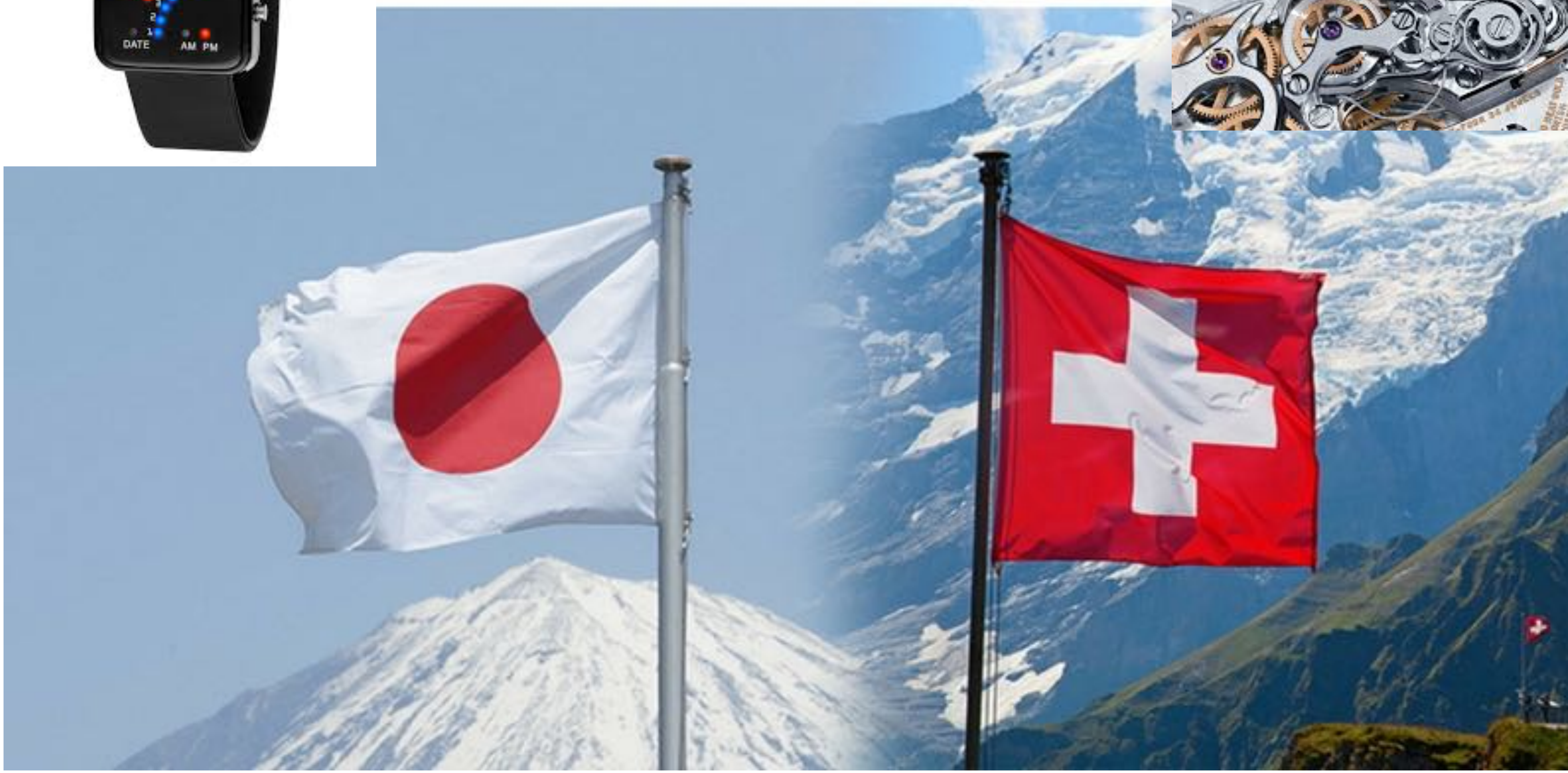
Japanese vs Swiss

Replica Watch Movement



I. Komarov, C. La Licata, D.Tonelli

Belle II Italian meeting - Trieste, May 4, 2017

Why?

Until the mid-2000's B-factories had uncharted territory to explore freely: no real competition from CLEO or CDF/D0. Babar and Belle competed fiercely: similar detector performances made analysis-timing and sophistication key.

The scenario Belle II will play in will be quite different from what former Belle (and Babar) collaborators might be used to. Need to confront LHCb, a running, well-oiled flavor-paper factory.

Looks inefficient to aim at measurements where LHCb has shown to enjoy a disconcerting advantage.

We thought it could be interesting to give a stab at performance comparisons. Goal is to hopefully get indications that can inform our early physics choices.

What and How

The goal is to guesstimate the future performances of Belle II and LHCb for a few, broad classes of analyses

Scale the statistical resolutions of existing results of some common, representative measurements to project them for the expected future sample sizes.

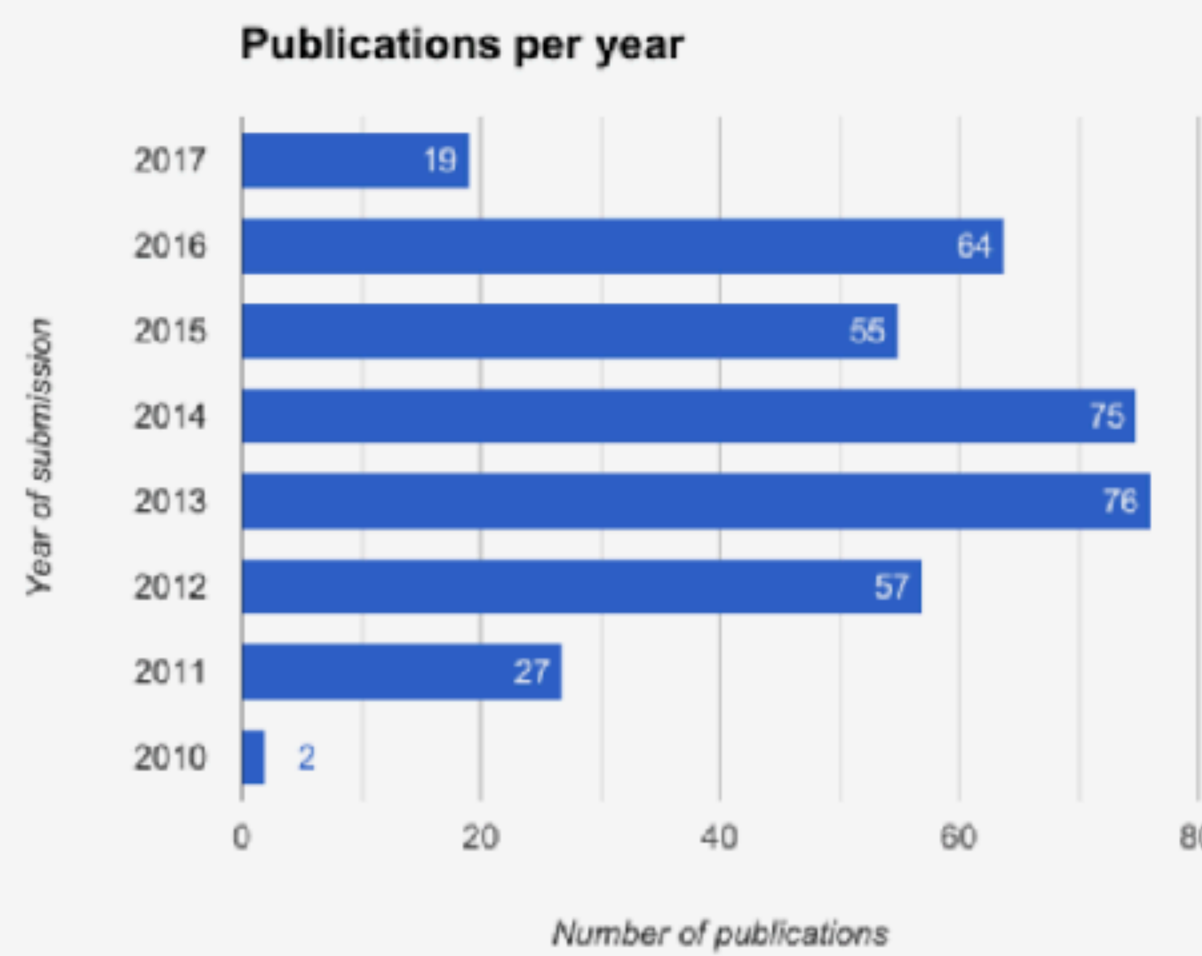
Use 2-3 analyses/class to average out the fluctuations due to differences in kinematic/topology/trigger/analysis techniques.

A few hours ago Francesco pointed out:
BELLE2-NOTE-PH-2015-004
BELLE2-NOTE-PH-2015-002
Similar exercise but we have updated inputs.

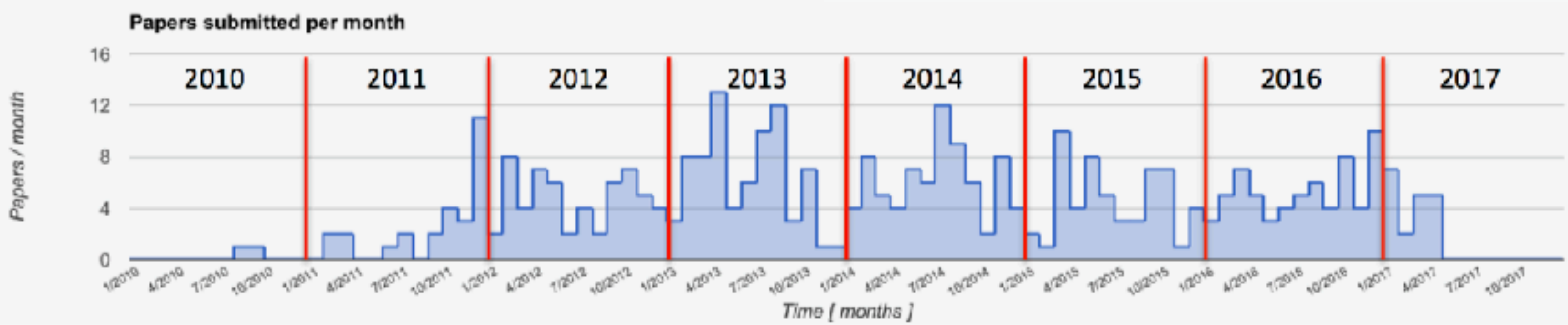
Assumptions:

- Nominal experimental schedules
- Frozen systematic uncertainties
- Statistical uncertainties independent from central values
- Upper limits scale as $1/\sqrt{N}$
- Offline analyses done in zero time
- 50% better performance of Belle II w.r.t. Belle
- Doubled trigger efficiency for LHCb past 2021
- Past 2021, LHCb will be able to trigger on K0s similarly to now.

LHCb: flavor-paper factory



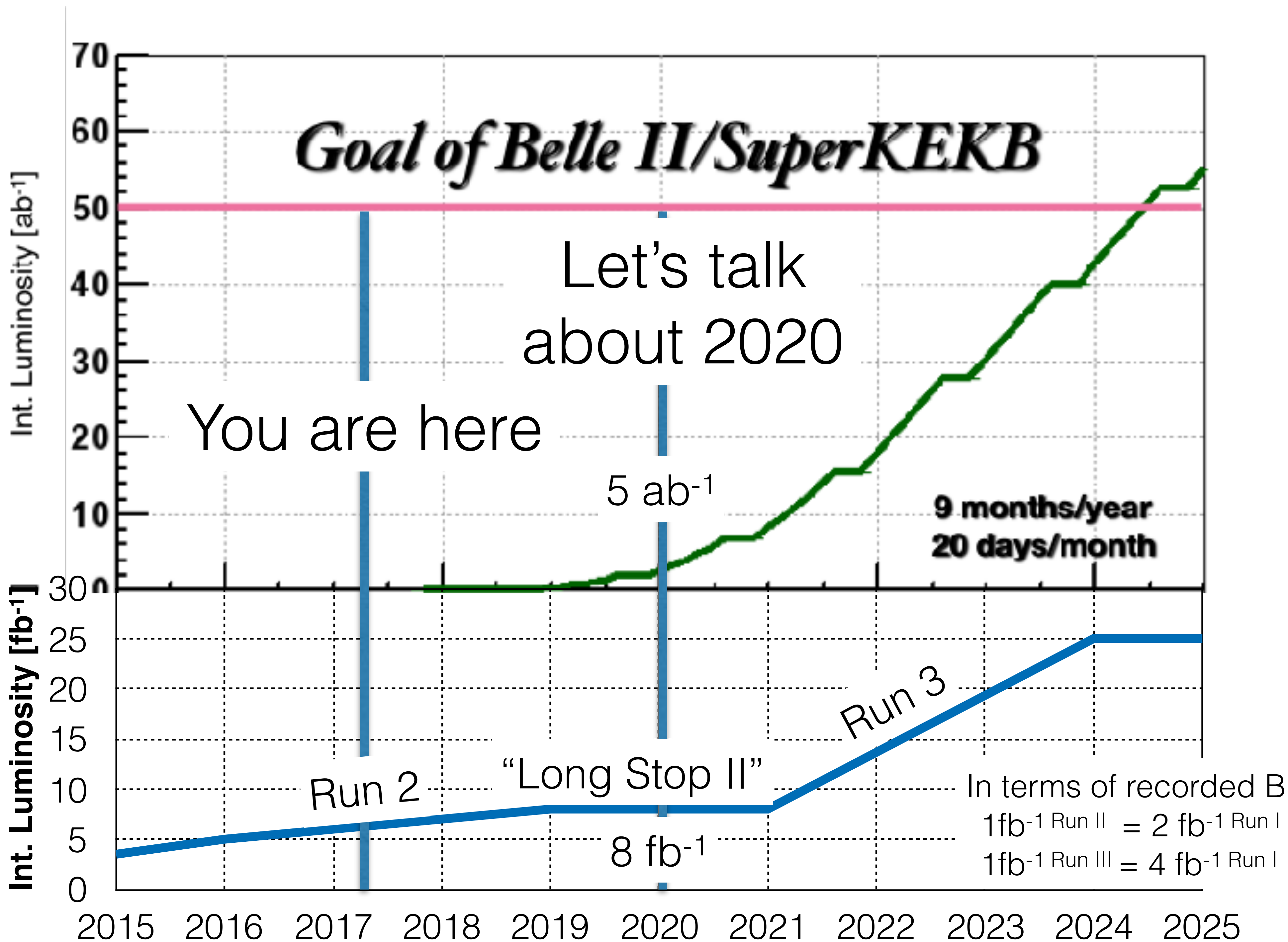
- Collecting data at increasing energy and luminosity since 2010
- ~50 papers/year



Schedules

1k B per second on disk

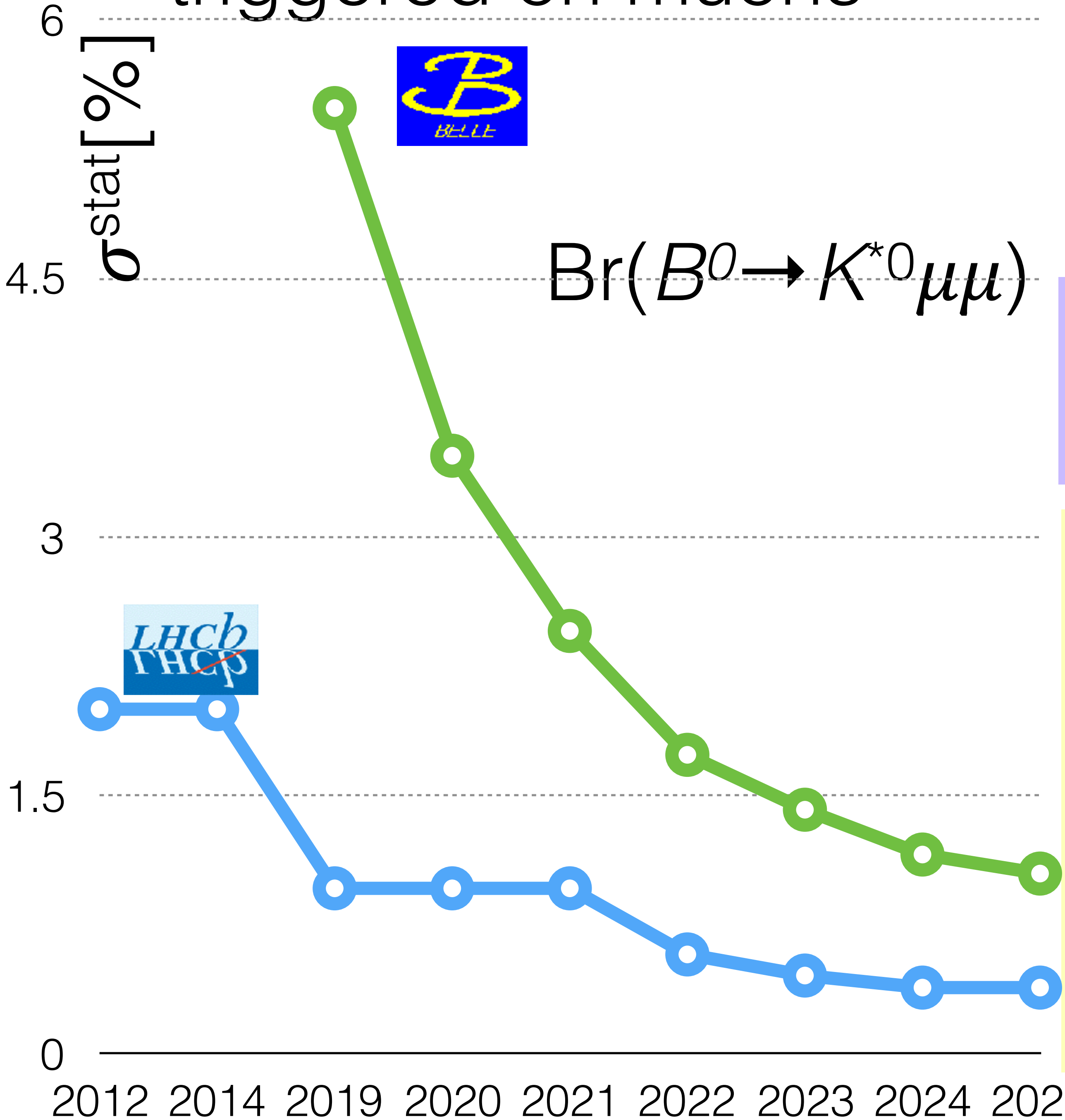
50-100k B per second on disk



All-tracks final states

BF($B^0 \to K^{*0}\mu\mu$)

4-track final state
triggered on muons



arxiv:1512.04442 arxiv:1604.04042

3 fb^{-1}	711 fb^{-1}
σ^{stat}~2%	~11%

In 2020:

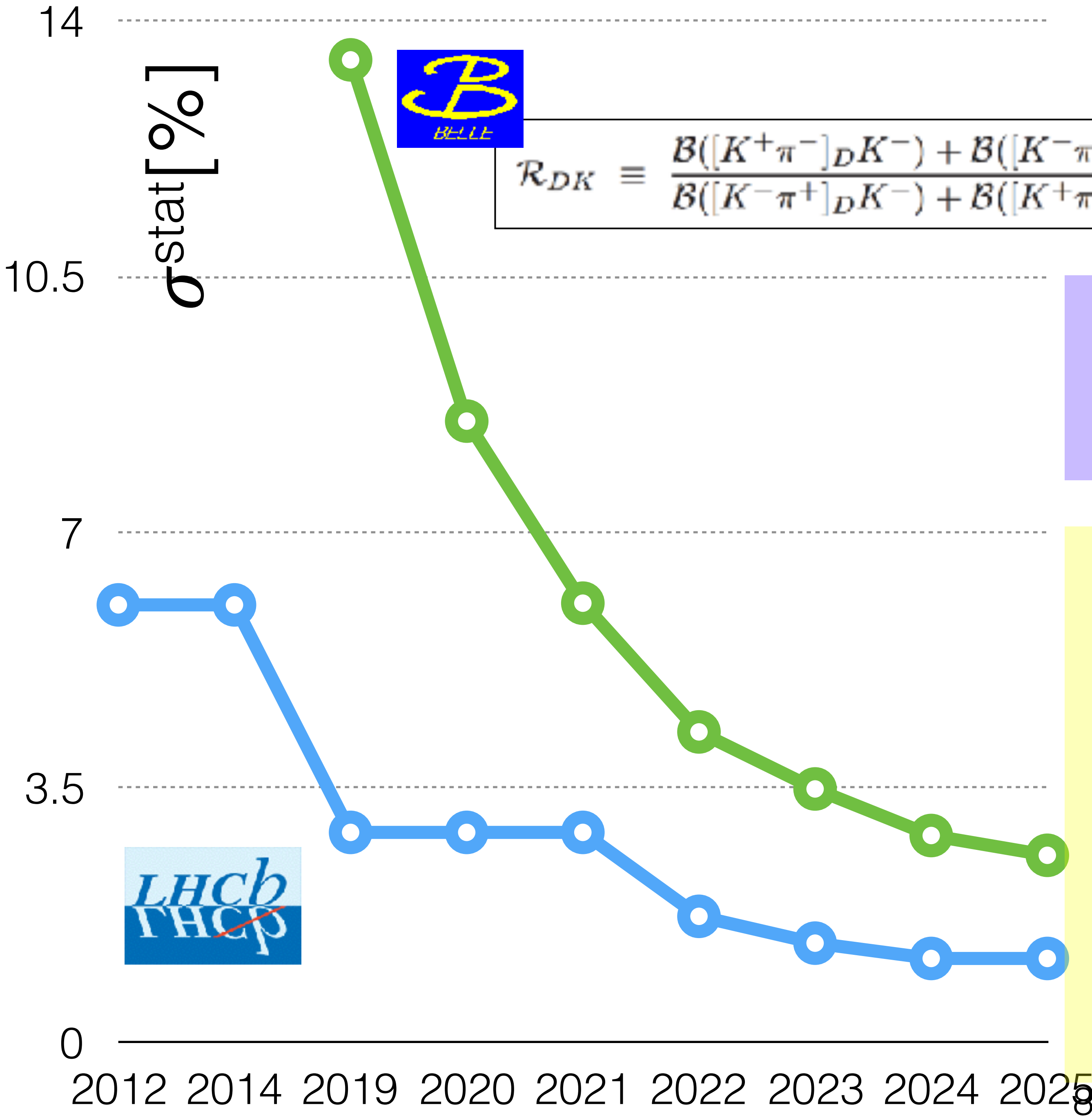
3^{RunI}+5^{RunII} fb^{-1}	5 ab^{-1}
σ^{stat}~1%	~3%

$B^0 \to D(\to K\pi)K$

3-track final state
triggered on hadrons

arxiv:1603.08993 arxiv:1103.5951

$$\mathcal{R}_{DK} \equiv \frac{\mathcal{B}([K^+\pi^-]_D K^-) + \mathcal{B}([K^-\pi^+]_D K^+)}{\mathcal{B}([K^-\pi^+]_D K^-) + \mathcal{B}([K^+\pi^-]_D K^+)}$$



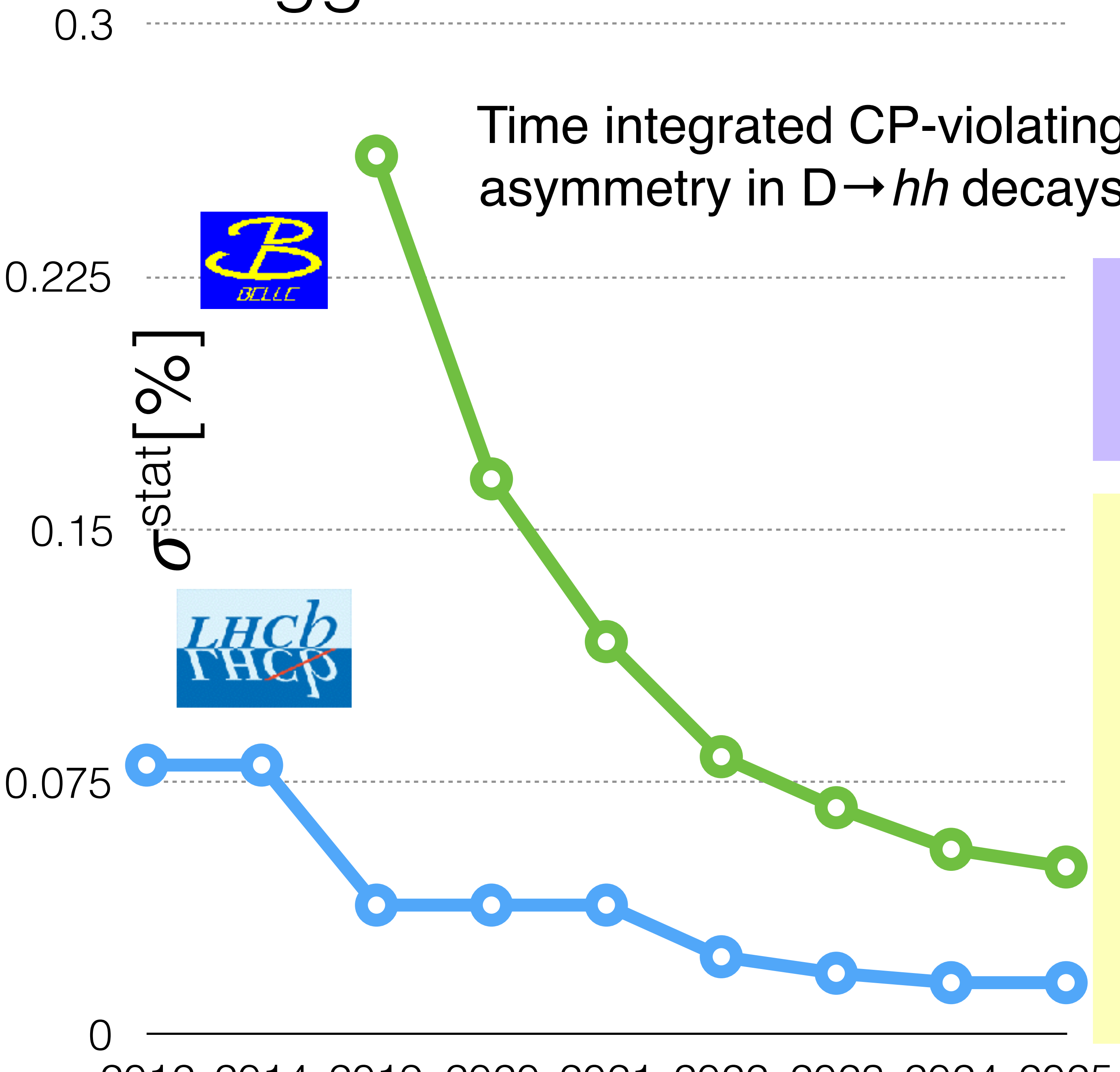
LHCb	Belle
3 fb^{-1}	711 fb^{-1}
σ^{stat}~6%	~27%

In 2020:

LHCb	Belle II
$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
σ^{stat} ~3%	~9%

$D \to hh$

2-track final state
triggered on hadrons



arxiv:1602.03160 arxiv:0807.0148

LHCb | Belle

3 fb^{-1} | 540 fb^{-1}

σ^{stat}~0.08% | ~0.6%

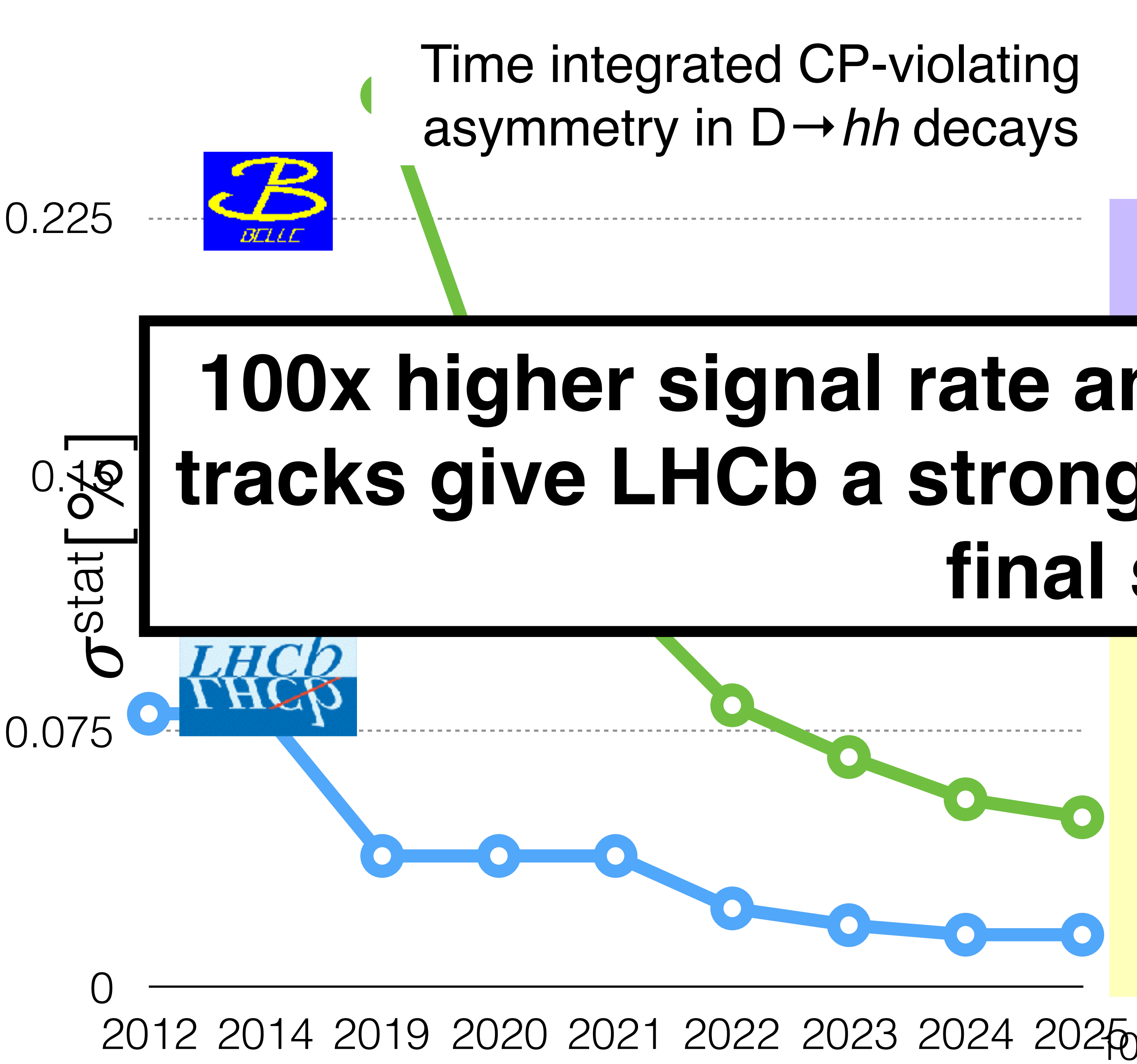
in 2020:

$3^{RunI}+5^{RunII}$ fb^{-1} | 5 ab^{-1}

σ^{stat}~0.04% | ~0.2%

$D \to hh$

2-track final state triggered on hadrons



arxiv:1602.03160 arxiv:0807.0148

LHCb	Belle
3 fb^{-1}	540 fb^{-1}
3^{RunI}+5^{RunII} fb^{-1}	5 ab^{-1}
σ^{stat}~0.04%	~0.2%

100x higher signal rate and similar performance on tracks give LHCb a strong advantage on "all-tracks" final states

However, in Japan, some things are much better than is Switzerland…

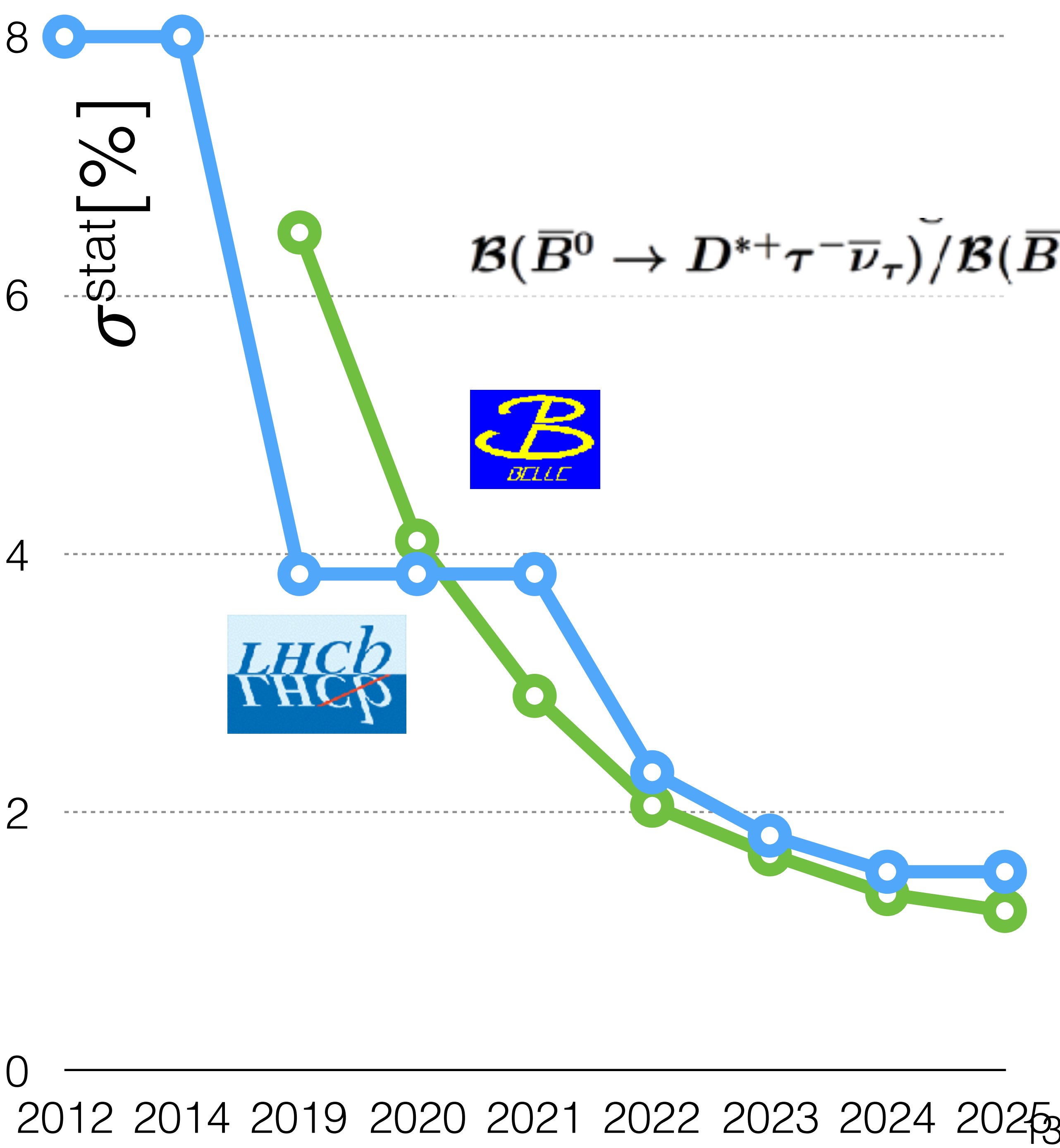
Partially reconstructed decays

$B^0 \to D^* l\nu$

2 neutrinos in final state

arxiv:1506.08614 arxiv:1612.00529

$\mathcal{B}(\overline{B}^0 \to D^{*+}\tau^-\overline{\nu}_\tau)/\mathcal{B}(\overline{B}^0 \to D^{*+}\mu^-\overline{\nu}_\mu)$



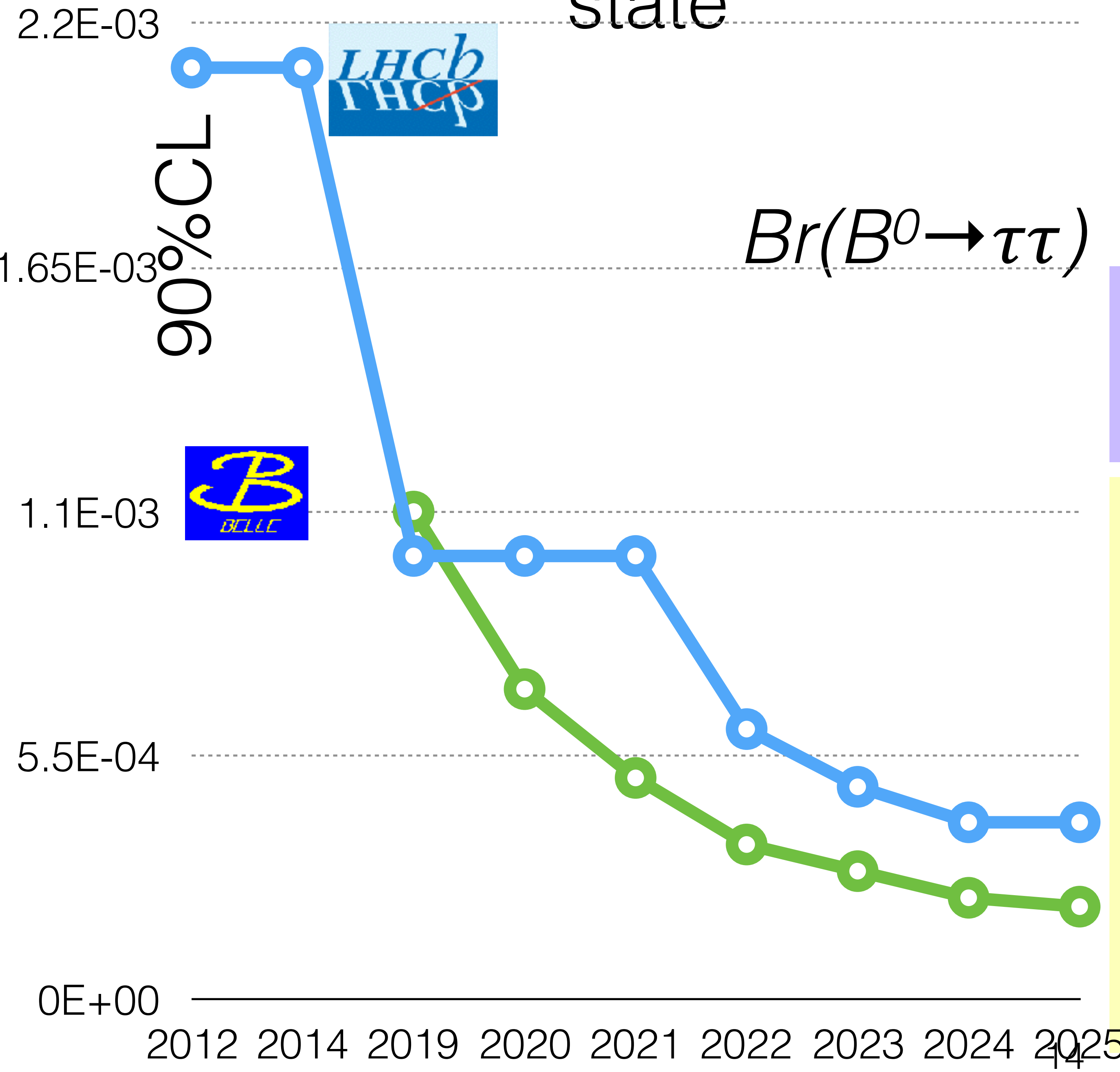
3 fb^{-1}	711 fb^{-1}
σ^{stat}~8%	~13%

In 2020:

$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
σ^{stat}~4%	~4%

$B^0 \to \tau\tau$

> 2 neutrinos in final state



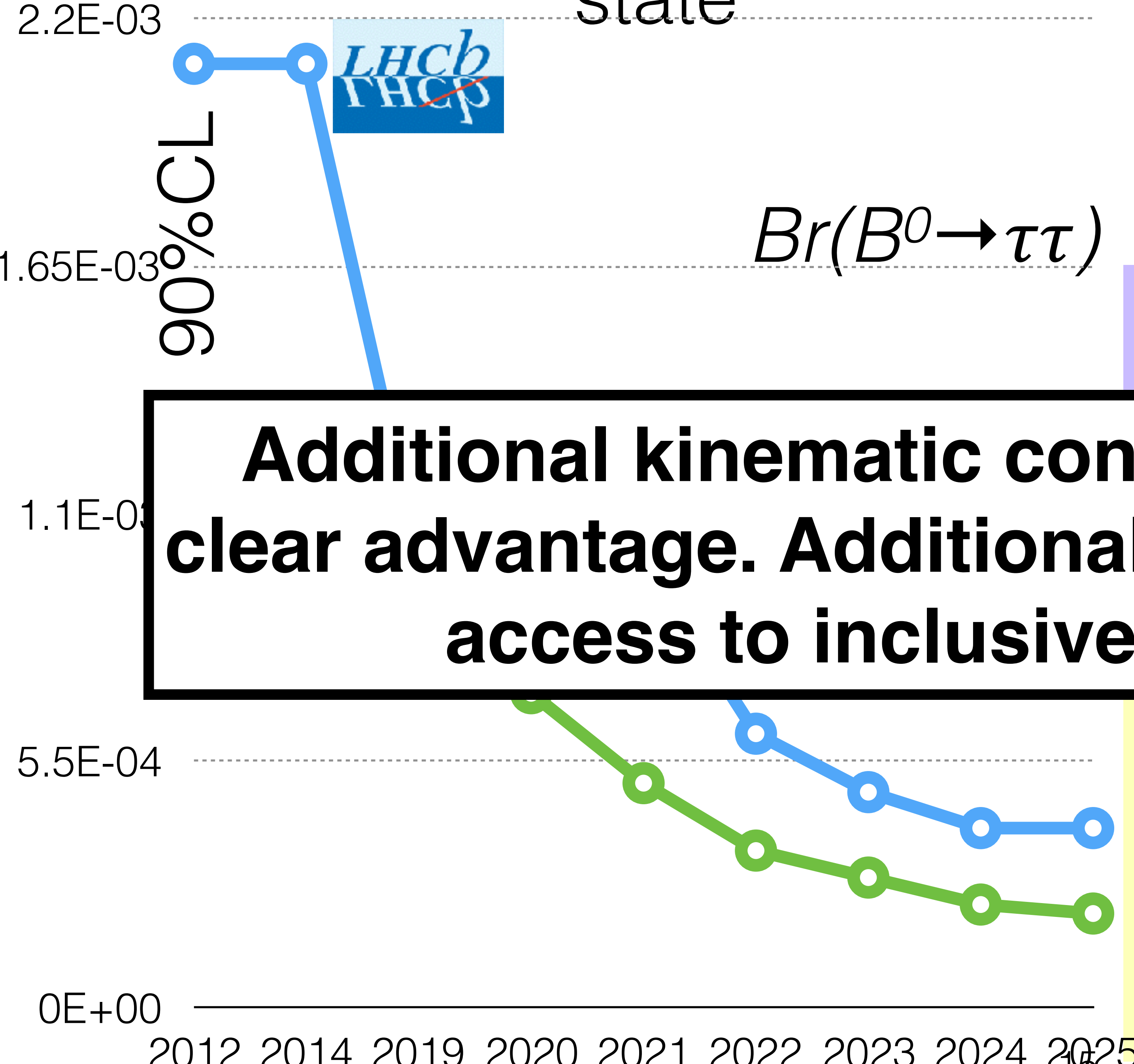
arxiv:1703.02508 (LHCb)	arxiv:hep-ex/0511015 (BaBar)
3 fb^{-1}	210 fb^{-1}
$<2.1\times10^{-3}$	$<4.1\times10^{-3}$

In 2020:

$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
$<1\times10^{-3}$	$<0.7\times10^{-3}$

$B^0 \to \tau\tau$

> 2 neutrinos in final state



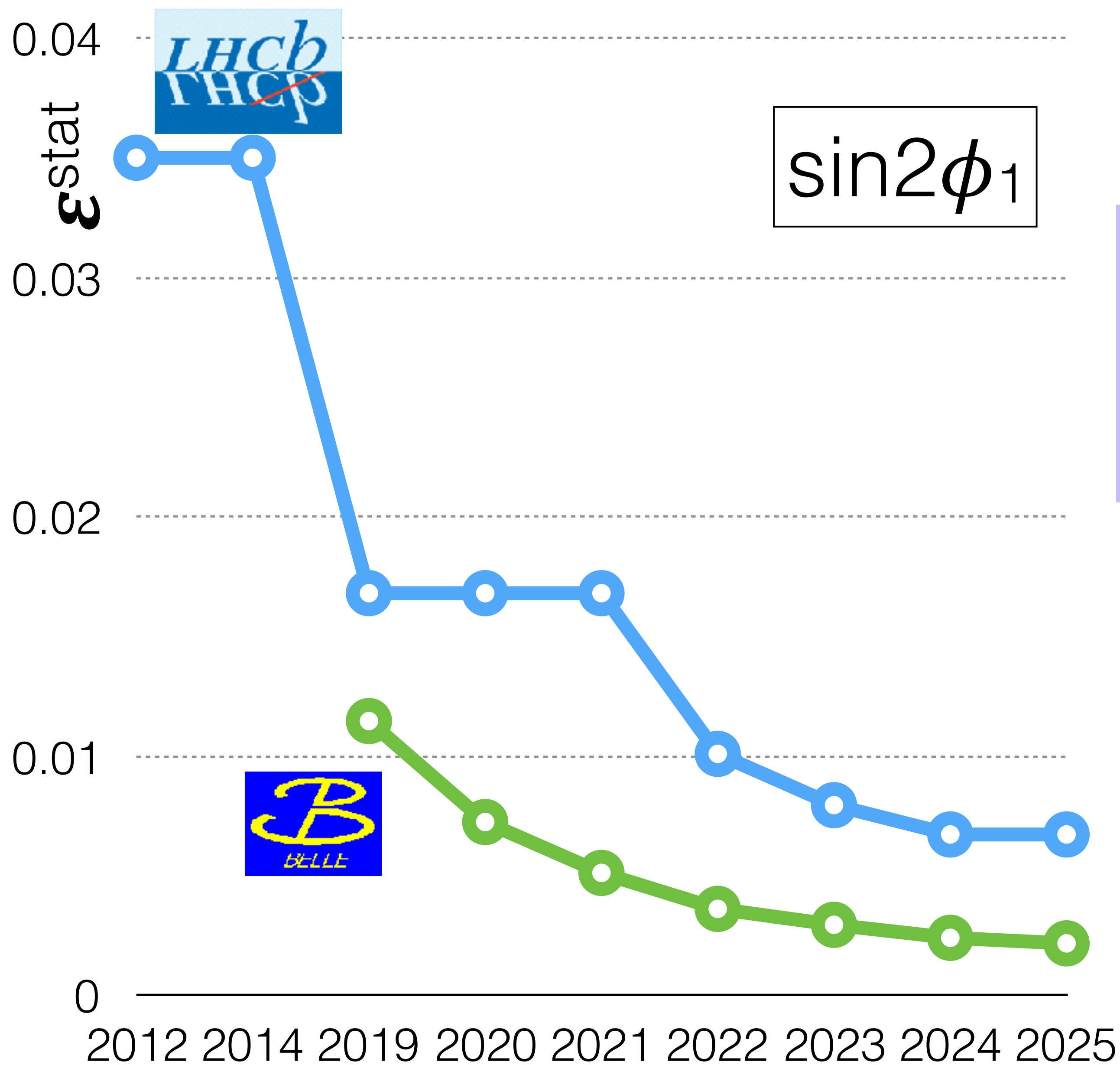
arxiv:1703.02508	arxiv:hep-ex/0511015
LHCb	BABAR
3 fb^{-1}	210 fb^{-1}
$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
$<1\times10^{-3}$	$<0.7\times10^{-3}$

Additional kinematic constraints in Y4S offer a clear advantage. Additional advantages come from access to inclusive measurements.

Measurements relying on flavor tagging

$B^0 \rightarrow J/\psi K^0_S$

Decay-time-dependent analysis on signal triggered on dimuons



arxiv:1503.07089 arxiv:1201.4643

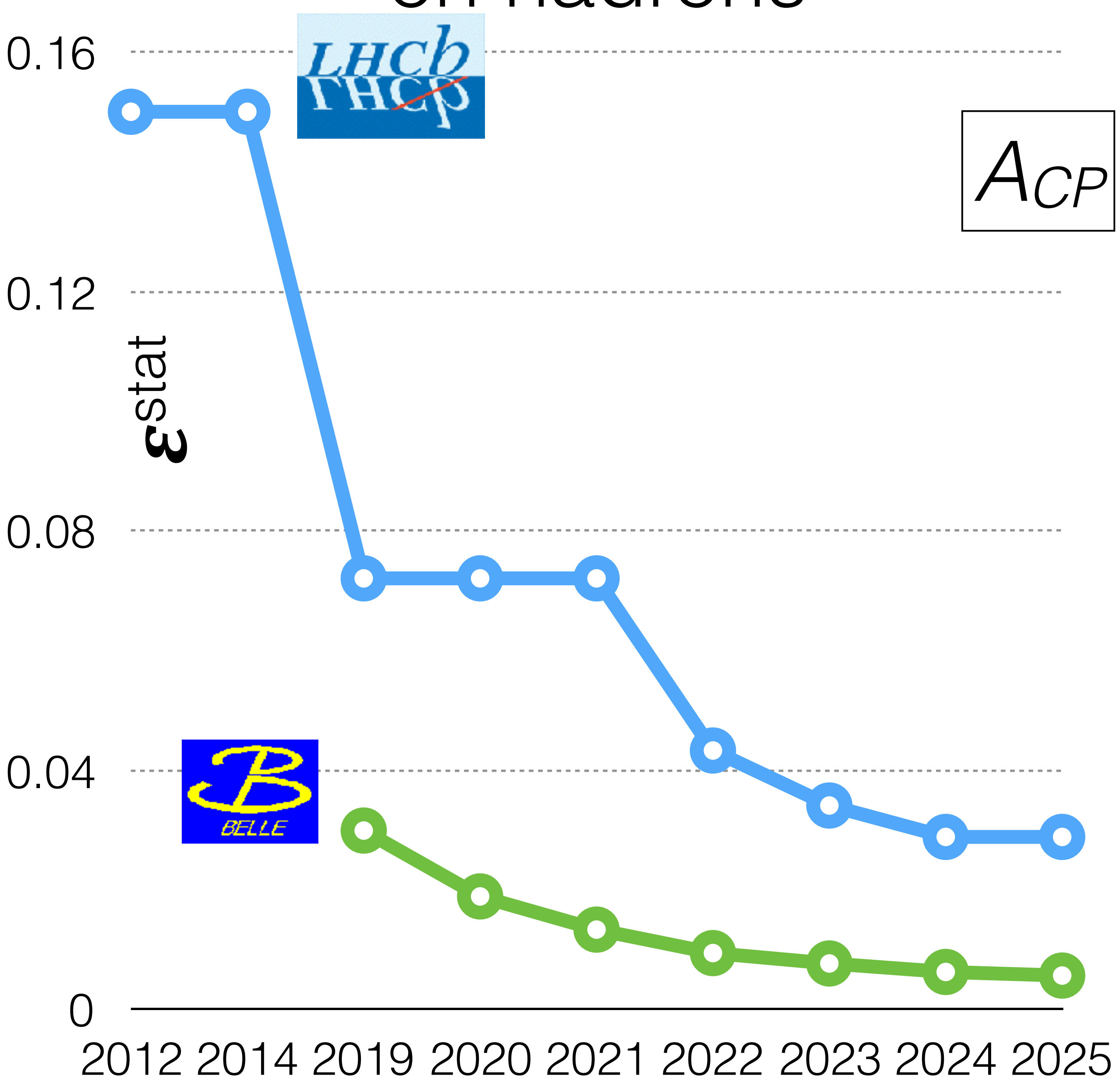
3 fb^{-1} RunI	711 fb^{-1}
ε^{stat}: ±0.035	±0.023

In 2020

3^{RunI}+5^{RunII} fb^{-1}	5 ab^{-1}
ε^{stat}: ±0.02	±0.007

$B^0 \to \pi^+\pi^-$

Decay-time-dependent analysis on signal triggered on hadrons



arxiv:1308.1428	arxiv:1302.0551
LHCb	BELLE
3 fb^{-1} RunI	711 fb^{-1}
ε^{stat}:±0.15	±0.06

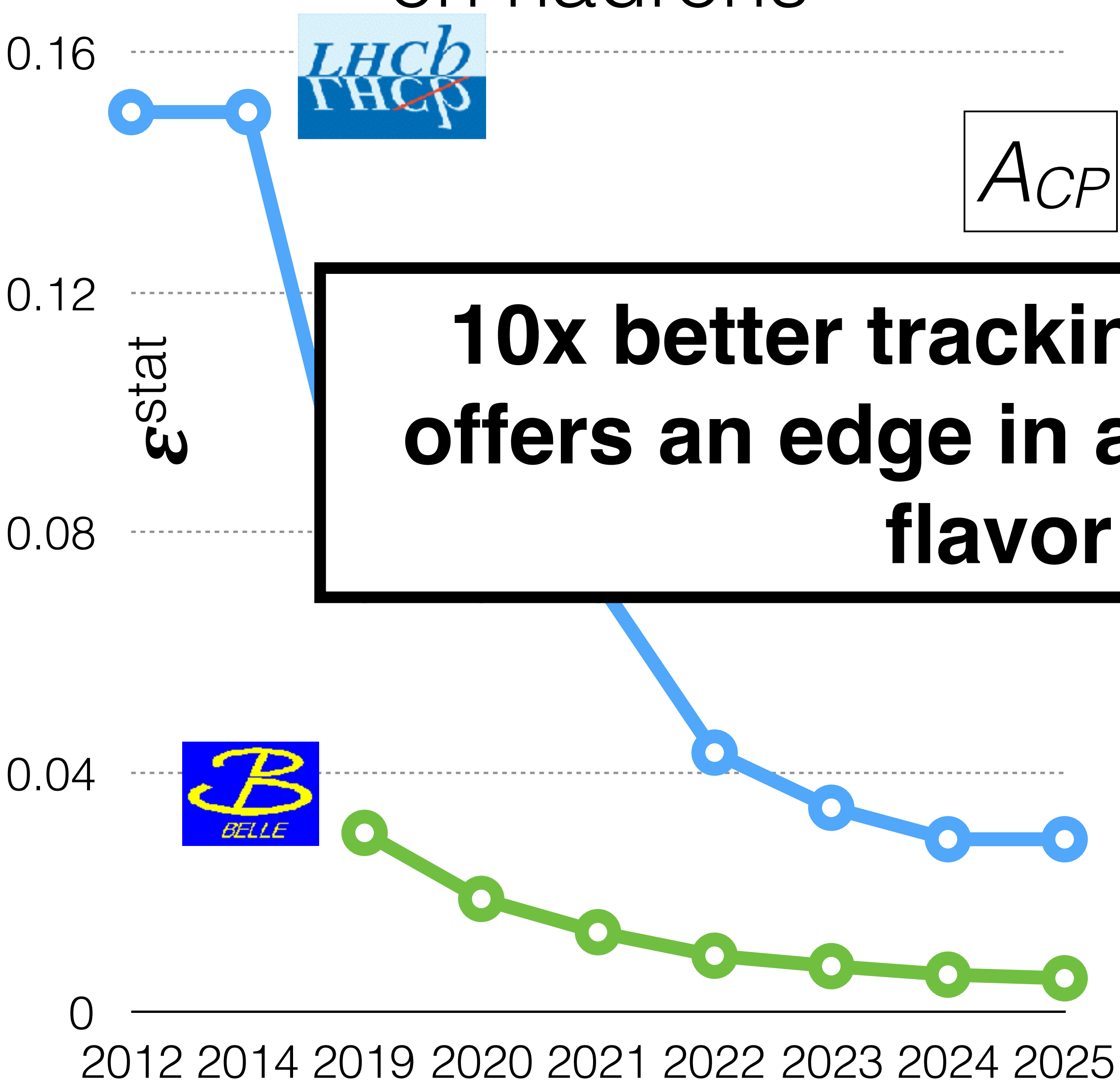
In 2020

$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
ε^{stat}:±0.7	±0.02

$B^0 \rightarrow \pi^+\pi^-$

Decay-time-dependent analysis on signal triggered on hadrons

arxiv:1308.1428 arxiv:1302.0551



A_{CP}

711 fb^{-1}

0.06

10x better tracking in Belle vs LHCb offers an edge in analyses that rely on flavor tagging

In 2020

3^{RunI}+5^{RunII} fb^{-1} 5 ab^{-1}

ε^{stat}: ±0.7 ±0.02

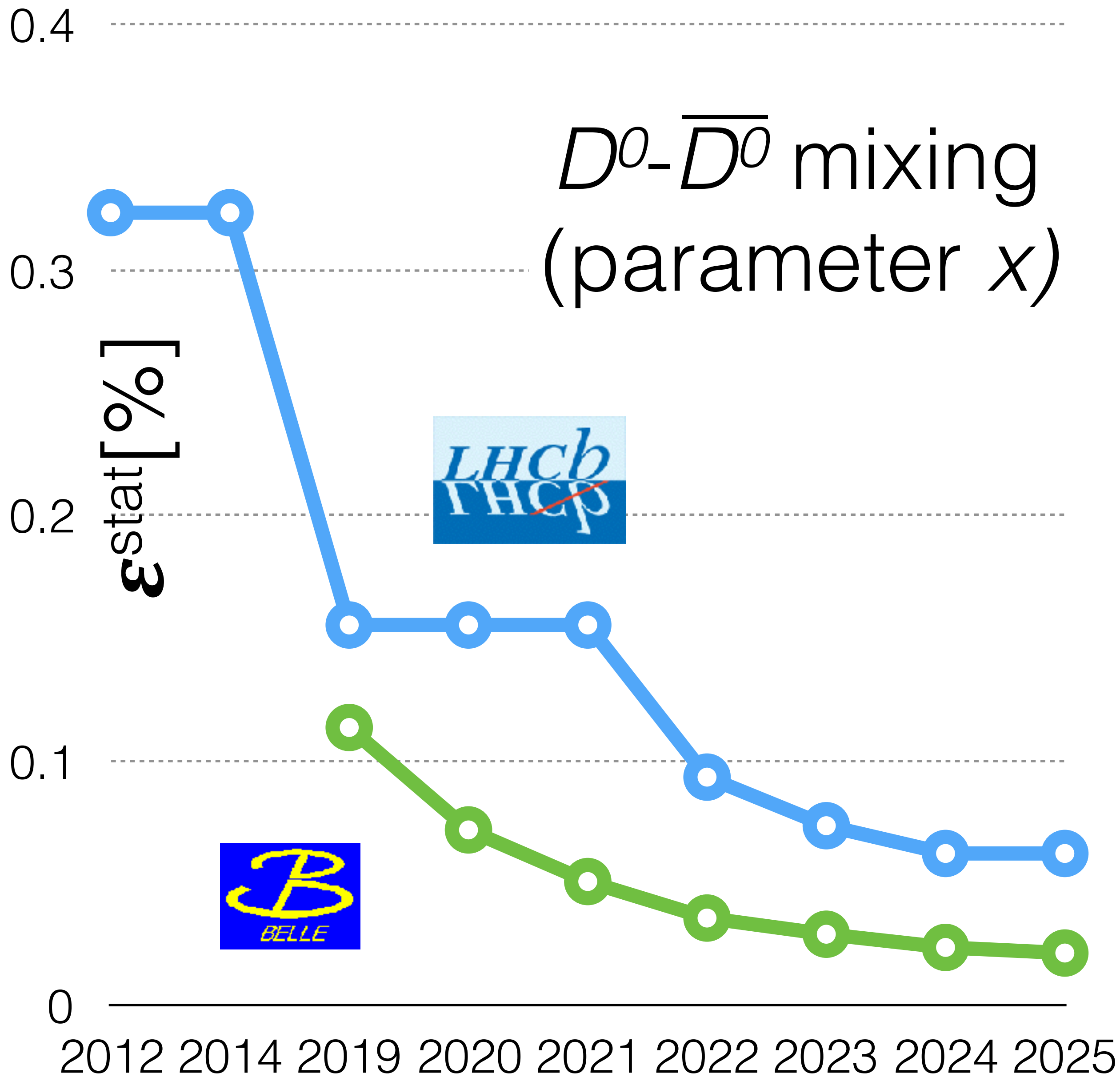
Dalitz analysis

$D \to K^0_S \pi\pi$

arxiv:1510.01664

arxiv:1404.2412

4-tracks, trigger on hadrons



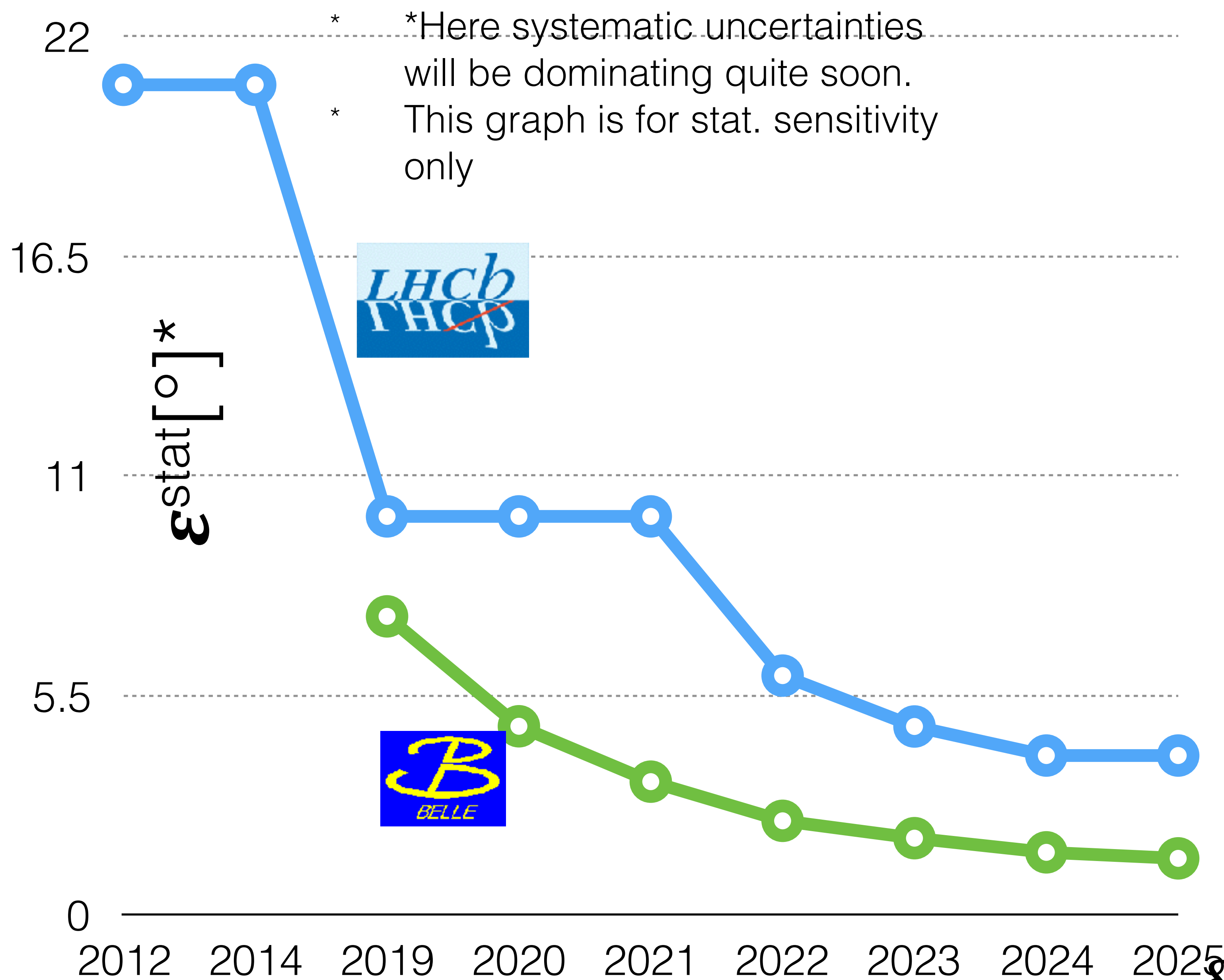
1 fb^{-1} RunI	921 fb^{-1}
ε^{stat}:±0.56%	±0.2%

In 2020

$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
ε^{stat}~0.15%	~0.08%

$B^+ \to DK^+,\ D \to K^0_S\pi\pi$

5-tracks, triggered on hadrons



arxiv:1209.5869 arxiv:1204.6561

1 fb^{-1} RunI — 711 fb^{-1}

$\delta\phi_3^{comb}$ ±40° — ±16°

In 2020

$3^{RunI}+5^{RunII}$ fb^{-1} — 5 ab^{-1}

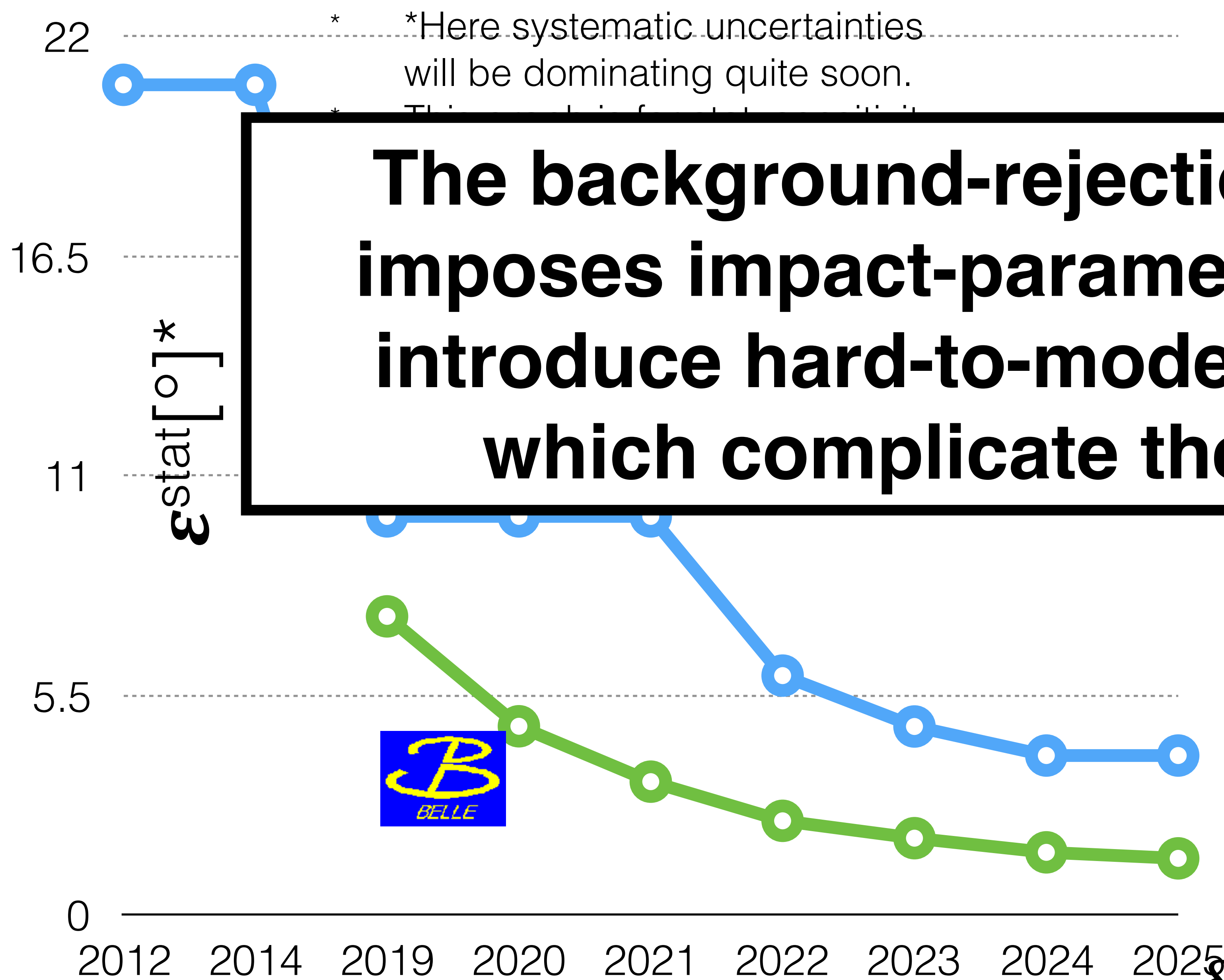
±24° — ±8°

$\delta\phi_3^{stat}$ ±10° — ±5°

$B^+ \to DK^+,\ D \to K^0_S\pi\pi$

arxiv:1209.5869 arxiv:1204.6561

5-tracks, triggered on hadrons



*Here systematic uncertainties will be dominating quite soon.

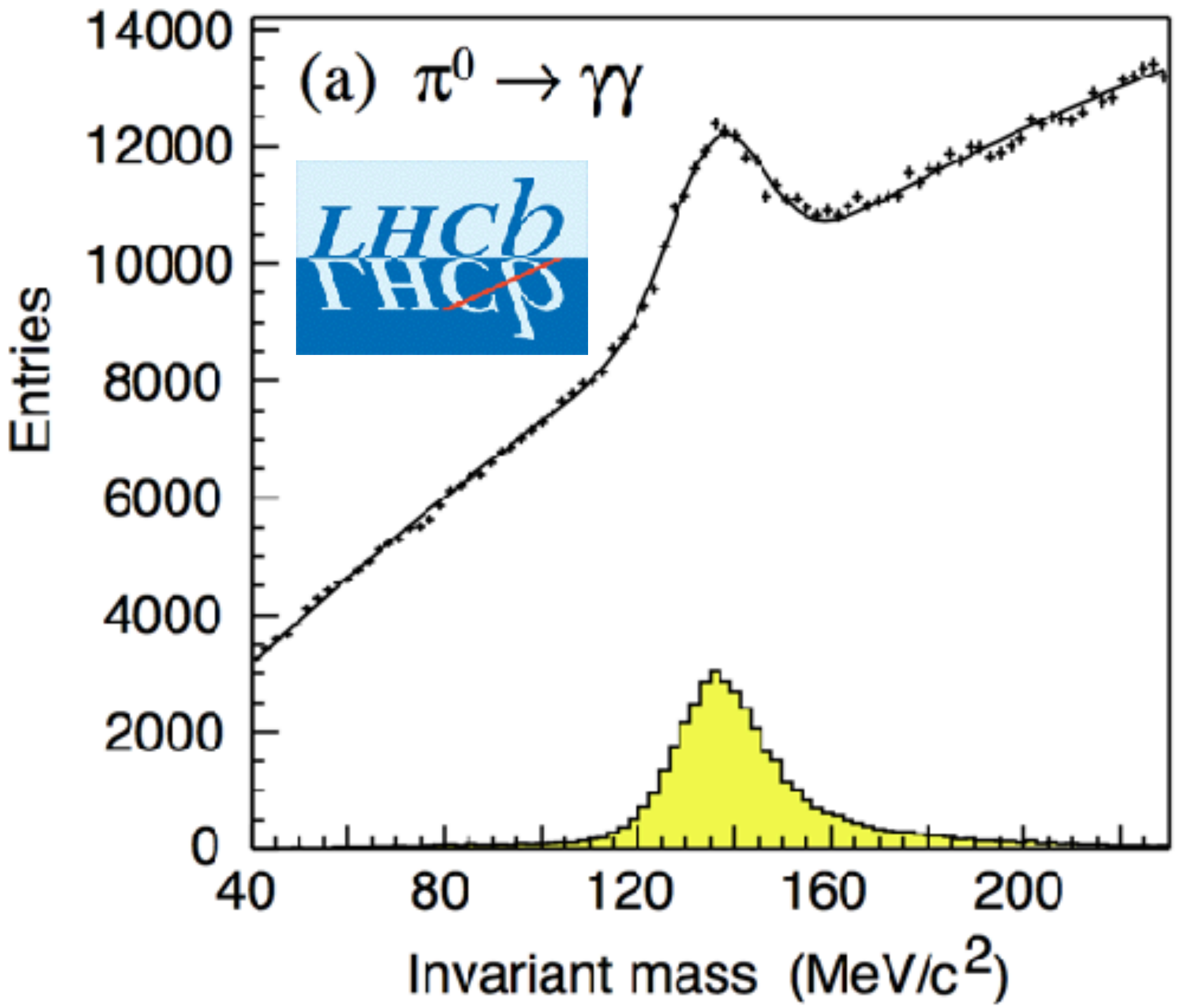
The background-rejection needed in LHCb imposes impact-parameter trigger cuts that introduce hard-to-model kinematic biases, which complicate the Dalitz analysis

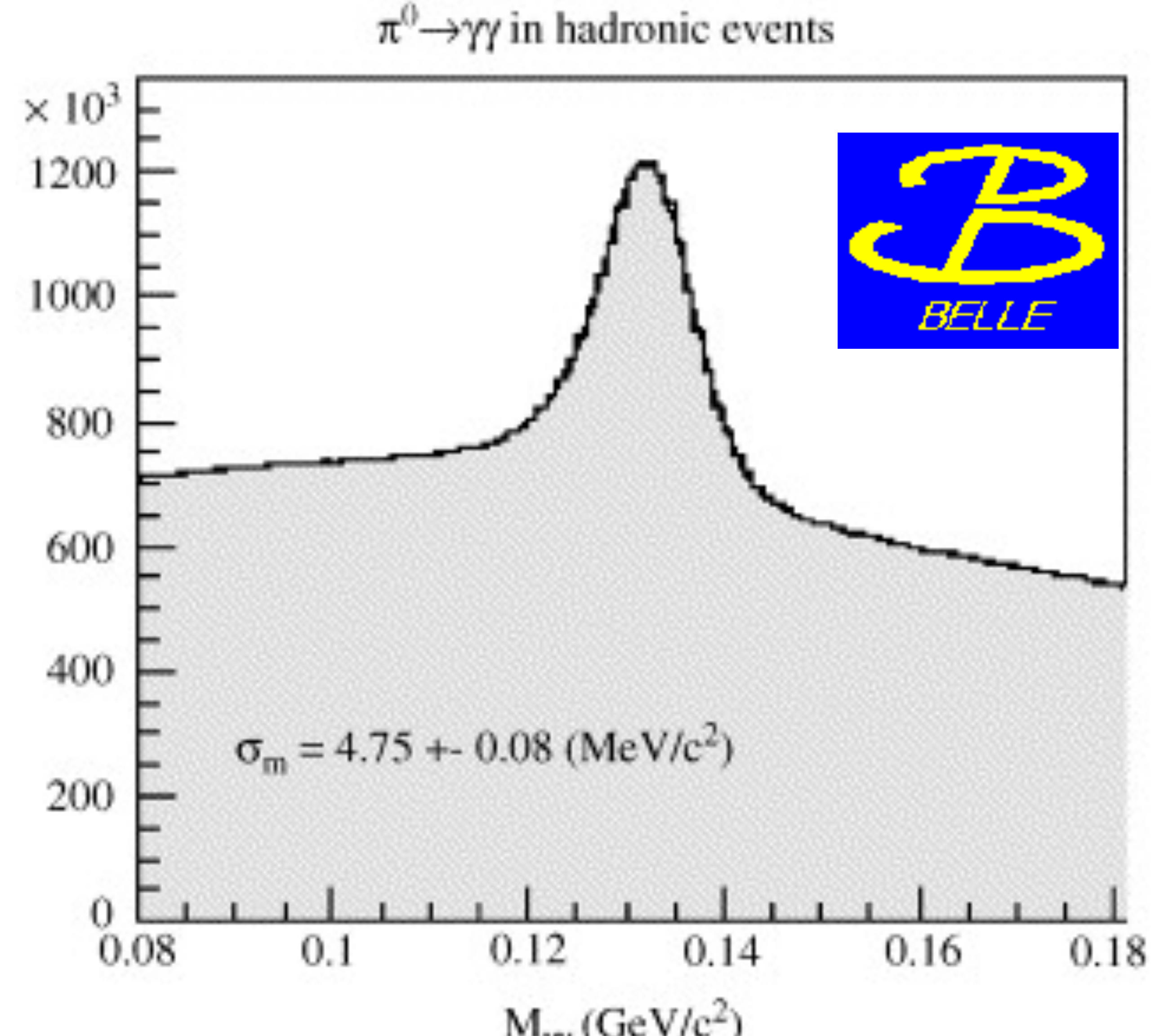
In 2020

	$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
	±24°	±8°
$\delta\phi_3^{stat}$	±10°	±5°

Final states with (visible) neutrals

At a glance





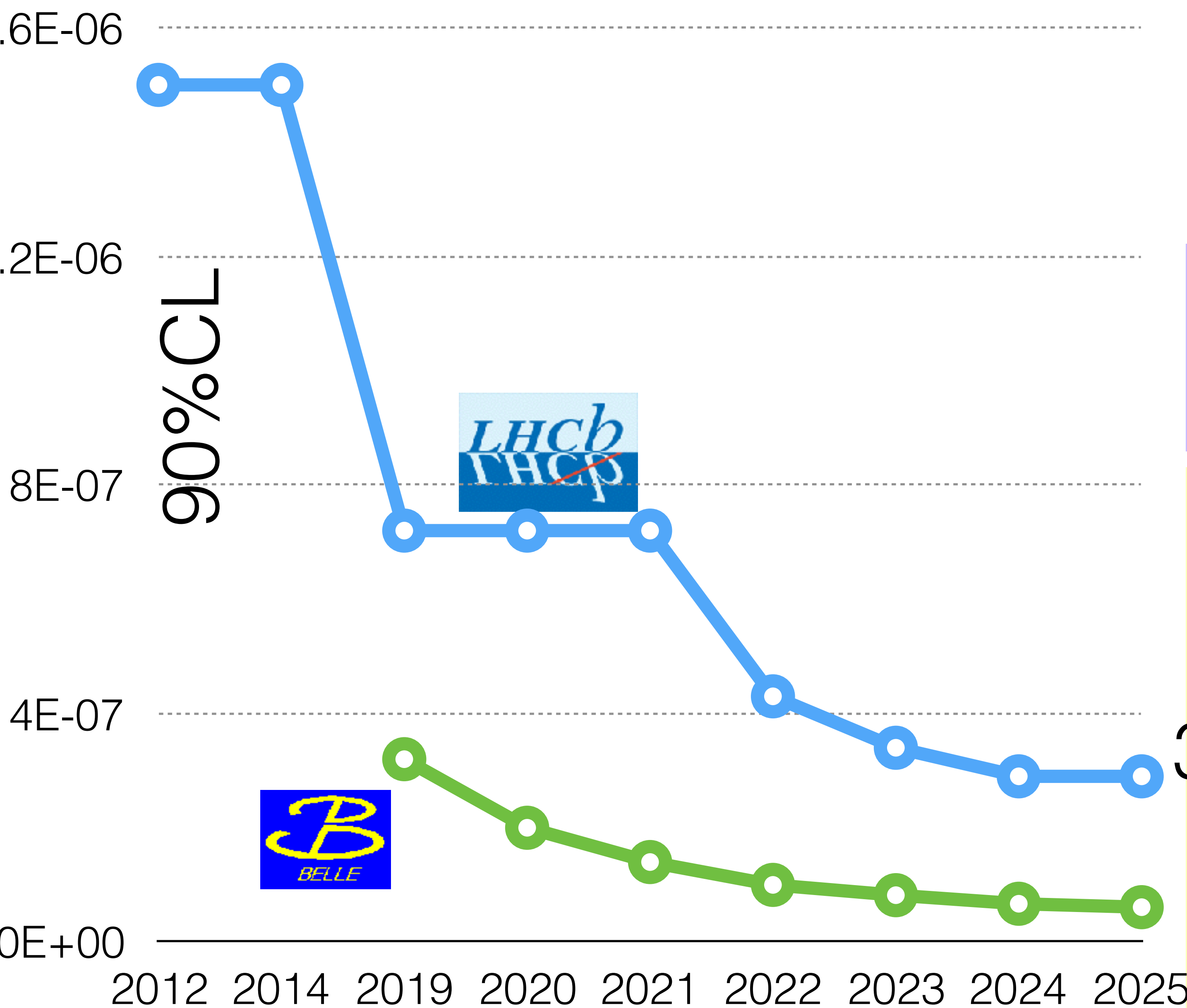
σ=10 MeV/c^2

σ = 5 MeV/c^2

In addition, LHCb purity requirements to extract a decent pi0 peak suppress strongly the efficiency.

$B^0 \to J/\psi\gamma$

One photon



arxiv:1510.04866

arxiv:hep-ex/040801

*No Belle results for this mode

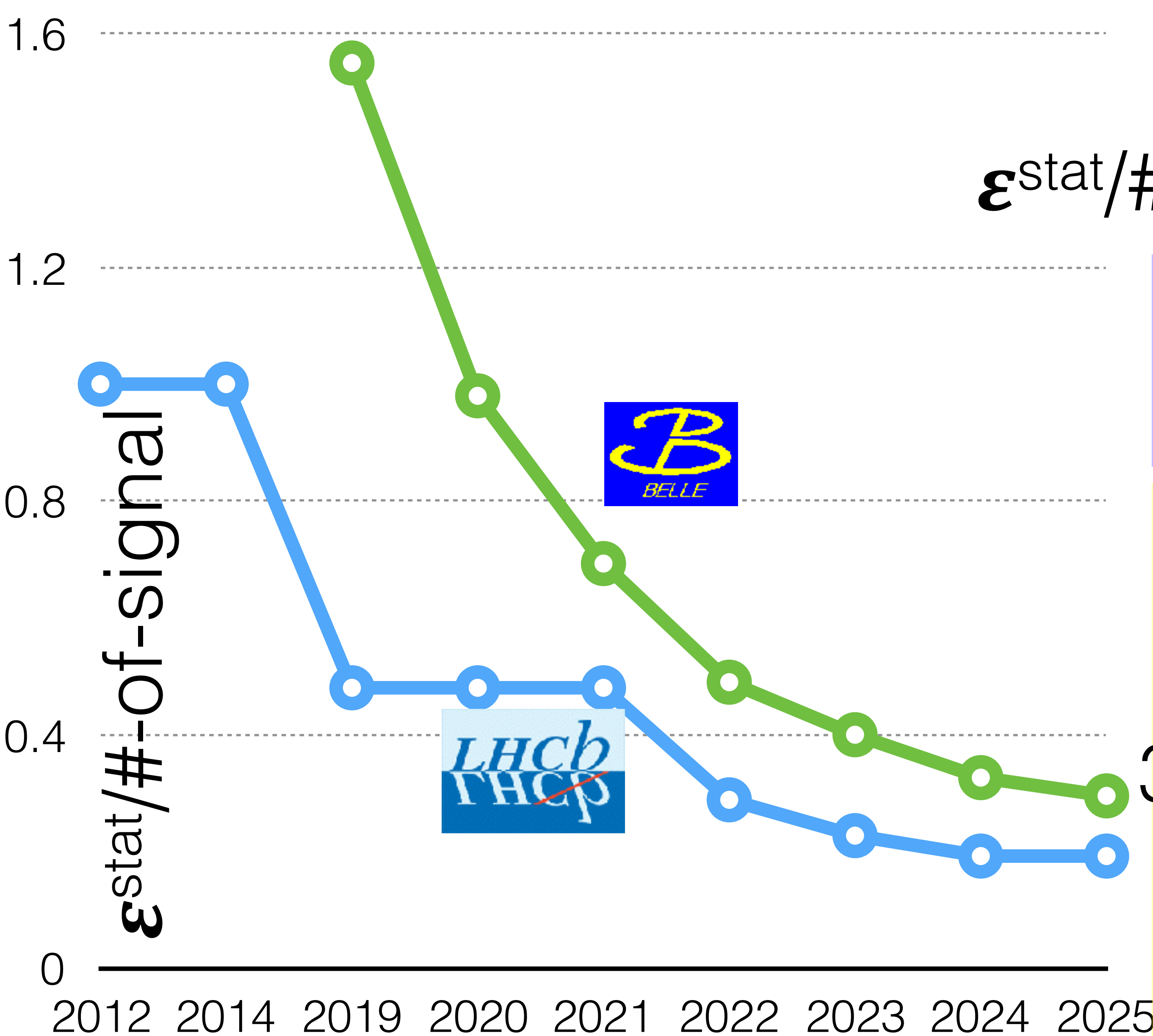
LHCb	BABAR
3 fb^{-1} Run I	113 fb^{-1}
$<1.5\times10^{-6}$	$<1.6\times10^{-6}$

In 2020

$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
$<7.2\times10^{-7}$	$<2\times10^{-7}$

$B^+ \rightarrow K^+\pi^+\pi^-\gamma$

One photon



arxiv:1402.6852

hep-ex/0412039

ε^{stat}/#-of-signal

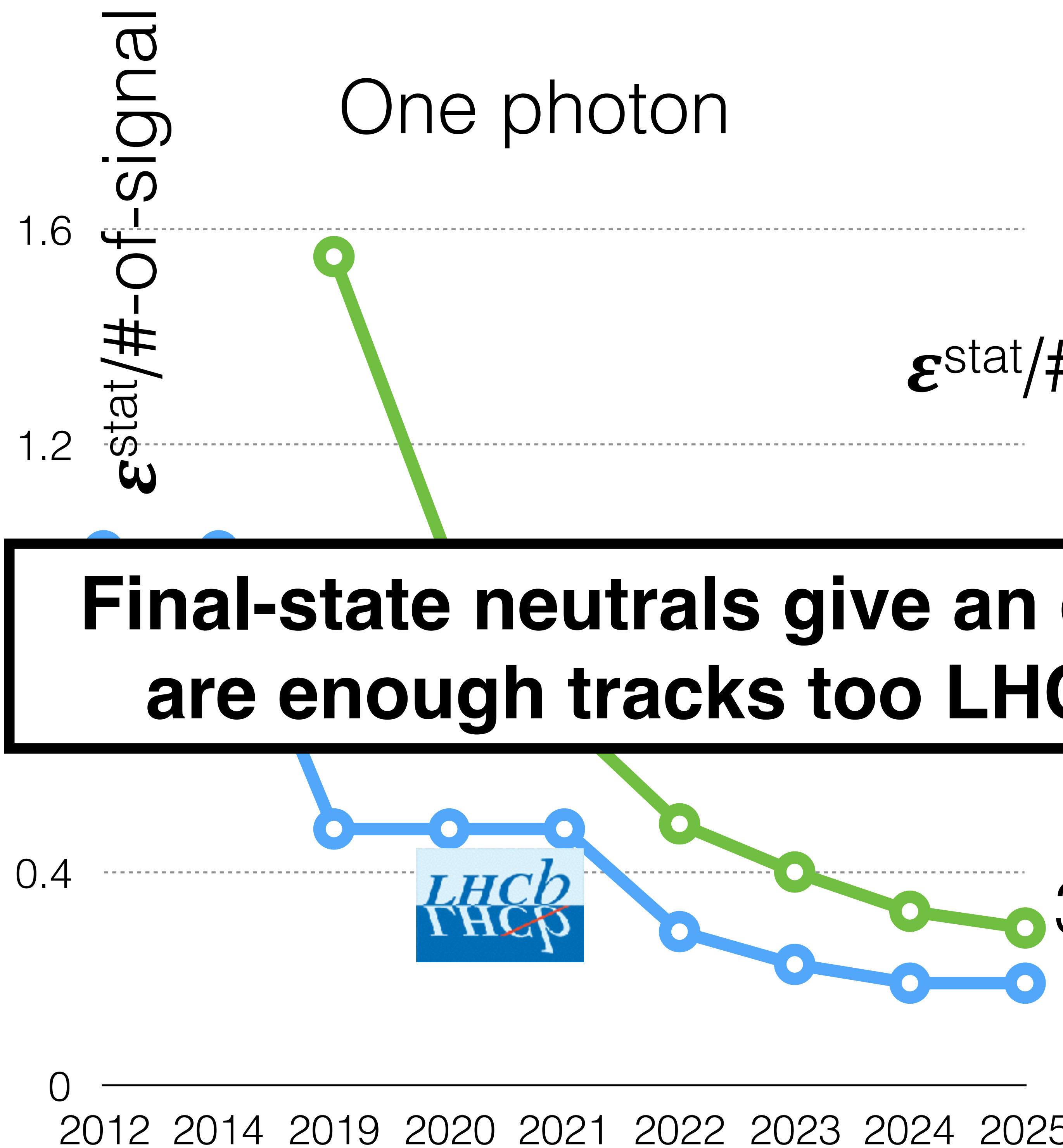
LHCb	Belle
3 fb^{-1} Run I	140 fb^{-1}
1%	7%

In 2020

LHCb	Belle II
$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
0.5%	1%

$B^+ \to K^+\pi^+\pi^-\gamma$

One photon



arxiv:1402.6852

hep-ex/0412039

ε^{stat}/#-of-signal

$3\ fb^{-1}$ Run I	$140\ fb^{-1}$
in 2020	
$3^{RunI}+5^{RunII}\ fb^{-1}$	$5\ ab^{-1}$
0.5%	1%

Final-state neutrals give an edge to Belle, but if there are enough tracks too LHCb remains competitive

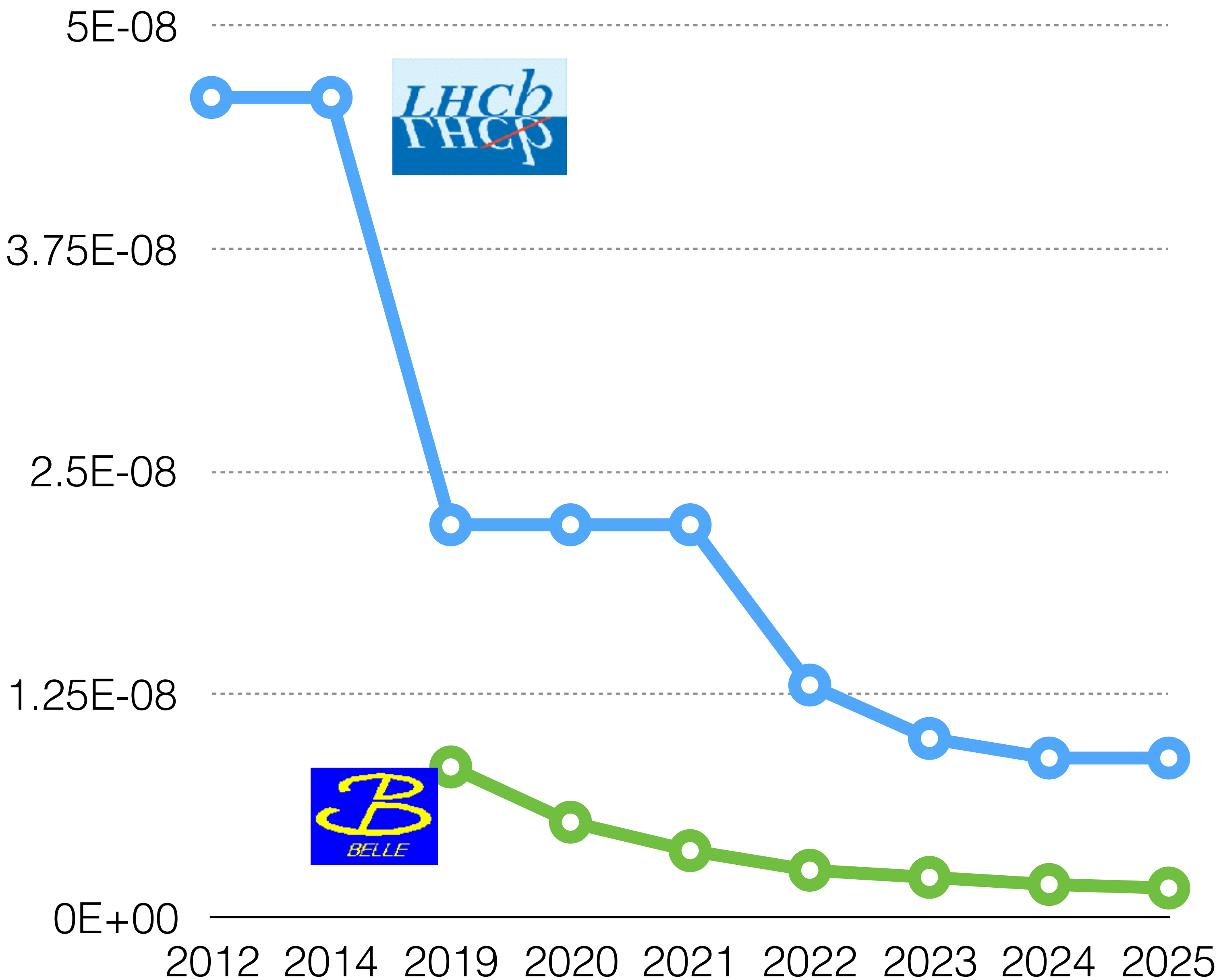
Tau physics

$\tau \to \mu\mu\mu$

arxiv:1409.8548 arxiv:1001.3221

90%CL

Exotics



3 fb^{-1} RunI	782 fb^{-1}
$<4.6\times10^{-8}$	$<1.6\times10^{-8}$

In 2020

$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
$<2.2\times10^{-8}$	$<0.6\times10^{-9}$

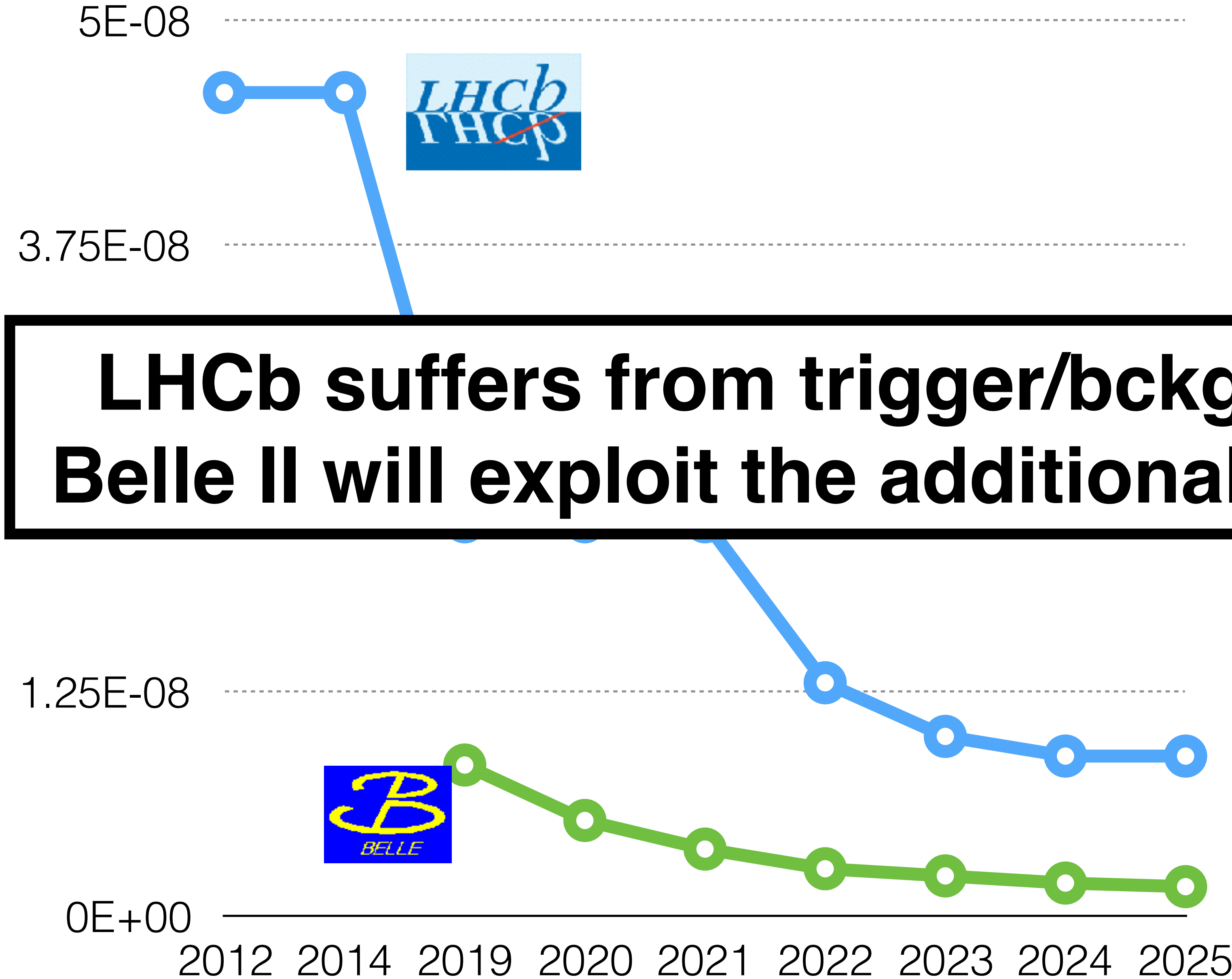
$\tau \to \mu\mu\mu$

90%CL

Exotics

arxiv:1409.8548

arxiv:1001.3221



3 fb^{-1} RunI	782 fb^{-1}
$<4.6\times10^{-8}$	$<1.6\times10^{-8}$

LHCb suffers from trigger/bckg-rejection issues and Belle II will exploit the additional kinematic constraints

In 2020

$3^{RunI}+5^{RunII}$ fb^{-1}	5 ab^{-1}
$<2.2\times10^{-8}$	$<0.6\times10^{-9}$

Luminosity matching

Class of analyses	Belle II equivalent luminosity for $1 fb^{-1}$ Run II LHCb
All-tracks	**10 - 20 ab^{-1}**
Missing energy	**0.5 -1.2 ab^{-1}**
Neutral in final state	**0.08 - 3 ab^{-1}**
Flavour tag	**0.1 - 0.3 ab^{-1}**
Dalitz-plot	**0.2 ab^{-1}**

Summary

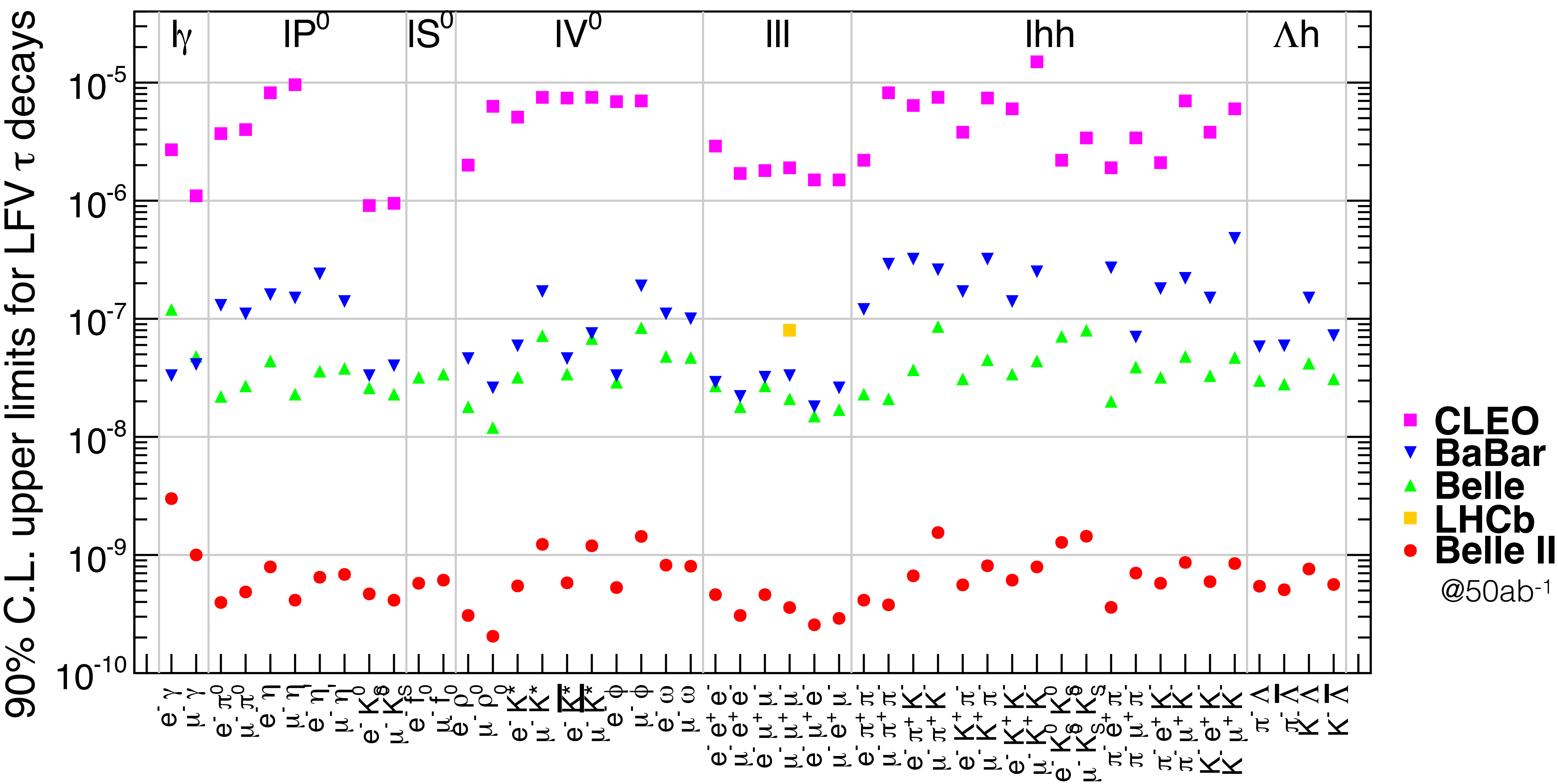
Belle II will do physics in competition with a well-oiled experiment that enjoys >100x more signal rate.

Unwise to indulge on measurements where LHCb has a clear edge.

The message is getting through (as the talks of this meeting show). Still looks useful to offer a rough performance comparison for various classes of analyses.

Many approximations and assumptions. But it looks clear that we should forget about all-track final states (except for flavor-tagged analyses,Dalitz analyses, or analyses involving Ks).

Belle II tau physics prospects



Highlights of Belle II golden modes

Mode	Physics	Why Belle II?
$B \to J/\psi\ K^0_S$	$\phi 1$	Time-dependent
$B \to \pi\pi$	$\phi 2$	Neutrals in F.S.
$B \to D(^*)K/\pi$	$\phi 3$	Dalitz plot
$B \to\ K^0_S \pi^0$	DCPV	Neutrals in F.S.
$B \to X_c l \nu$	Vcb	Missing E
$B \to X_{s+d} \gamma$	FCNC	Neturals in F.S.
$D_s \to \mu\nu,\ D_s \to \tau\nu$	LFU	Missing E
$e^+e^- \to A' \to$ invisible	BSM	Low backgrounds
$\tau \to \mu\mu\mu$	LFV	Low backgrounds
$e^+e^- \to\ \pi^+\pi^- J/\psi$	QCD	Machine-specific

As you can see, Belle II priorities are chosen accounting LHCb future performance