

Bottomonium-like exotics and new physics in bottomonium decay at Belle II



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On behalf of the Belle II collaboration



Federal Ministry
of Education
and Research



JOHANNES GUTENBERG
UNIVERSITÄT MAINZ

B Factories: past and present

- Legacy of first generation *B* Factories
- Next generation *B* Factory

Bottomonium-like exotics and NP: Belle II potential (selected list of topics in exotica and NP perspective)

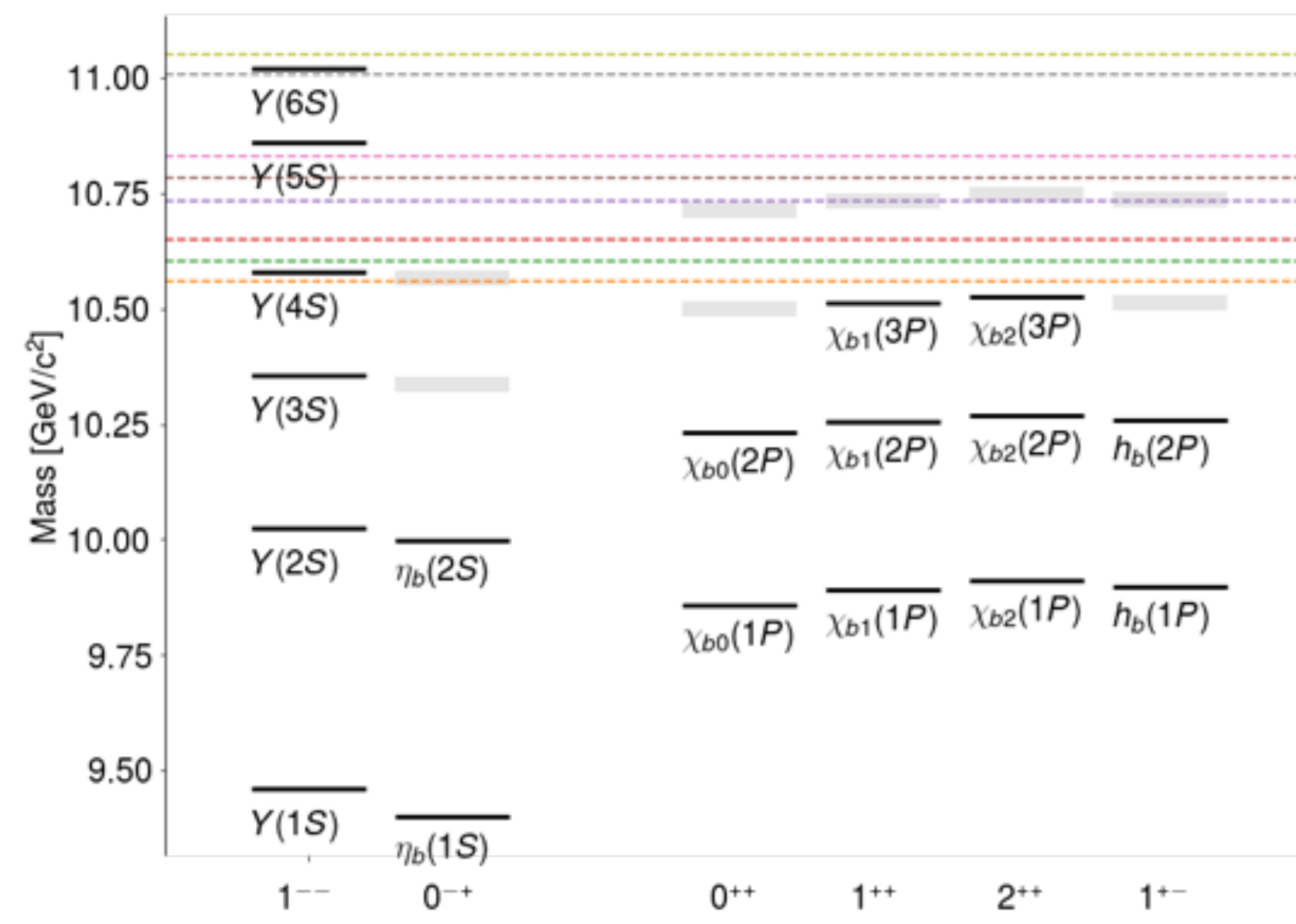
- Exotica(?): 10.75 GeV
- NP: LFV
- Exotica/NP: double strange di-baryon

Belle II @ HADRON2021

- 1) Results of Belle and the perspectives for Belle II - V. Bhardwaj
- 2) ISR studies at Belle II - S. Jia
- 3) Studies of the $X(3872)$ at Belle II - E. Prencipe
- 4) Bottomonium-like exotics and new physics in
bottomonium decay at Belle II - B. S.
- 5) Bottomonium results and prospects at Belle II - B. Fulsom

B Factory: collider experiment designed to produce a large number of B mesons

➤ (1st generation) Belle, BaBar: e⁺e⁻ colliders with center of mass energy tuned to the Y(4S) resonance peak

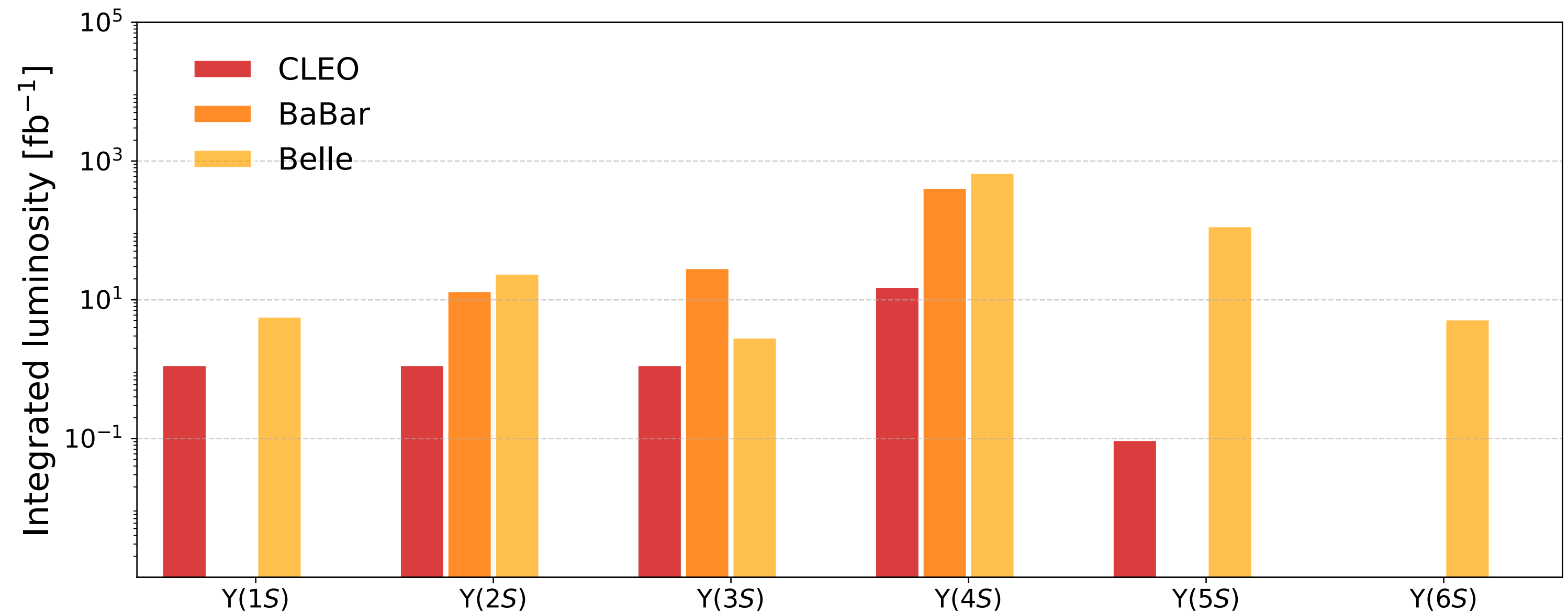
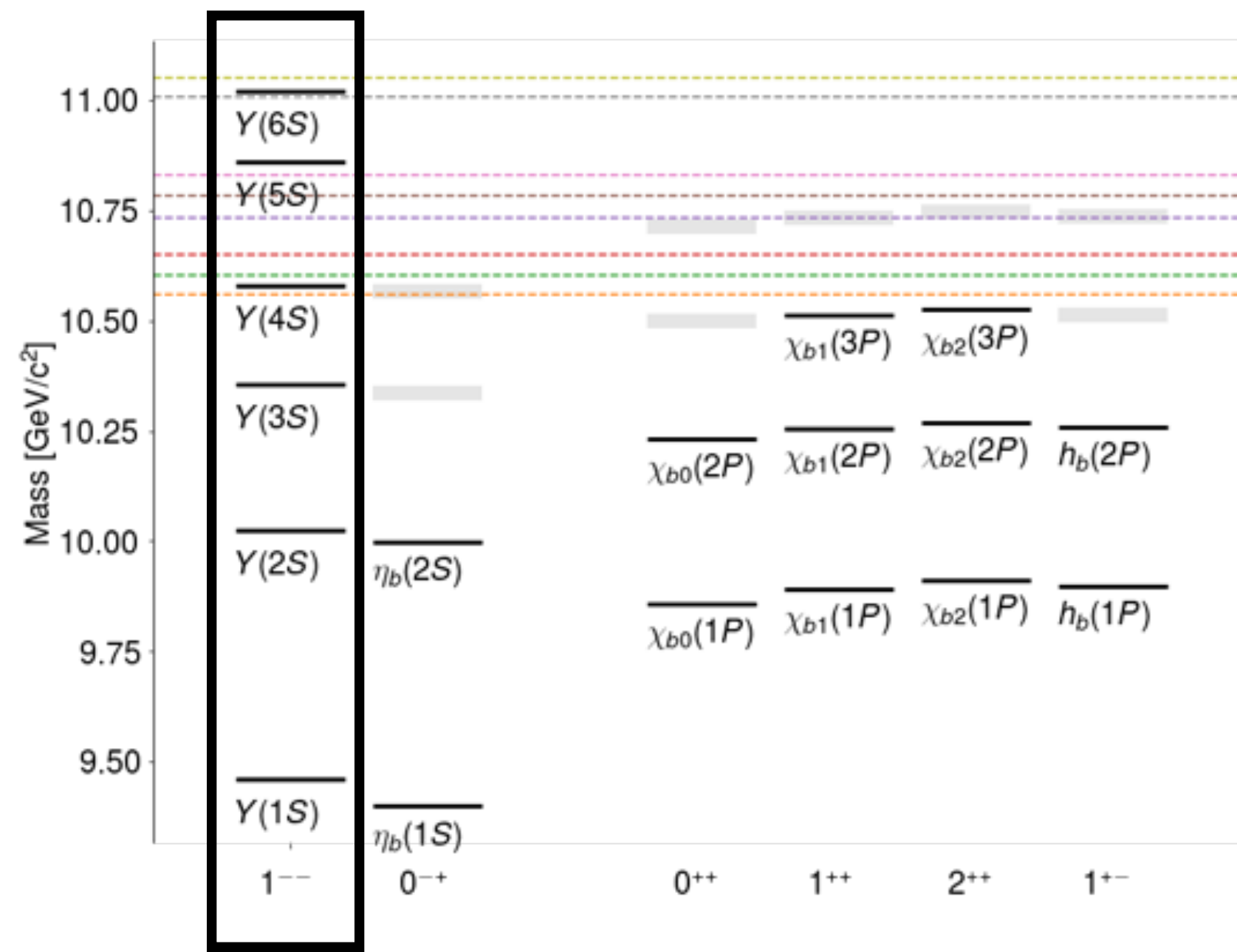


B Factory: collider experiment designed to produce a large number of B mesons

➤ (1st generation) Belle, BaBar: e^+e^- colliders with center of mass energy tuned to the $Y(4S)$ resonance peak

B Factories extended their physics programs with non $Y(4S)$ data

➤ 1^- directly accessible with e^+e^- colliders

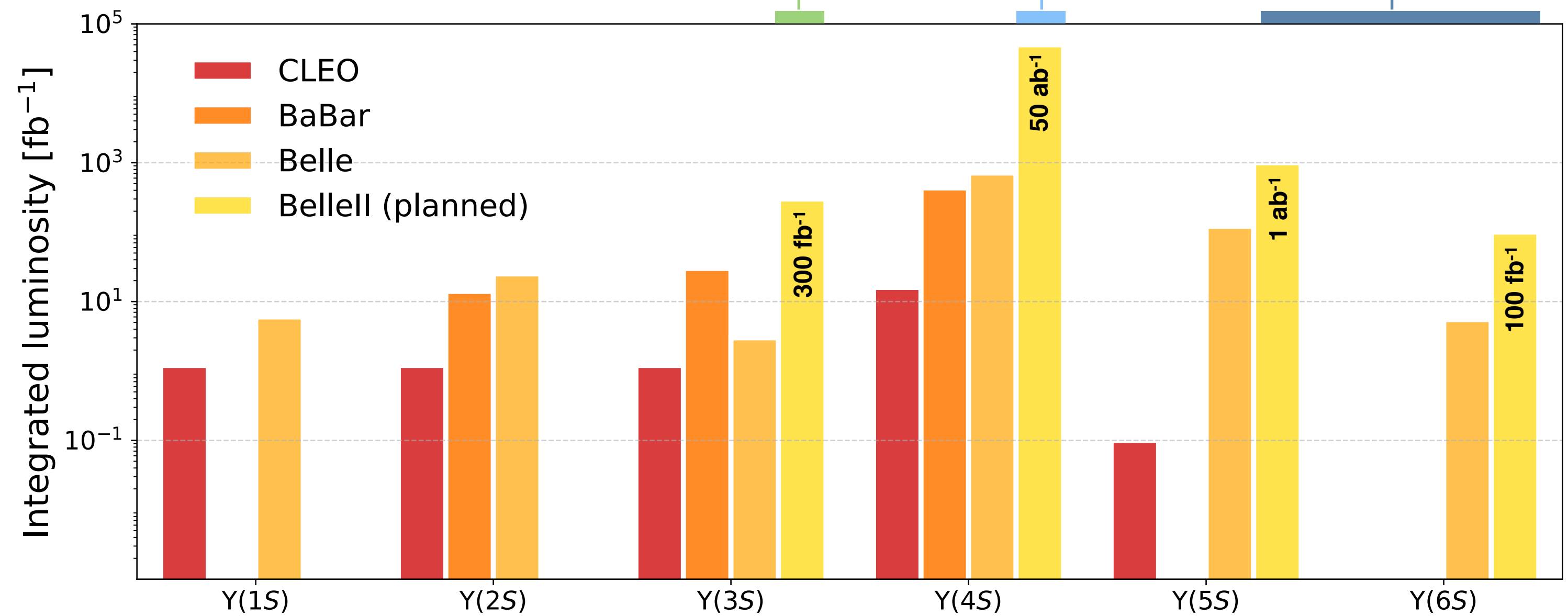


Broad physics program

- > LFV, LUV, invisible decays, hyperons production and correlation, charmonia and di-baryon exotica, deuterons, ...
- > ISR, Precision spin-singlet spectroscopy, ...
- > Exotica, threshold exploration, precision spin-singlet spectroscopy, high-statistics scan, ...

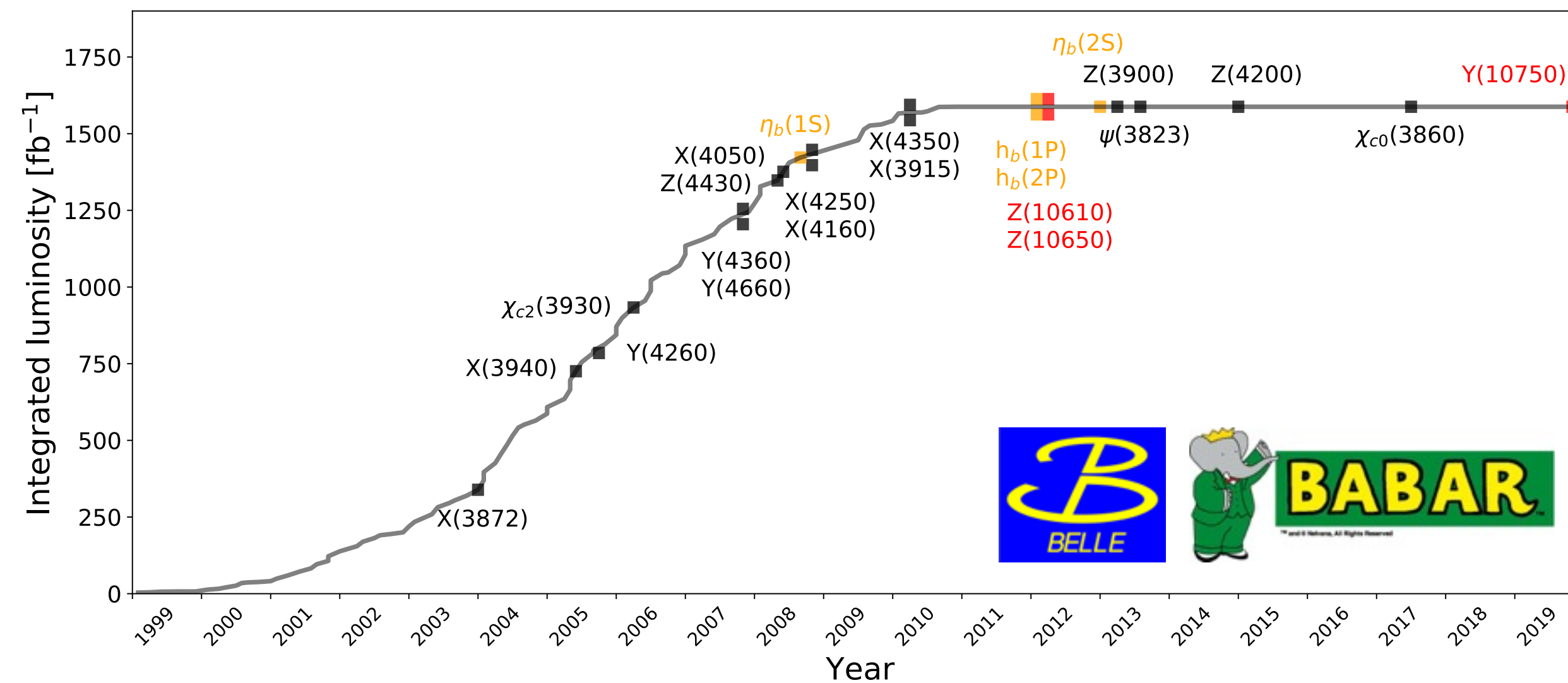
..with possible implications in many sectors

- > Hadron physics, astrophysics, DM,



Bottomonium is much less accessible than charmonium

- > Direct production in e^+e^- collisions
- > Prompt production



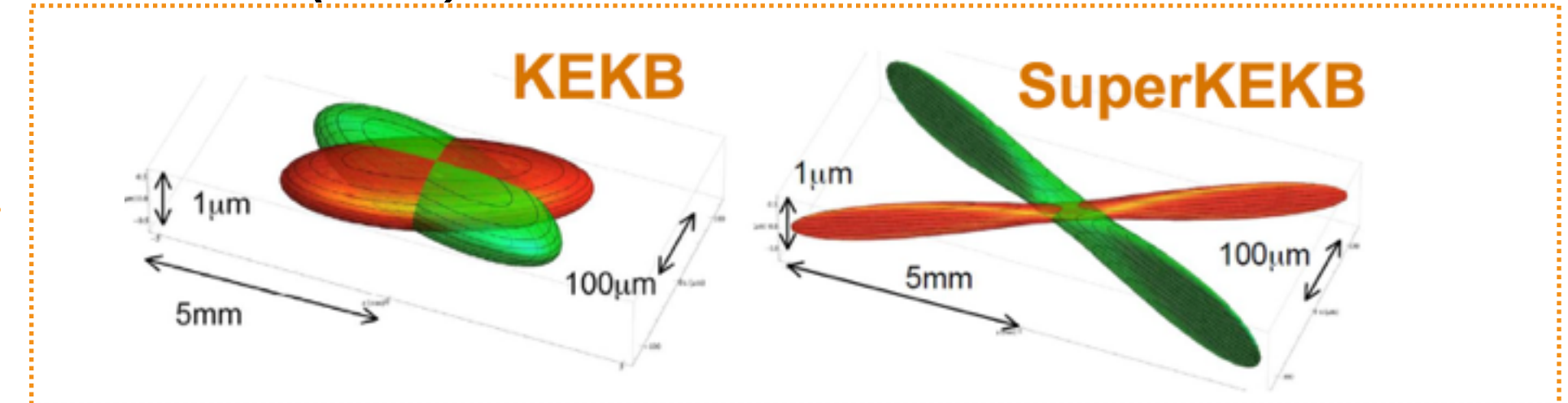
Belle II is in a unique position

- > Only the LHC experiments will cover bottomonia with strong limitations

Statistics, statistics, statistics!

- SuperKEKB and the nano-beam scheme

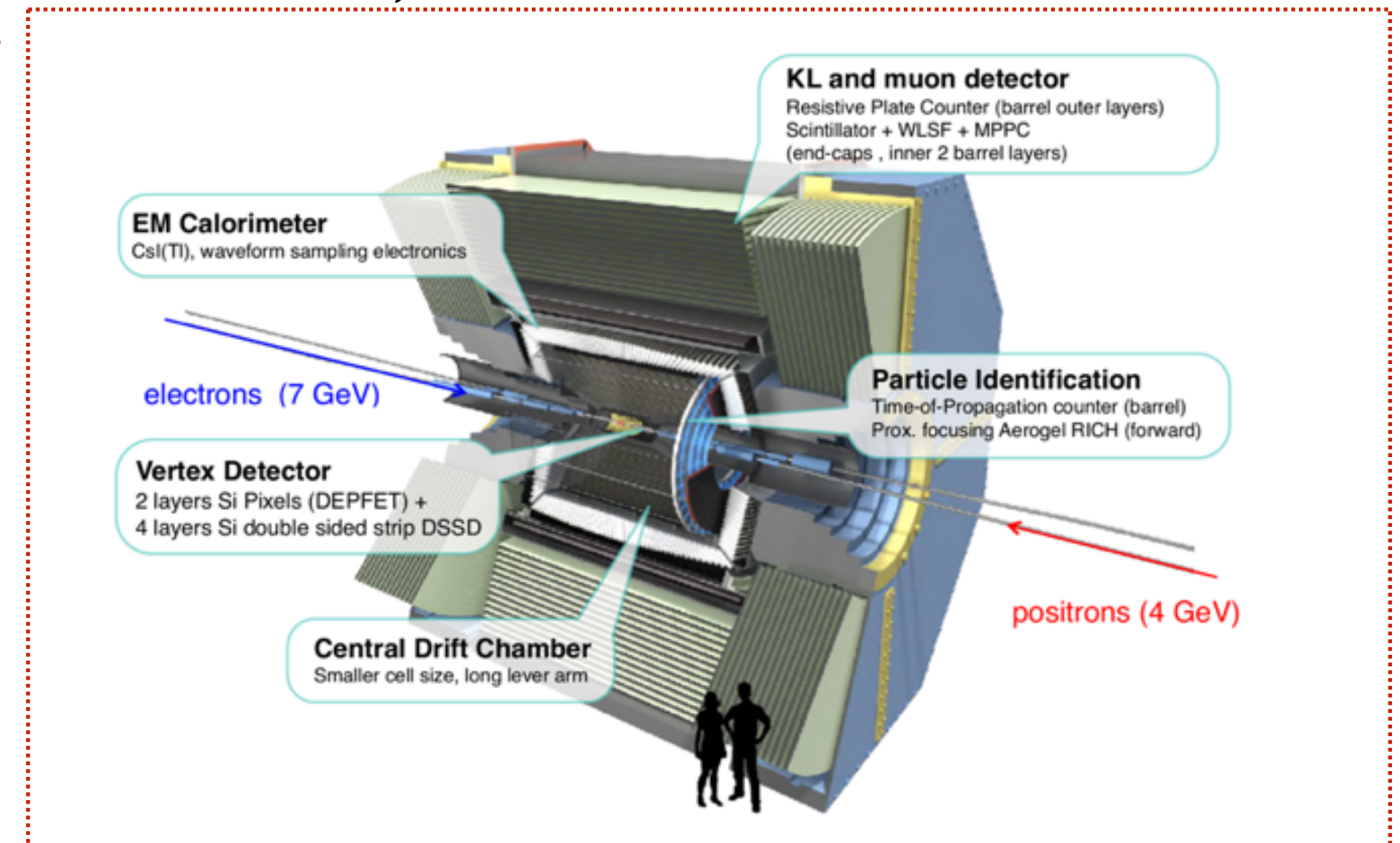
NIM A 907 (2018) 188-199



Hermeticity

- The Belle II detector

arXiv:1011.0352, Belle II TDR



Reduce systematics & electron/muon separation

- Belle II detector & software performance

Statistics, statistics, statistics!

- > SuperKEKB and the nano-beam scheme

Nano beam scheme does not come for free

- > (Currently) better algorithms and electronics/detector are only enough to compensate the increased backgrounds

Hermeticity

- > The Belle II detector

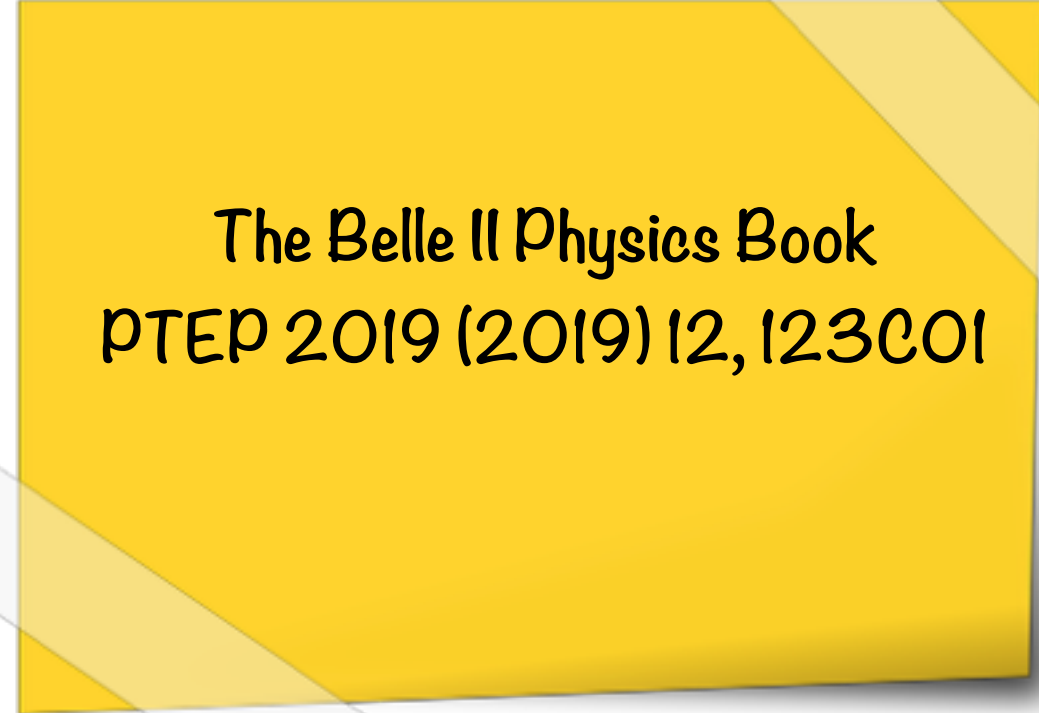
Reduce systematics & electron/muon separation

- > Belle II detector & software performance

	 vs 	
Tracking		Comp. Phys. Comm. 259 (2021) 107610
FEI		Comput. Softw. Big Sci 3, 6 (2019)
Neutrals		paper in preparation
PID		paper in preparation

Bottomonium-like exotics and NP: Belle II potential

- Exotica(?): 10.75 GeV
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- Exotica/NP: double strange di-baryon



The Belle II Physics Book
PTEP 2019 (2019) 12, 123C01

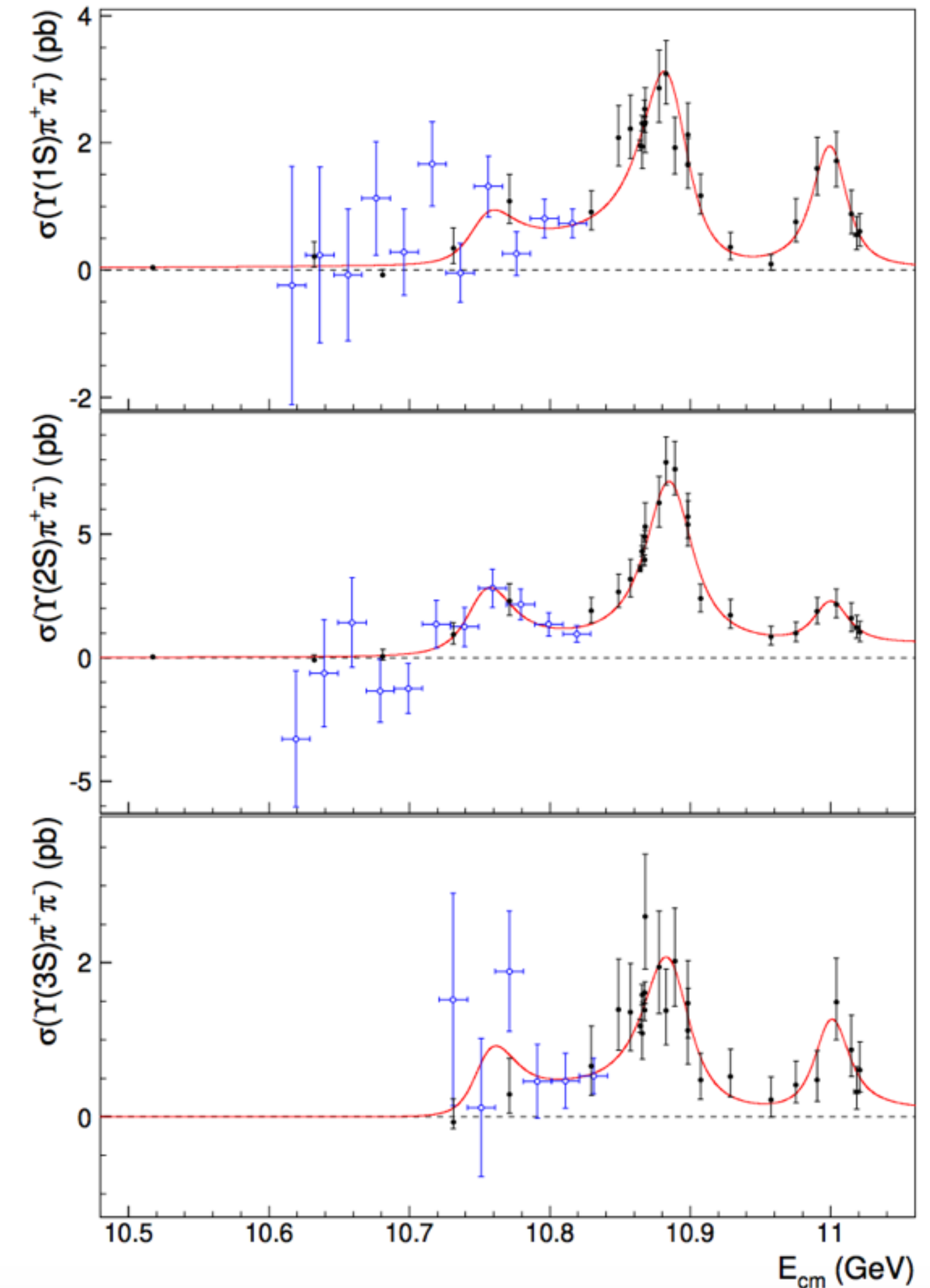
A (personal and) not comprehensive
selected list of topics

Recent result (2019)

- Observation of a new structure near 10.75 GeV in the energy dependence of the $e^+e^- \rightarrow Y(nS) \pi \pi$

	$\Upsilon(10860)$	$\Upsilon(11020)$	New structure
M (MeV/c ²)	$10885.3 \pm 1.5^{+2.2}_{-0.9}$	$11000.0^{+4.0}_{-4.5} {}^{+1.0}_{-1.3}$	$10752.7 \pm 5.9^{+0.7}_{-1.1}$
Γ (MeV)	$36.6^{+4.5}_{-3.9} {}^{+0.5}_{-1.1}$	$23.8^{+8.0}_{-6.8} {}^{+0.7}_{-1.8}$	$35.5^{+17.6}_{-11.3} {}^{+3.9}_{-3.3}$

JHEP10 (2019) 220, Belle



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Exotica?

- Unlikely to be a molecule as it's far from any S- threshold
- No direct matching to conventional states (but may be an S-D mixing?)



Conventional D- or S-D mixed state

Phys.Rev.D 101 (2020) 1, 014020
 Phys.Lett.B 803 (2020) 135340
 Eur.Phys.J.C 80 (2020) 1, 59

“Exotica”

Arxiv:2008.05605
 Chin.Phys.C 43 (2019) 12, 123102
 Phys.Lett.B 802 (2020) 135217
 Phys.Rev.D 102 (2020) 1, 014036

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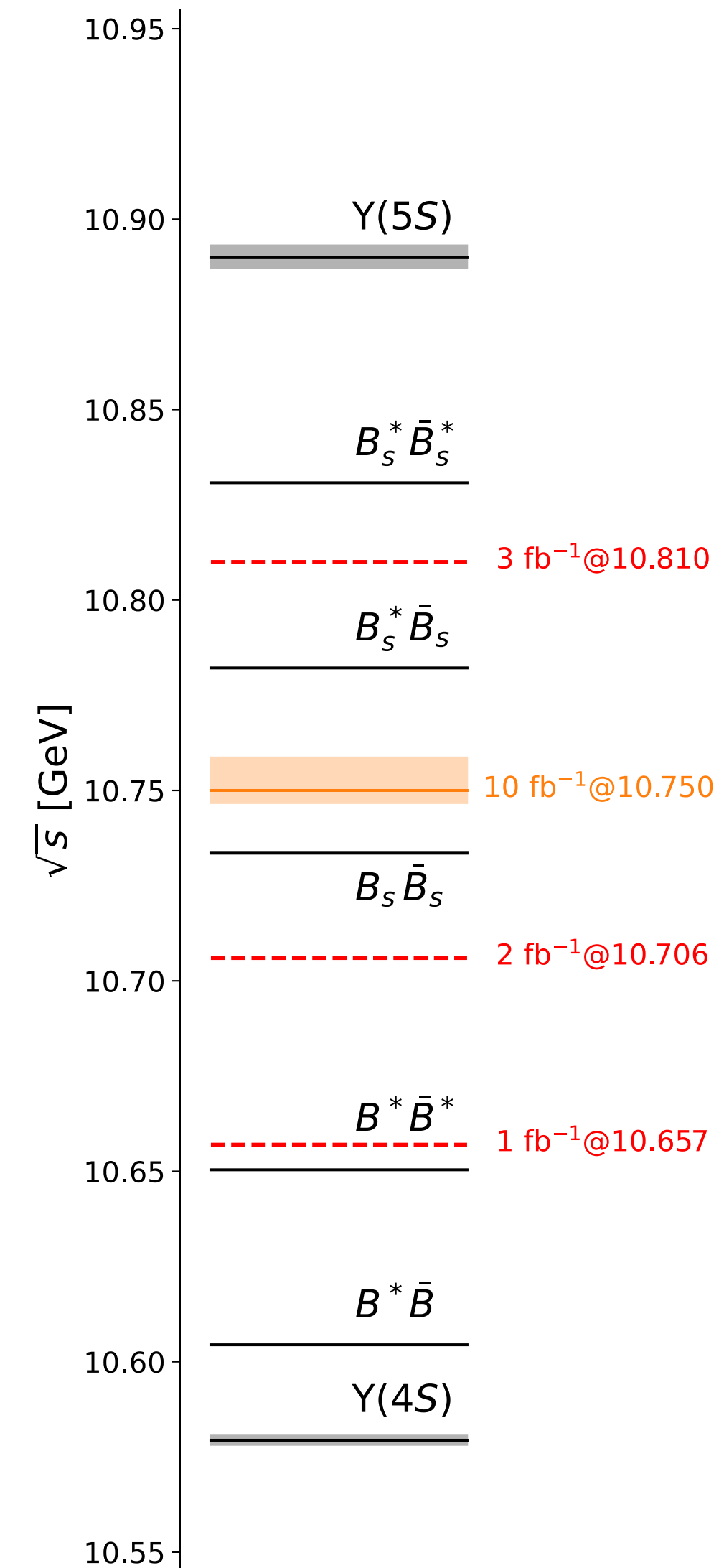
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10.75 @ Belle II

- Revisit this energy region with greater statistics
- First non-Y(4S) run this fall, 10 fb⁻¹ on resonance + 3 scan points



The observation of CLFV transitions would provide clean probes of NP

Experimental information on vector quarkonia leptonic decays can be converted to experimental bounds on Wilson coefficients

- The restricted kinematics of two-body transitions reduces the reliance on single operator dominance assumption

[PRD 94,074023 (2016), Hazard, Petrov]

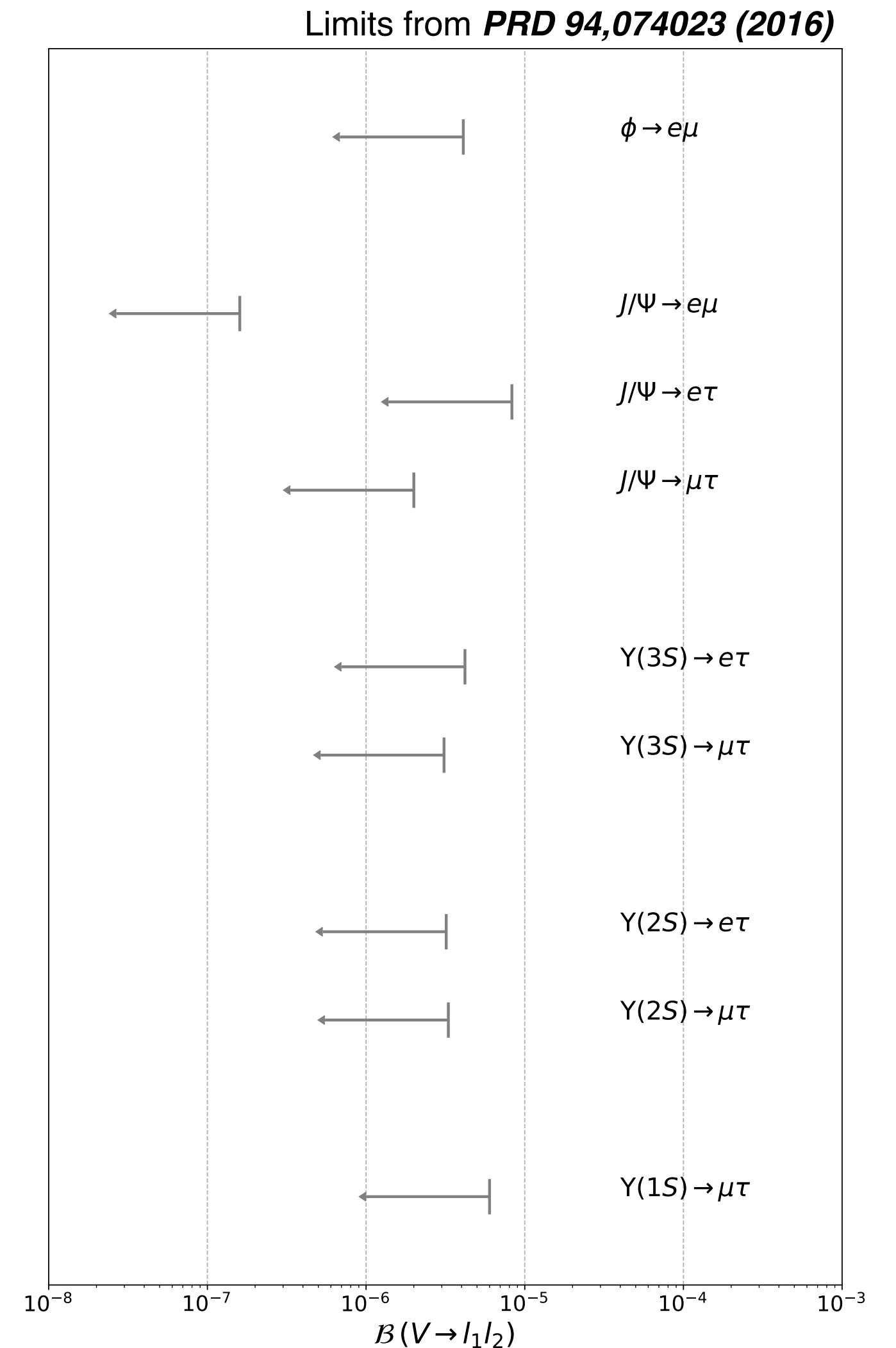
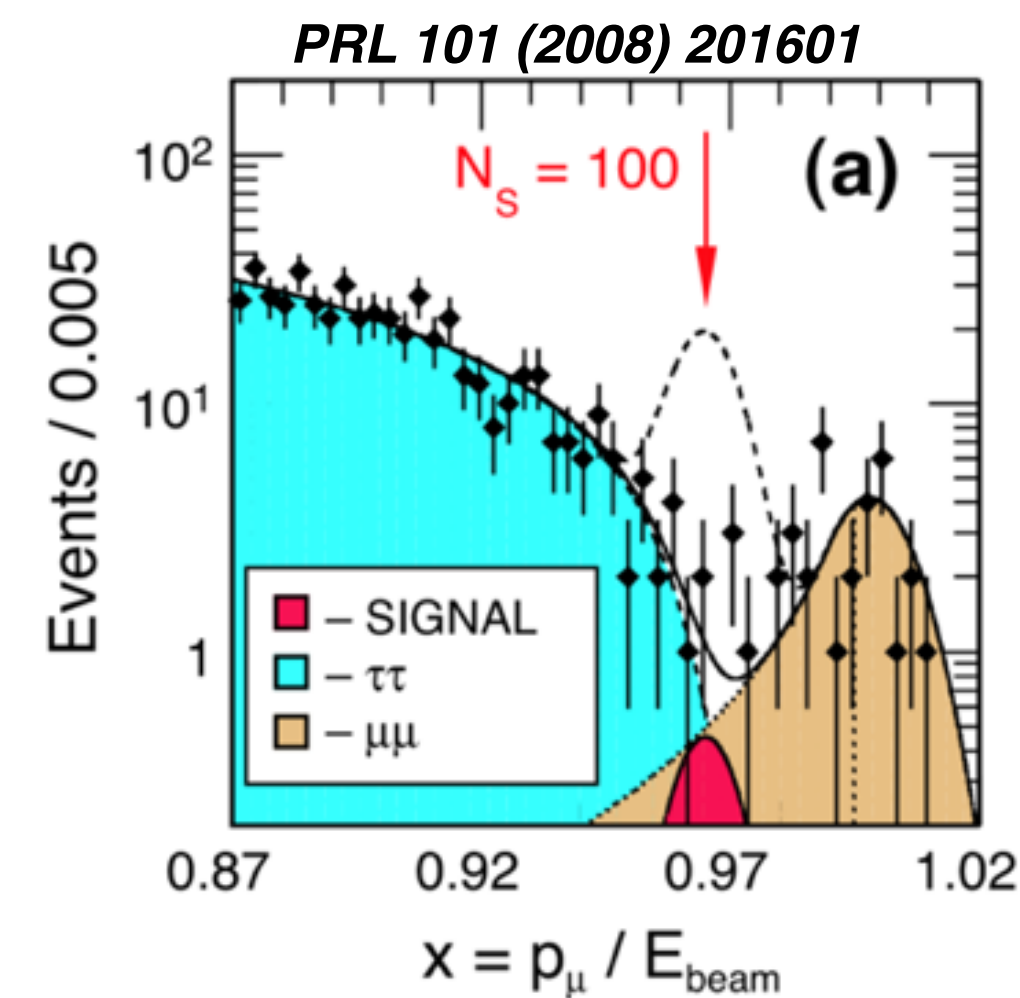
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LFV @ B Factories: where are we

- > Available experimental upper bounds on $B(V \rightarrow l_1 l_2)$
- > ...some of them still from CLEO..



The observation of CLFV transitions would provide clean probes of NP

Experimental information on vector quarkonia leptonic decays can be converted to experimental bounds on Wilson coefficients

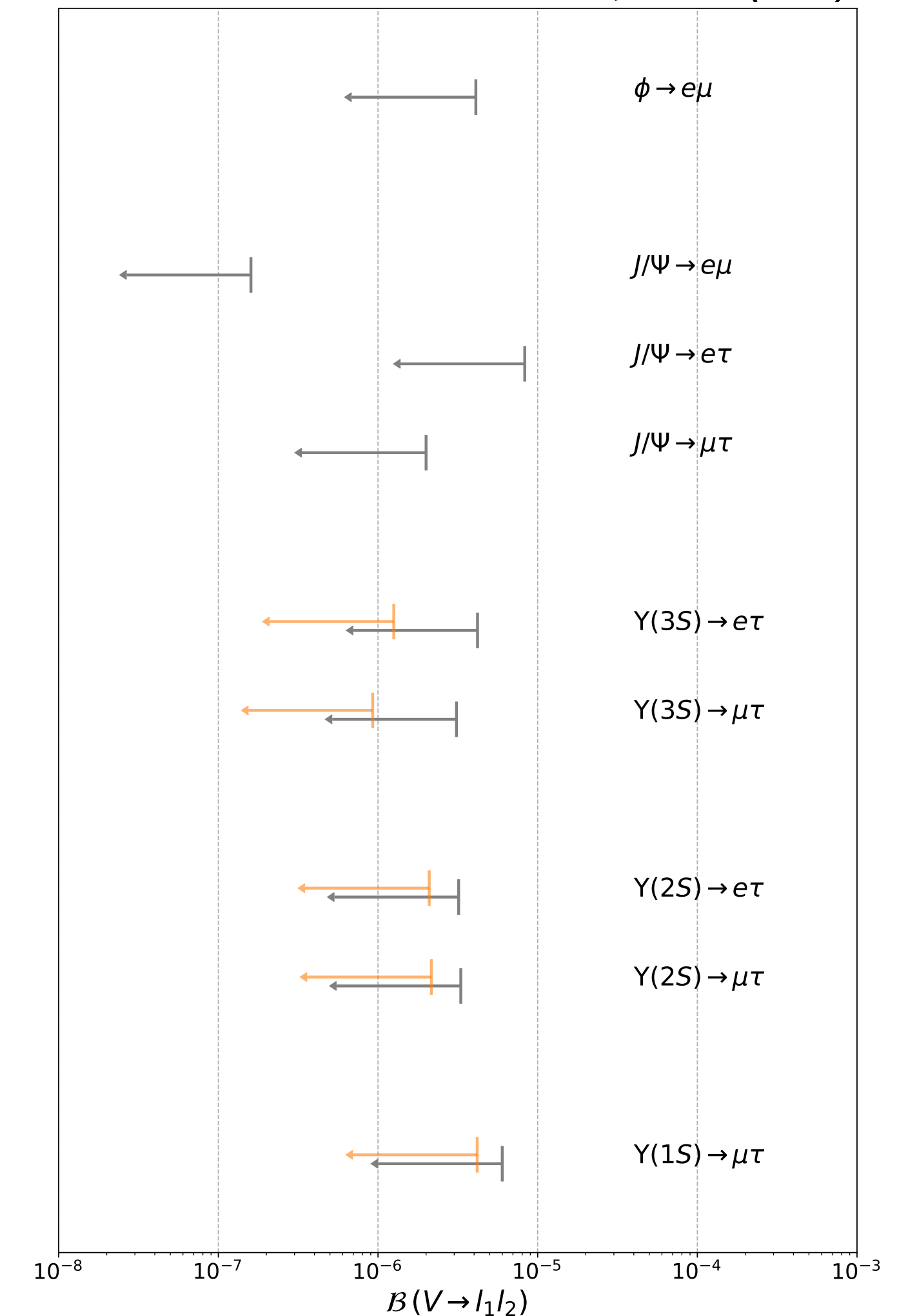
- > The restricted kinematics of two-body transitions reduces the reliance on single operator dominance assumption
[PRD 94,074023 (2016), Hazard, Petrov]

LFV @ Belle II

- > Push as much as possible the sensitivity on $Y(nS) \rightarrow e\tau, \mu\tau, e\mu$

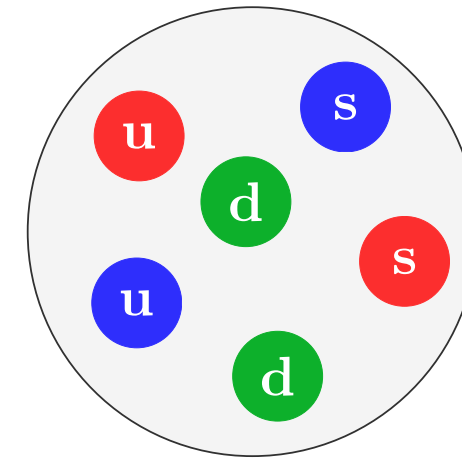
Lumi-scaling extrapolation using 300 fb^{-1} @ $Y(3S)$

Limits from PRD 94,074023 (2016)



Loosely bound H-dibaryon (*)

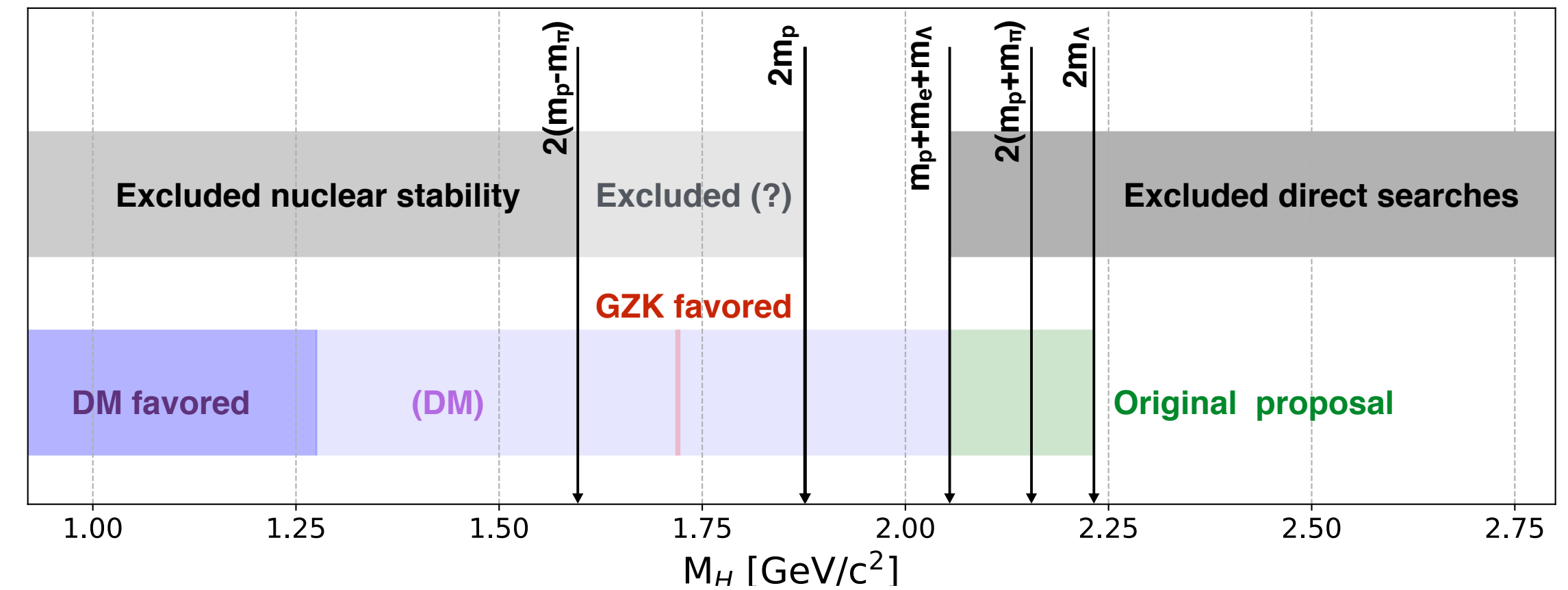
> [PRL 38 \(1977\) 195-198, Jaffe](#)



Deeply bound exaquark (**)

> [JETP Lett. 70 \(1999\) 491-494, Kochelev](#)

> [arXiv:1708.08951 \[hep-ph\], Farrar](#)



Double strange di-baryon @ B Factories: why/how

- > Similarities between hadronic collisions and narrow bottomonia annihilations
- > Good place to look for strange (exotic) baryons

(*) New predictions

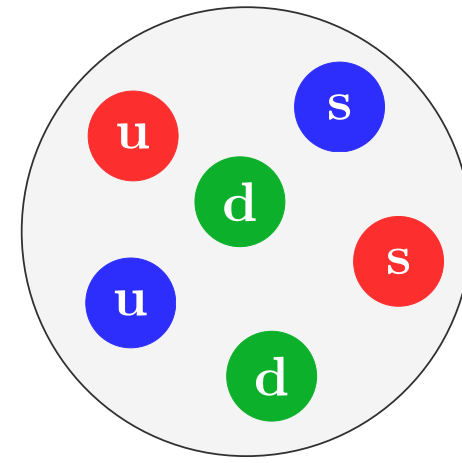
See D.Marietti's talk @ HADRON2021
Jul 28, h.15.25: Predicting the production of loosely bound di-baryons in bottomonium decays

(**) Against it

Phys.Rev.D 99 (2019) 3, 035013
 Phys.Rev.D 99 (2019) 6, 063519
 PRD 98 (2018) no.6, 063005

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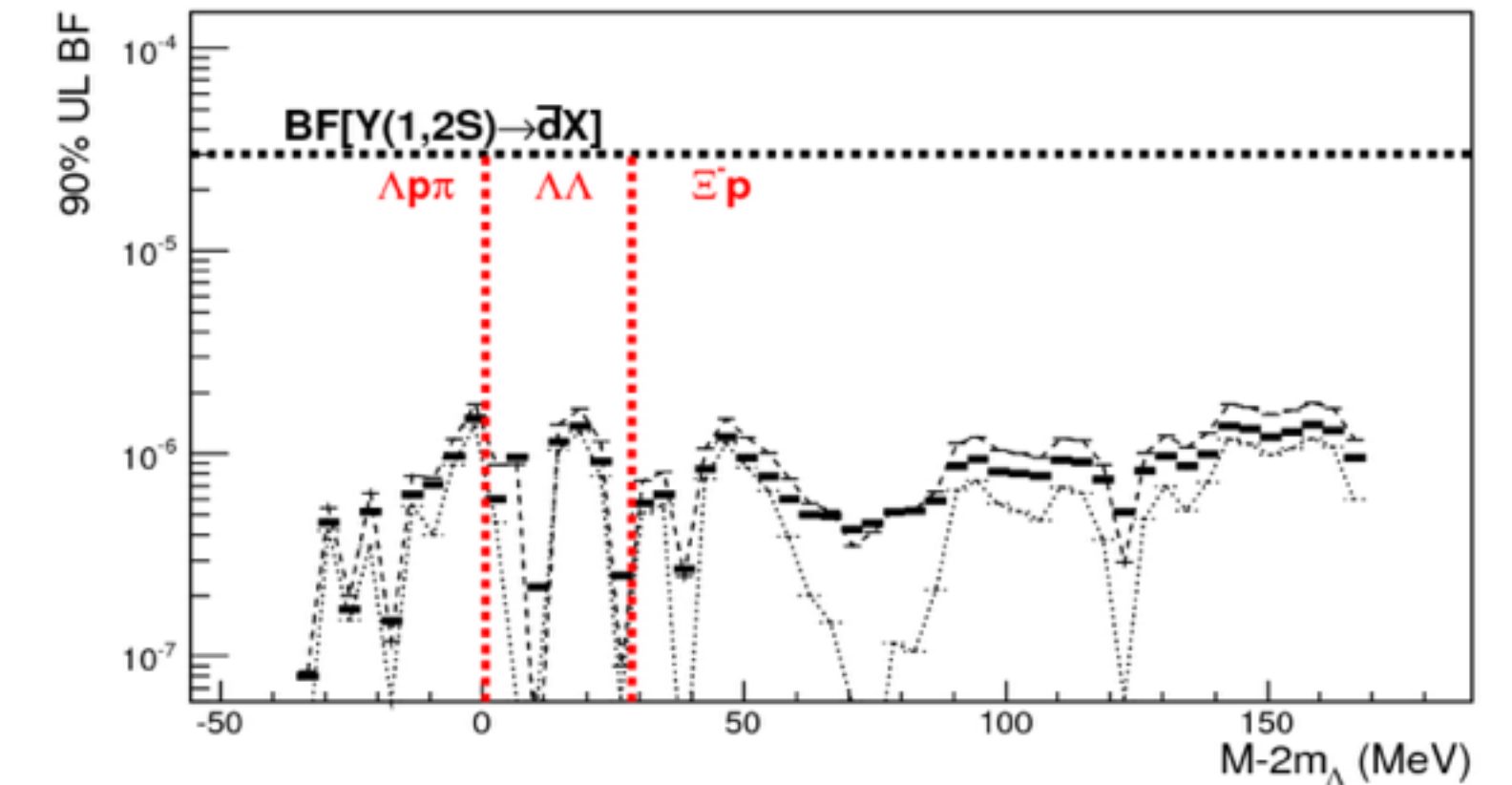
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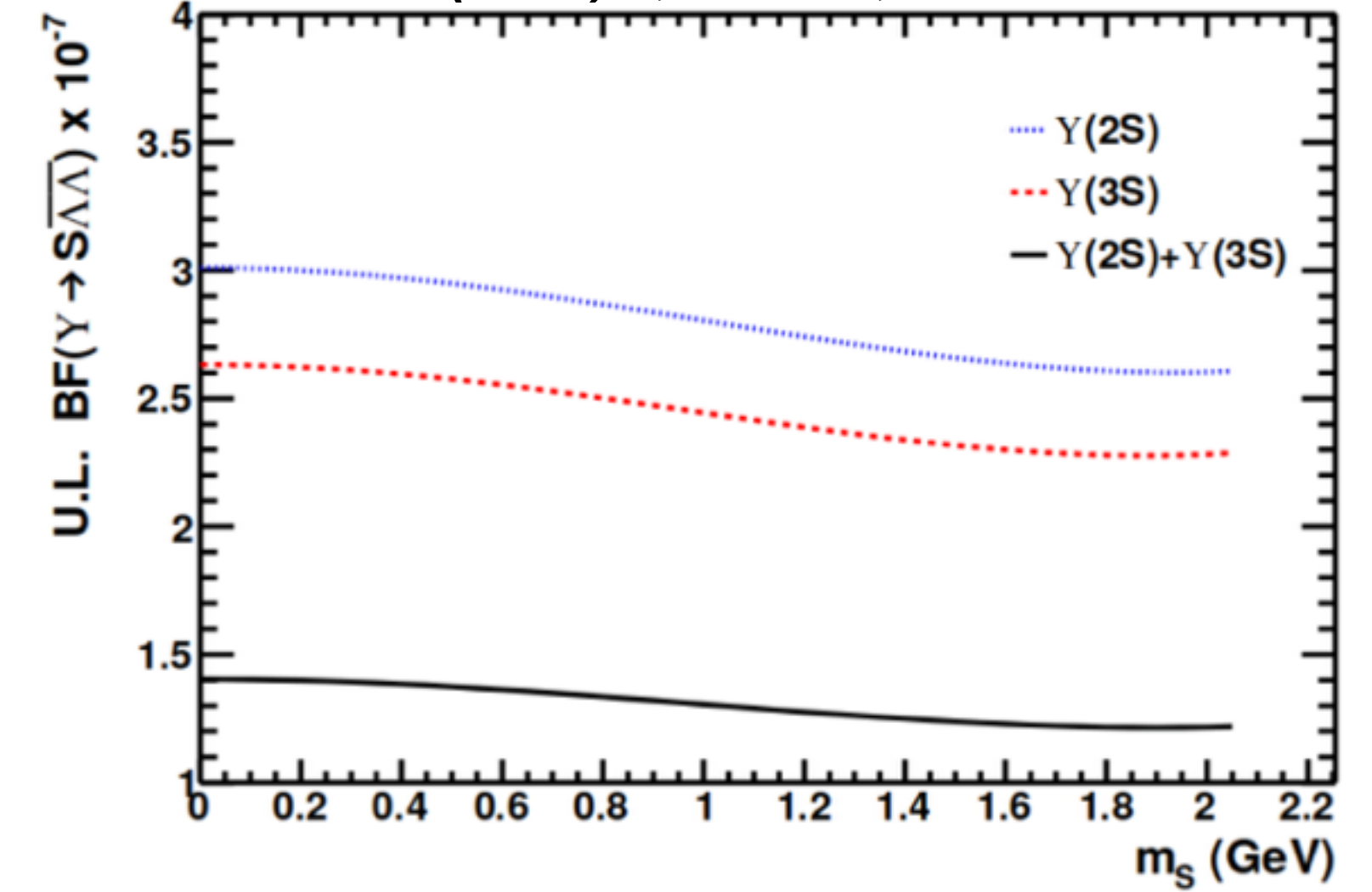
Double strange di-baryon @ B Factories: where are we

- > Belle: PRL 110, 222002 (2013)
- > BaBar: Phys.Rev.Lett. 122 (2019) 7, 072002

PRL 110, 222002 (2013), Belle

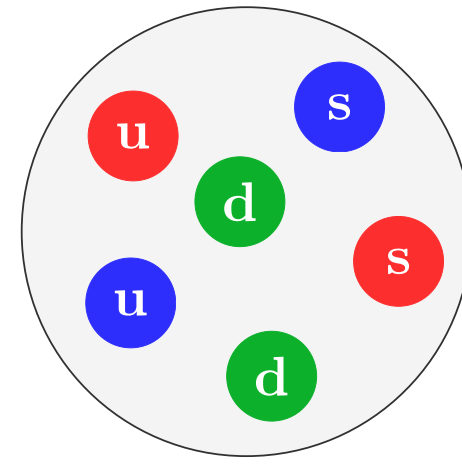


PRL 122 (2019) 7, 072002, BaBar



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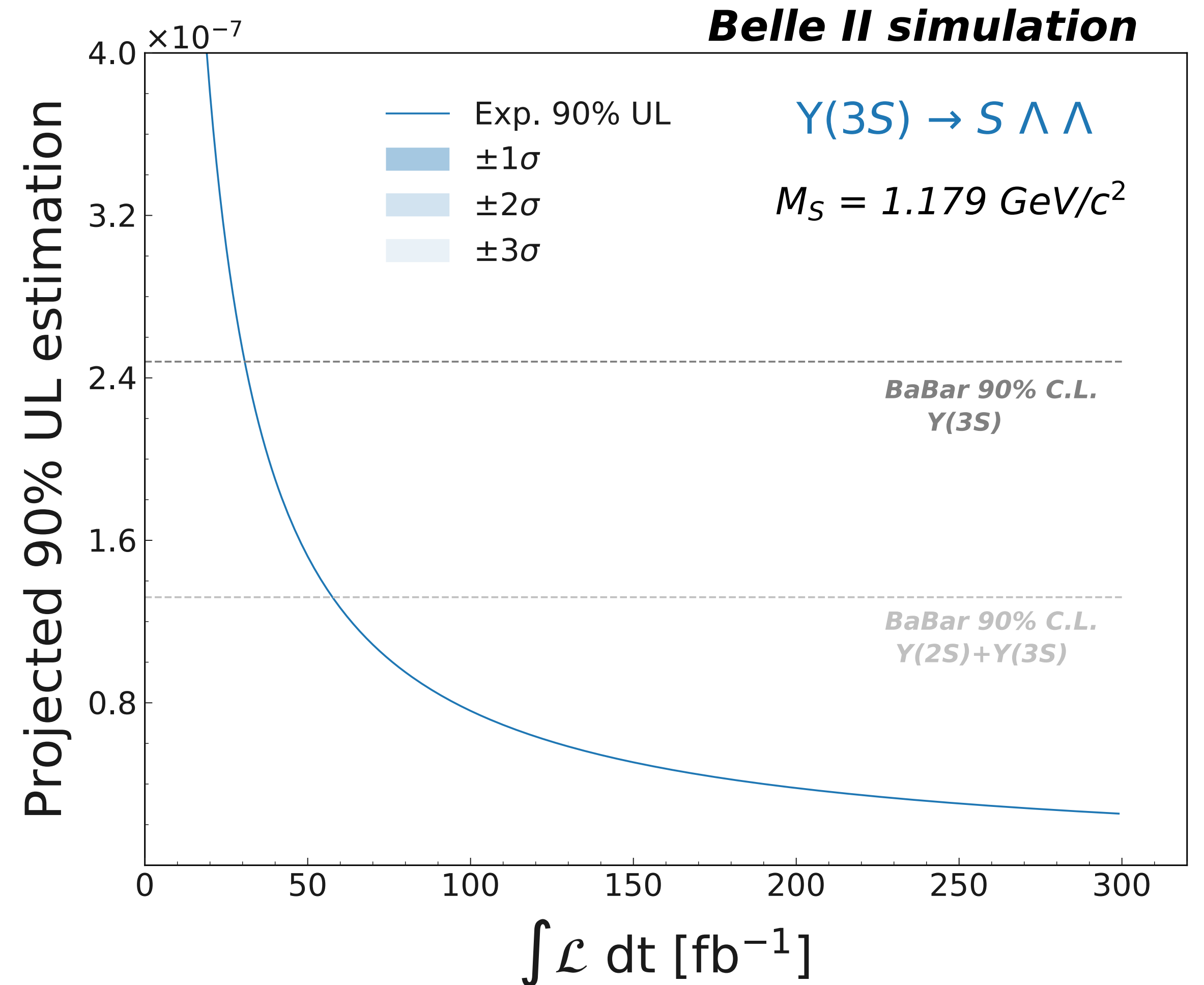
> JETP Lett. 70 (1999) 491-494, Kochelev

> arXiv:1708.08951 [hep-ph], Farrar

Double strange di-baryon @ Belle II

> Improve the UL estimation (more data)

> Additional mesons in the final state



Belle II started data taking

- Will soon match the Belle dataset @ Y(4S)

We're at the beginning of an exciting bottomonium program

- Early results (rediscoveries) on track

Belle II bottomonium program includes

- Early run at Y(10.75), fall 2021
- 300 fb⁻¹ of Y(3S)
- 1ab⁻¹ of Y(5S), 500 fb⁻¹ of scan above Y(5S), 100 fb⁻¹ of Y(6S)

Bottomonium-related schedule is under discussion

- Input and theoretical support is very welcome

Next Belle II talk
@ HADRON2021

Jul 29, h.12: Bottomonium
results and prospects at Belle II
(B. Fulsom)

Not explicitly mentioned today

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PTEP 2019 (2019) 12, 123C01

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Thank you for your attention!