WP1 status
(Belle II software and physics case)

Christoph Schwanda (HEPHY)

JENNIFER Consortium General Meeting

Paris, October 30, 2018

Objectives of WP1

*Exploit the physics potential of Belle II by*

- Task 1.1: Developing the detector-related software (charged track reconstruction, alignment, particle identification, …)
- Task 1.2: Implementing software tools for physics analysis
- Task 1.3: Identify the key measurements for Belle II (Belle II-theory interface platform)

EU grant n.644294

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Phase 2 pilot run (April to July 2018)
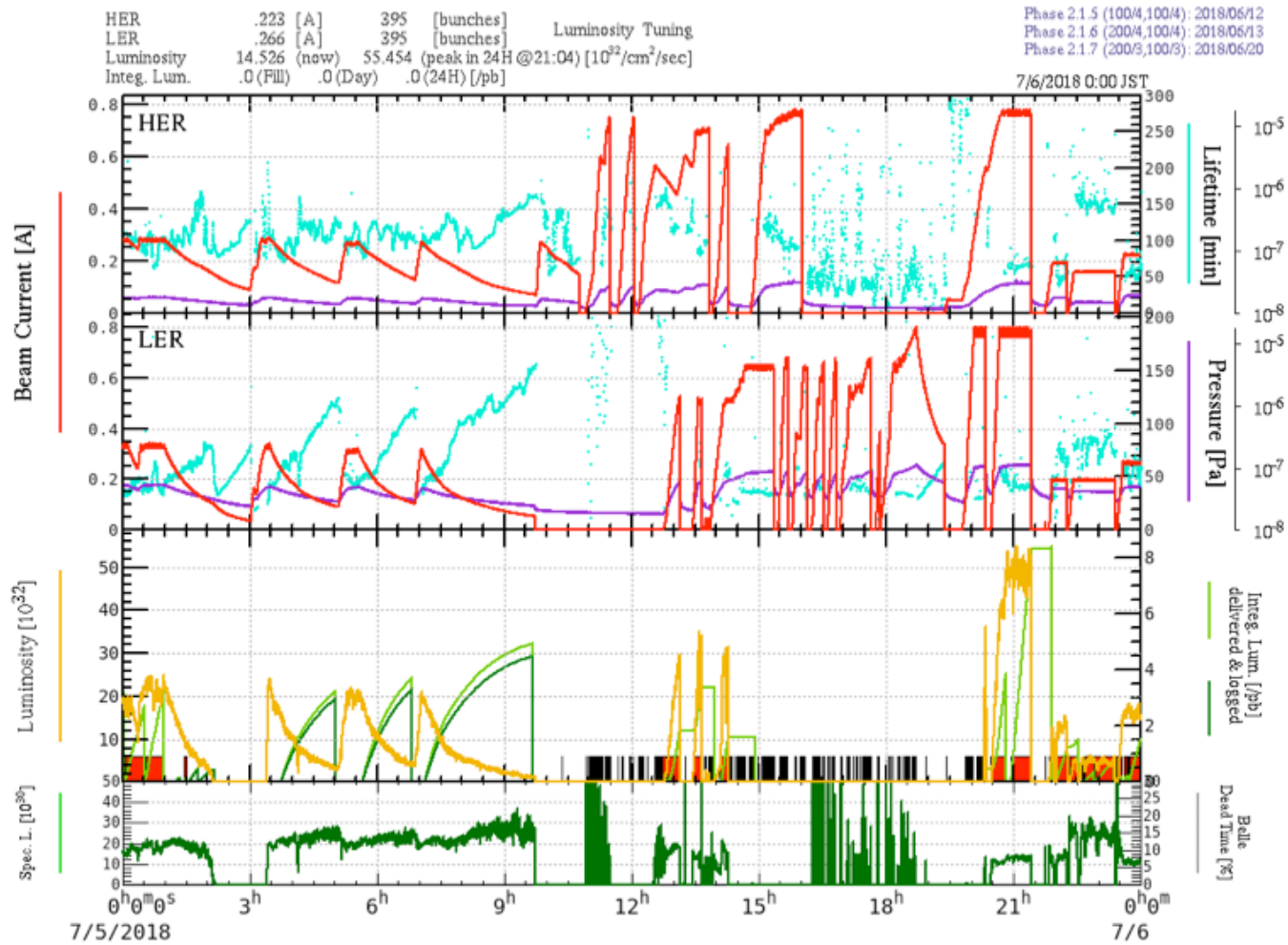

First e$^+$e$^-$ collisions on
April 26, 2018
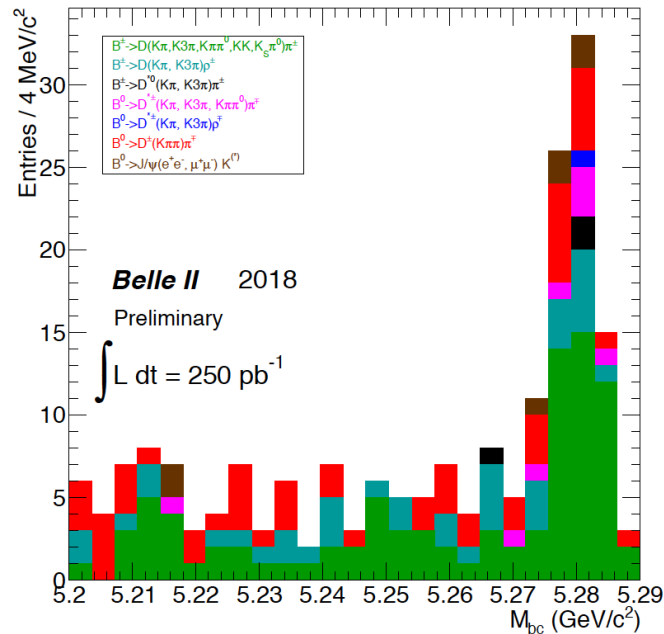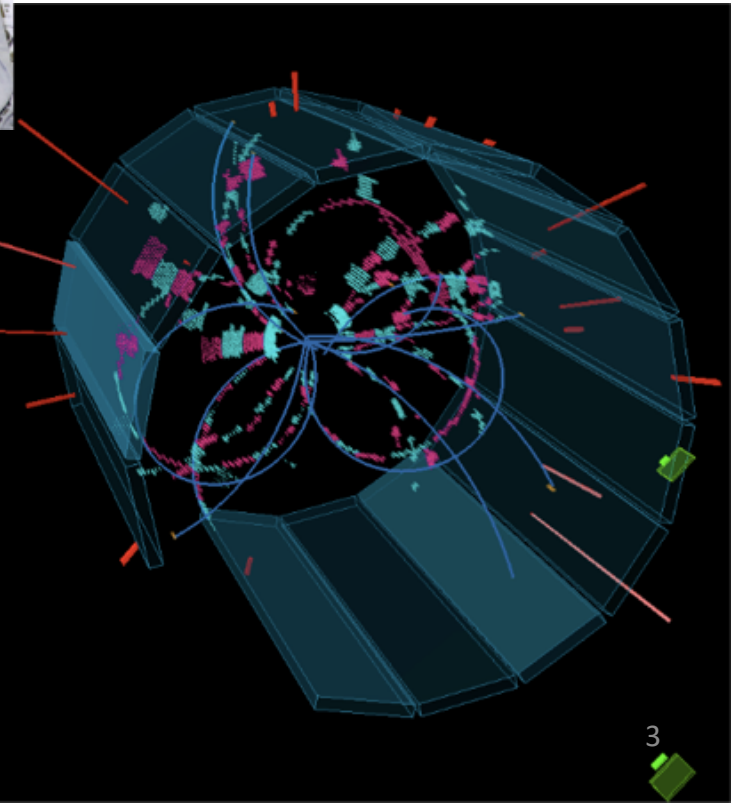
~88
B mesons
in 250/pb
of phase 2
data

~0.5/fb of integrated luminosity
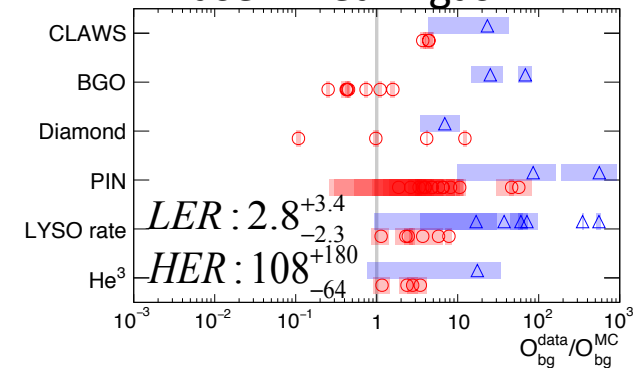

Phase 2,
July 2018

$$L_{peak} = 5.5 \times 10^{33} \, / \, cm^2 \, / \, \sec$$
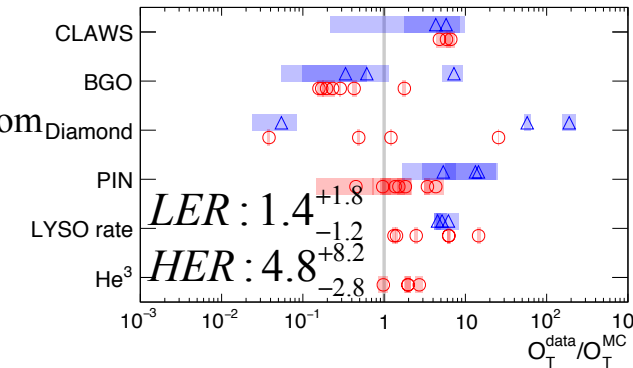
Beam Background "Big Picture"

- Phase 1:
  - SR: not detected
  - Integrated doses: as expected
  - Touschek: mildly elevated
  - Beam-gas: HER ~100 x MC
  - Neutrons: mildly elevated
- Phase 2:
  - SR: *observed* in diamonds, PXD, FANGS from both rings.
    New: SR *post*dicted after removing Geant4 low-energy cut
  - Dose: as predicted in diamonds. PXD suggests higher dose.
    New: Radio-chromic foils confirm higher dose (10x diamonds), likely from low-energy particles
  - **Backgrounds in Belle II: dominated by LER, already problematic for CDC**
  - New: Touschek, Beam-gas versus run-specific bkg simulations
    - LER: ~10 x MC in SVD
    - **HER: ~1000 x MC in SVD**
    - When extrapolated to Phase 3, this predicts beam-gas dominates over luminosity BG in SVD.
   - **Occupancy and dose too high, even w/o injection background**

Phase 1 Beam-gas

$$LER : 2.8^{+3.4}_{-2.3}$$
$$HER : 108^{+180}_{-64}$$

$O_{bg}^{data}/O_{bg}^{MC}$

https://doi.org/10.1016/j.nima.2018.05.071

Phase 1 Touschek

$$LER : 1.4^{+1.8}_{-1.2}$$
$$HER : 4.8^{+8.2}_{-2.8}$$

O_T^{data}/O_T^{MC}

Data/MC: Phase 2 SVD L3

	June 11,12	July 16
HER BeamGas	270-610	230-600
HER Touschek	260-350	850-1700
LER BeamGas	11-13	34-39
LER Touschek	2.3-2.9	3.5-4.6

(H. Tanigawa)

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CDC background studies

Aiqiang Guo, Carsten Niebuhr.

1 event

10 events = nominal phase 3 current.
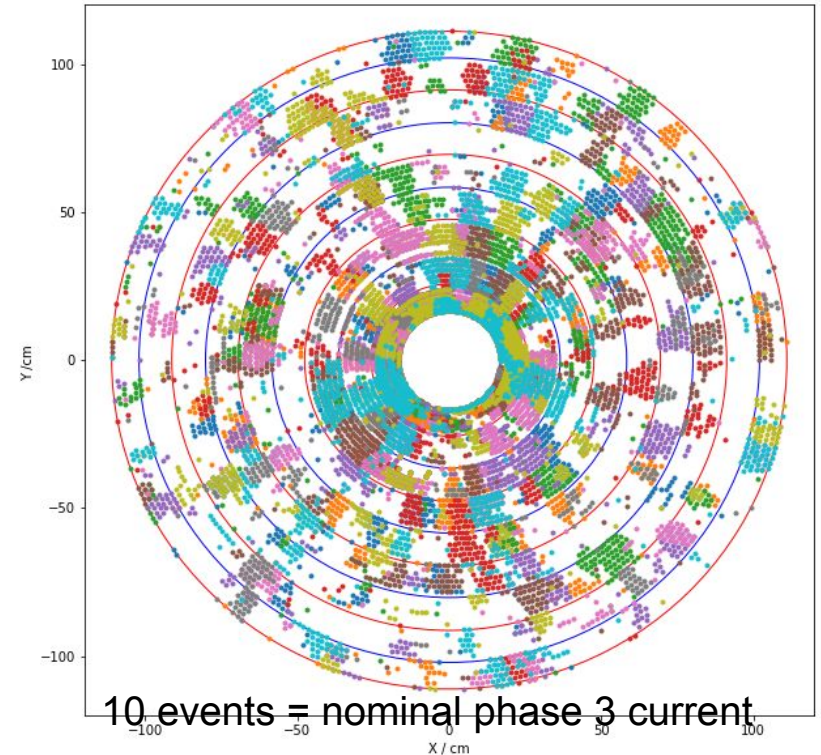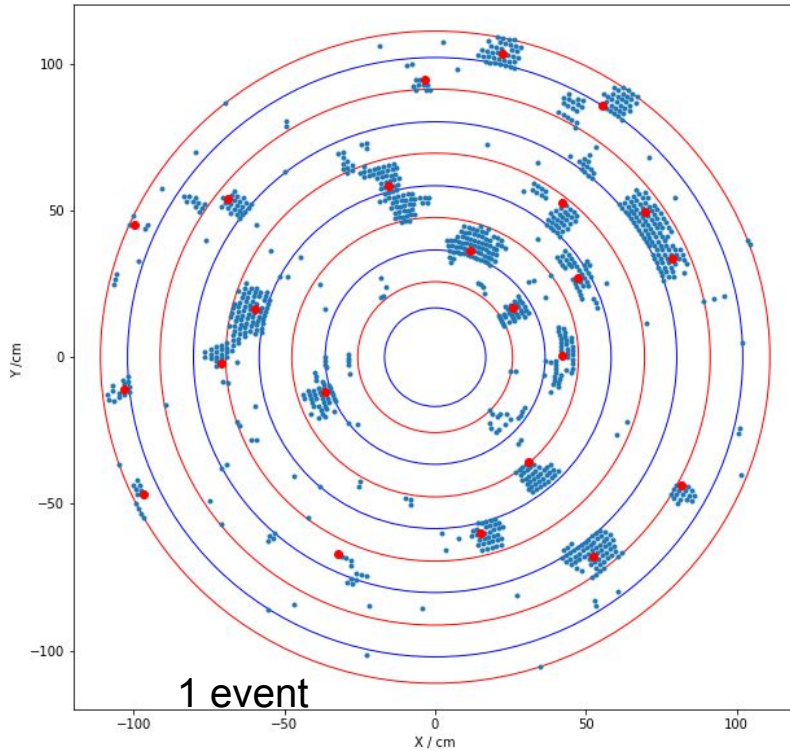
Study CDC hits using data with LER (HER) beam only. Observe clusters of CDC hits. Current explanation, supported by cluster boundaries (within superlayer, readout board) and timing (hits in-time) that the clusters are triggered by background photons which causes electronic cross-talk.
→ Tracking may be severely affected by them, to be watched/optimized (reduce gain/increase threshold ?)

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Sensitivity of the tracking to background

Thomas Lueck

SVD standalone tracking

| bkg scale	efficiency	fake rate	hit efficiency	occupancy L3 U/V
bkg × 1	0.961	0.054	0.957	0.013/0.012
bkg × 2	0.946	0.098	0.948	0.023/0.021
bkg × 3	0.935	0.136	0.937	0.032/0.030
bkg × 5	0.907	0.227	0.920	0.052/0.047
bkg × 10	0.819	0.488	0.884	0.102/0.090

Full tracking chain

bkg scale	efficiency	fake rate	hit efficiency	occupancy L3 U/V
bkg × 1	0.955	0.053	0.818	0.013/0.012
bkg × 2	0.939	0.086	0.744	0.023/0.021
bkg × 3	0.919	0.119	0.635	0.032/0.030
bkg × 5	0.856	0.189	0.422	0.052/0.047
bkg × 10	0.726	0.422	0.407	0.102/0.090

→ SVD standalone reconstruction seems to be more robust vs full tracking chain for high background situation. SVD-driven tracking could be a backup solution.

Tracking efficiency studies: radiative bhabha events
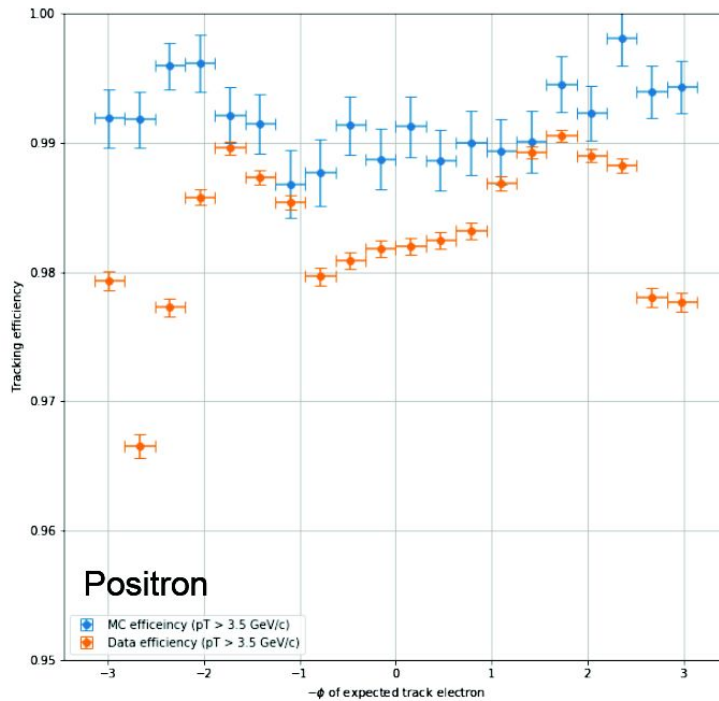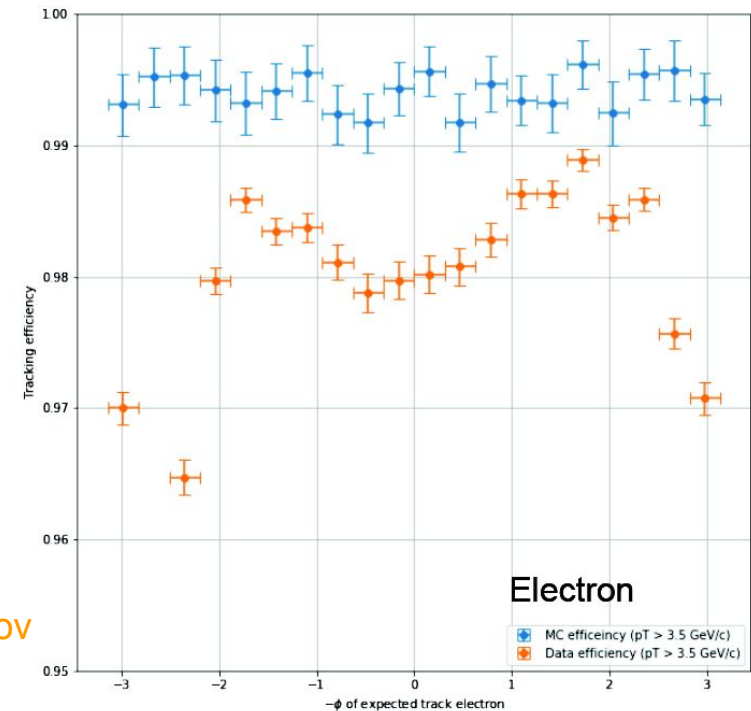
Potentially can be used to map efficiency vs p, shown are result for high pt>3.5 GeV (no background subtraction at the moment). Some charge dependence, overall difference at 1.5% level.

Software Progress

➤ Major Release: release-02-00-00

- ✔ Full geometry construction from database
- ✔ Improved modeling of passive material
- ✔ More accurate magnetic field
- ✔ Some trigger information on mdst
- ✔ Improved tracking performance
- ✔ Option to simulate the PXD in gated mode
- ✔ Improved documentation (see software.belle2.org)
- ✔ Many more improvements in simulation, reconstruction, analysis tools

➤ Two patch releases: release-02-00-01 and release-02-00-02

➤ Minor release-02-01-00 (coordinated by Francesco Tenchini)
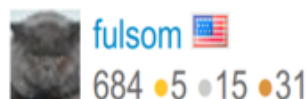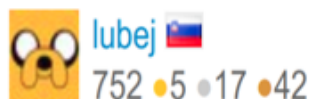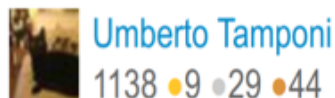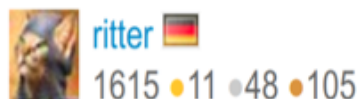
- ✔ Some PID improvements

Analysis software

DESY, KIT, Munich, Melbourne, Torino, Strasbourg, ..

- Active user support → [questions.belle2.org](#)

    Most questions answered in ≲ 12h

- Doc in very good shape →
[software.belle2.org](#)

Questions leaderboard

scunliff 🇬🇧	Torben Ferber 🇩🇪	
2821 ●8 ●42 ●99	2177 ●12 ●41 ●78	
ritter 🇩🇪	tkuhr	
1615 ●11 ●48 ●105	1208 ●17 ●33	
Umberto Tamponi	jbennett 🇺🇸	
1138 ●9 ●29 ●44	979 ●14 ●33	
lubej 🇸🇮	fulsom 🇺🇸	
752 ●5 ●17 ●42	684 ●5 ●15 ●31	
ikomarov	bilokin	
484 ●3 ●20 ●41	413 ●6 ●16	

- Light releases for fast access to new features:

    > `b2setup light-1810-conero`

- Recent analysis-level improvements from:

    Curler track tagging
    TreeFitter (now better than RAVE)
    EventShape / EventKinematics frameworks
    Improvements to RestOfEvent

- (Very) new sub-group: **multivariate analysis:** Unify efforts to tackle NN systematics

Software Documentation and Training

Documentation:
Steadily improving analysis software documentation is now available at
https://software.belle2.org

Questions are still asked (and answered) at
**questions.belle2.org**

Training:
The third edition of the StarterKit.

the format of the workshop is established, program has been extended and tuned to cover current needs of the collaboration.

- **30 students** (thank you for efforts)
- **9 volunteers** (many thanks for hard job!)

I. Komarov et al

Now use the full Phase 2 dataset and apply the FEI (Full Event Interpretation) technique based on boosted decision trees (BDTs, a machine learning technique)
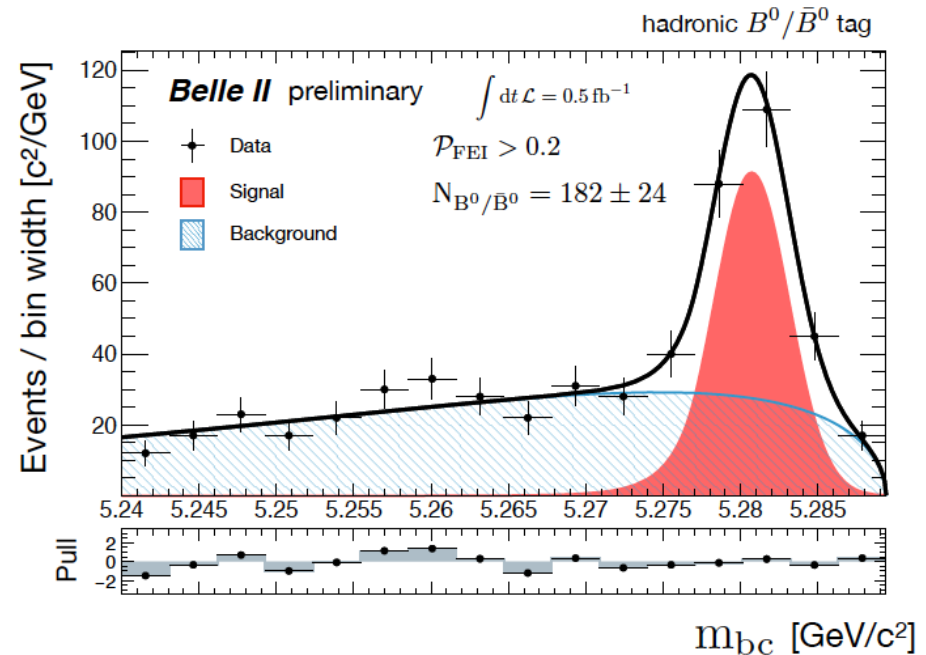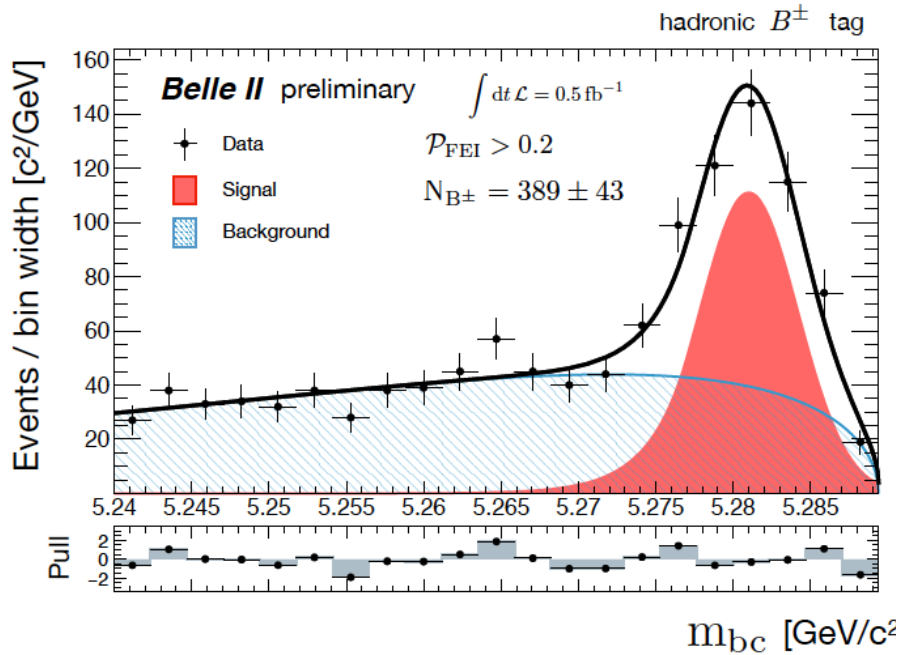
We now observe ~571 fully reconstructed B mesons (389+182) or an improvement of a factor of ~O(3.6) in overall efficiency by using this advanced analysis method that covers many more decay channels.

B2NOTE-2018-031-1,
W. Sutcliffe, F. Bernlochner

Further improvement (X 2) is definitely possible (PID, low p tracking will play a major role).

Dark Sector @Belle II

ALPs: Multi-photon

(LFV) Z' : missing momentum/mass

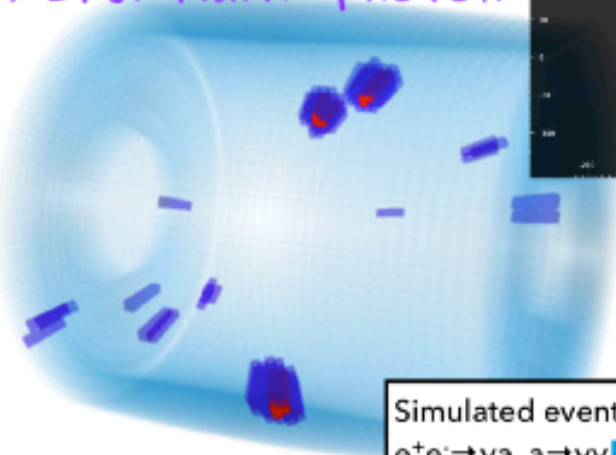$g = 1e$
$m = 4.5$ GeV
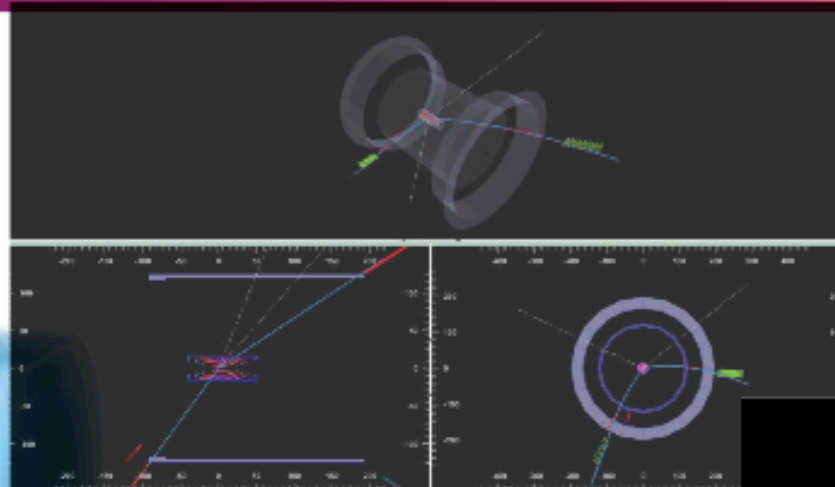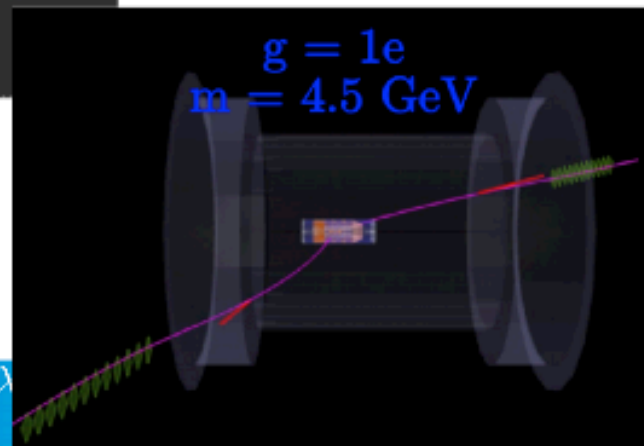
... And other exotic signatures

Simulated event:
$e^+e^- \rightarrow \gamma a, a \rightarrow \gamma\gamma$
(m_a=1 GeV)

Single Photon: missing energy

Magnetic Monopoles: high energy release and 'unconventional' tracks

| Channel	Target luminosity	Comment
Single Photon $e^+e^- \rightarrow \gamma\,A'(A'\rightarrow inv)$	10 fb^{-1}	Need inner KLM
ALPs $e^+e^- \rightarrow \gamma a(a\rightarrow\gamma\gamma)$	Phase 2	Publication plan
$Z'\rightarrow$ invisible	Phase 2	Publication plan
LFV -$Z'\rightarrow$ invisible	Phase 2	Publication plan
Magnetic monopoles	Phase 2	Publication plan
Magnetic monopoles in PXD	(Phase 2)	Feasibility study started

BLIND DATA!

BLIND DATA!

BLIND DATA!

Details in Backup

Z' to Invisible: sensitivity

- 90% CL upper limits computed as Poisson counting experiments → conservative estimate (even better significance is expected by fitting the recoil mass distribution).

Expected Sensitivity: early Phase 3
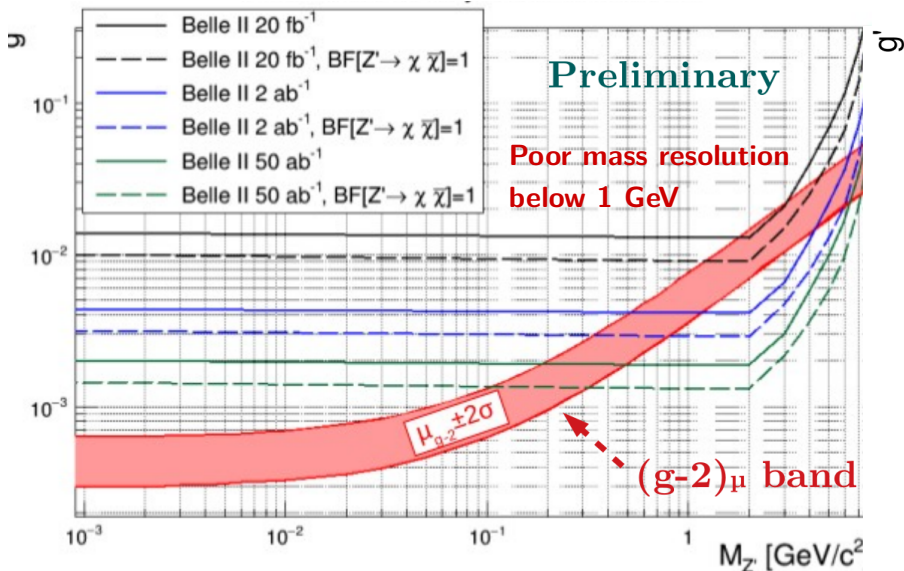
Phase 2 effective integrated luminosity (264 pb^{-1})
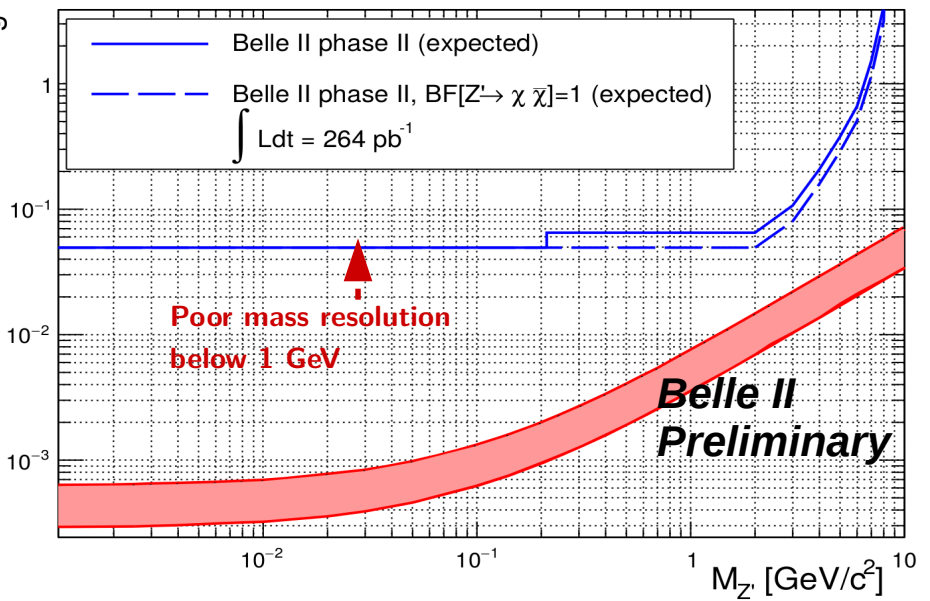
B2TiP report finally available

https://arxiv.org/pdf/1808.10567.pdf

The Belle II Physics Book

E. Kou[74,¶,†], P. Urquijo[143,§,†], W. Altmannshofer[133,¶], F. Beaujean[78,¶], G. Bell[120,¶],
M. Beneke[112,¶], I. I. Bigi[146,¶], F. Bishara[148,16,¶], M. Blanke[49,50,¶], C. Bobeth[111,112,¶],
M. Bona[150,¶], N. Brambilla[112,¶], V. M. Braun[43,¶], J. Brod[110,133,¶], A. J. Buras[113,¶],
H. Y. Cheng[44,¶], C. W. Chiang[91,¶], M. Ciuchini[58,¶], G. Colangelo[126,¶],
H. Czyz[154,29,¶], A. Datta[144,¶], F. De Fazio[52,¶], T. Deppisch[50,¶], M. J. Dolan[143,¶],
J. Evans[133,¶], S. Fajfer[107,139,¶], T. Feldmann[120,¶], S. Godfrey[7,¶], M. Gronau[61,¶],
Y. Grossman[15,¶], F. K. Guo[41,132,¶], U. Haisch[148,11,¶], C. Hanhart[21,¶],
S. Hashimoto[30,26,¶], S. Hirose[88,¶], J. Hisano[88,89,¶], L. Hofer[125,¶], M. Hoferichter[166,¶],
W. S. Hou[91,¶], T. Huber[120,¶], S. Jaeger[157,¶], S. Jahn[82,¶], M. Jamin[124,¶],
J. Jones[102,¶], M. Jung[111,¶], A. L. Kagan[133,¶], F. Kahlhoefer[1,¶]

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Physics week Oct 22-26 @ KEK

- **Dark matter lectures**: theory, collider searches, direct searches, Belle II studies
  - Stefania Gori (UC Santa Cruz), Patrick Stengel (Stockholm), Hyun-Min Lee (Chung-Ang U)
- **Lepton Flavour Universality Violation lectures**: B->D$^{(*)}$l ν (l=e,μ,τ), b→s ll (l=e, μ), theory and experiment (Belle II/LHCb), tutorials on theory programs for B→D$^{(*)}$l ν modelling
  - John Gargalionis (Melbourne), Dean Robinson (UC Santa Cruz & LBL), Takaaki Nomura (KIAS Seoul), Guy Wormser (LAL), Shoji Hashimoto (KEK)
- **Seminars by collaborators on** Belle and Belle II measurements and machine learning.
- Informal sessions on latest/recent Belle II rediscoveries and data challenge outcomes.

https://kds.kek.jp/indico/event/27330
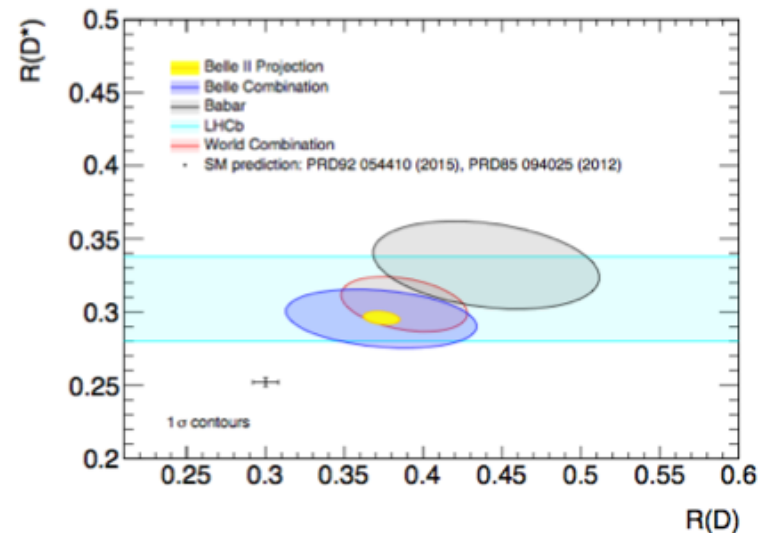
Social event: Kasama visit + dinner Kasama-no Kiku (Crysanthemum) Matsuri (Festival) Oct 20-Nov 25

WP1 deliverables

- D1.1 Offline workshop ✓
  - Description: Annual workshops amongst participants to discuss the status of offline software, outstanding issues and possible improvements, and to exchange knowledge amongst involved researchers
  - Due: March 2016
  - Delivered: September 2016
- D1.2 Belle II tutorials ✓
  - Description: Tutorial courses for Belle II members (especially ESRs) attached to Belle II collaboration meetings, to demonstrate the use of physics analysis tools
  - Due: March 2016
  - Delivered: September 2016

JENNIFER

EU grant n.644294

WP1 deliverables

- D1.3 Reference guide ✓
  - Description: Writing and maintaining a reference data reconstruction and analysis tools guide
  - Due: March 2018
  - Delivered: April 2018 (submitted but not approved yet?)
- D1.4 B2TiP report ✓
  - Description: "Belle II Yellow Report" summarizing all important observables and including a "milestone table", clarifying the targets for the first 5/ab, 10/ab as well as for the final goal at 50/ab
  - Due: March 2017
  - Delivered: May 2017

EU grant n.644294

Summary

- Belle II/SuperKEKB have completed the phase 2 pilot run, accumulating ~0.5/fb on the Y(4S) resonance and putting also the software to a test

- Beam backgrounds have been significantly over expectation and large efforts have been made to understand the situation

- Nevertheless, physics results are coming, especially in the field of dark sector searches

- WP1 is supporting all these activities
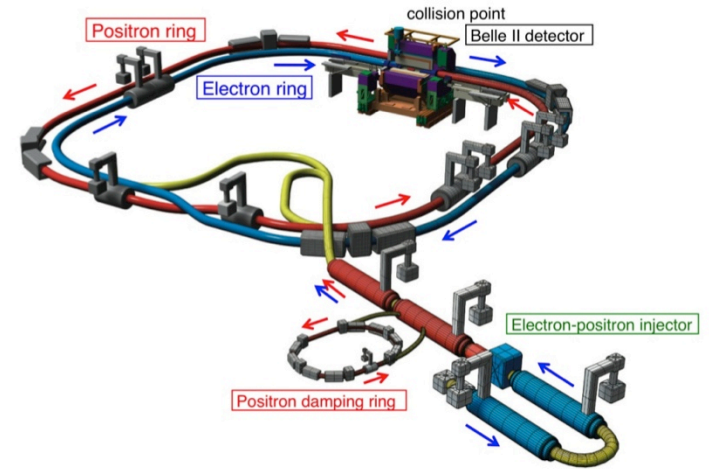 - All deliverables have now formally been prepared
  - WP1 secondment situation?

BACKUP

Belle II upgrade

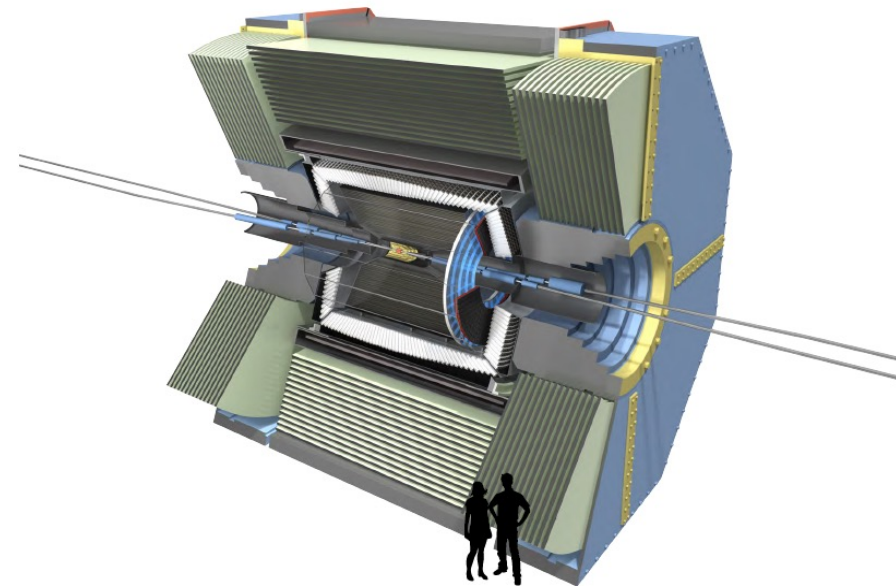
SuperKEKB

- 2011-2018: major upgrade of both the collider and the detector
  (Belle $\rightarrow$ Belle II,
  KEKB $\rightarrow$ SuperKEKB)
- Physics data taking starts early 2019
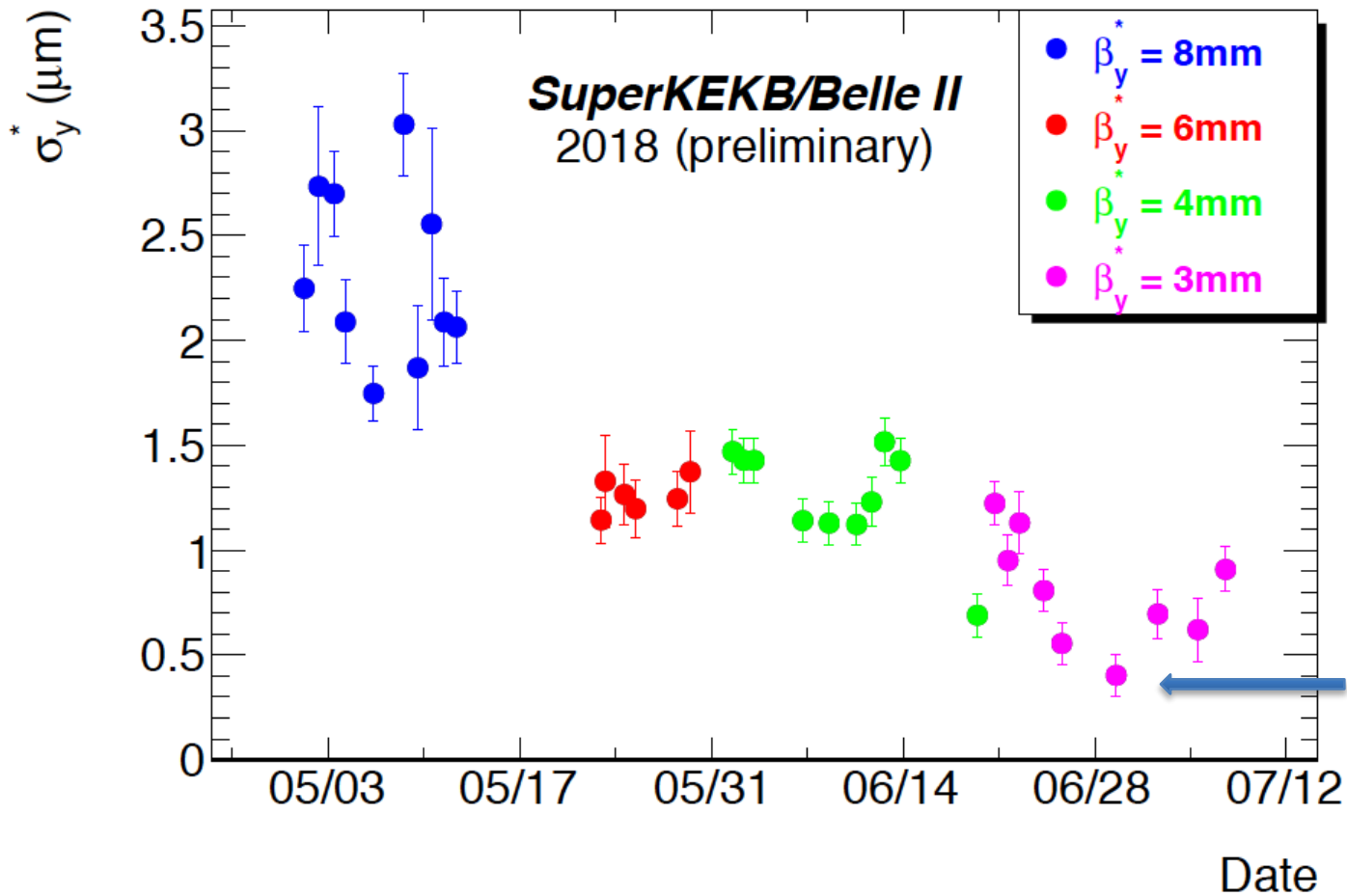- Aim to increase the Belle data set by a factor of 50

Belle II

β*_y squeezing

The record is 400 nm at beam currents of only ~15mA

S. Di Carlo et al. (LAL Orsay)

B2TiP

- The "Belle II Theory Interface Platform" is a joint theory-experiment effort to define the Belle II physics program

- B2TiP is organized in 9 working groups

- The charge of each WG is to identify the "golden modes", perform simulation studies and finally produce a chapter of the B2TiP report

- The activity is driven by a series of workshops

EU grant n.644294

B2TiP WG structure

WG1	Semileptonic & Leptonic B decays
WG2	Radiative & electroweak penguins
WG3	α (ϕ_2) and β (ϕ_1)
WG4	ϕ_3
WG5	Charmless hadronic B decays
WG6	Charm physics
WG7	Quarkonium-like states
WG8	Tau, low multiplicity and electroweak physics
WG9	New Physics (models)

B2TiP workshop series

1. October 30-31, 2014 @ KEK
2. April 27-29, 2015 @ Krakow
3. October 28-29, 2015 @ KEK*)
4. May 23-25, 2016 @ Pittsburgh*)
5. November 15-17, 2016 @ MIAPP Munich (editorial meeting)

plus the kickoff meeting June 16-17, 2014 @ KEK and a few focused meetings

*) co-funded by JENNIFER