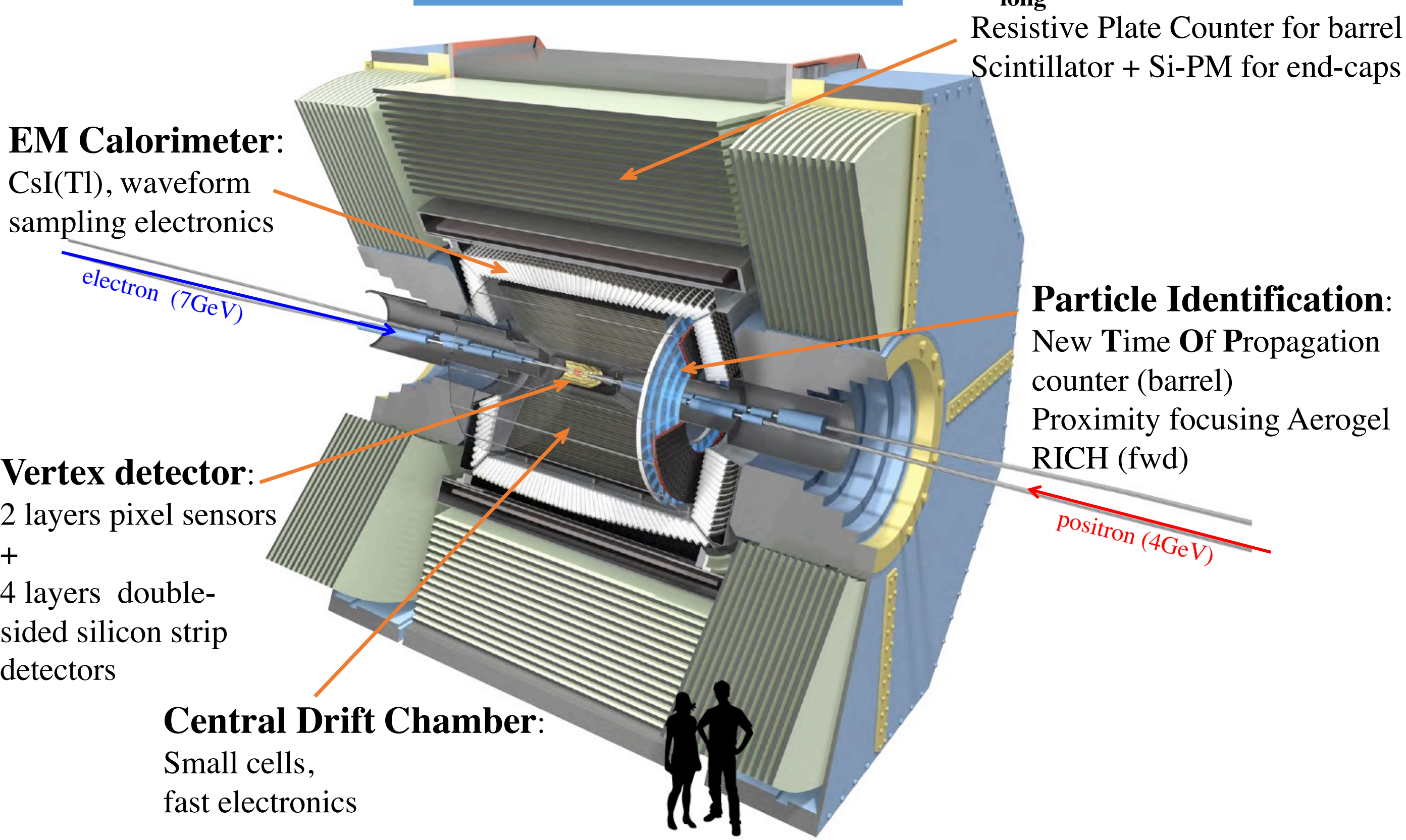


Semileptonic and leptonic B decay results from early Belle II data

Andrea Fodor, on behalf of the Belle II collaboration
McGill University, Canada

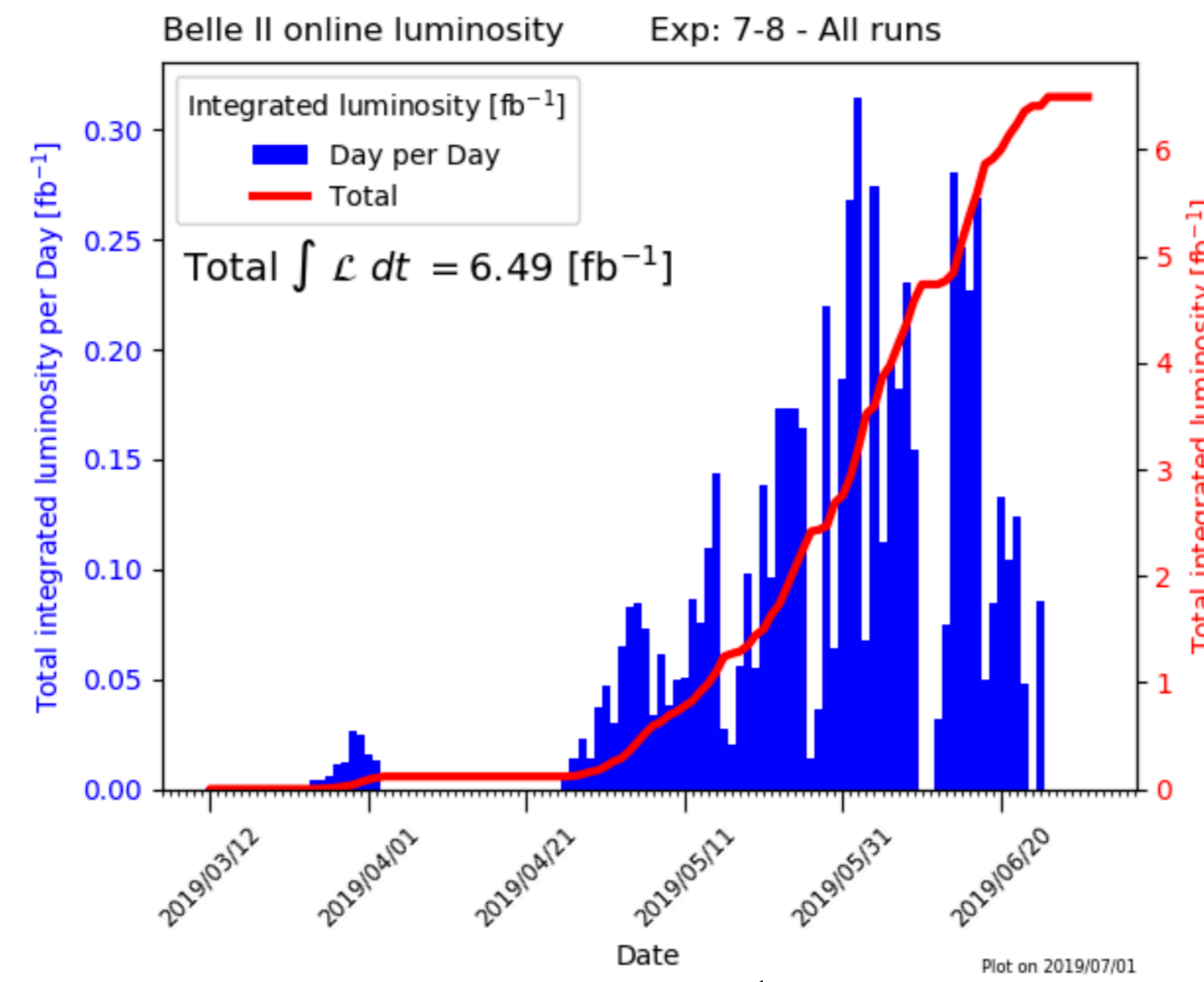


Belle II detector



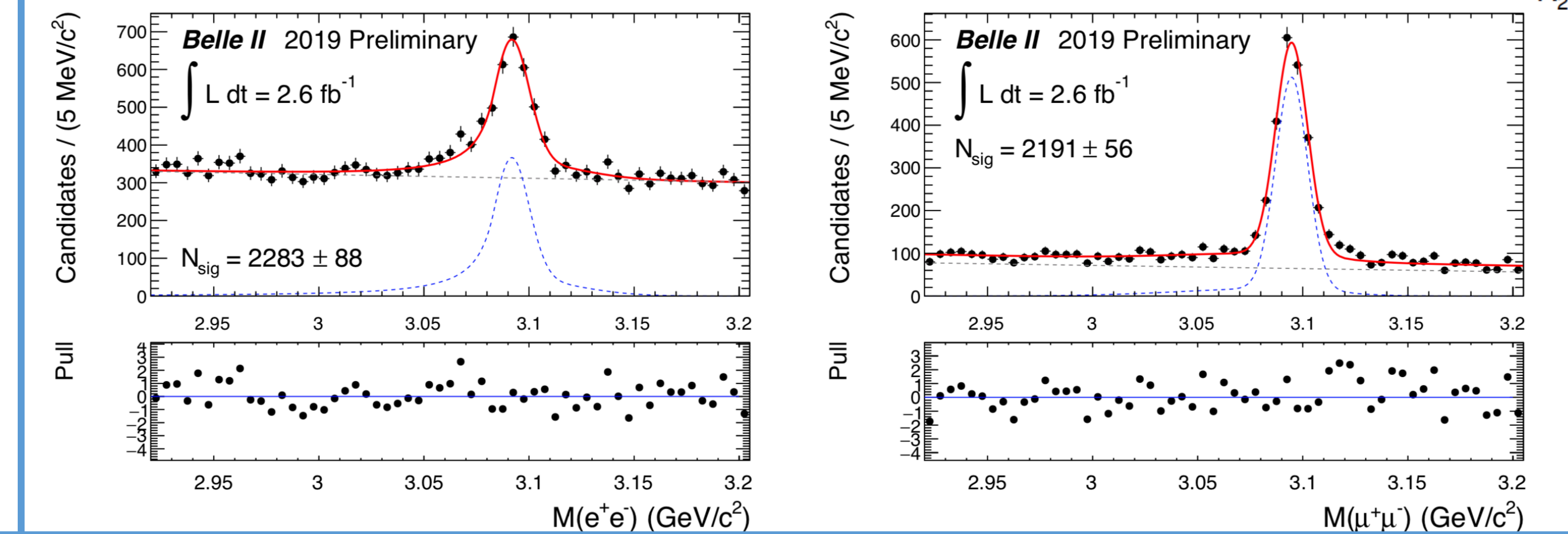
Belle II run in 2019

- First Belle II official data taking run with the full detector installed from March to July 2019
- Reached an instantaneous luminosity of $5.5 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$



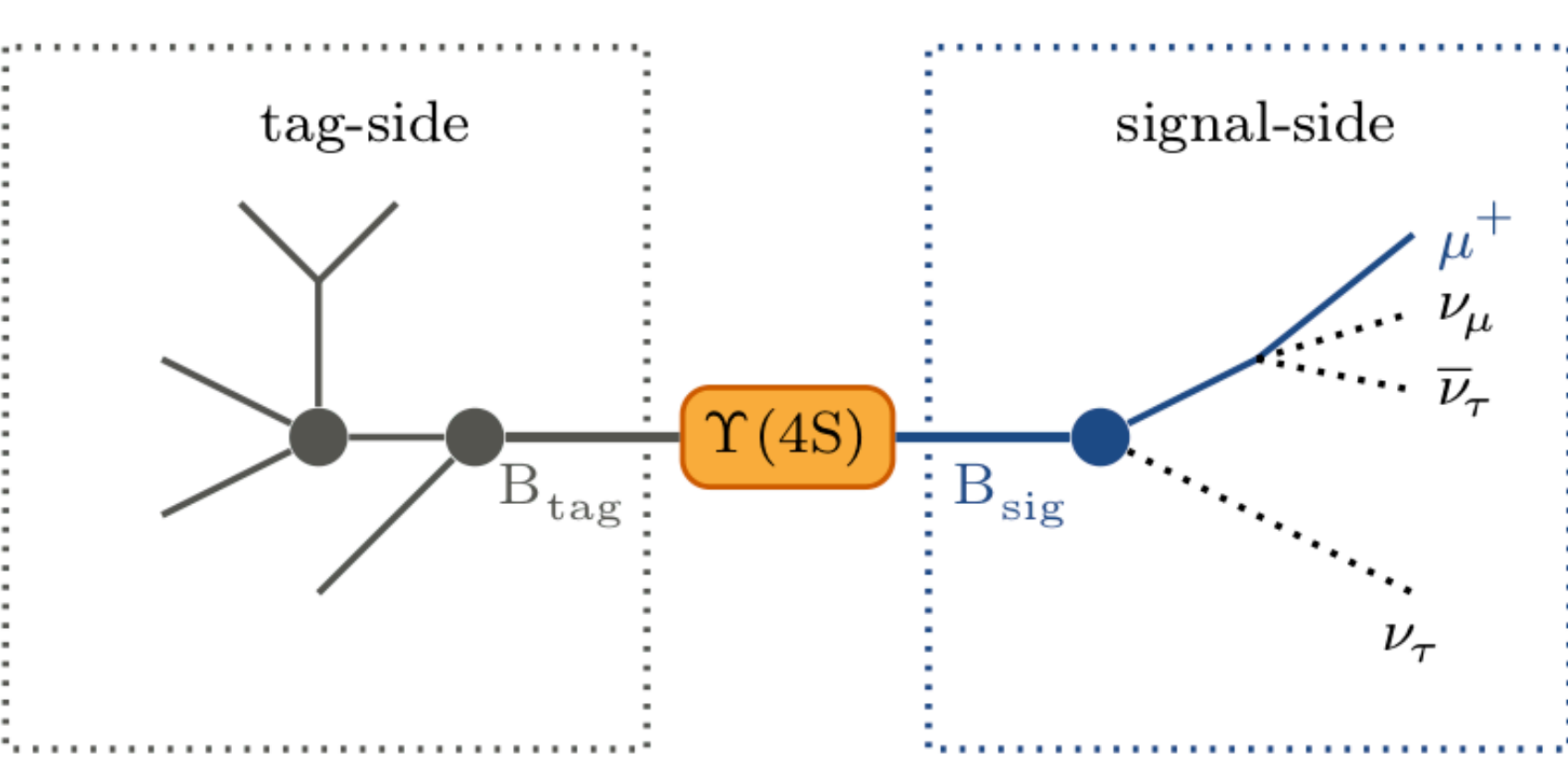
Belle II Performance

- B-meson detection:** Data/MC comparison of R2, ratio of second and zeroth Fox-Wolfgram moment – a good indicator of collisions at $\Upsilon(4S)$ resonance
- Particle Identification:** Identification efficiency for electrons and muons tested using $J/\psi \rightarrow \ell^+ \ell^-$ decays



B-meson reconstruction and Full Event Interpretation

- $e^+ e^-$ collided at the $\Upsilon(4S)$ resonance which decays almost exclusively to **B-meson pairs**
- B-mesons produced almost **at rest in the CoM frame**
- Several approaches in the analysis depending on the treatment of the companion B-meson, **B_{tag}**



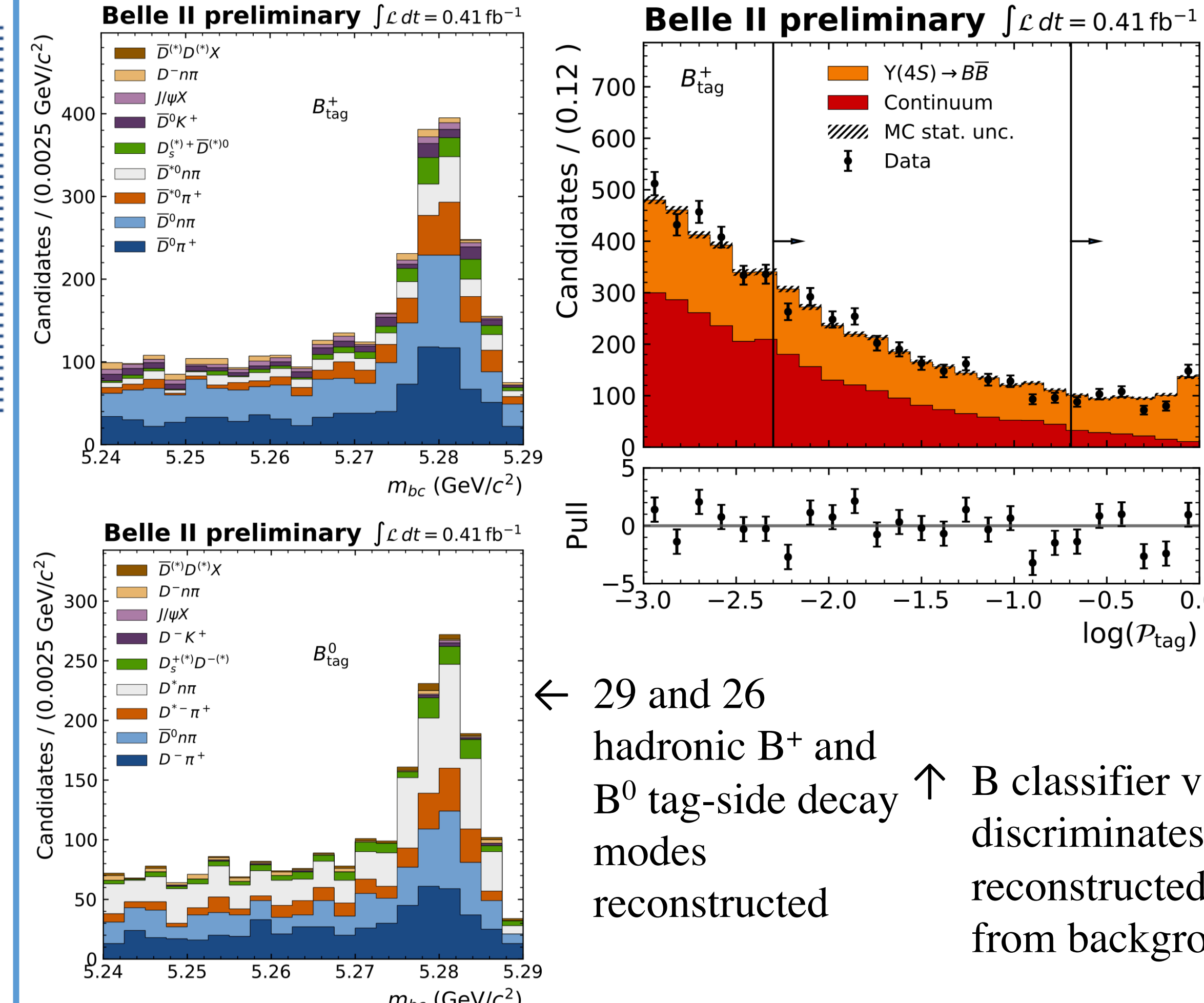
Inclusive Tag
 $\epsilon = \mathcal{O}(100)\%$
Consistency of B_{tag}

Semileptonic Tag
 $\epsilon = \mathcal{O}(1)\%$
Knowledge of B_{tag}

Hadronic Tag
 $\epsilon = \mathcal{O}(0.1)\%$
Exact knowledge of B_{tag}

- **Untagged reconstruction** – signal reconstruction without full B_{tag} reconstruction
- **Tagged approach** – reconstruction of the B_{tag} first using semileptonic or hadronic decay modes and attributing the remaining detected depositions to the B_{sig}
- **Full Event Interpretation** – tagging approach implemented by Belle II that uses Machine Learning and reconstructs B_{tag} from more than 200 different decay modes, improving the B_{tag} reconstruction efficiency; enables precise determination of the energy carried by undetected neutrinos

Hadronic FEI tagging performance



← 29 and 26 hadronic B⁺ and B⁰ tag-side decay modes reconstructed

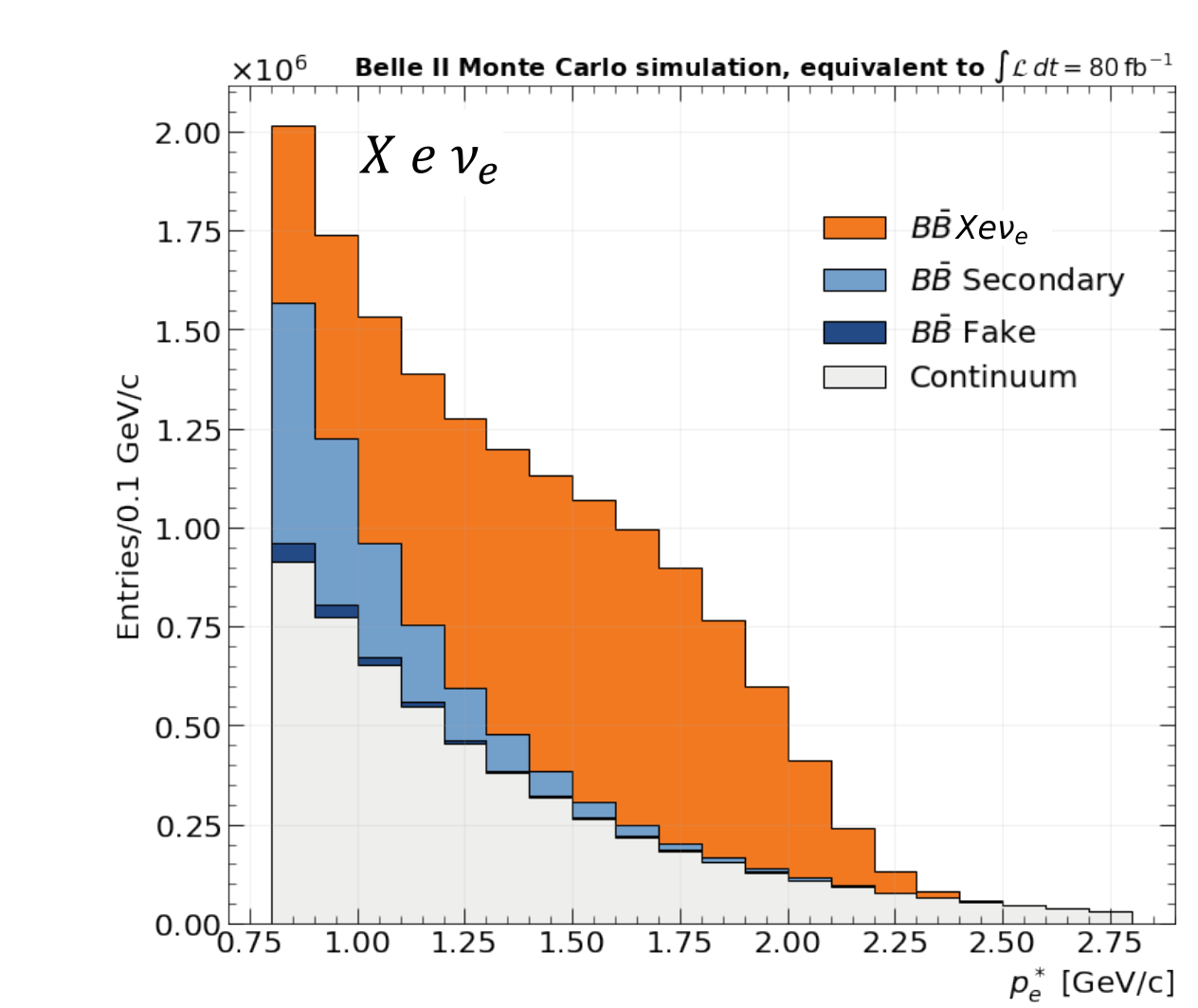
↑ B classifier value, P_{tag}, discriminates correctly reconstructed tag-sides from background

↑ Determine the correctly reconstructed tag-side yield by fitting the mass of the reconstructed B_{tag}

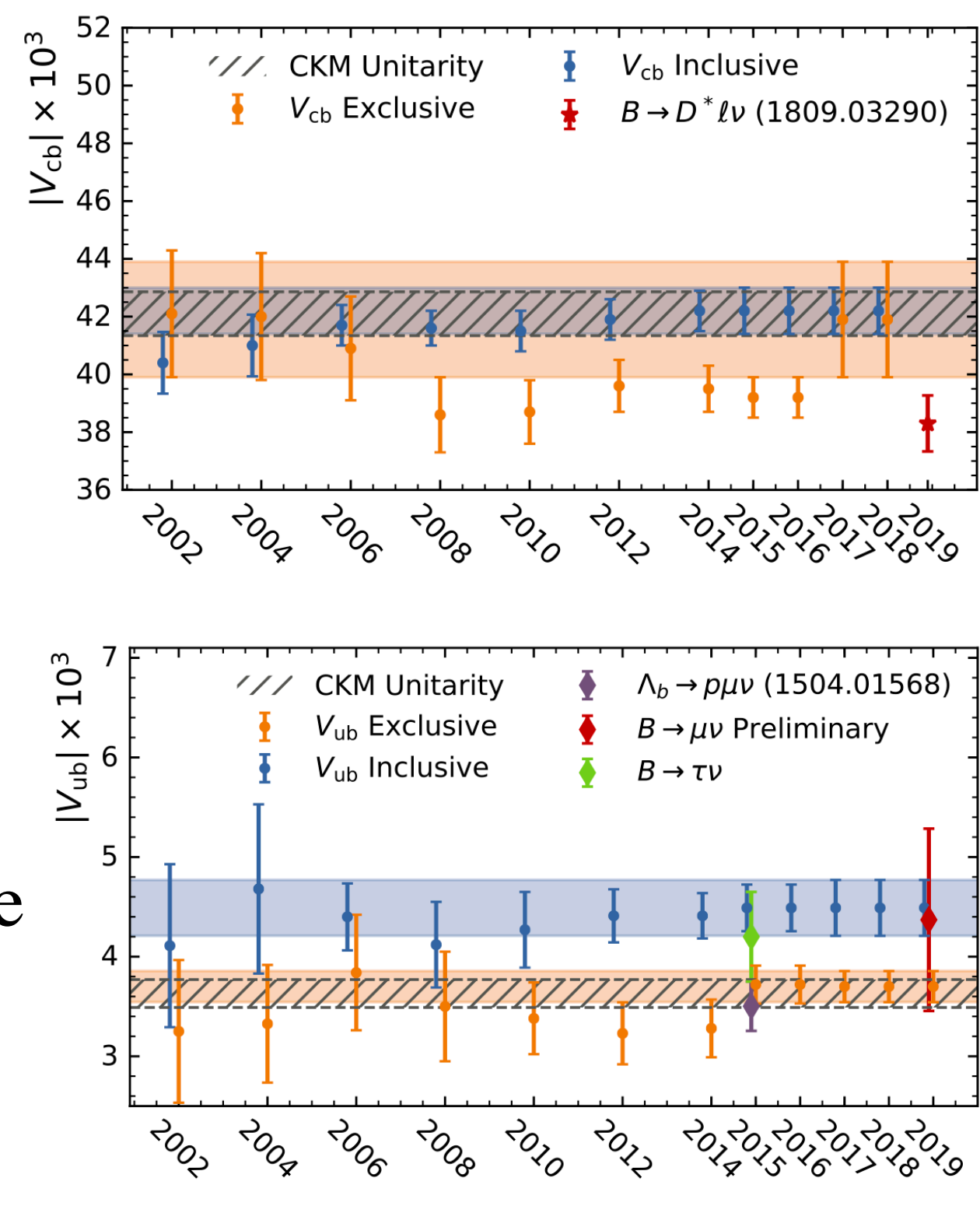
$$m_{bc} = \sqrt{E_{beam}^2/4 - p_{B_{tag}}^2}$$

B → X ℓ ν_ℓ – untagged reconstruction

- Can be used to measure $|V_{ub}|$ and $|V_{cb}|$ CKM matrix elements
- Current measurements show disagreement of $|V_{ub}| / |V_{cb}|$ in inclusive and exclusive final states



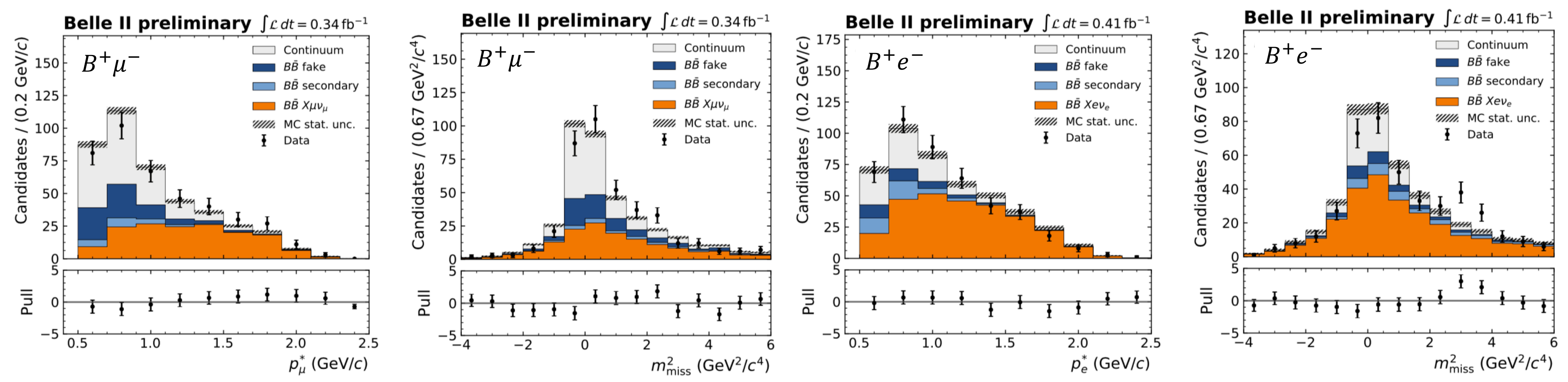
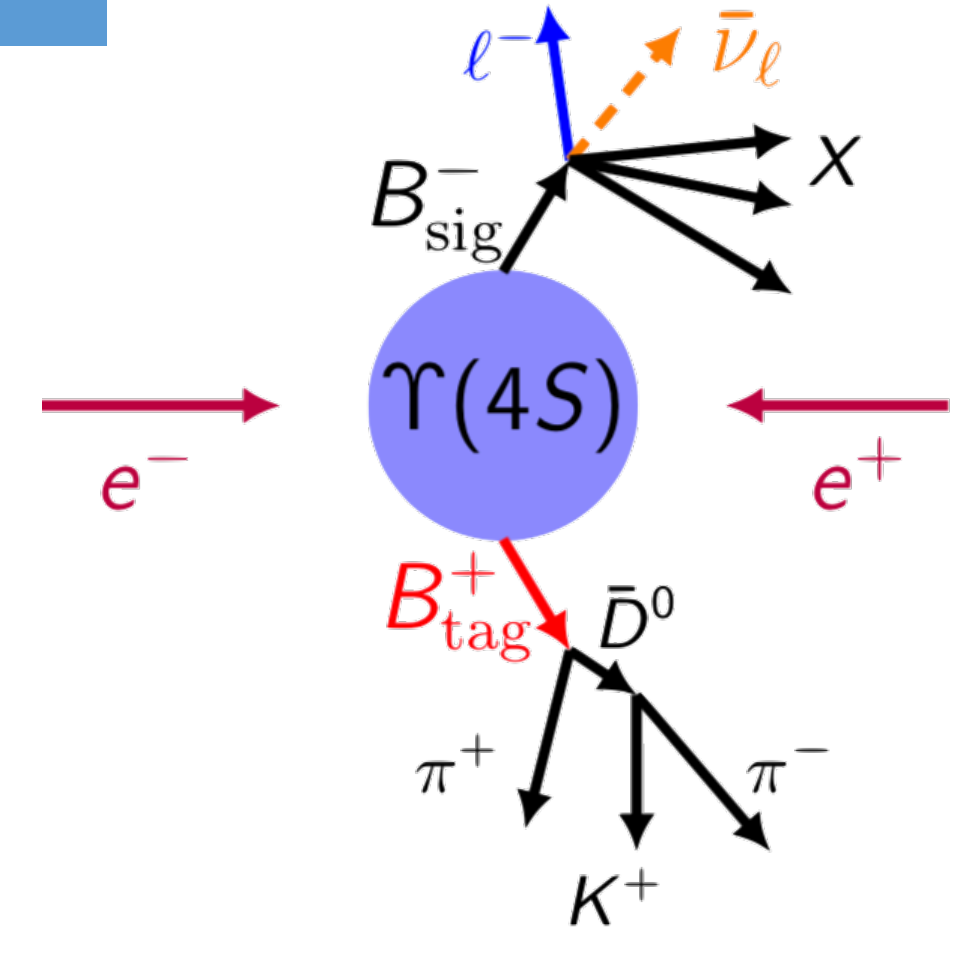
- Analysis of the lepton spectrum close to the kinematic endpoint to be used to separate between $X_c \ell \nu_\ell$ and $X_u \ell \nu_\ell$ decay modes
- Untagged analysis; suppression of continuum processes using multi-variate methods
- Off-resonance data available to describe continuum



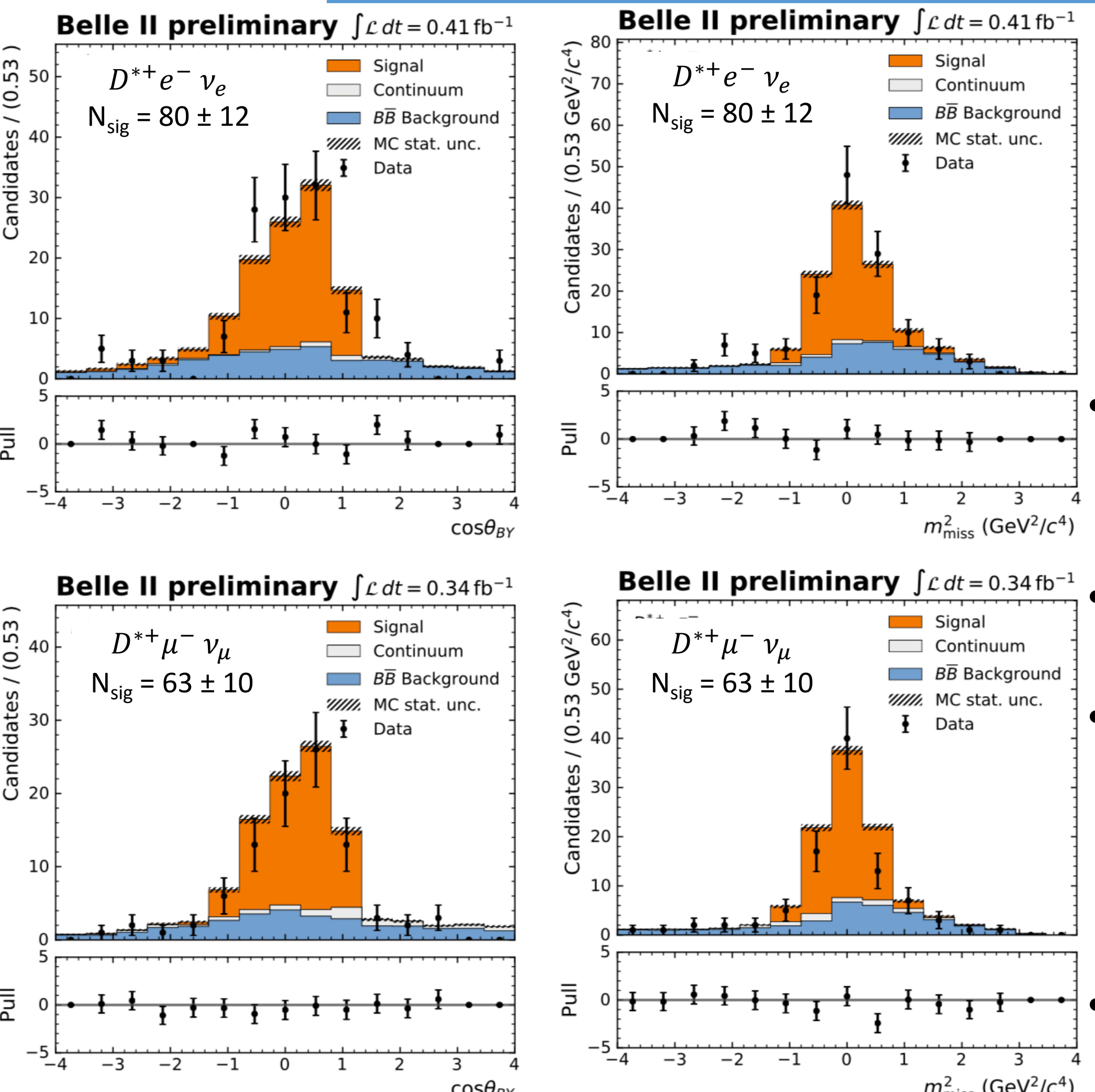
B → X ℓ ν_ℓ – hadronic FEI tagging

- Evaluate hadronic FEI tagging performance in early data
- Highest momentum lepton selected from the remaining tracks not associated with B_{tag}
- $p_\ell^* > 0.6 \text{ GeV}/c$, $m_{bc}^{\text{tag}} > 5.27 \text{ GeV}/c^2$
- The missing neutrino momentum is equivalent to the missing mass squared, reconstructed using:

$$p_\nu^2 \equiv m_{\text{miss}}^2 = (p_{ee} - p_{\text{tag}} - p_\ell - p_X)^2$$



B → D* ℓ ν_ℓ – untagged reconstruction



- $D^{*\pm}$ candidates reconstructed from the $D^{*\pm} \rightarrow D^0 \pi^\pm$ decays; D^0 mesons reconstructed in the decay mode $K^\pm \pi^\mp$
- Electrons/muons paired with the $D^{*\pm}$ to form signal candidates
- Signal events identified using the missing mass squared and the angle between the B-meson and the $D^* \ell$ system:
$$m_{\text{miss}}^2 = \left(\frac{p_{ee}}{2} - p_Y\right)^2, \quad \cos \theta_{BY} = \frac{2 E_B^* E_Y^* - M_B^2 - m_Y^2}{2 p_B^* p_Y^*}$$
where Y indicates the $D^* \ell$ system
- To be used for $|V_{cb}|$ measurements

Conclusion

- Belle II has completed its first physics run and collected 6.5 fb⁻¹ of data
- First data analyzed to validate the detector performance
- FEI hadronic tagging performance tested with $B \rightarrow X \ell \nu_\ell$ decay mode
- Validation of Monte Carlo simulation using $B \rightarrow D^* \ell \nu_\ell$ untagged analysis
- Untagged $B \rightarrow X \ell \nu_\ell$ measurements under preparation