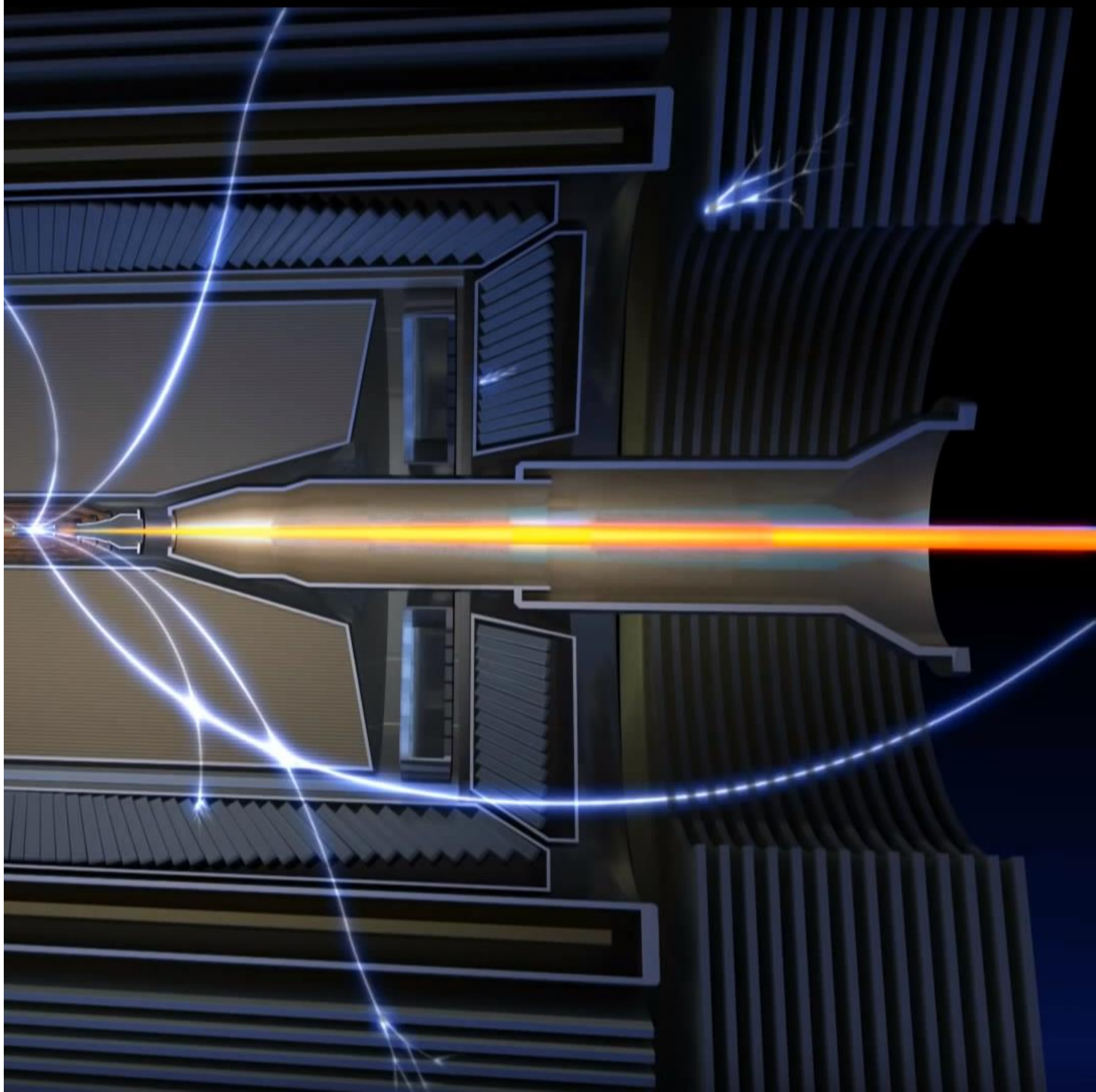
Belle II Overview

June 24, 2020

Bryan Fulsom (PNNL)

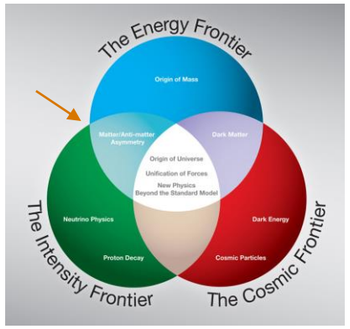
Snowmass EF06 Subtopic Meeting



PNNL is operated by Battelle for the U.S. Department of Energy

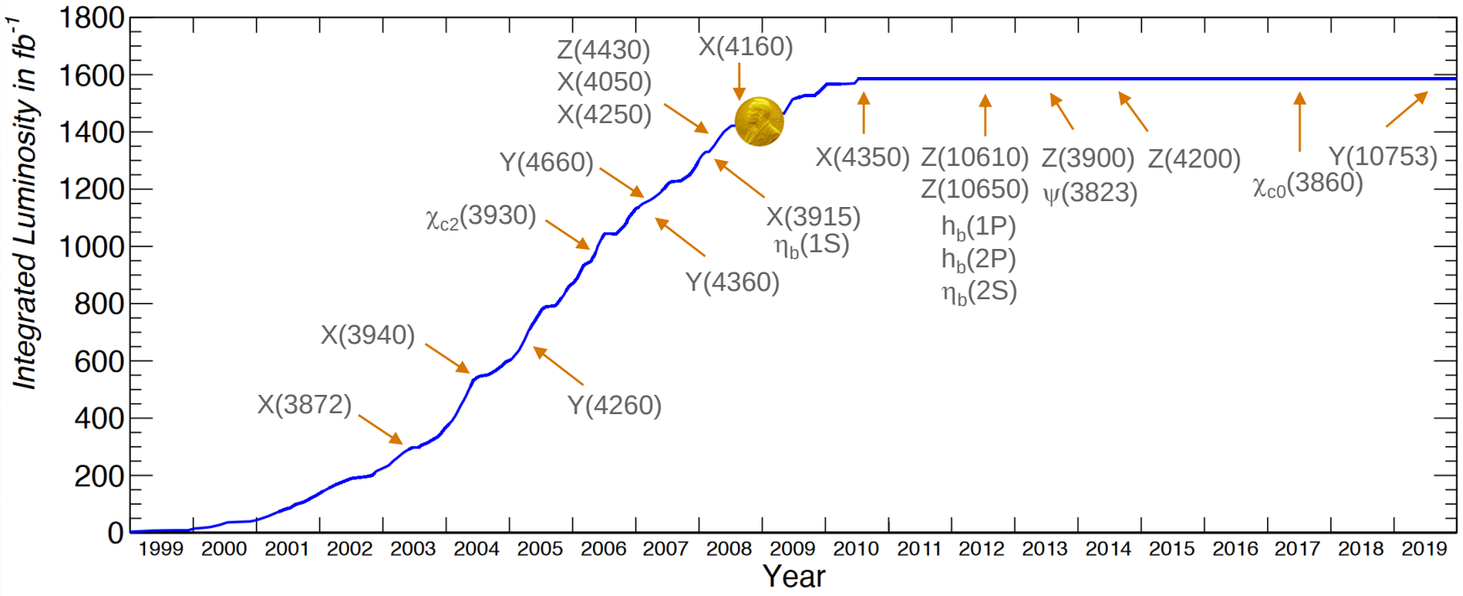
B-Factories Legacy

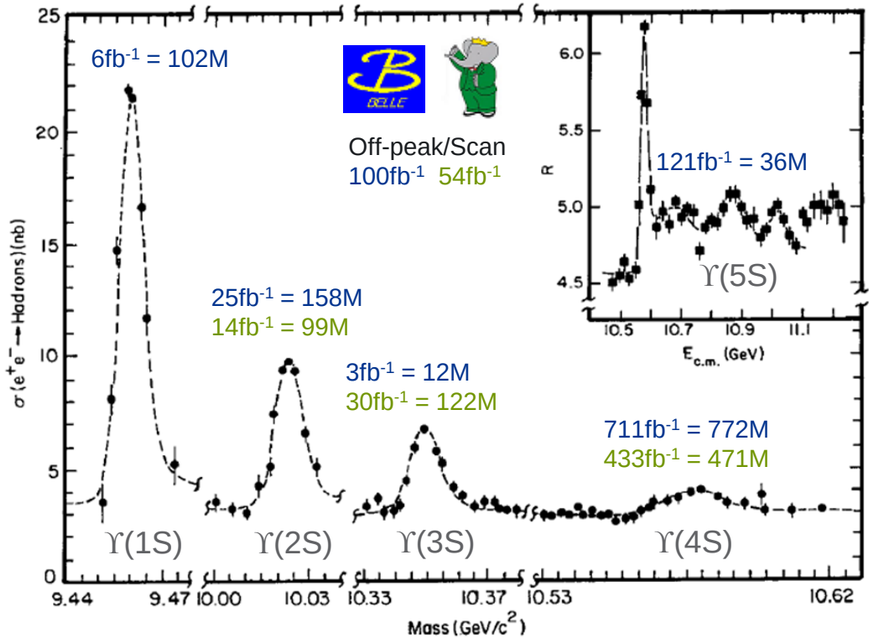
- ~2000 – 2010 : BaBar (SLAC) & Belle (KEK)
- Flavor physics: CKM/UT, CPV in B decays
- Hints for NP in rare processes
- New particle discoveries: “XYZ” states



2008

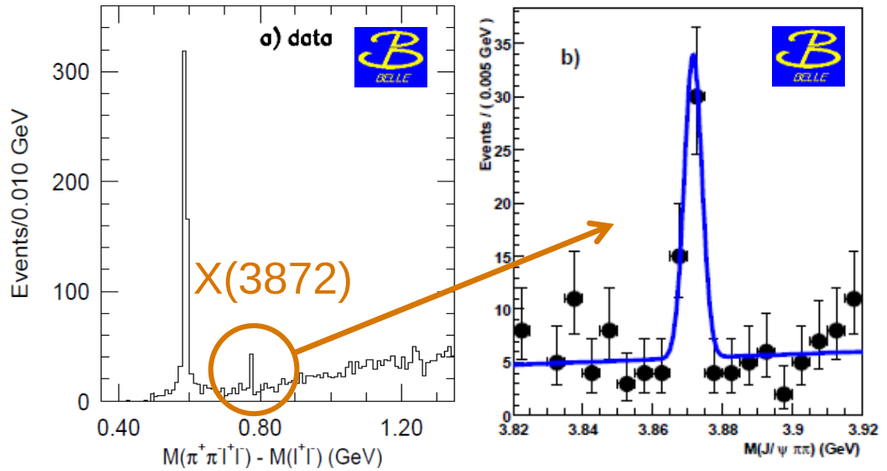
e.g.: “The Physics of the B Factories”, EPJC 74, 3026 (2014)

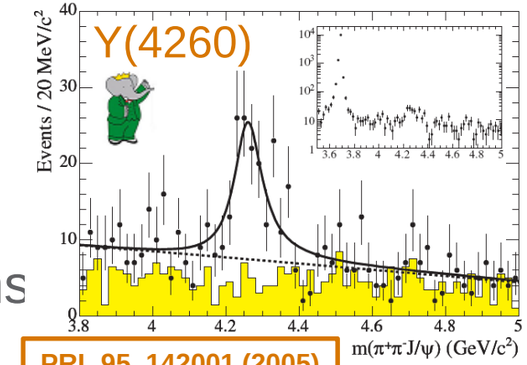




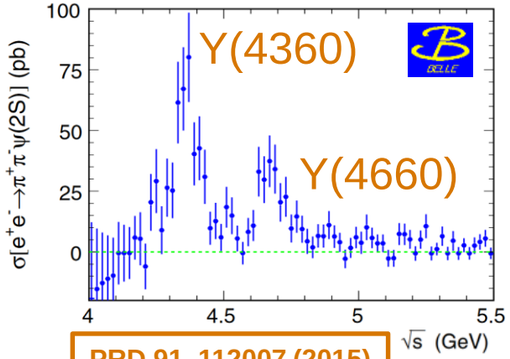
The New Alphabet: X, Y, Z

- X(3872) **PRL 91, 262001 (2003)**
  - Mass consistent with $D^0\bar{D}^{0*}$ molecular state
  - Found in B decay, large production also in pp
- Y(4260, 4320, 4660, …)
  - Produced in initial state radiation and E_{CM} scans
  - $J^{PC}=1^{--}$ overpopulated for charmonium
- $Z_c^{\pm}$(3900, 4430, …)
  - Seen in B, $q\bar{q}$, and XY decays
  - Non-zero charge: cannot be $q\bar{q}$

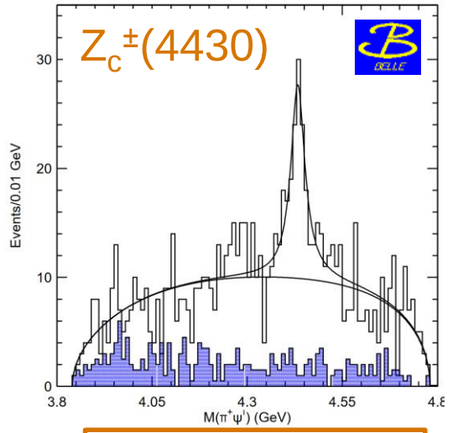




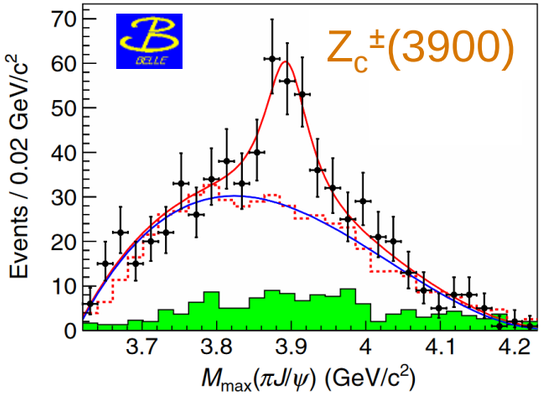
PRL 95, 142001 (2005)



PRD 91, 112007 (2015)



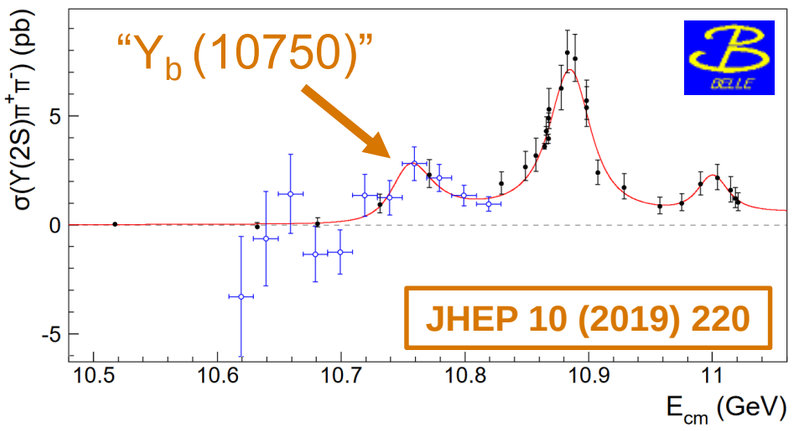
PRL 100, 142001 (2008)

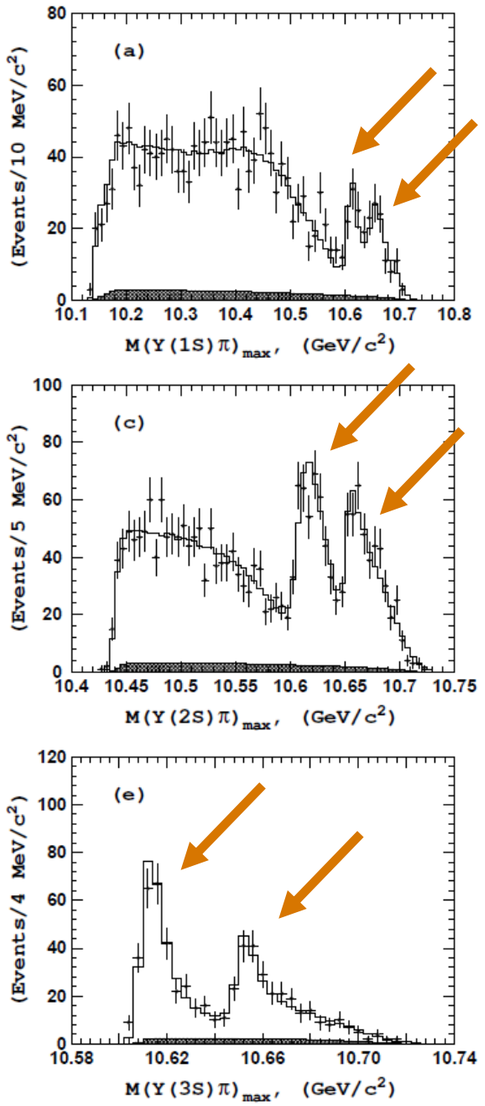


PRL 110, 252002 (2013)

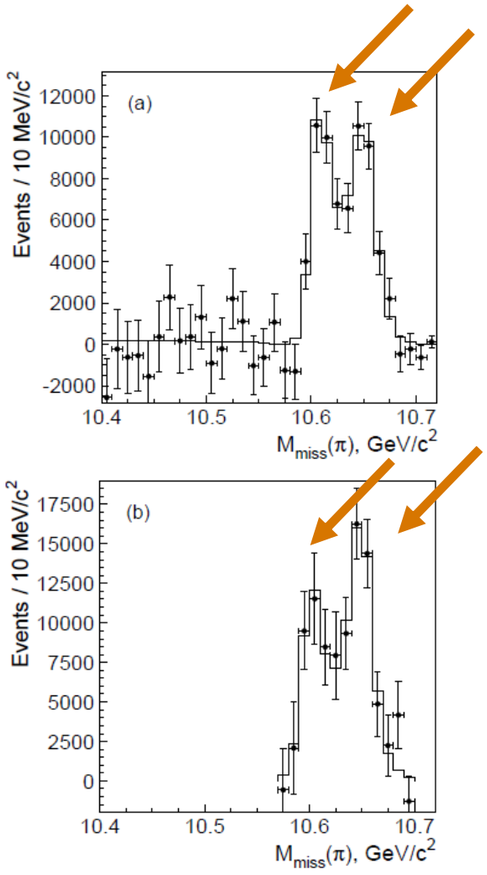
Bottom Analogues

- Data collected above $\Upsilon(4S)$ = 10.58 GeV
- $Z_b^{\pm}(10610, 10650)$
  - Unexpectedly high $\Upsilon(5S)$ dipion transition rates
  - Discovery of h_b, η_b, and exotic Z_b
- "$Y_b(10750)$"
  - Study of similar final states
  - Enhancement seen in energy scan data





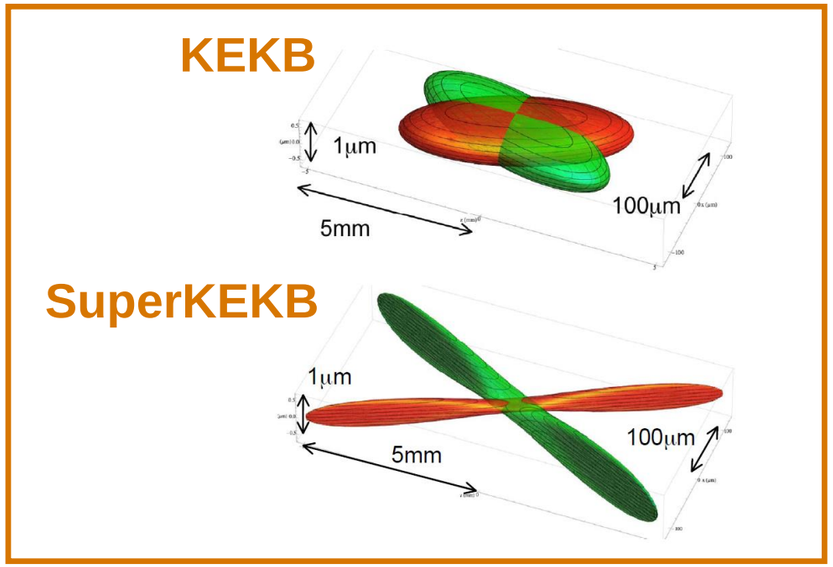
$Z_b^{\pm}(10610/50)$



PRL 108, 122001 (2012)
PRL 109, 232002 (2012)

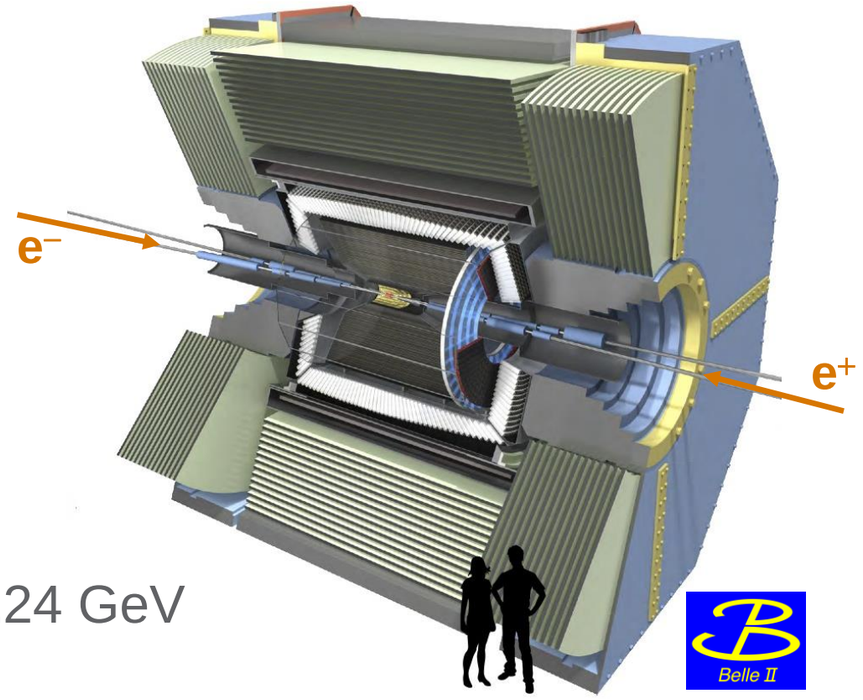
Belle II Capabilities

- Belle II is the next generation B-Factory
  - ~1000 members (~100 US @ 18 institutions)
  - ~10-year program ongoing since last year
- Upgraded detector and accelerator



- Extensive quarkonium physics program
- Advantages
  - 50x instantaneous and integrated luminosity
  - Full event reconstruction and decays involving neutrals
  - Multiple production mechanisms for exotics
  - Nominal $\sqrt{s}$ = 10.58 GeV = Υ(4S), potential to reach 11.24 GeV

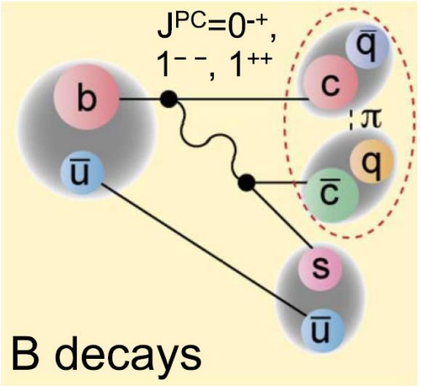
PTEP 2019 123C01 (2019)

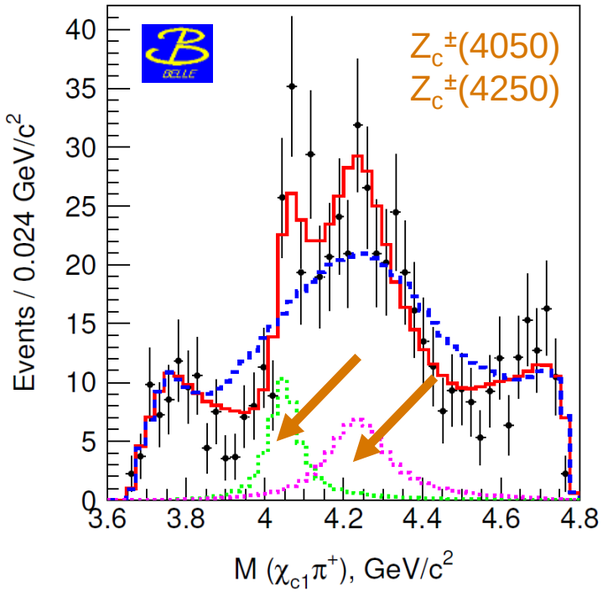


arXiv:1011.0352 (2011)

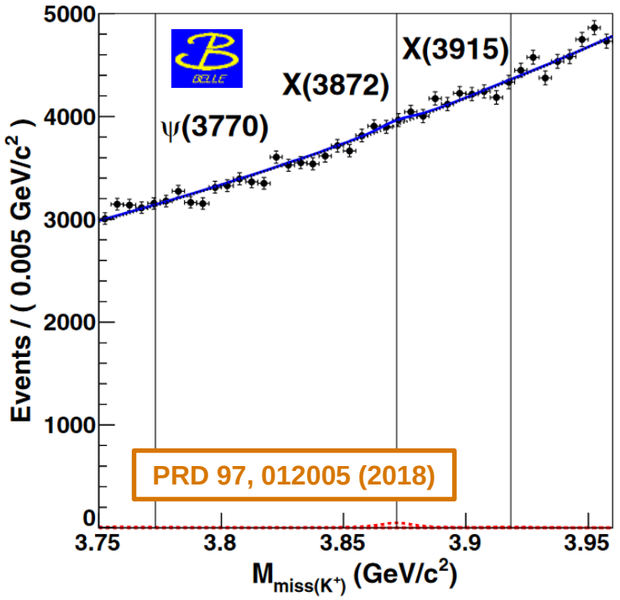
Belle II Potential – B Decay

- High-statistics continuation from B-Factories
- Competition from LHCb, advantages for modes with neutrals
  - Confirm Z_c states and search for neutral partners
  - Absolute branching fractions $B \to X(3872,3915)\ K$
  - Confirmation of X(3872) width measurement with $D^0\bar{D}^0\pi^0$

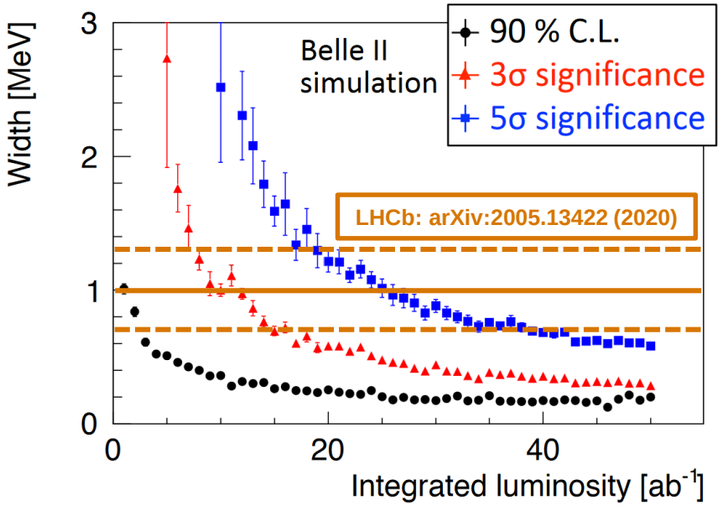




PRD 78, 072004 (2008)



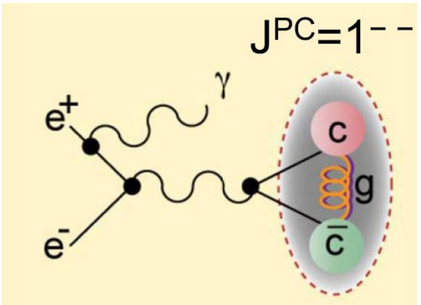
PRD 97, 012005 (2018)



LHCb: arXiv:2005.13422 (2020)

H. Hirata (KMI/Nagoya), MSc Thesis (2019)

Belle II Potential – Initial State Radiation

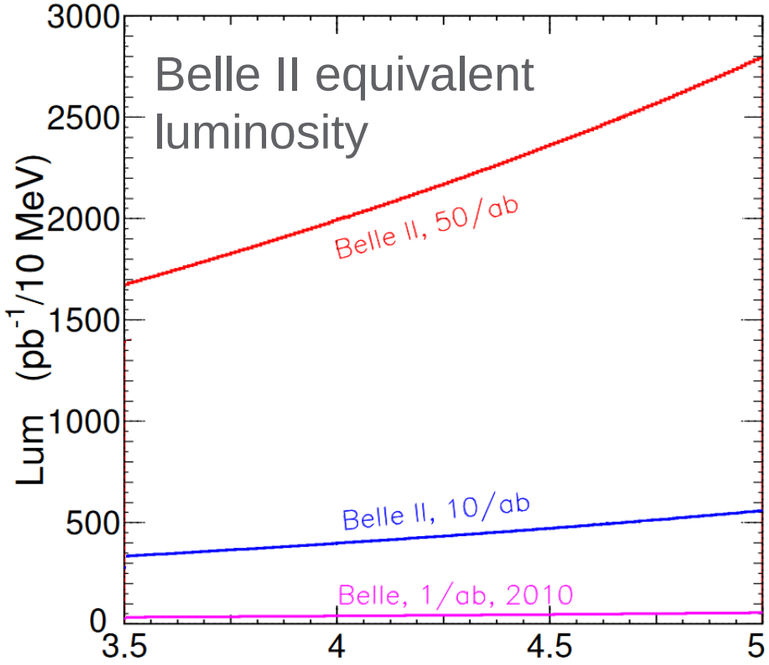


Initial state radiation

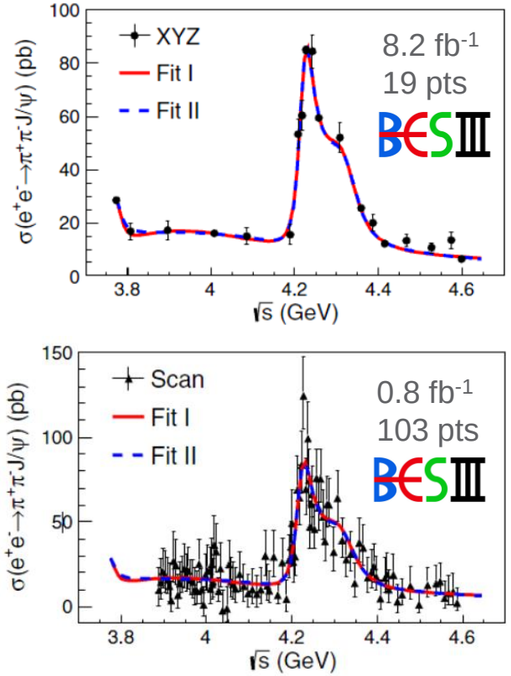
- Study Y states complementary to BESIII direct E_{CM} scans

- Belle II advantages
  - Comparable sample sizes
  - Continuous mass range
  - Access E > 4.6 GeV

- Potential contributions
  - Improved $\sigma(e^+e^- \rightarrow \gamma_{ISR}(c\bar{c})(x))$
  - Higher masses/channels (e.g. $\gamma_{ISR}\Sigma_c\bar{\Sigma}_c$)
  - Confirm Z_c states (e.g. $e^+e^- \rightarrow h_c\pi\pi$)



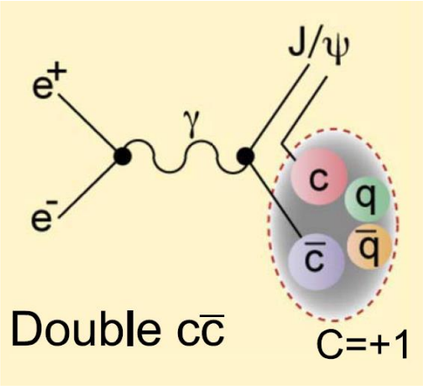
PTEP 2019 123C01 (2019)



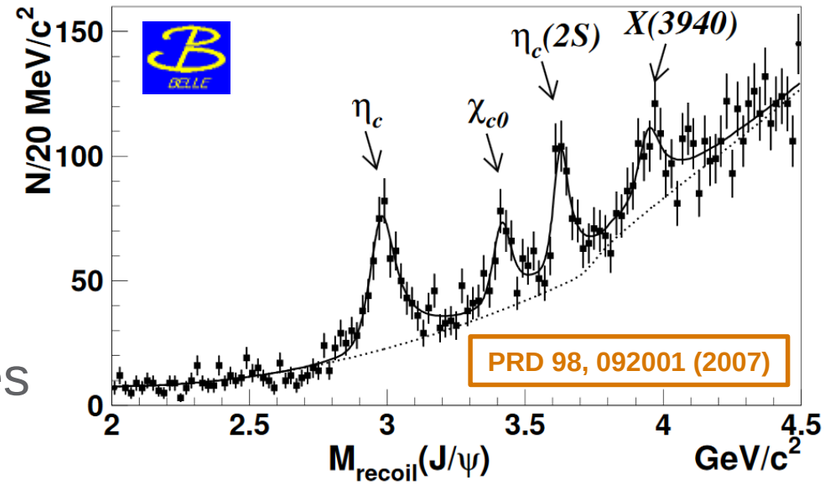
PRL 118, 092001 (2017)

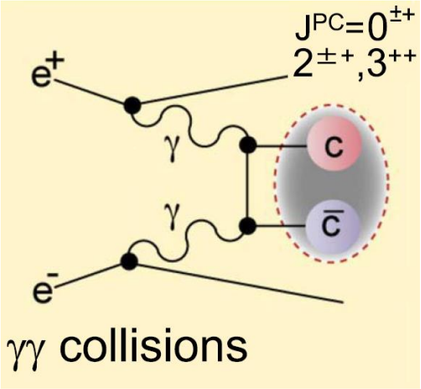
Belle II Potential – Double Charmonium and Two-Photon Processes

- Unique production modes at Belle II

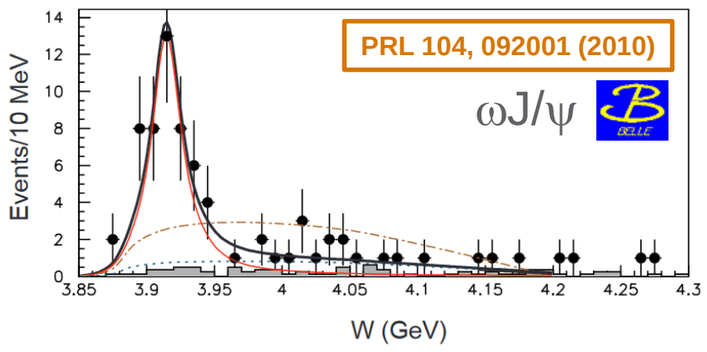


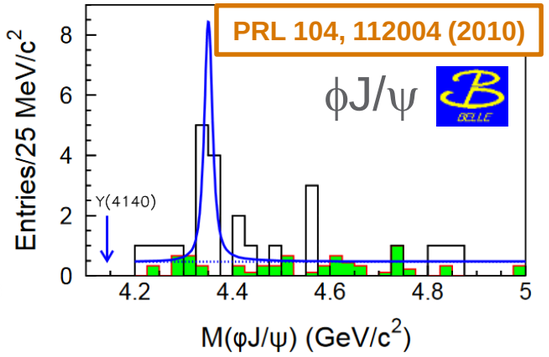
- Double-$c\bar{c}$
  - $e^+e^- \rightarrow (c\bar{c})_{J=1}(c\bar{c})_{J=0}$ production rule
  - Discovery of X(3940, 4160)
  - Expand to other $c\bar{c}$, search for new states



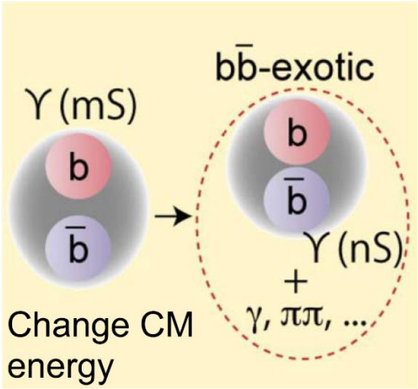


- Two-Photon
  - J^{PC} of X(3915)
  - Confirm $\phi J/\psi$ state?
  - $D^{(*)}\bar{D}^{(*)}$ final states

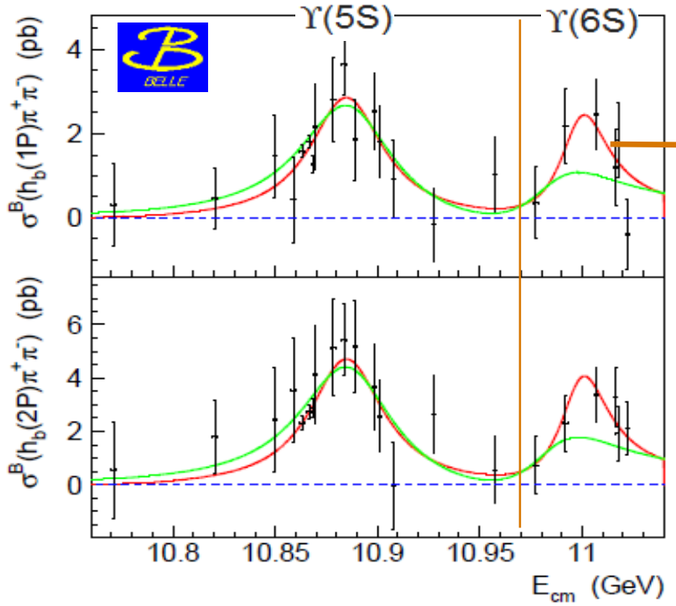


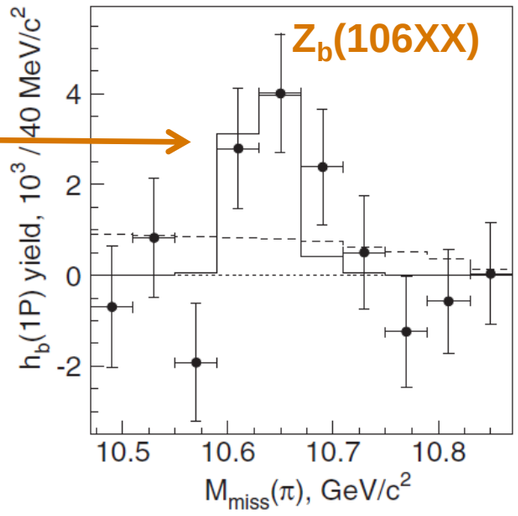


Belle II Potential – Above ϒ(4S)

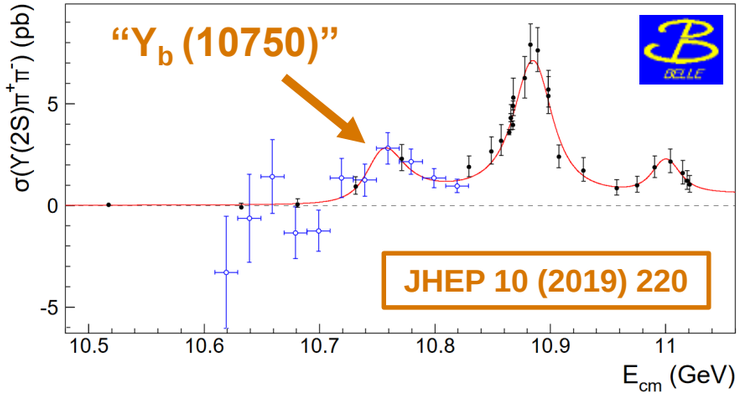


- Aside from ϒ(5S), B-Factories collected limited data above ϒ(4S)
- ϒ(6S) = 11 GeV, L_{eff} = ~3 fb^{-1}
  - Study nature of Z_b and ϒ(6S)
  - Higher energy: pathway to other states?
- "Y_b(10750)", L = ~1 fb^{-1}
  - Further study needed





PRL 117, 142001 (2016)



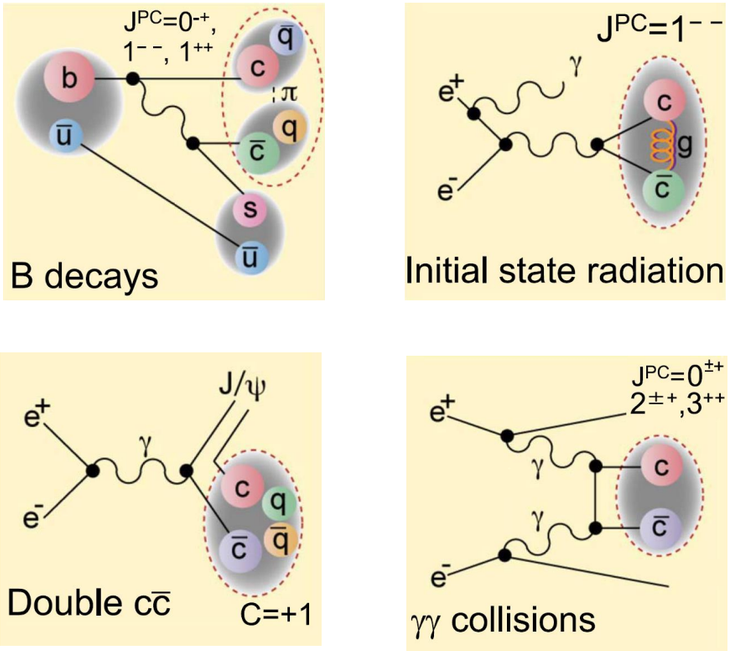
JHEP 10 (2019) 220

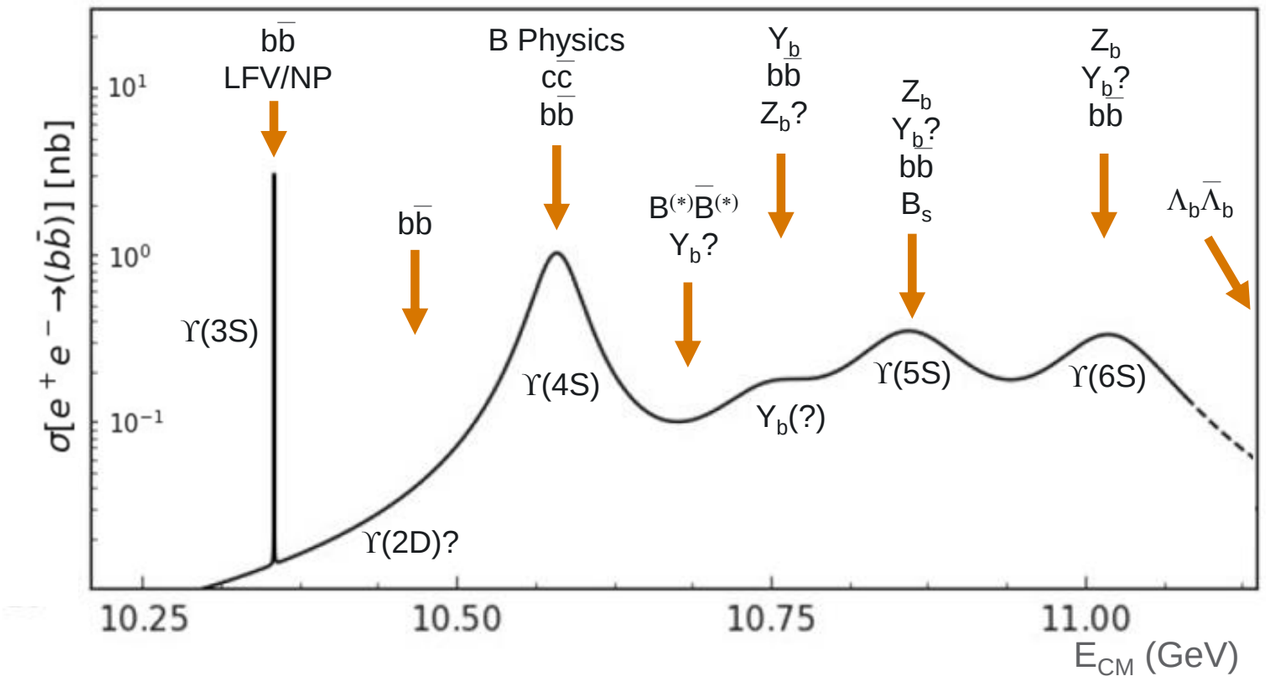
- Unique potential for SuperKEKB/Belle II

MPLA 32, 1750025 (2017)

Summary

- Belle II: next generation B-Factory building upon success of Belle
- Wide-ranging physics program including study of new XYZ states
- Many opportunities in unique production and decay modes





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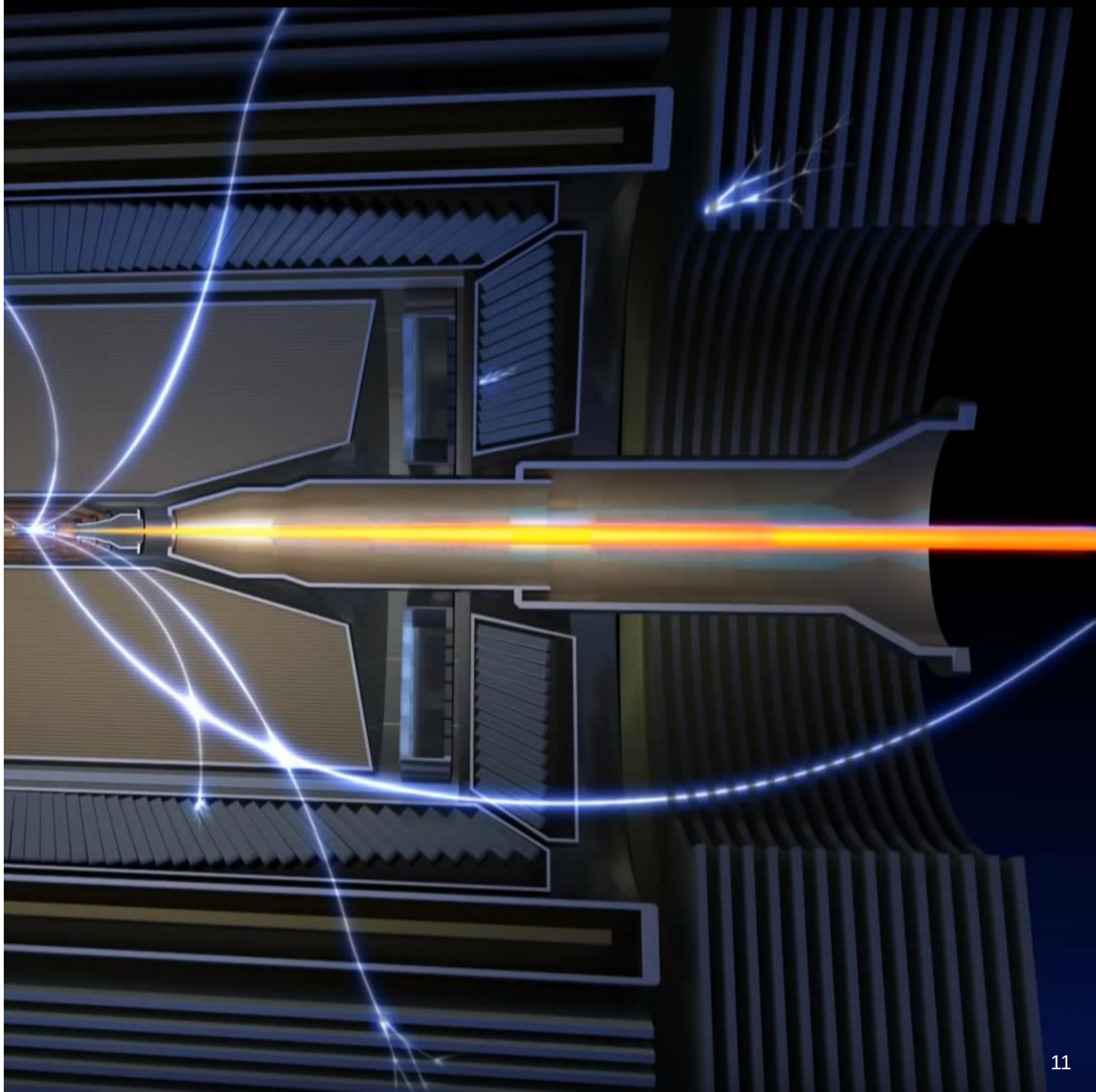
Thank you