

R2 : Search for Dark Matter in the B-meson precision-measurement experiment

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Belle II at SuperKEKB



Plan to collect **50 ab⁻¹** of collisions at and near $\Upsilon(4S)$
 Successor to Belle at KEKB (1.05 ab⁻¹)

At $\Upsilon(4S)$, $E_{CM} = 10.58$ GeV

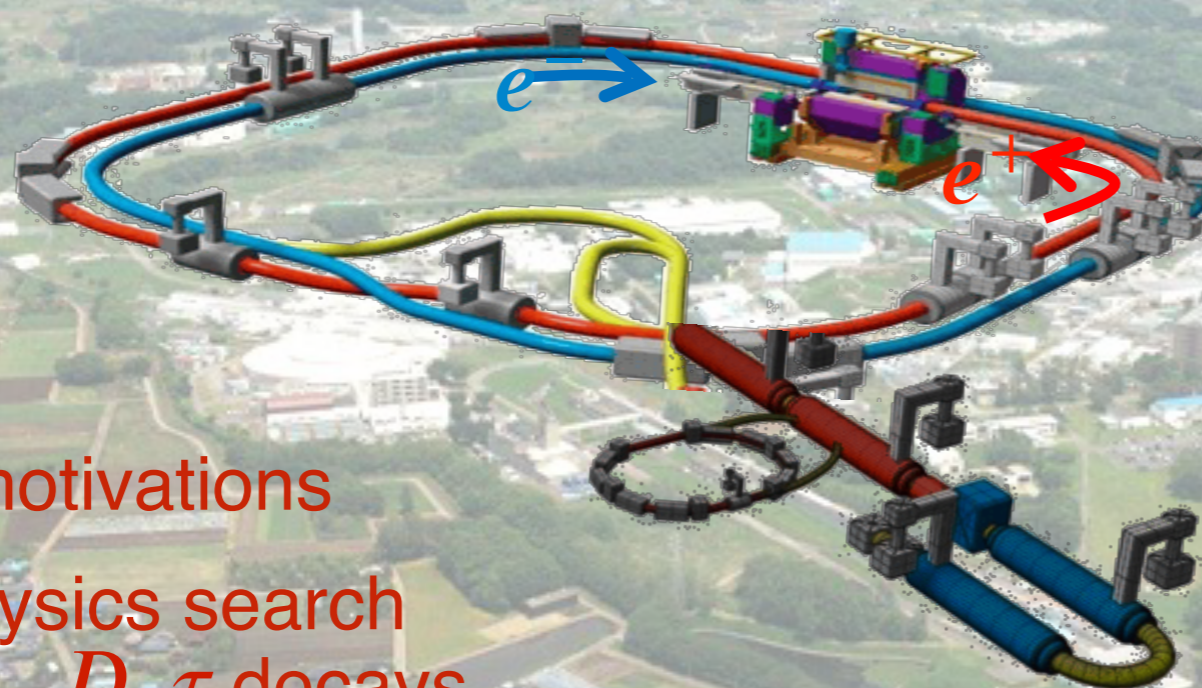
7 GeV e^- (HER; High Energy Ring)

4 GeV e^+ (LER; Low Energy Ring)

Nano beam scheme

$$\mathcal{L} = \frac{\gamma_{\pm}}{2er_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \frac{I_{\pm} \xi_{\pm y}}{\beta_y^*} \left(\frac{R_L}{R_y} \right)$$

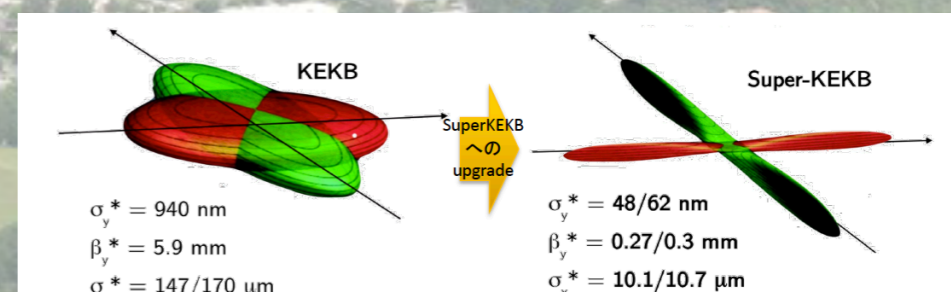
Belle II detector



5.9 → 0.3 mm
 KEKB SuperKEKB

Physics motivations

- New physics search in B , B_s , D , τ decays
- Direct search for light new particles
- Precise measurement of Standard Model
- Hadron physics



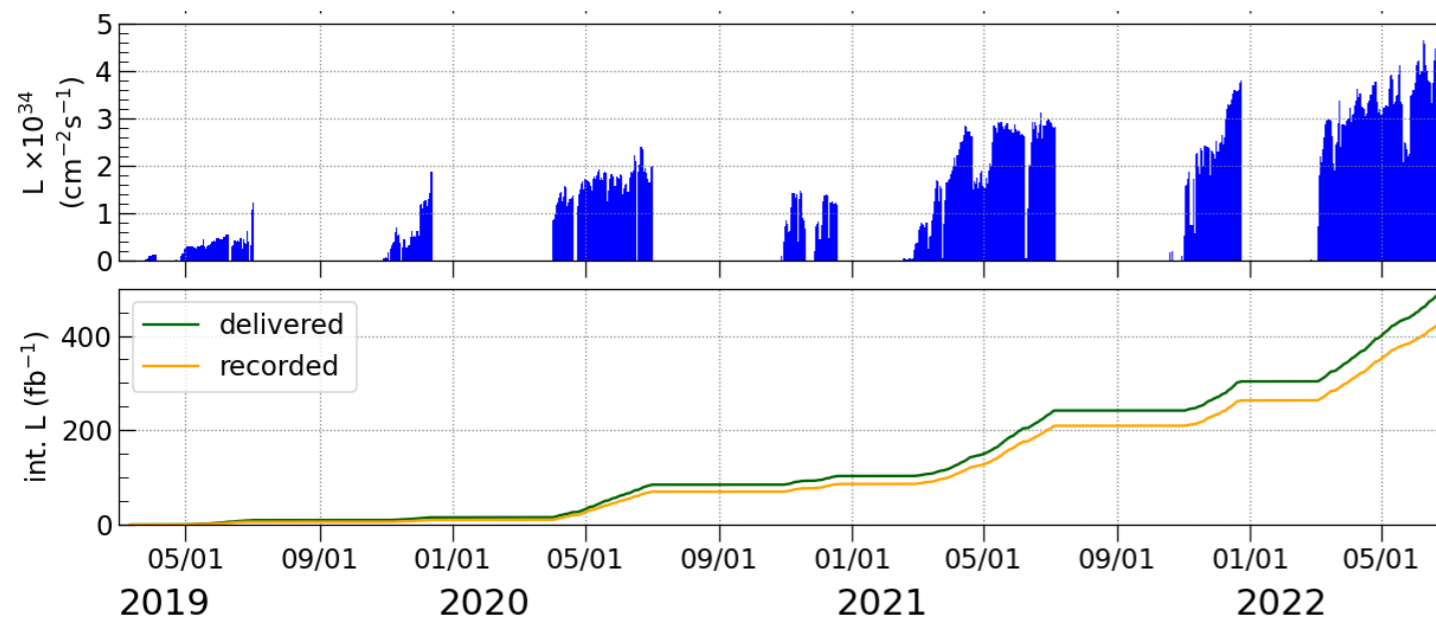
SuperKEKB/Belle II Luminosity Status

Major achievements;

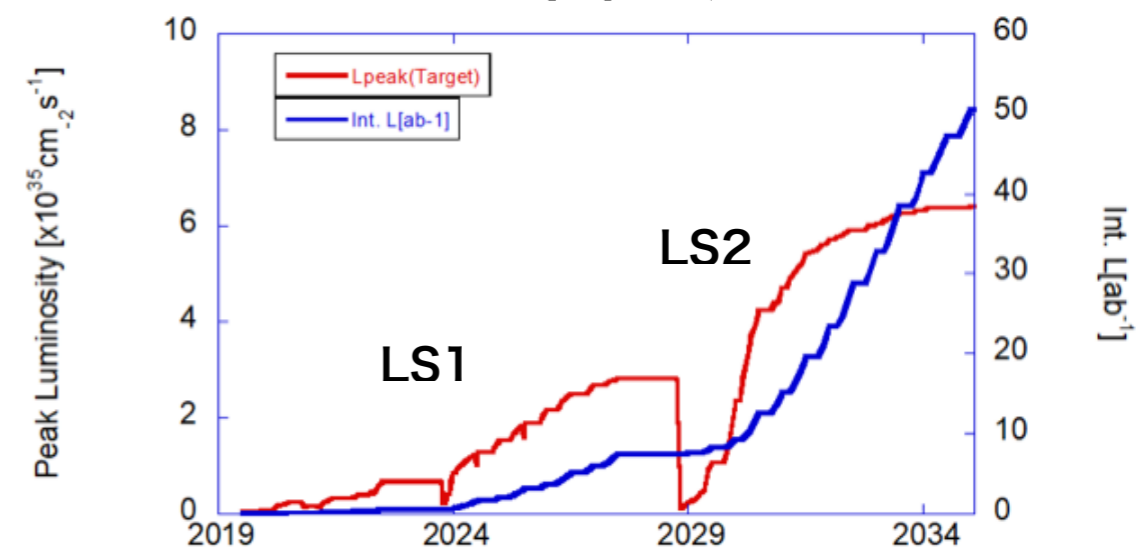
- $\sim 4.7 \times 10^{34} / \text{cm}^2 / \text{s}$, the new world record luminosity more than twice of KEKB.
- Integrated luminosity: **428/fb**
 - Recorded about half of the BaBar data set in one year
- We could continue operations despite pandemic.

Now in the Long Shutdown I

- Installation of fully equipped PXD2
 - Some works in subsystems
- Modification of accelerators for
 - Higher injection efficiency
 - Longer beam lifetime
 - Better stability etc.
- Plan to resume in fall 2023



Luminosity projection



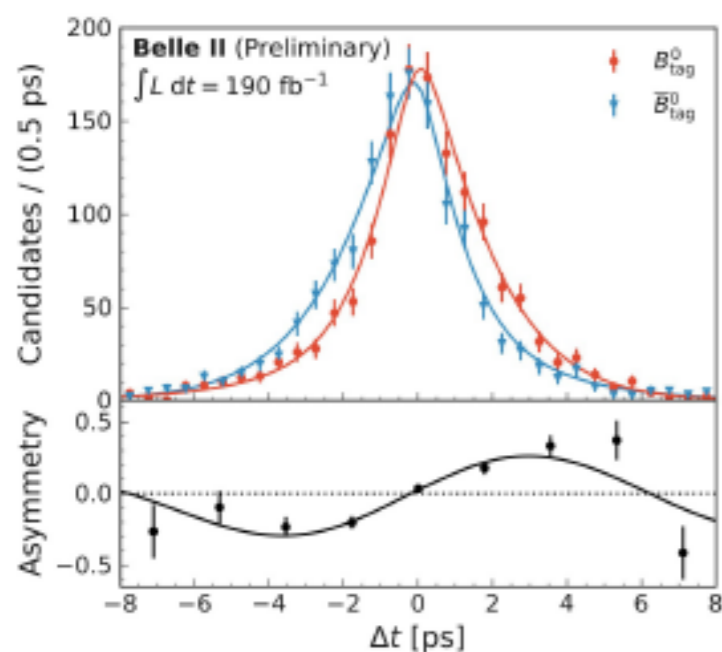
Recent results (example)

Results with 189fb^{-1} @ICHEP2022

$CPV (B^0 \rightarrow J/\psi K_S^0)$

$CPV (B^0 \rightarrow K_S^0 K_S^0 K_S^0)$

$Br (B^0 \rightarrow \rho^+ \rho^-)$

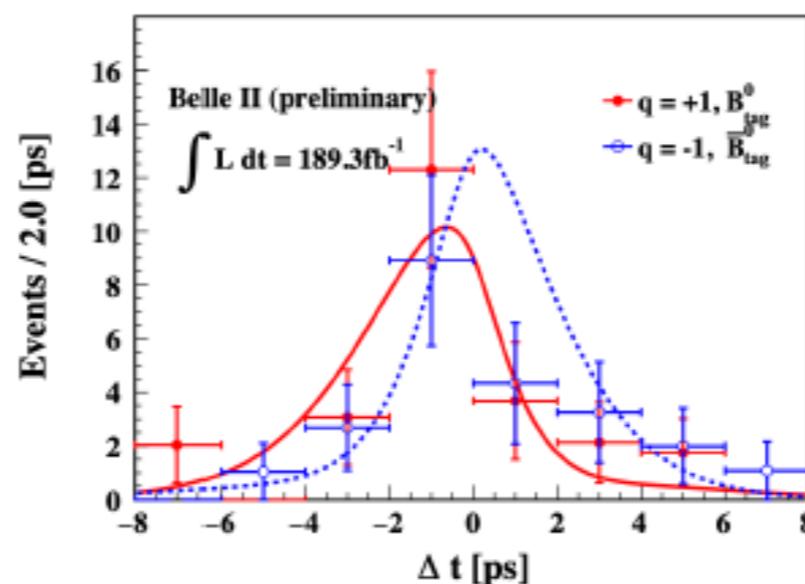


C. La Licata @ ICHEP 2022

$$S_{CP} = 0.720 \pm 0.062(\text{stat}) \pm 0.016(\text{syst}),$$

$$A_{CP} = 0.094 \pm 0.044(\text{stat}) \begin{matrix} +0.042 \\ -0.017 \end{matrix} (\text{syst})$$

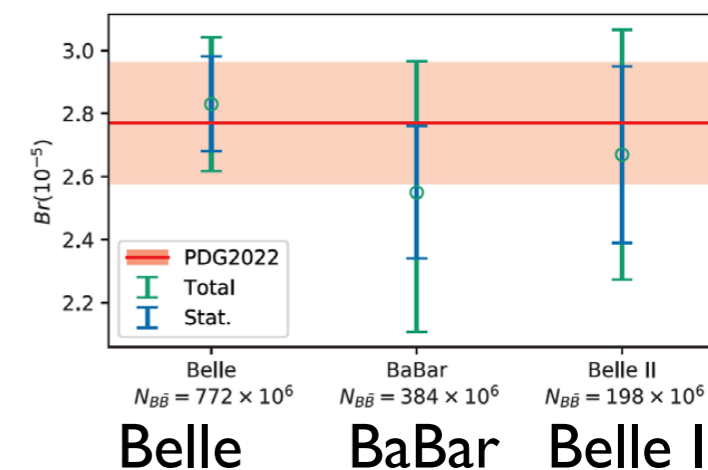
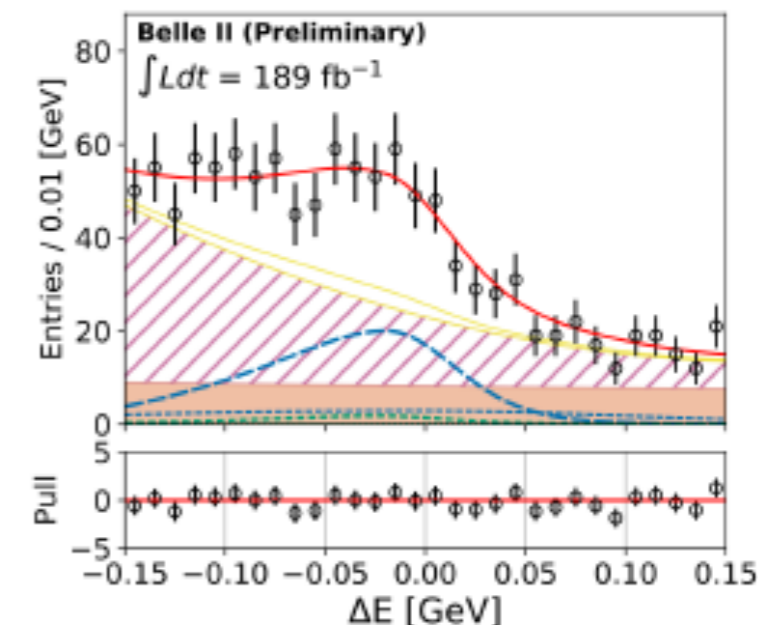
World Average: $S_{CP} = 0.695 \pm 0.019,$
 $A_{CP} = 0.000 \pm 0.020$



$$S_{CP} = -1.86_{-0.46}^{+0.91}(\text{stat}) \pm 0.09(\text{syst}),$$

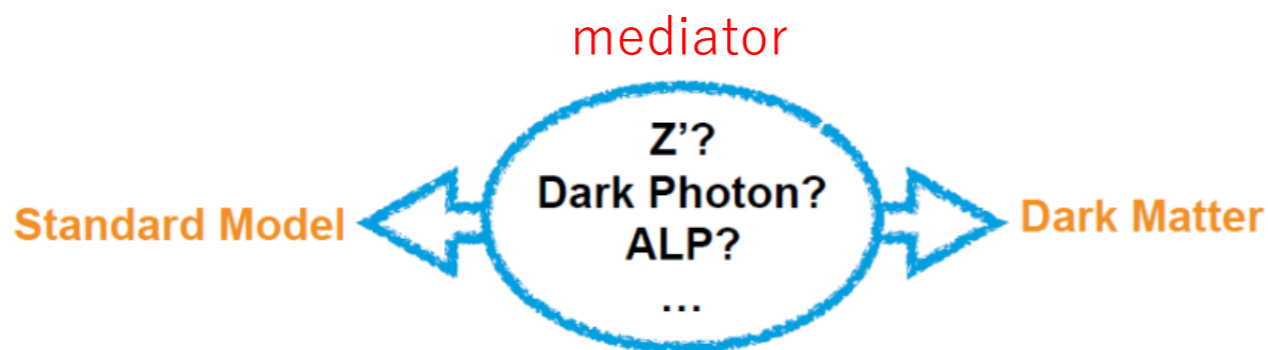
$$A_{CP} = -0.22_{0.27}^{+0.30}(\text{stat}) \pm 0.04(\text{syst})$$

World Average: $S_{CP} = -0.82 \pm 0.17,$
 $A_{CP} = -0.14 \pm 0.12$



Results with 428fb^{-1} ~ BaBar data set + improved resolution + efficiency
 → Results competitive to Belle, LHCb (target @ Moriond 2023)

Dark Sector Results (examples)



Possible portals;

- Scalar: dark Higgs, ...
- Vector: dark photon, Z' , ...
- Pseudoscalar: axion, ALP, ... [PRL124 (2020), 141801]
- Fermion: sterile neutrino, ...

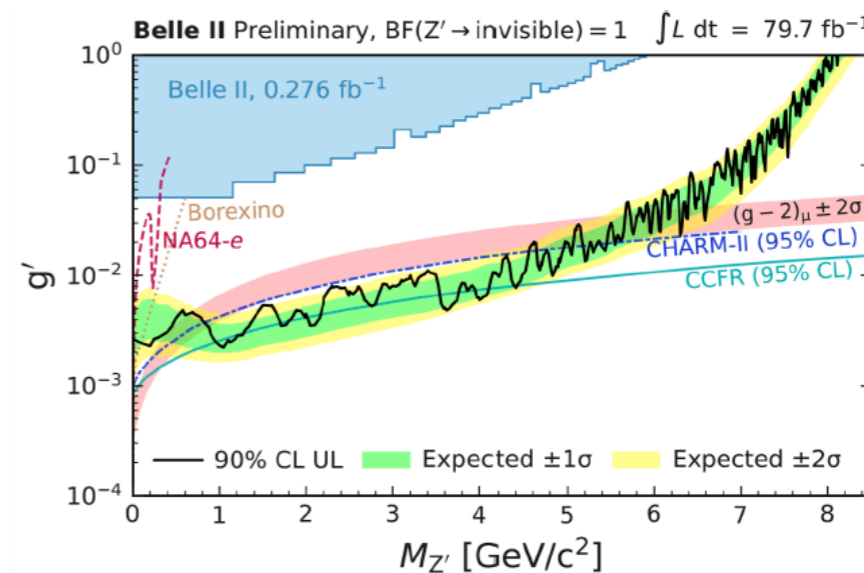
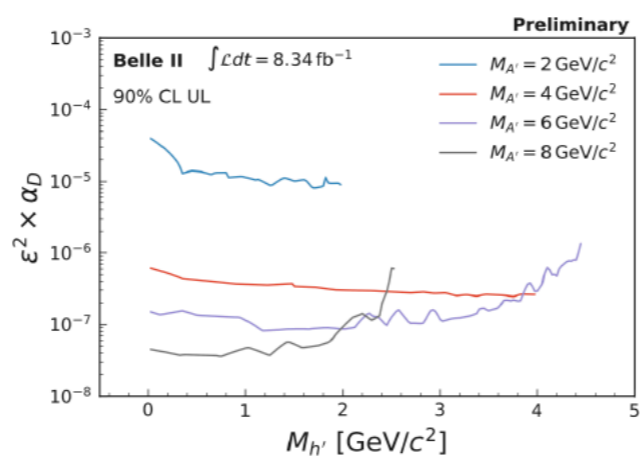
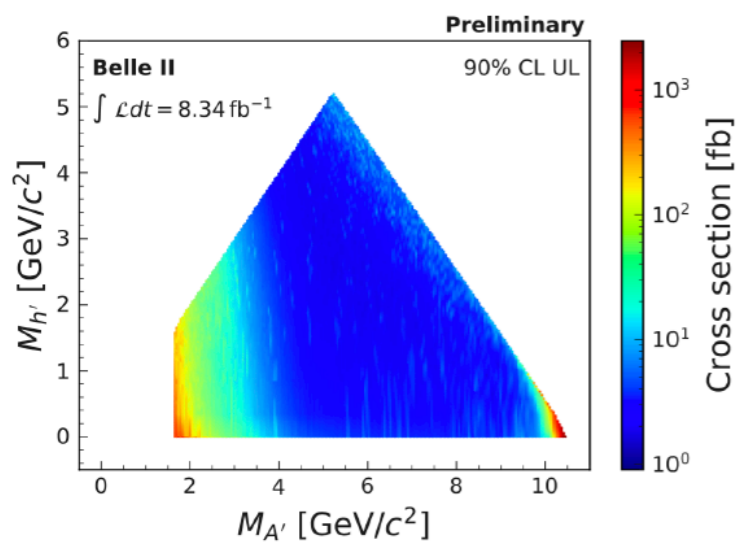
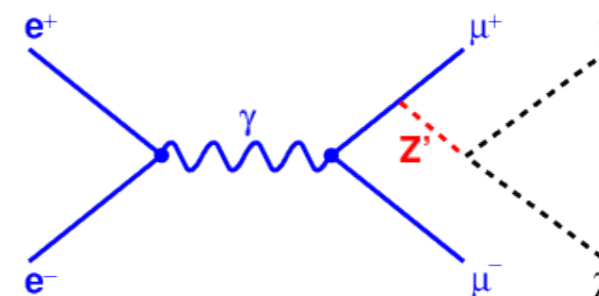
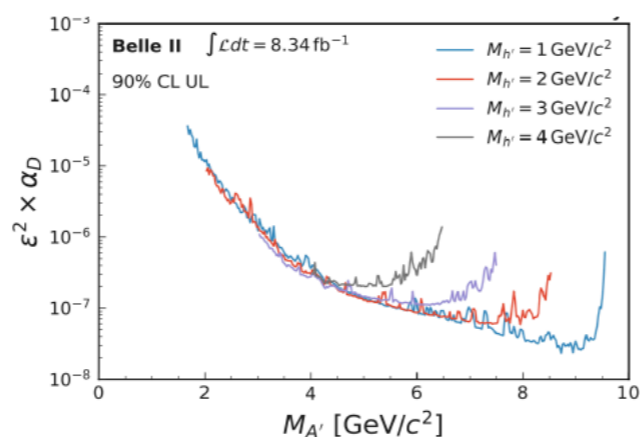
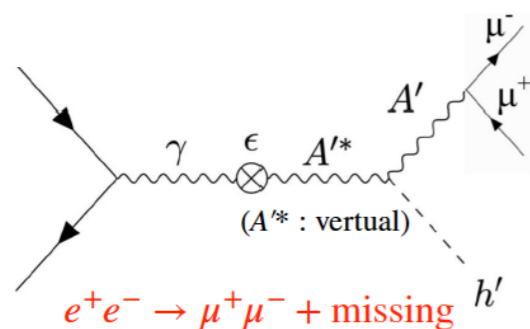
Some of them may explain DM, g-2 anomaly,

Dark Higgs: $e^+e^- \rightarrow A'h'$

arXiv: 2207.00509

Z' : $e^+e^- \rightarrow \mu^+\mu^-Z'$, $Z' \rightarrow \text{invisible}$

1st results (276pb⁻¹) in PRL124 (2022), 141801



Italian group is the main contributor to these subjects

R2 activities

Belle II experiments

- Physics analyses in variety of subjects
- including dark sector physics
- Operation of the PID detector (TOP)
- R&D for detector upgrade

Neutron experiments

+ New additions?

- FASER @ LHC ATLAS forward
- Beam dump @ KEK Linac

Presentation at workshop/conferences (in person)

- Keisuke Yoshihara, Belle II US Summer School 2022 (Aug 1-5, 2022 at Iowa State U.)
- Ryogo Okubo, RICH2022 workshop (Sep. 12-16, Edinburgh)
- Kazuki Kojima, Qidong Zhou, Belle II general meeting + visits to U. Bonn for R(D*) analysis

Looking forward to the workshop at Padova in 2023