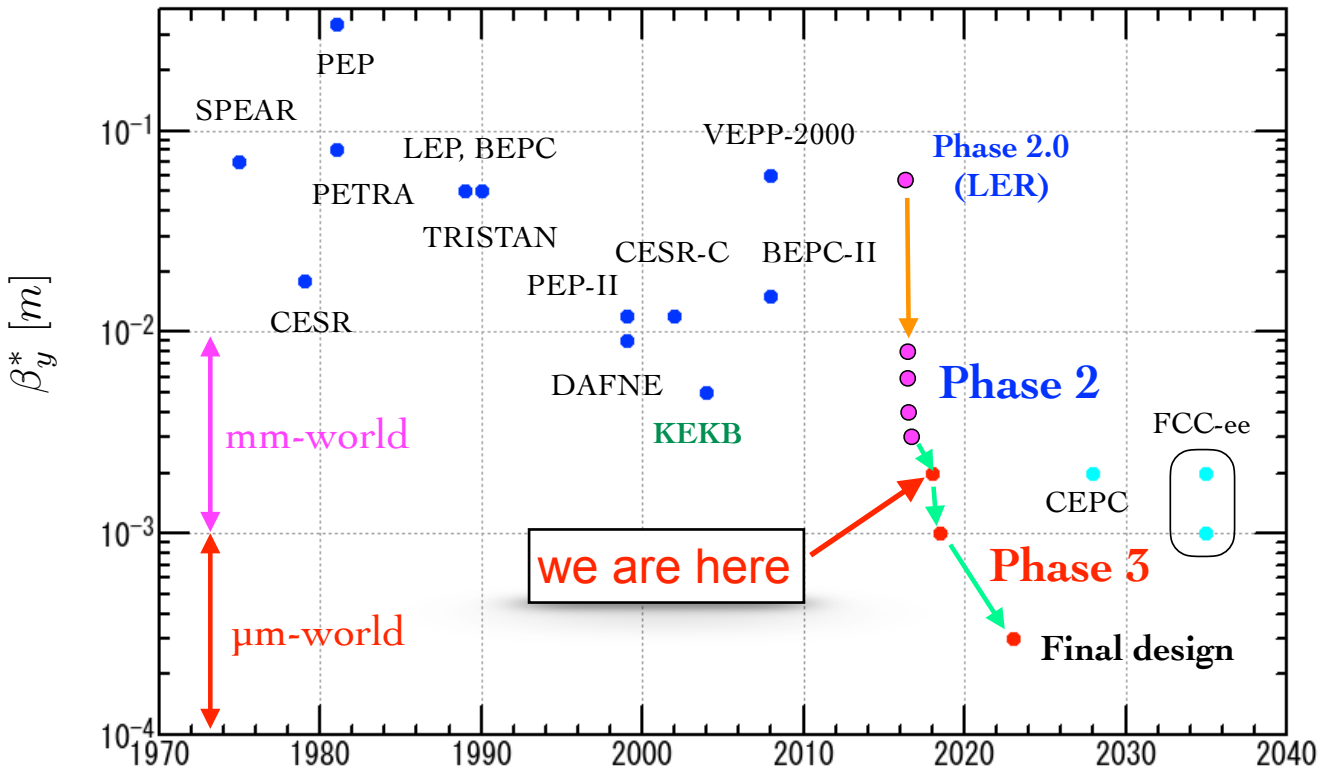




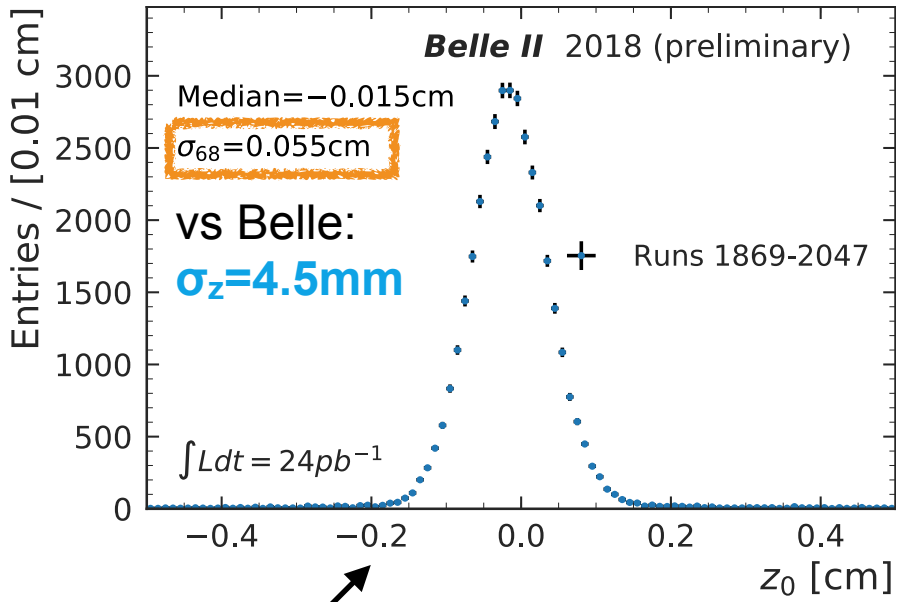


- May-July 2019: Physics run with full detector setup.
- Luminosity ramp-up + switch to continuous injection.
- Peak Luminosity: **6.1 x 10^{33} cm^{-2}s^{-1}** (Belle II ON)
  1.2 x 10^{34} cm^{-2}s^{-1} (Belle II OFF)
- Final goal: 8 x 10^{35} (vs 2.1 x 10^{34} of Belle)

Tightening the Luminous Region



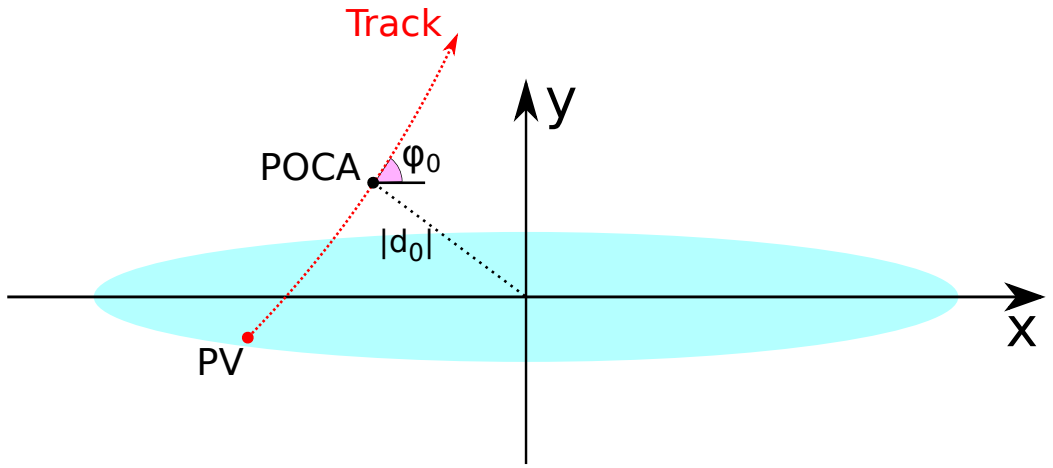
- **β^*_y = 3mm** in 2018
- **β^*_y = 2mm** end of Summer 2019 (w/ Belle II off)
- Final luminosity will require **β^*_y = 300µm**

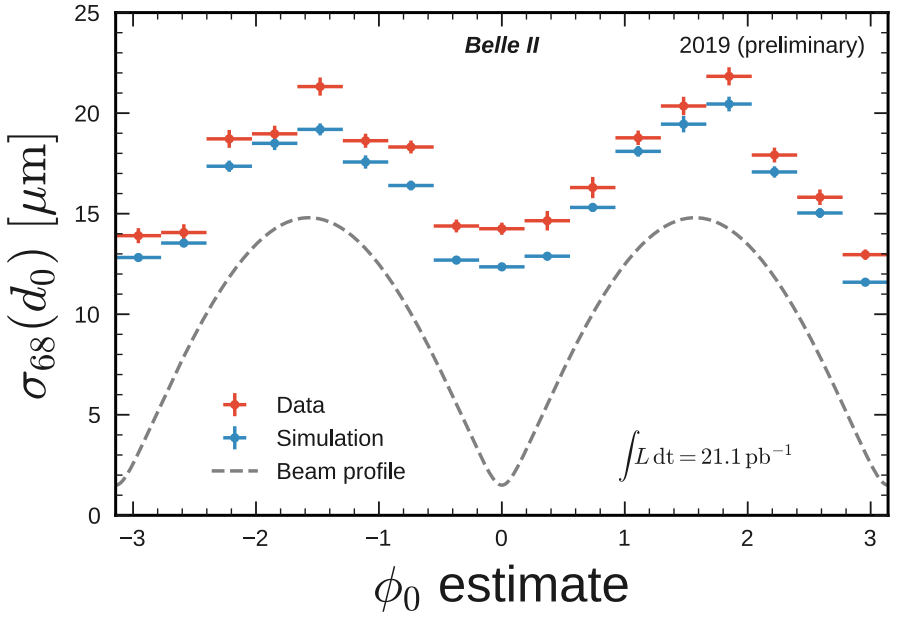


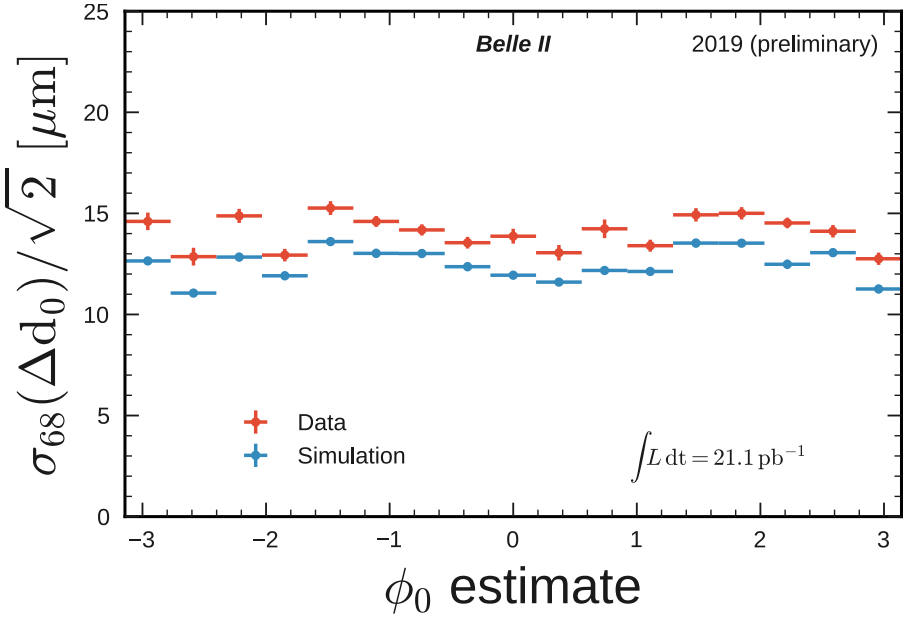
- Possible thanks to rapid feedback between accelerator team and tracking group.

Beam Spot Measurement

- Phase 3 vertex detectors make it possible to accurately measure the interaction region.
- Vertex fit of 2-track events (~Bhabha) selecting "good" tracks with PXD, SVD and CDC hits.
- **14.1±0.1(stat) μm** resolution (x2 better than Belle)

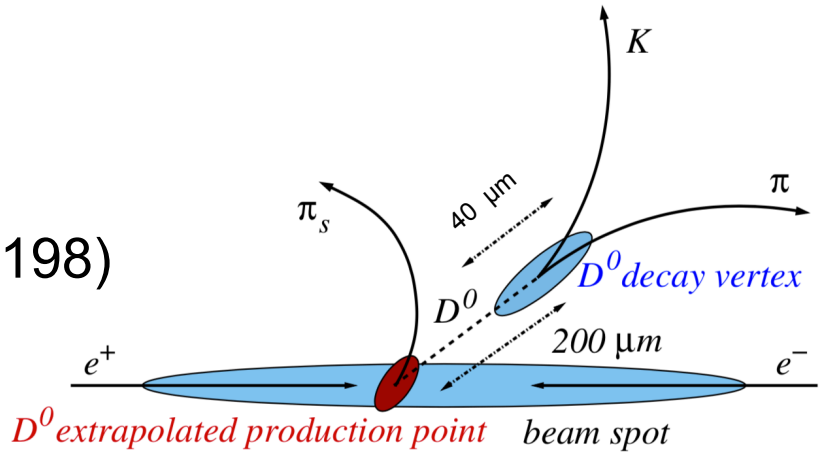


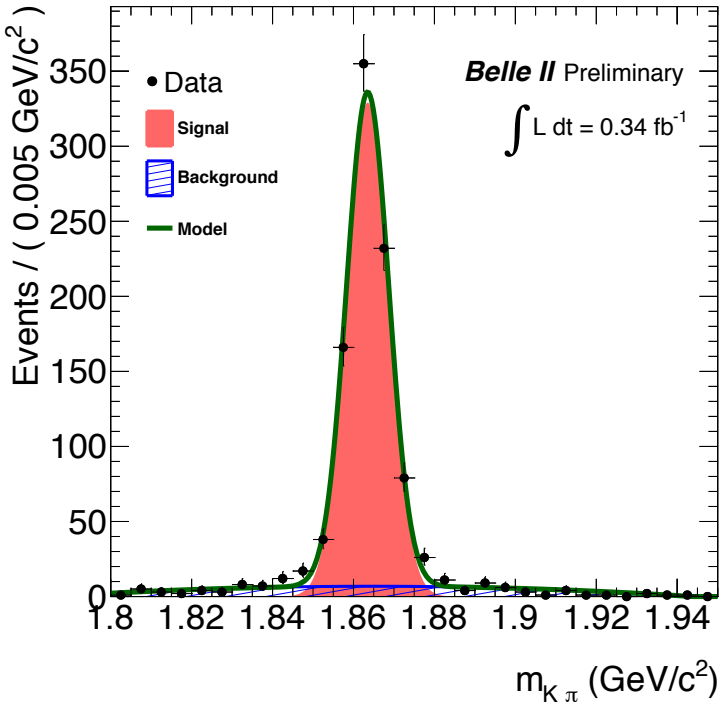


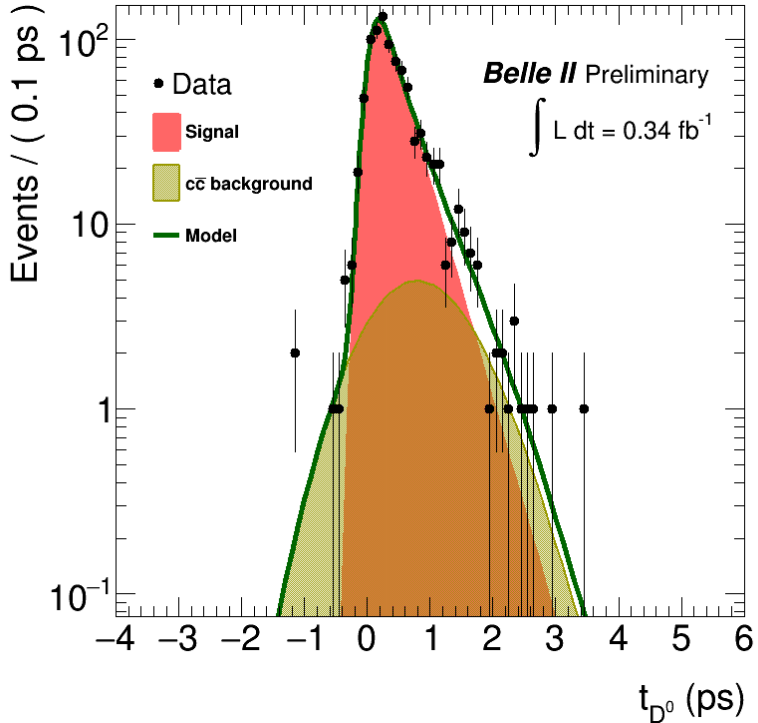


D0 Lifetime Measurement

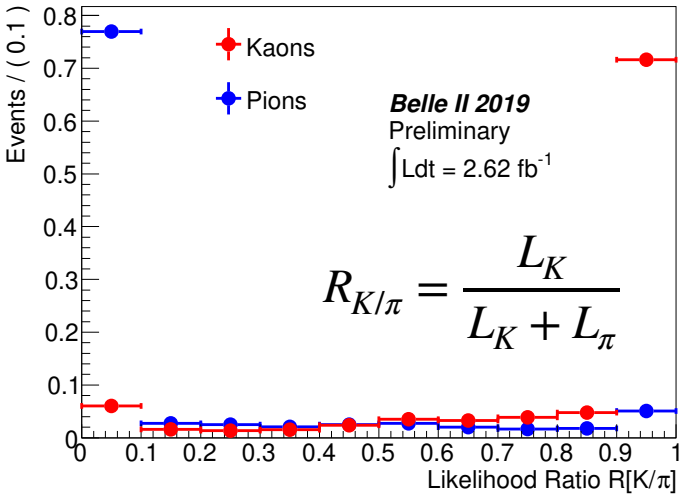
- Powerful test of Belle II vertex fitting performance
- TreeFitter algorithm for full decay chain fitting (arXiv:1901.11198)
  - Direct extraction of long lived particles lifetimes
- D* (short lived) constrained to measured beam spot region
- **τ(D0) = 370 ± 40 fs** using limited data (May/early June)



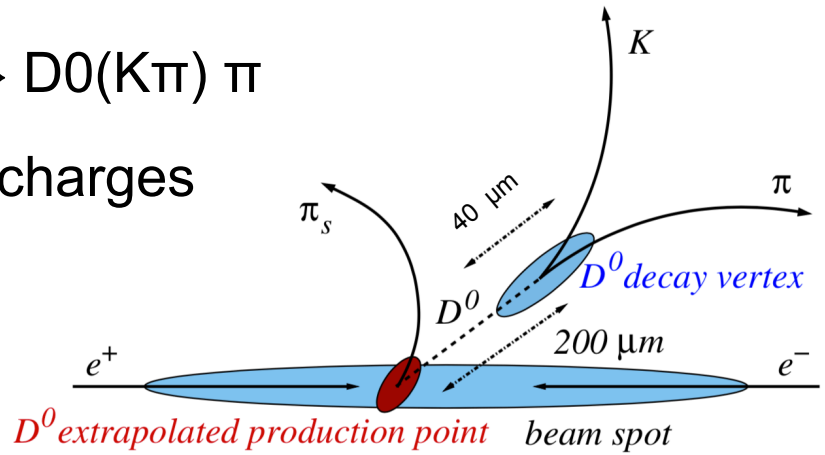


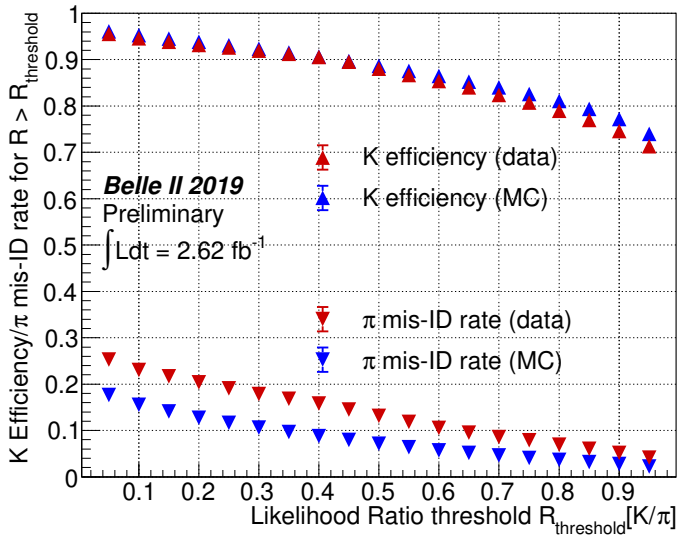


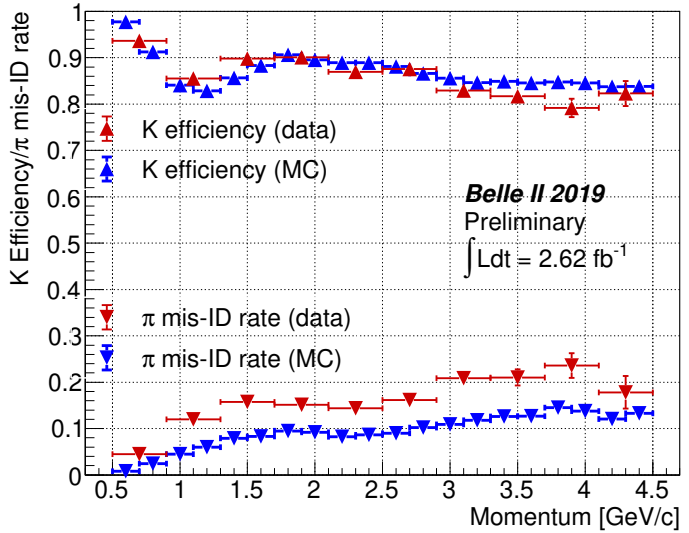
Hadron ID Performance

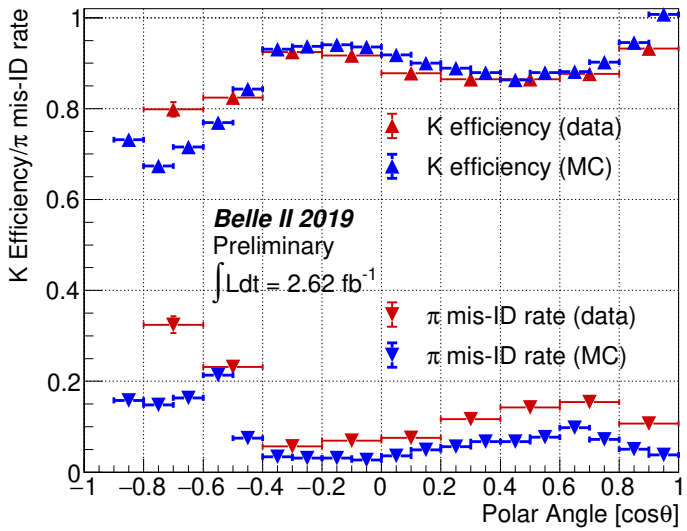


- Dominant contribution from TOP+ARICH
- Tag-and-probe on D*→ D0(Kπ) π
- Slow pion tags the Kπ charges









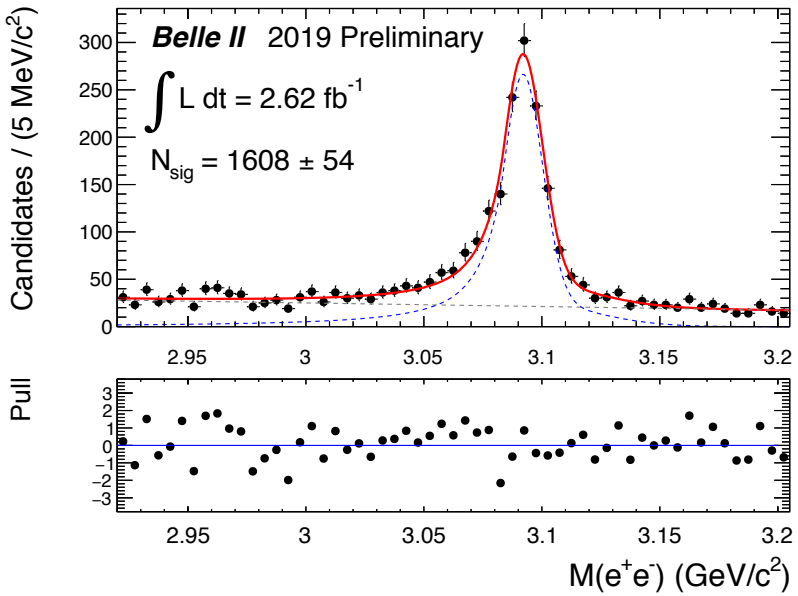
R(K/π)>0.5

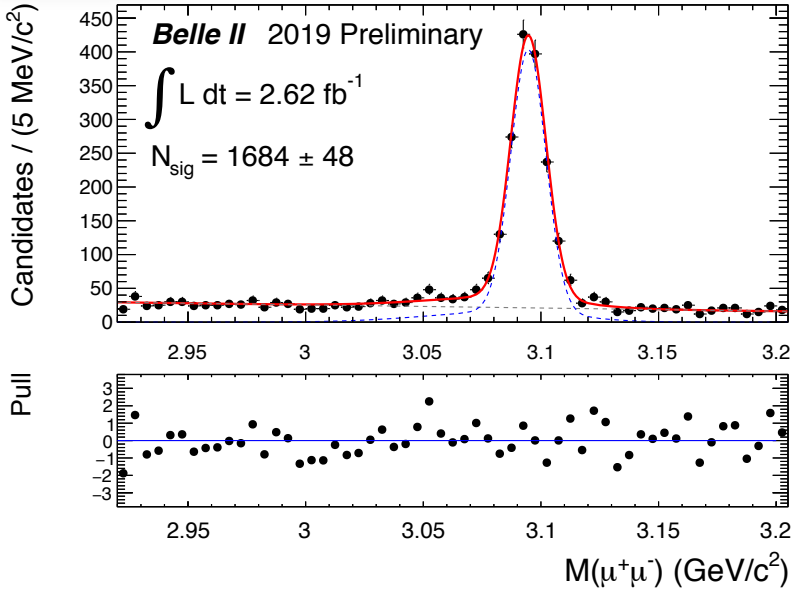
Lepton ID and Particle Reconstruction

$$R_e = \frac{L_e}{L_e + L_\mu + L_\pi + \ldots}$$

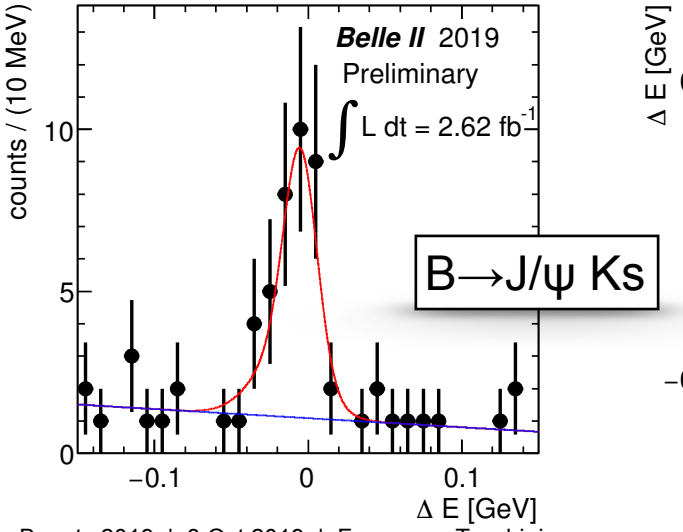
- Dominant contribution from:
  - eID: ECL (E/p)
  - muID: ECL+KLM

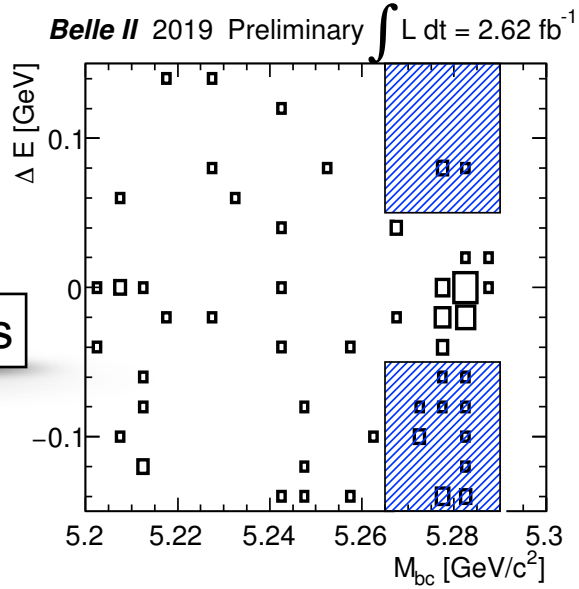
B→J/ψ X

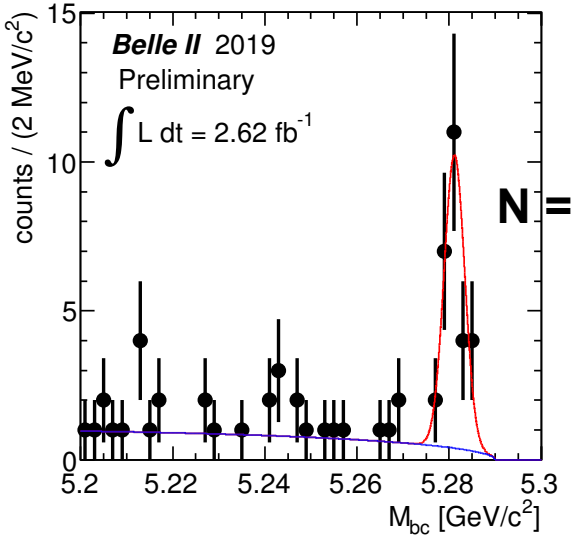




B→J/ψ Ks

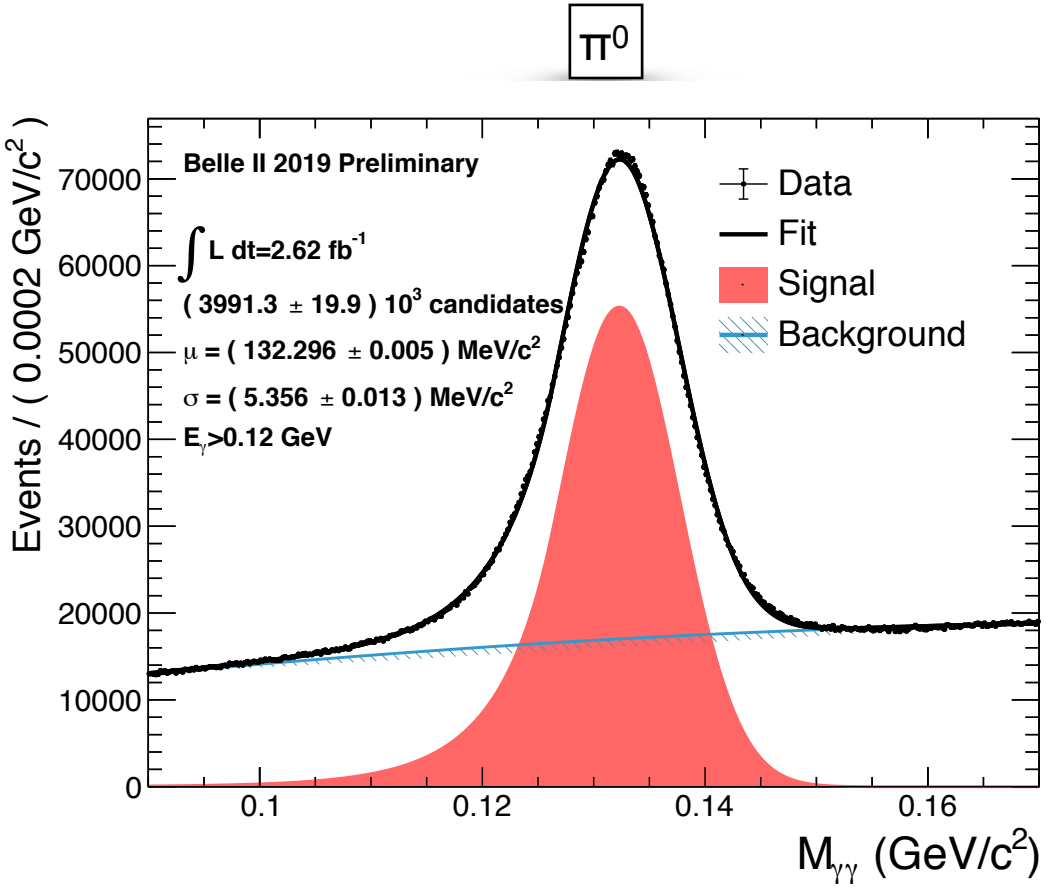


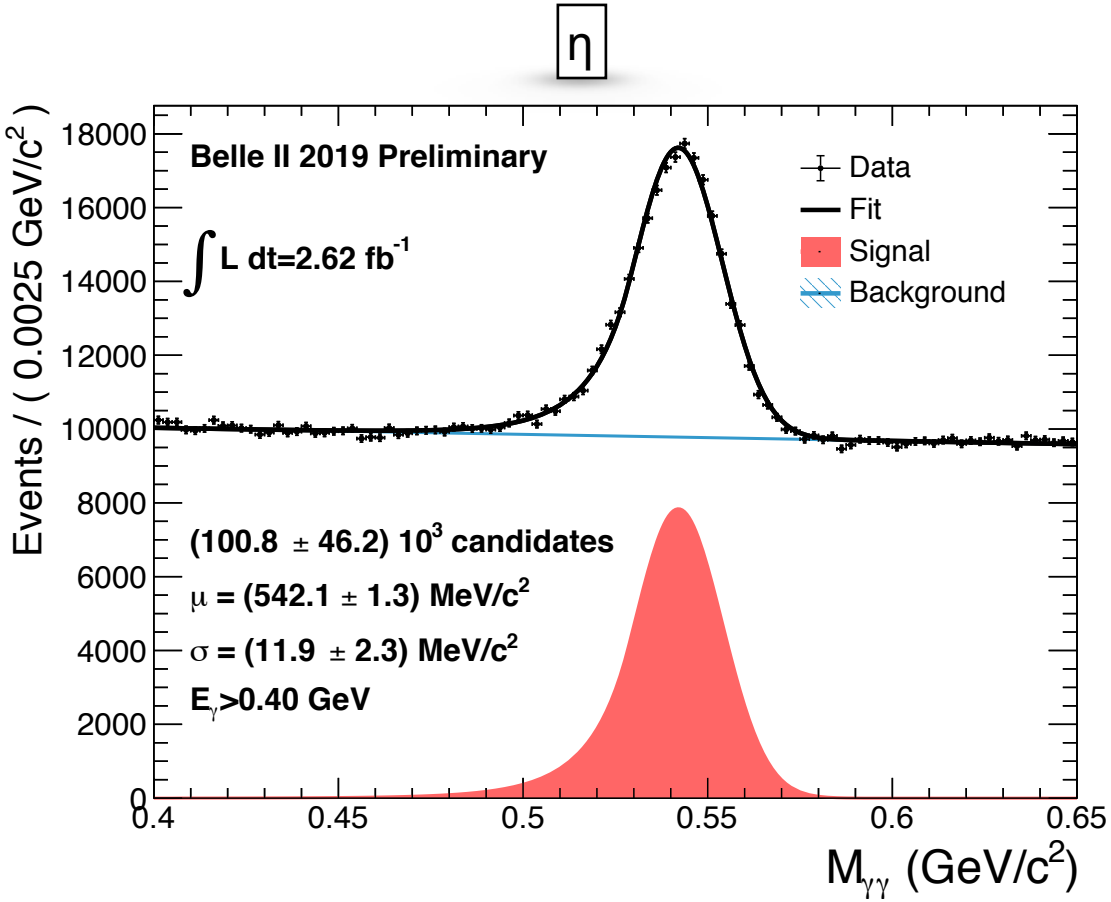




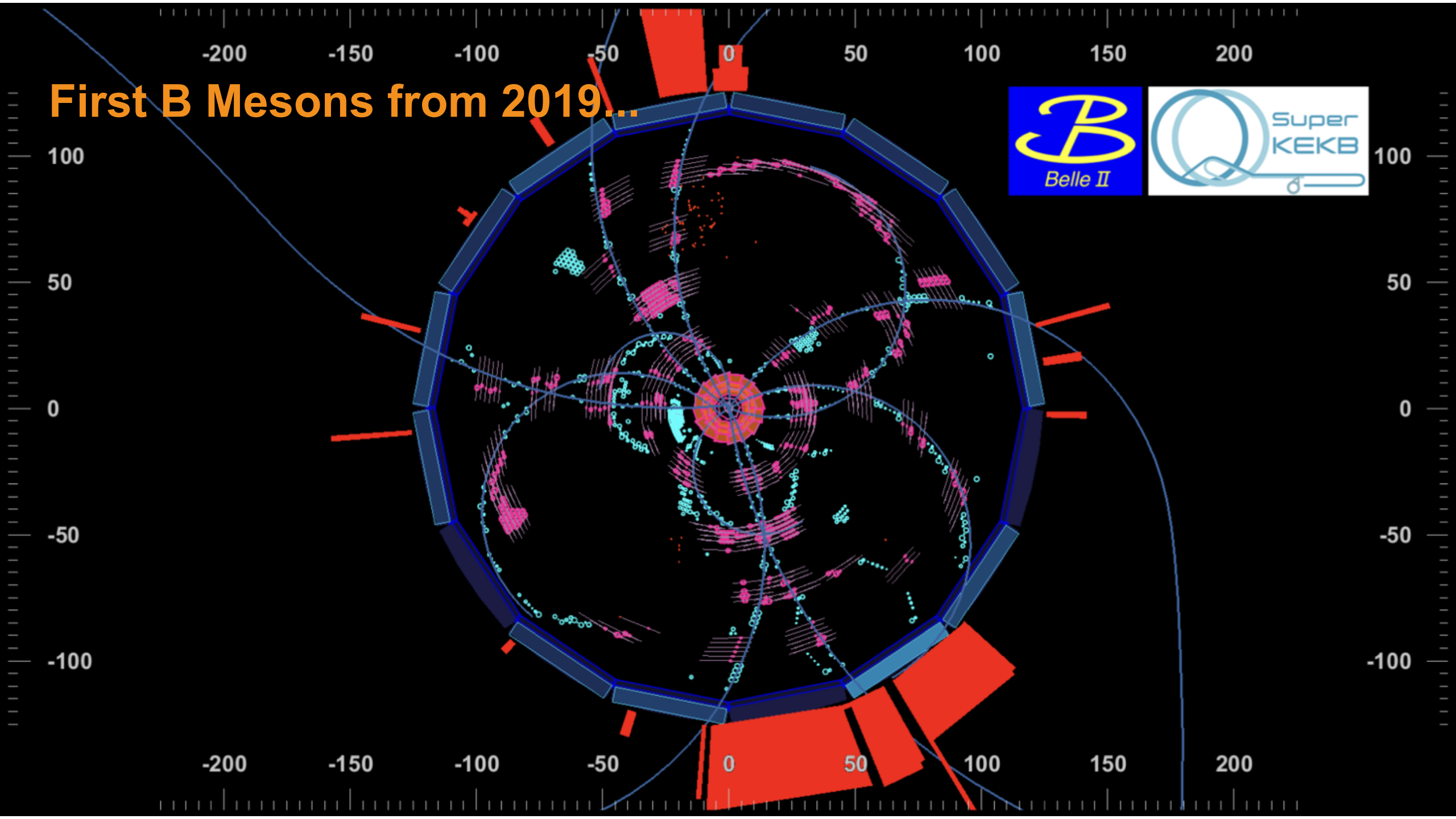
N = 26.9 ± 5.2

Neutral Particles



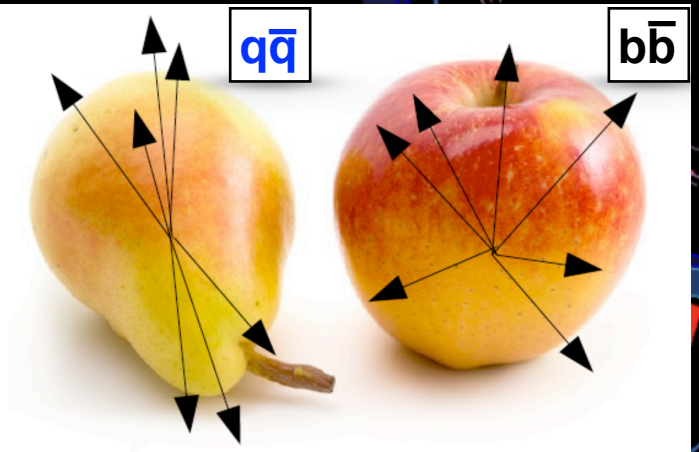


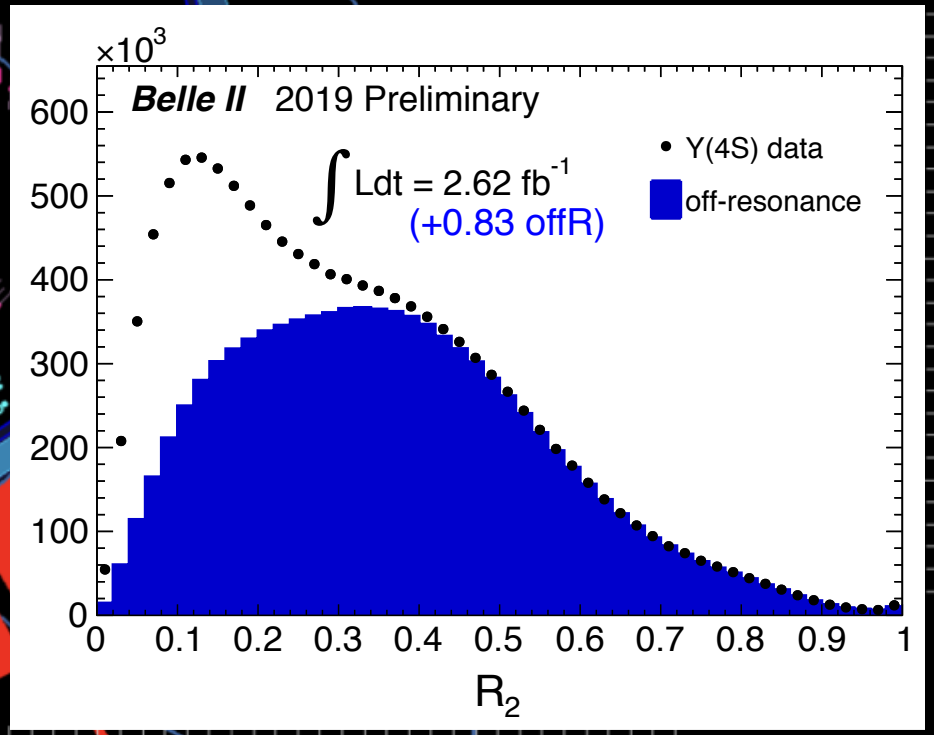
- Photon selection on plots above based on ECL cluster shape (E9/E25).
- Combinatorial background can be further suppressed with appropriate classifiers.


First B Mesons from 2019...
Belle II
Super KEKB
-200
-150
-100
-50
0
50
100
150
200
100
50
0
-50
-100

... and Event Shape

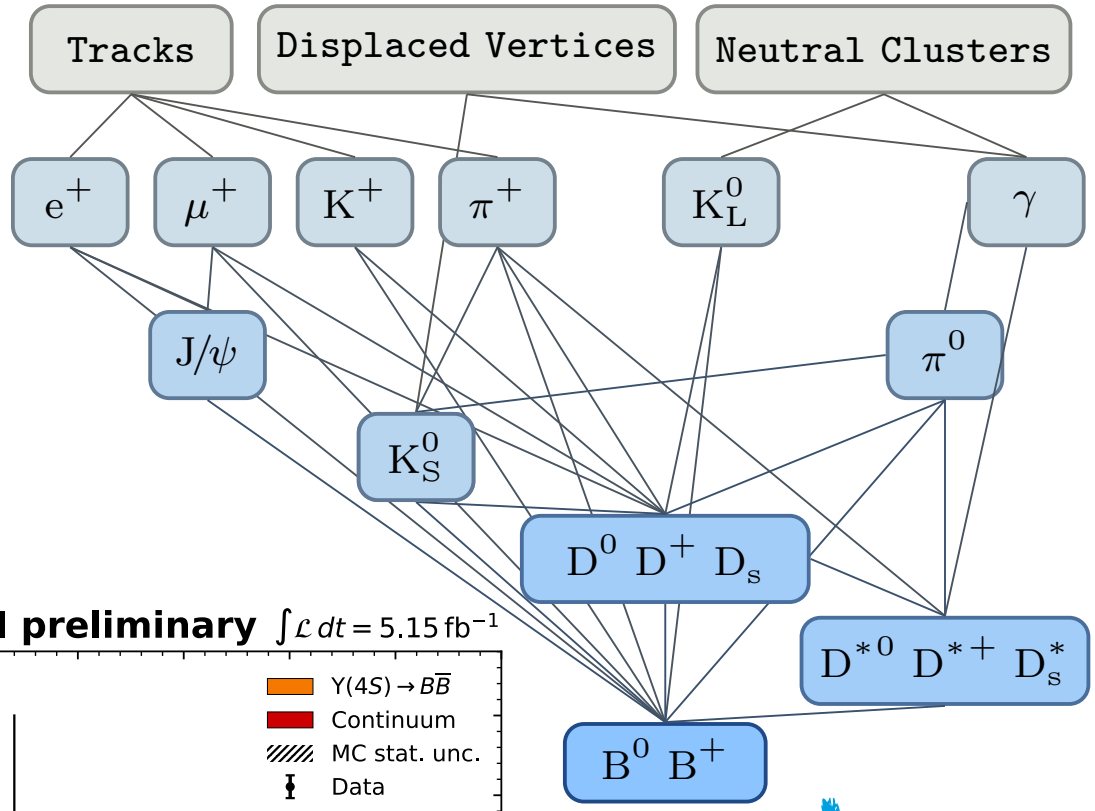
$$R_2 = \frac{H_2}{H_0}$$

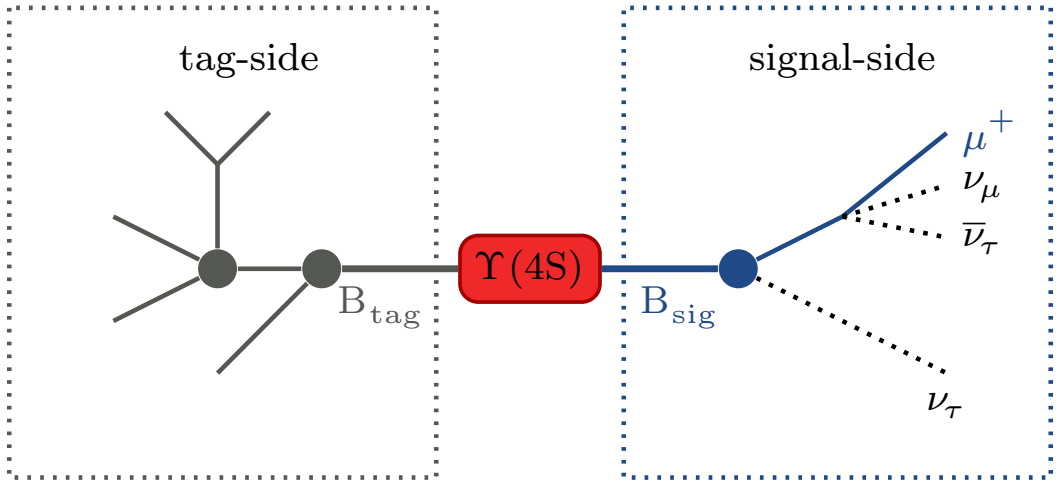


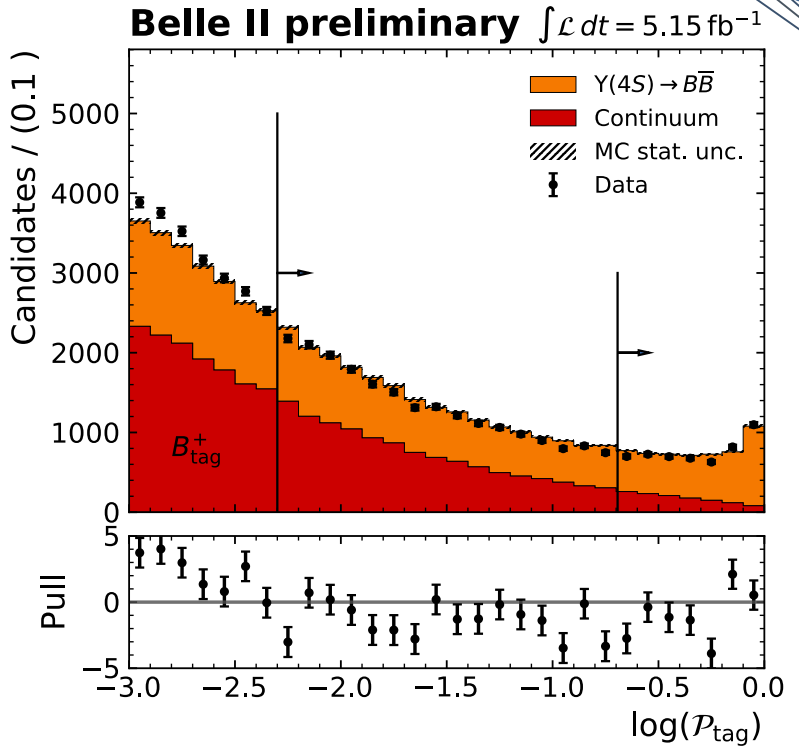


Full Event Interpretation

- Reconstruction of the second B meson (B-tagging) is fundamental for the study of missing energy decays
- Exclusive reconstruction via multi-stage classifier over ~100 of channels:
  - Semileptonic tag (higher efficiency)
  - Hadronic tag (cleaner)

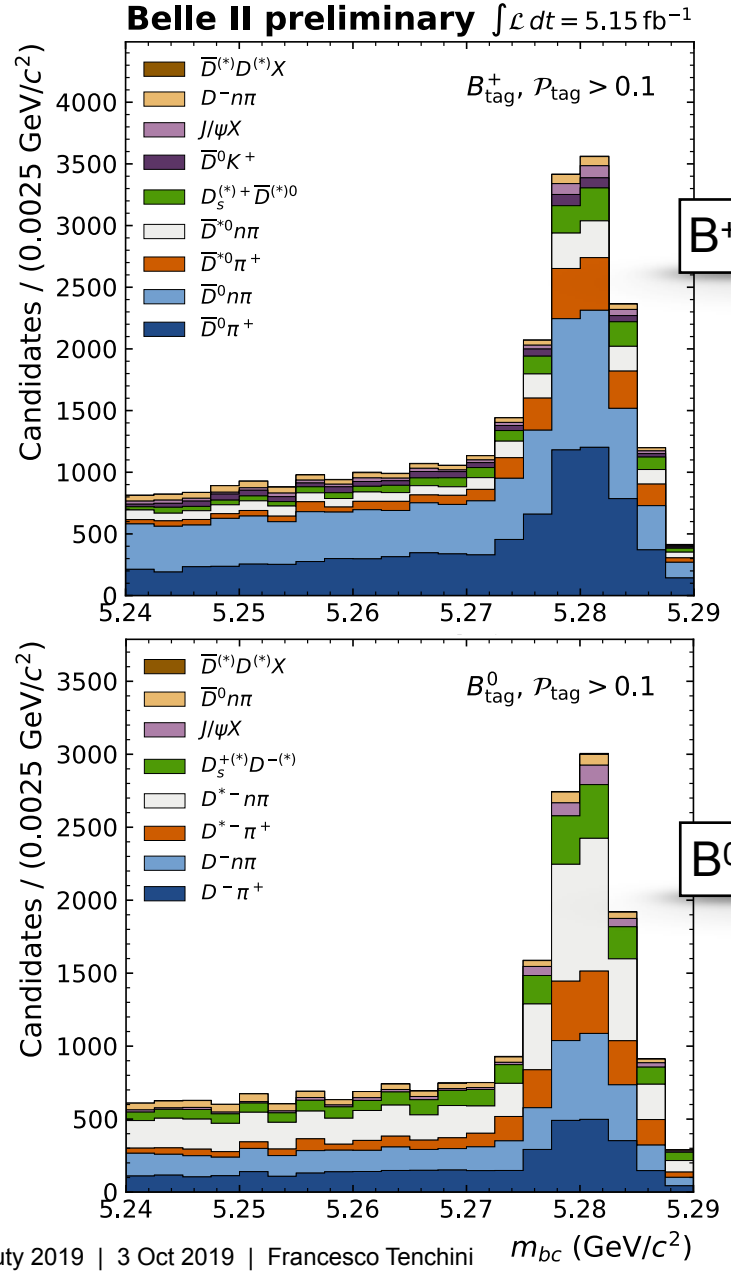


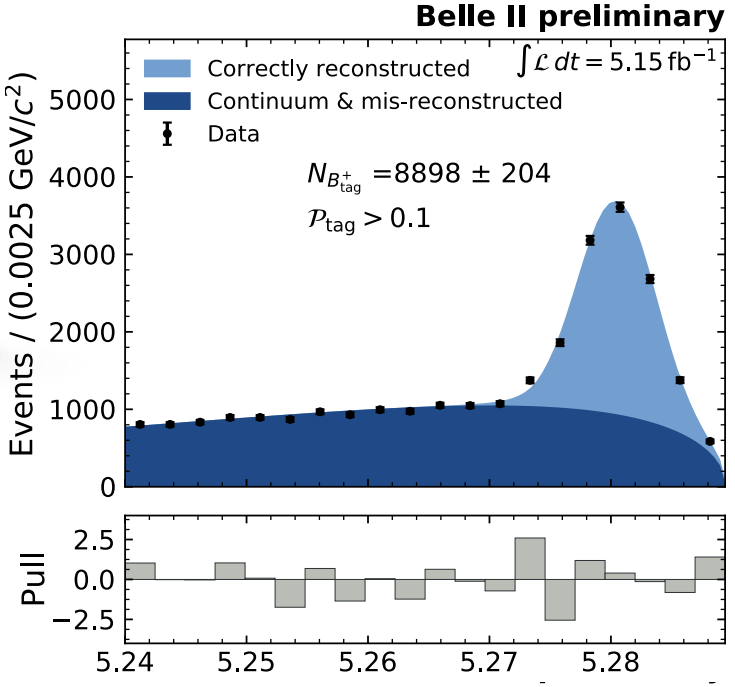


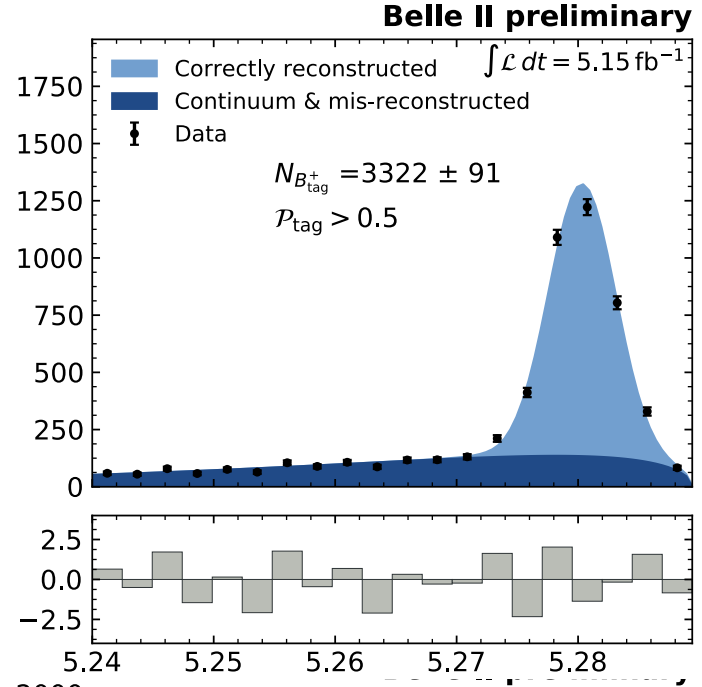


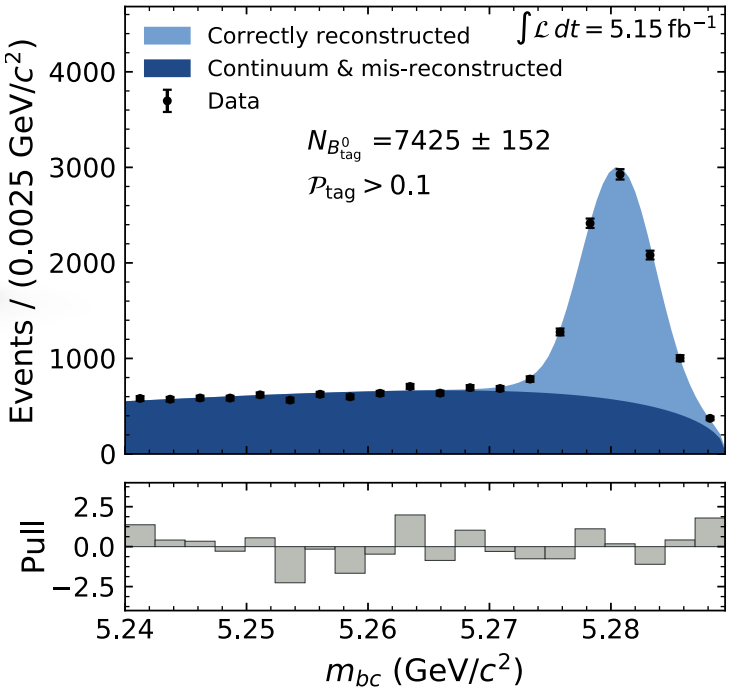
FEI, arXiv:1807.08680

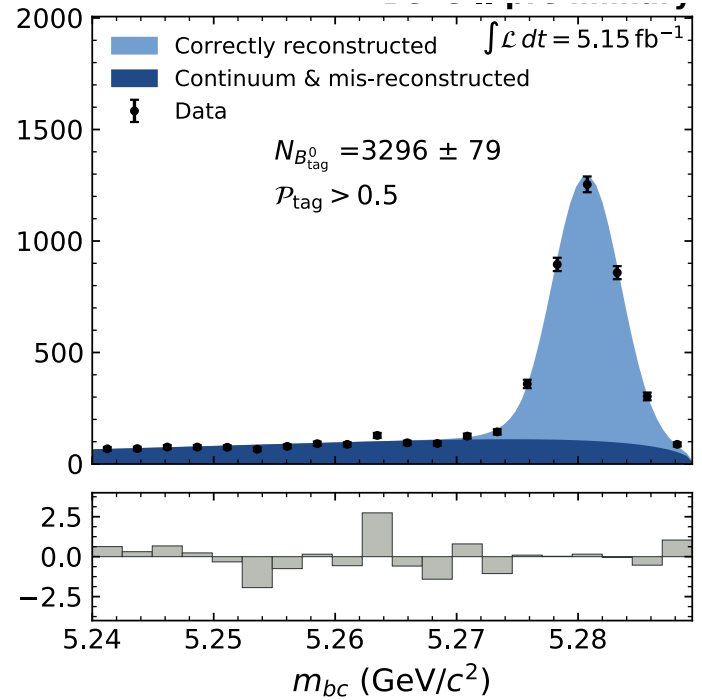
FEI with Early 2019 Data



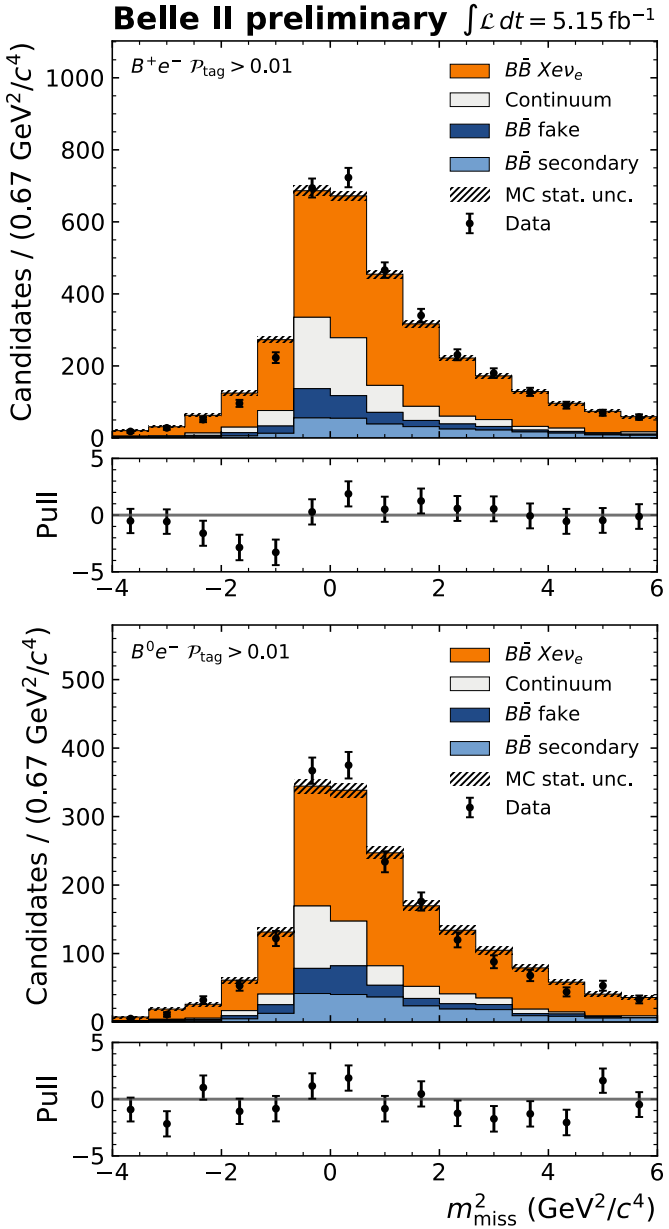


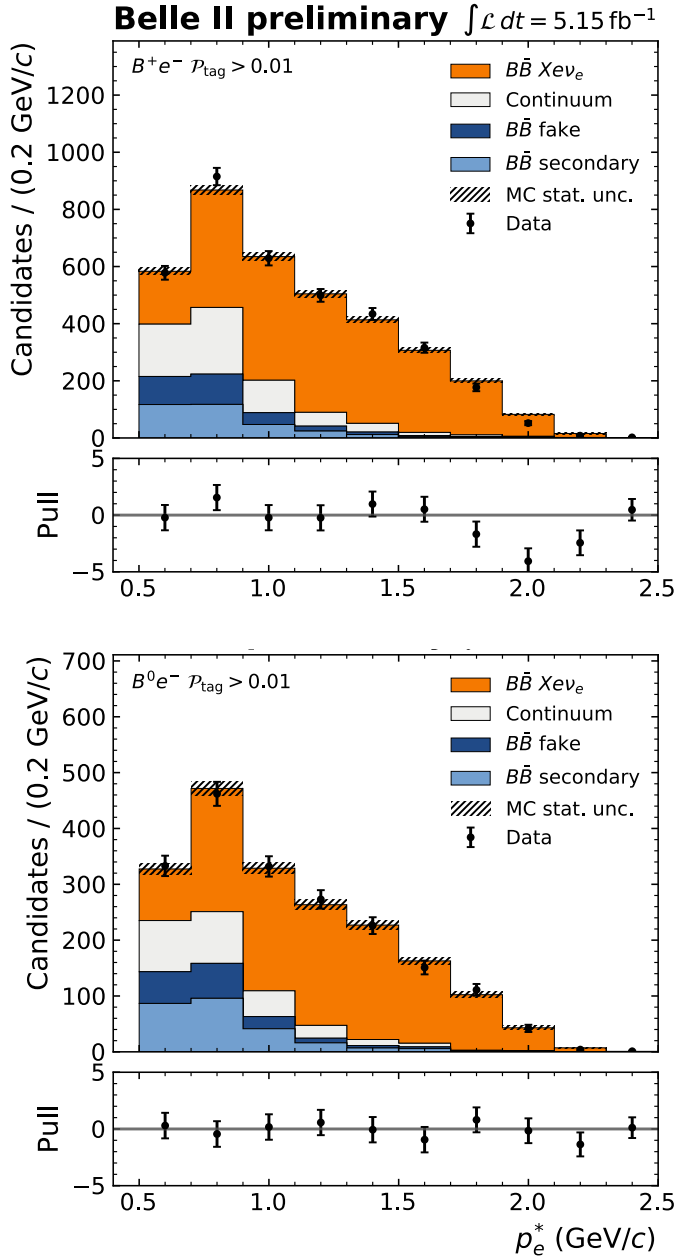






A Physics Example, B→Xev





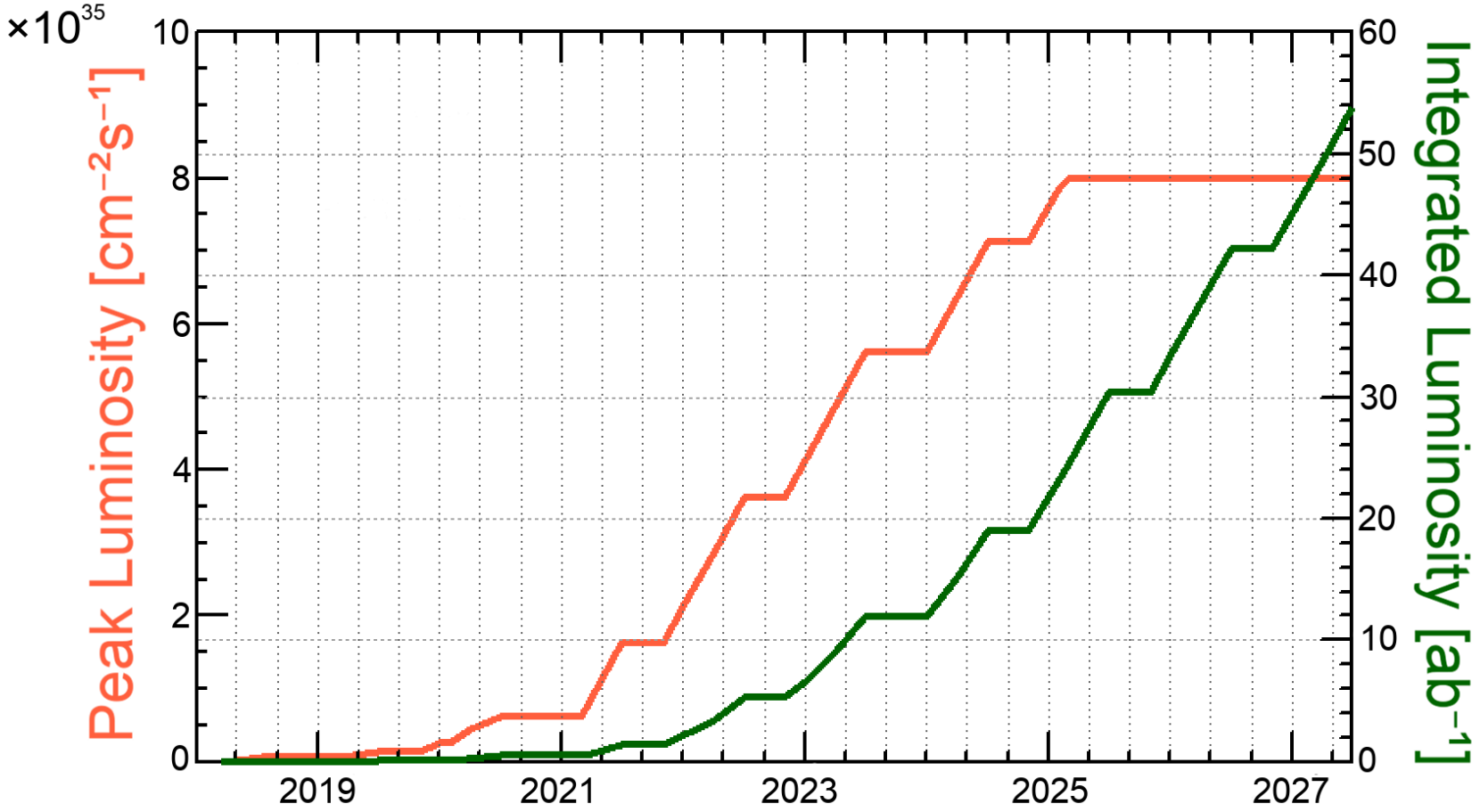
Conclusions and Outlook

- Belle II provides a unique environment to study rare B, D and τ decay processes.
- Highly performing reconstruction is essential to handle the high luminosity environment:
  - Vertex reconstruction
  - Final state particle identification
  - Particle reconstruction
  - Event shape
  - Full Event Interpretation
  - ... and more.

- Operations are currently restarting in preparation for the Autumn 2019 run.

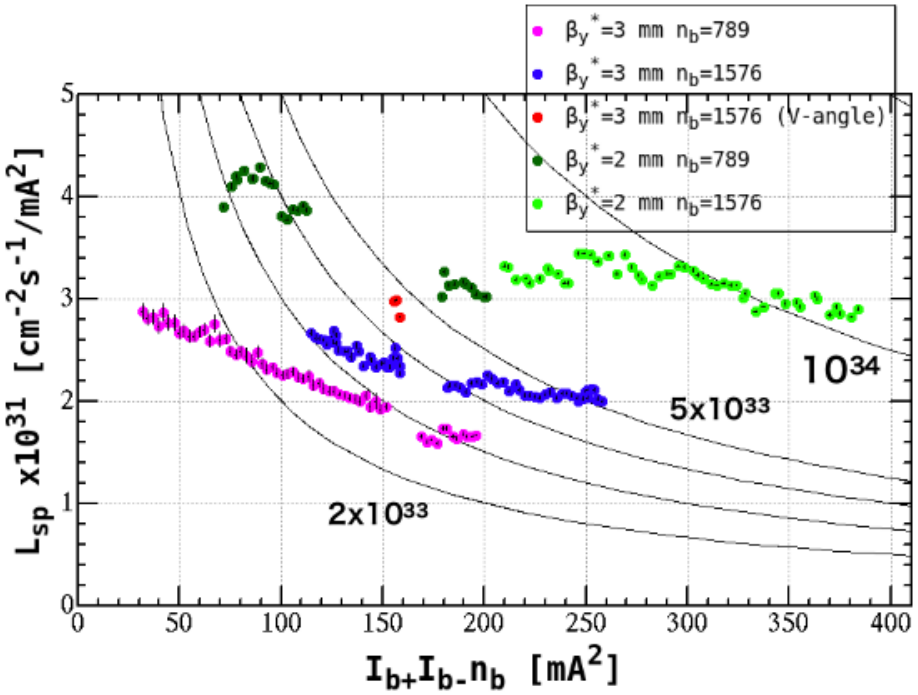
Backup

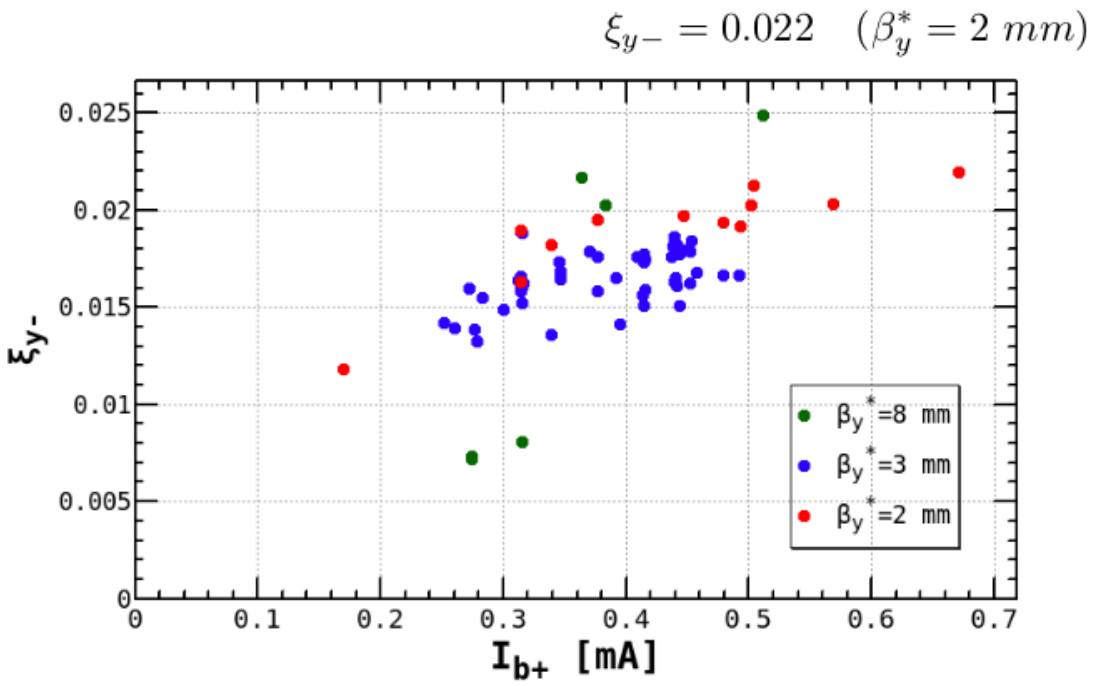
Luminosity Projection



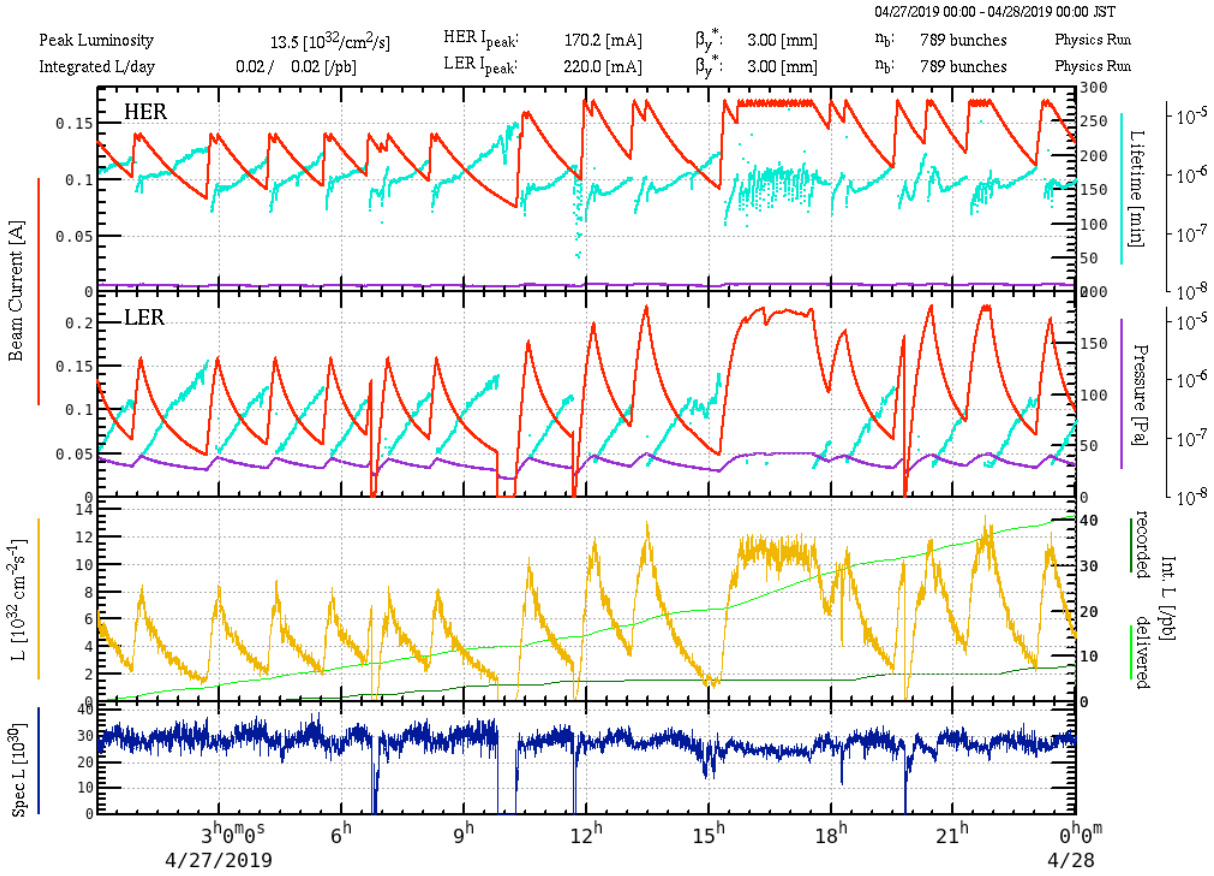
High Luminosity Study (Belle II off)

Luminosity Performance

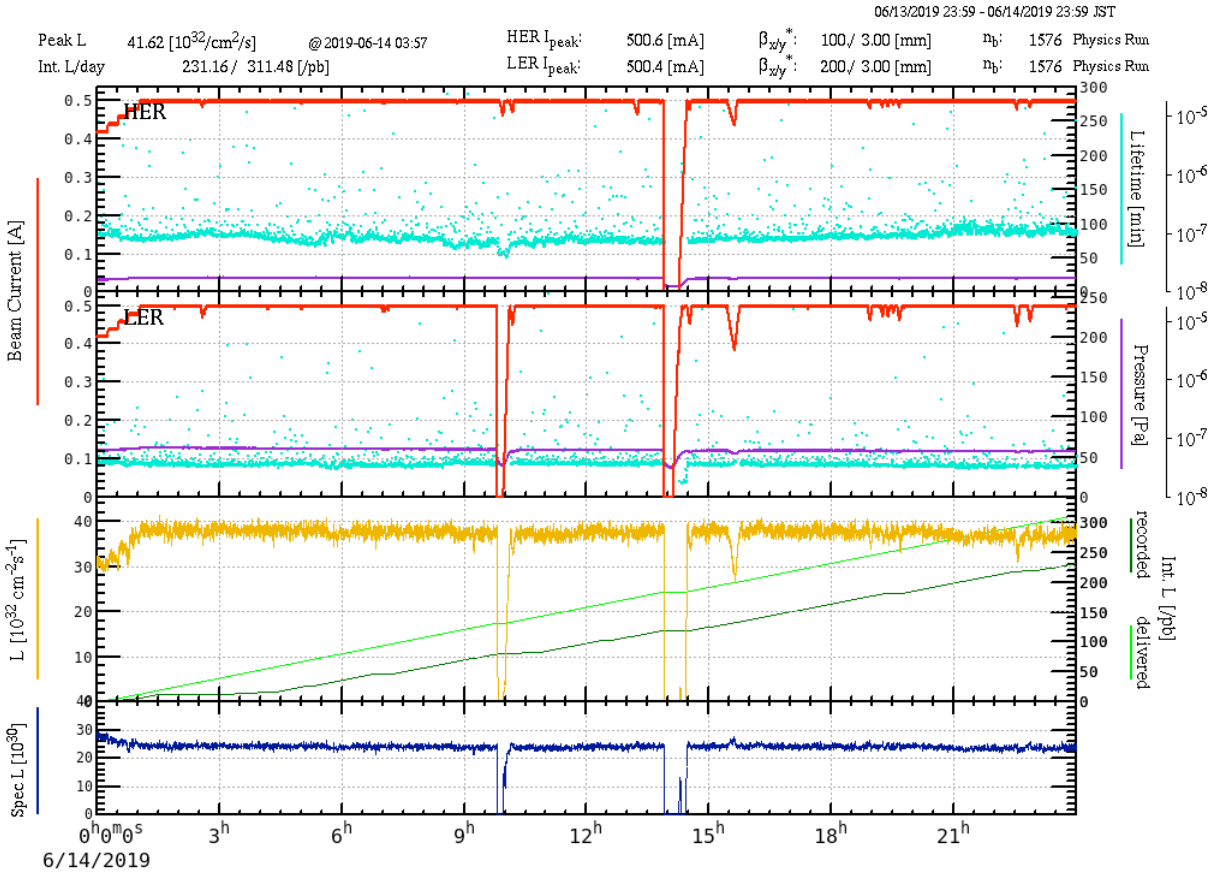




Phase 3 Injection

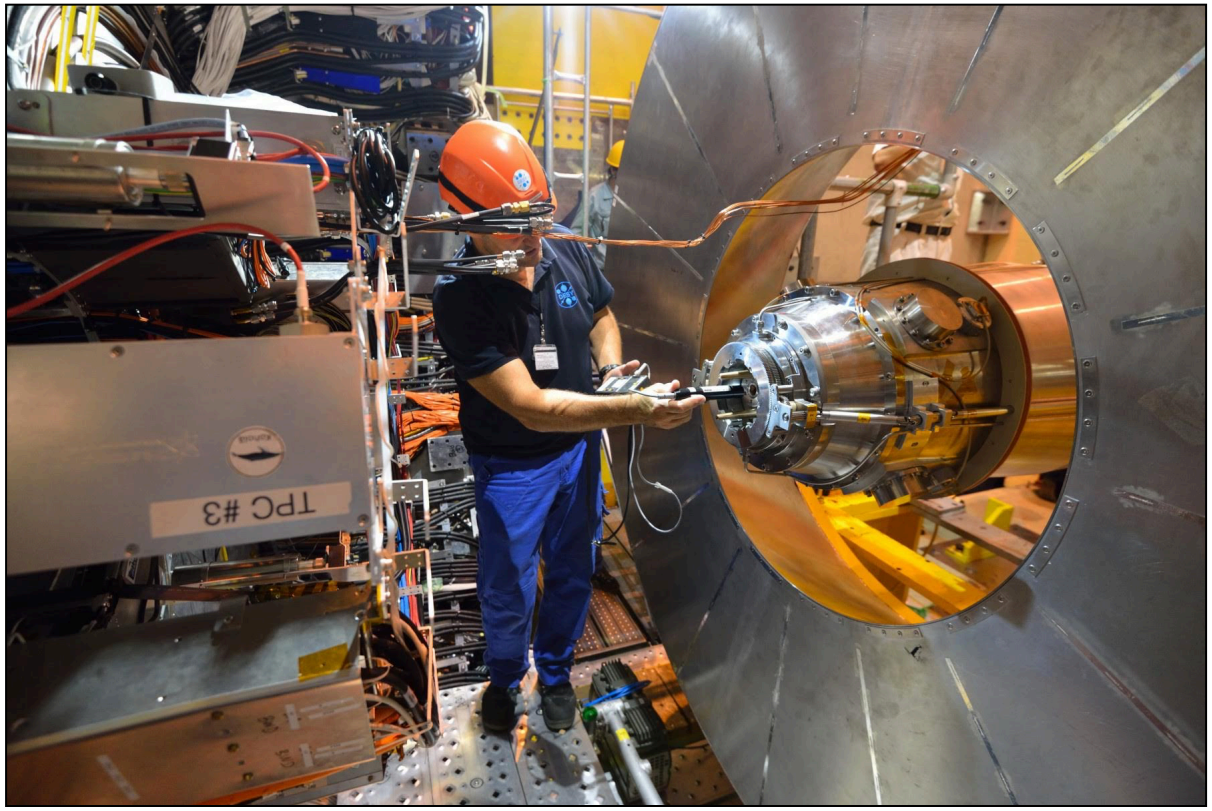


Decay mode

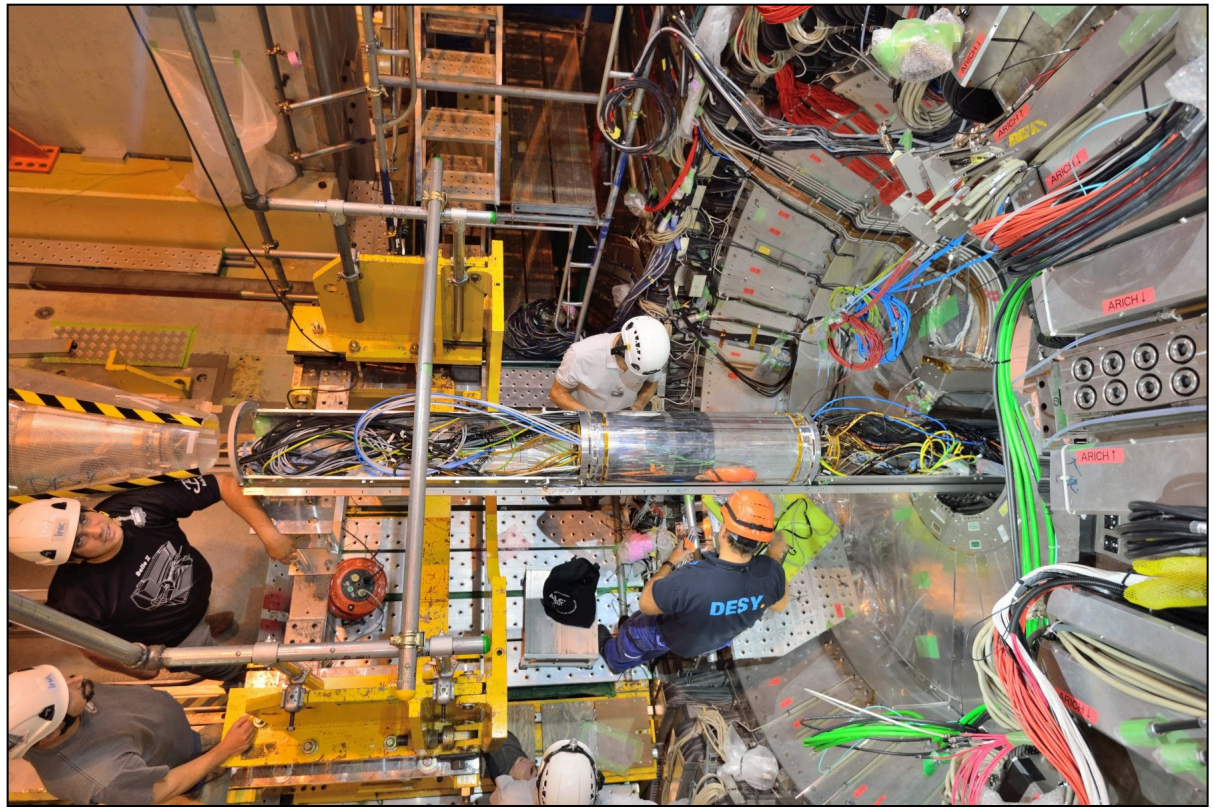


Continuous

Phase 3 Preparations

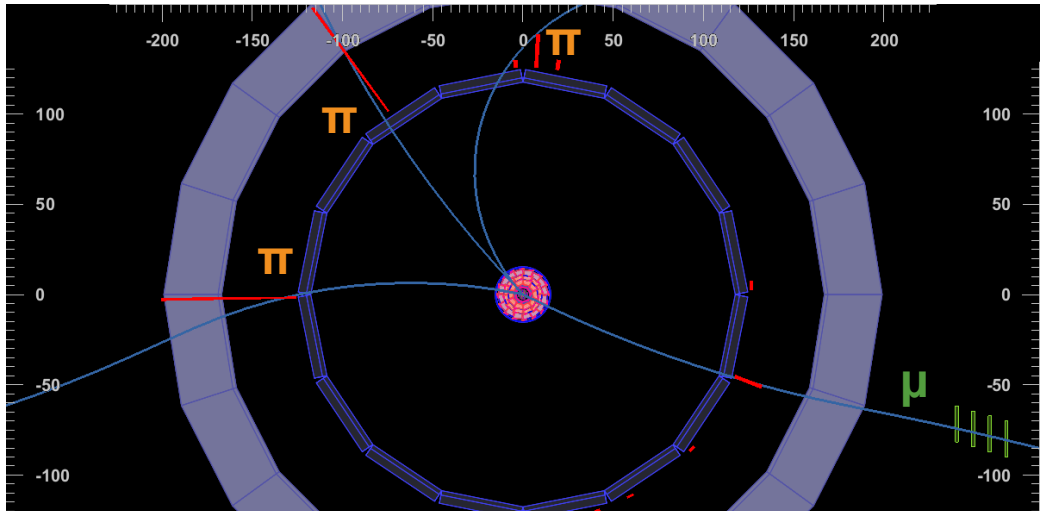


RVC opening and QCS extraction

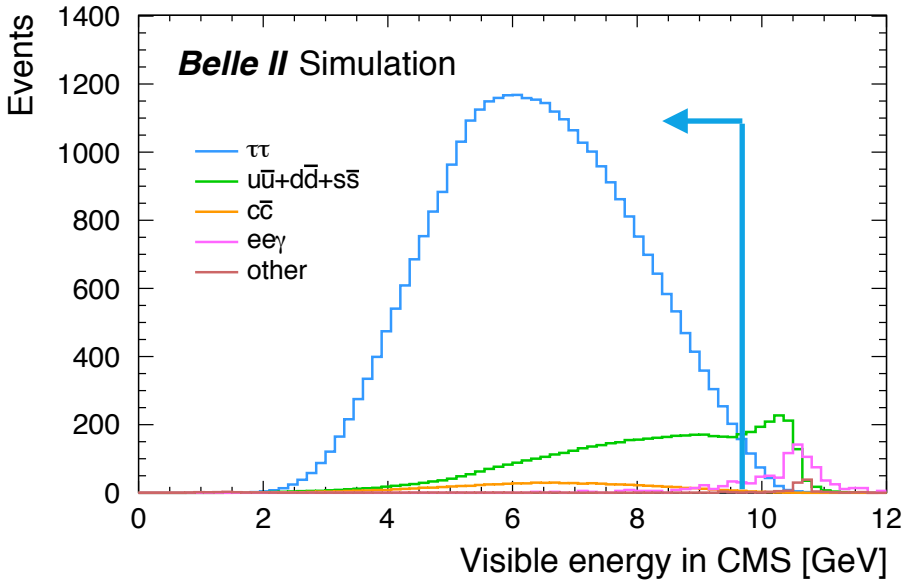


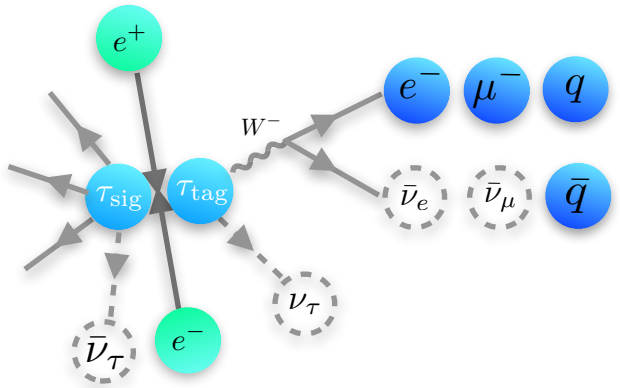
BEAST II extraction

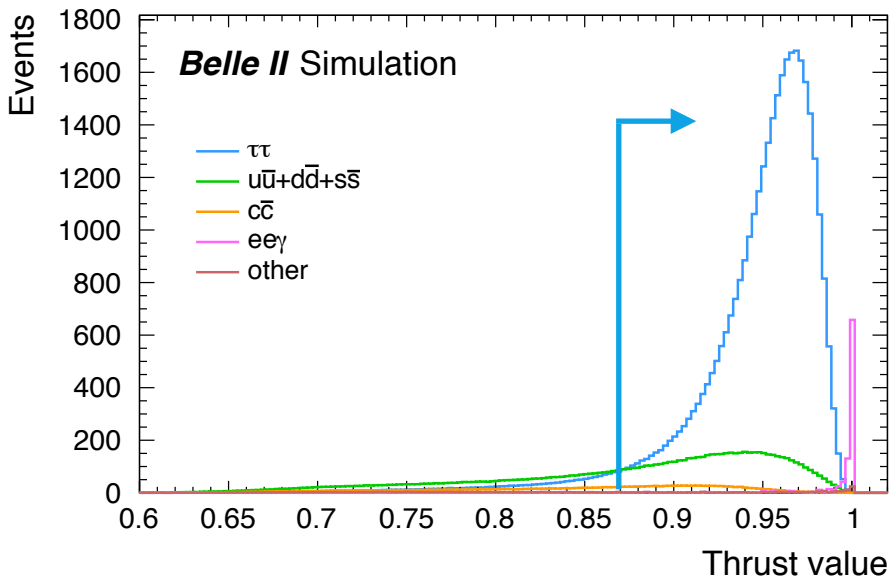
Tau Observation



- Preliminary study and preparation for future analyses
- 3x1-prong topology:
  - $\tau_{signal} \rightarrow 3\pi\nu$ ($+n\pi^0$), $\tau_{tag} \rightarrow \ell\nu\bar{\nu}/\pi\nu$
  - Identified through event thrust = $\sum_h \frac{\vec{p} \cdot \hat{T}}{|p_h|}$
- Dominant backgrounds: $q\bar{q}$ and $ee\gamma$ (radiative Bhabha)





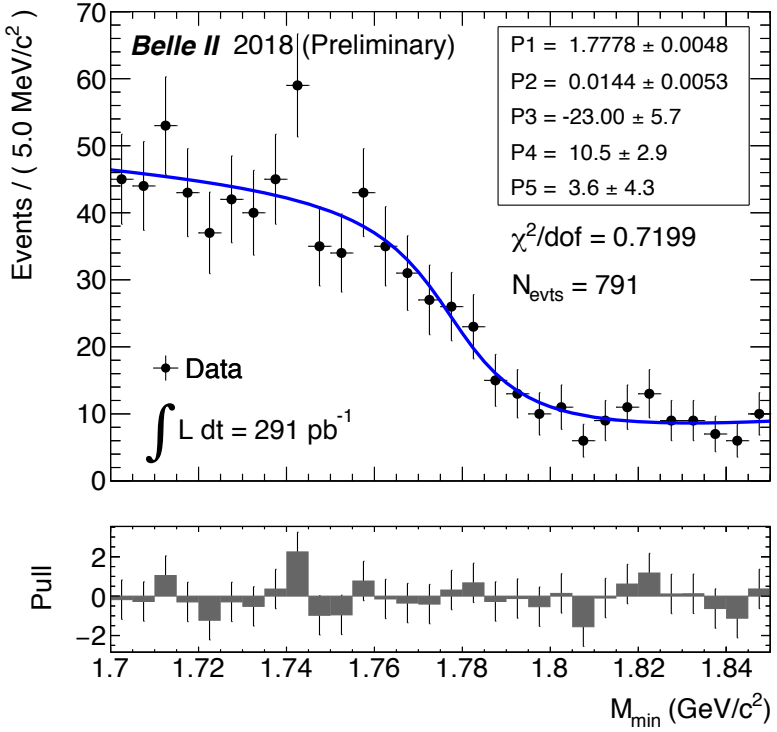


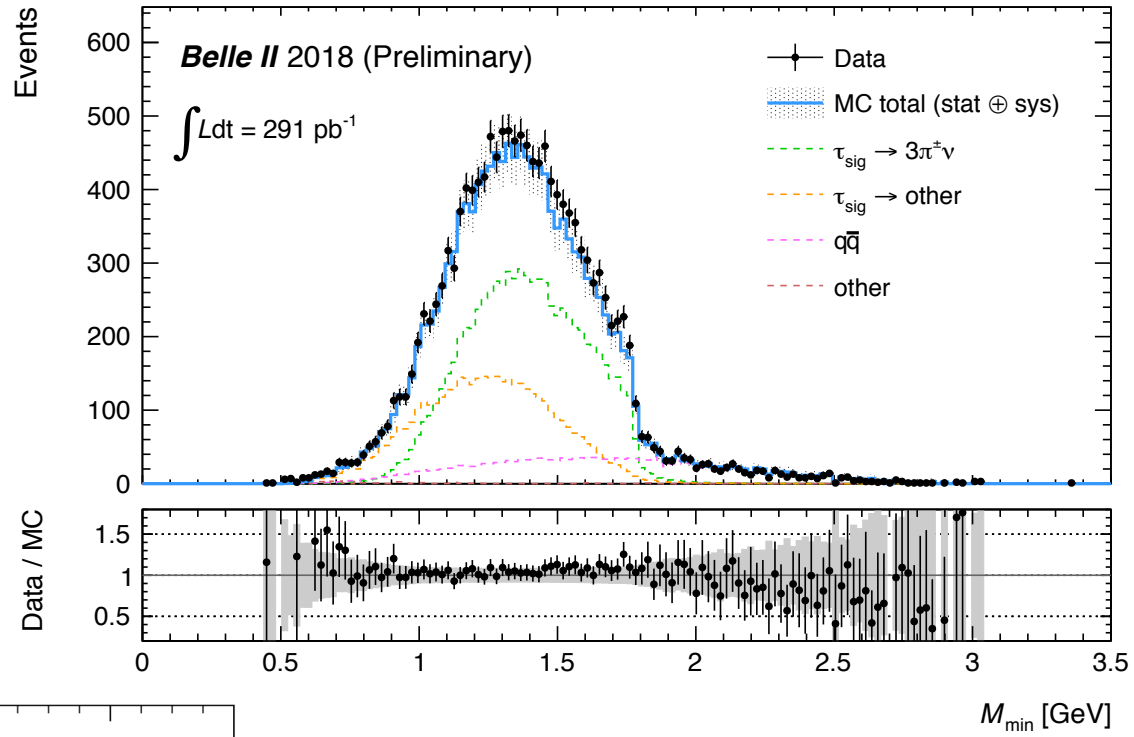
Tau Mass Measurement

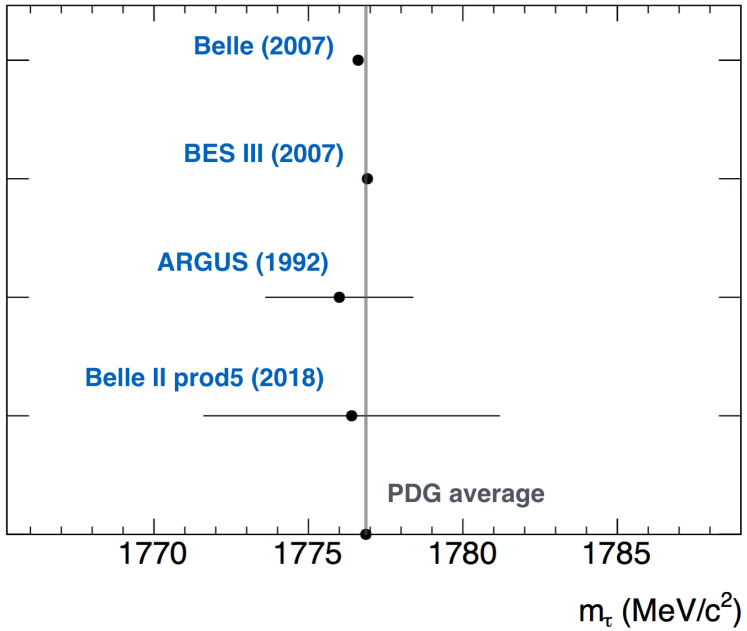
- Measurement in the exclusive $\tau \to 3\pi\nu$ channel using pseudomass technique developed at ARGUS:

$$M_{min} = \sqrt{M_{3\pi}^2 + 2(E_{beam} - E_{3\pi})(E_{3\pi} - P_{3\pi})}$$

- Fit with empirical edge function







m_τ = (1776.4 ± 4.8(stat)) MeV/c²

- First τ physics result from Phase 2
- Good agreement with existing measurements!