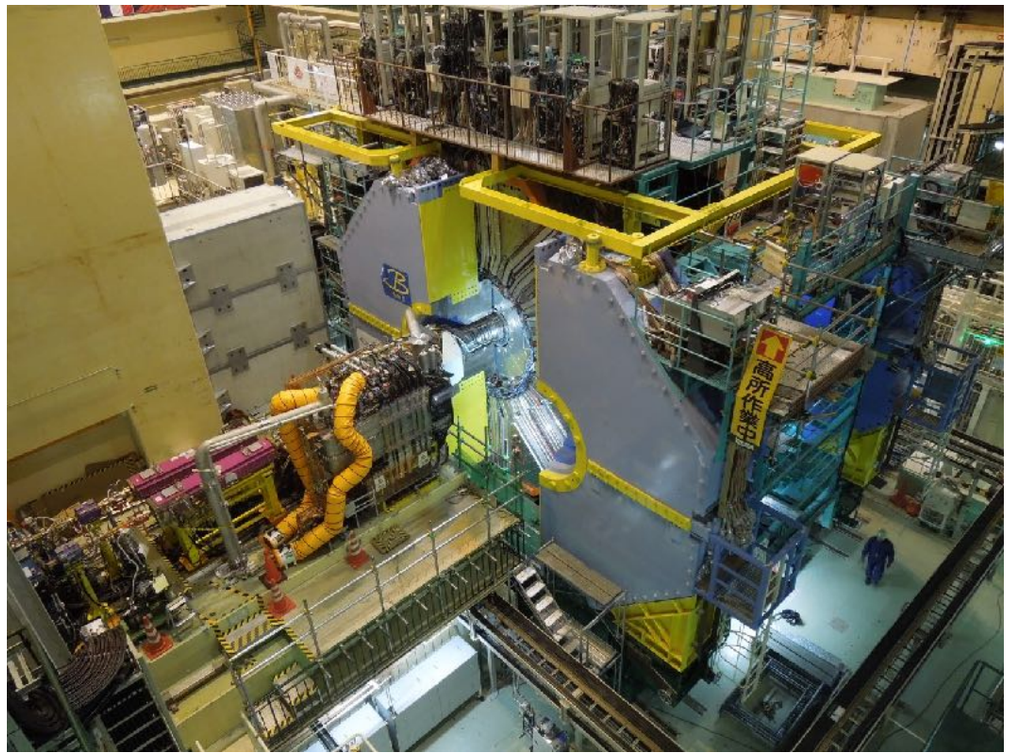
Belle II Status



Toru Iijima
Belle II spokesman (2019.6 -)
Nagoya University

July 8, 2019
The 23rd KEKB Accelerator Review Committee

Note: physics-related plots are internal and will be updated for LP2019

New Belle II Management

- Spokesperson: Toru Iijima
- Deputy spokes: Karim Trabelsi
  - Assist the spokesperson in performing tasks that require the spokesperson's attention or authority.
- Project Manager: Yutaka Ushiroda
- Financial Officer: Shoji Uno

We thank Tom Browder for his years of leadership !

- IB chair/deputy: Gagan Mohanty / Takeo Higuchi (newly elected by IB)
- EB chair: Michael Roney
- Physics Coordinator: Alessandro Gaz (newly elected by IB)
- TB chair/deputy: Peter Krizan / Carlos Marinas

Communication between SuperKEKB and Belle II

- BCG (Belle II Commissioning Group) shift
  - 1 shifter in the ACC control room
- Several Belle II people (incl. Run coordinator, BCG) attend the KCG meeting.
- Belle II Monday meeting (every week)
  - Invite SuperKEKB people to present status
- EB meeting invites Tobiyama-san and some SuperKEKB people.
- MDI (Machine Detector Interface) meeting to discuss mitigation of machine background.

Belle II Collaboration

- 984 active members
  - 333 graduate students
- 115 institutes
- 26 countries

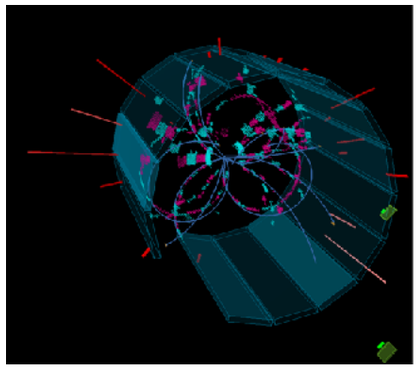
(B2MM on June 20, 2019)

Phase 2 in a nut shell

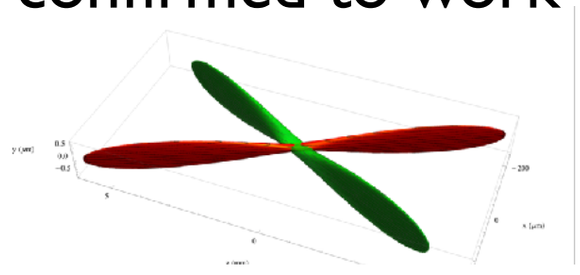
1. **Achieve a machine luminosity of O(10^34/cm^2/sec)** and see **a clear path to further improvement**.

2. **Examine the VXD background to verify that we can install the VXD *at the start of phase 3*** and then operate it for the initial first few years of phase 3.

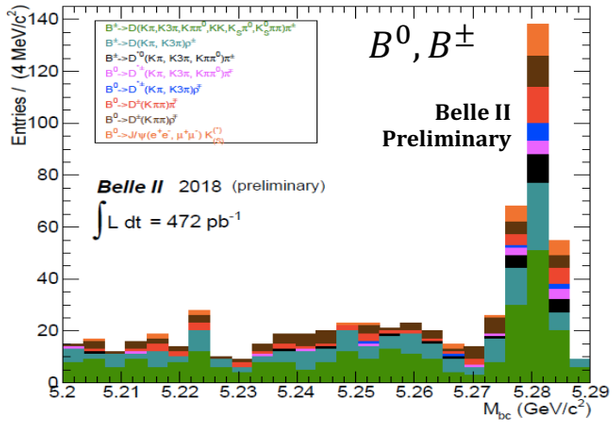
First collision (April 26, 2018)



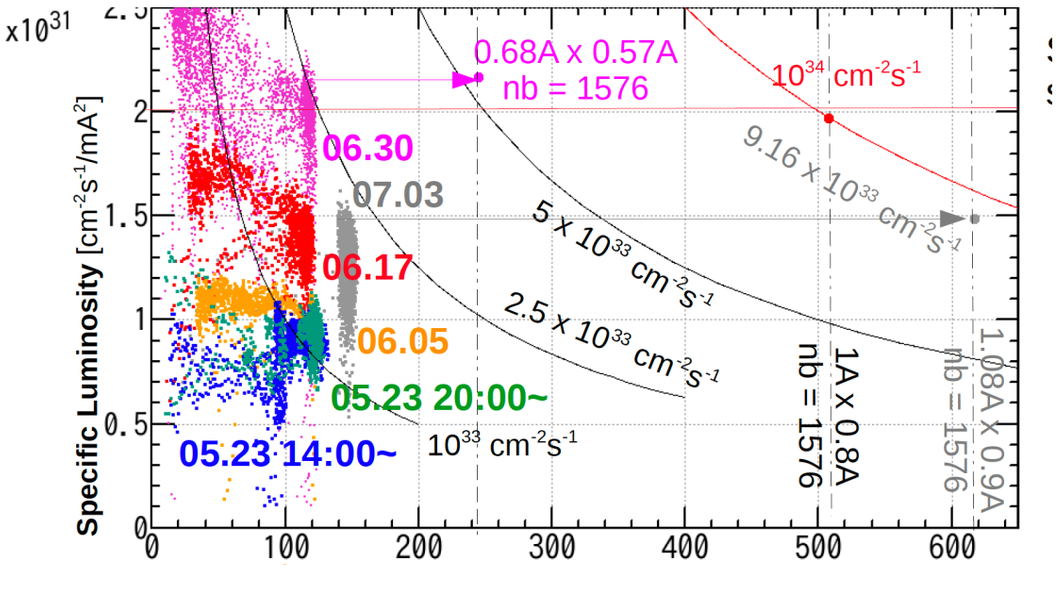
New collision scheme confirmed to work

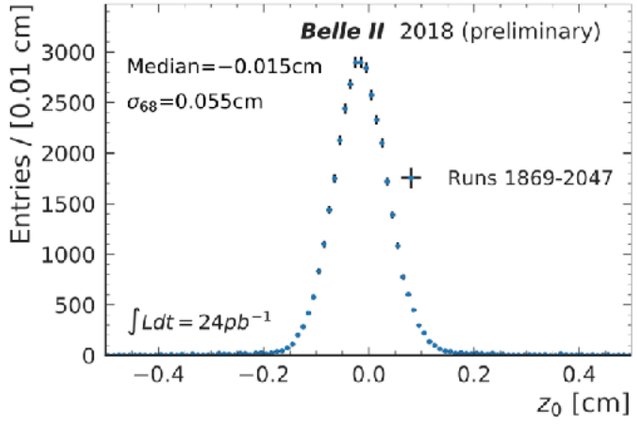


Initial data of ~500pb^{-1} recorded, and particle rediscoveries made.



Specific luminosity improved

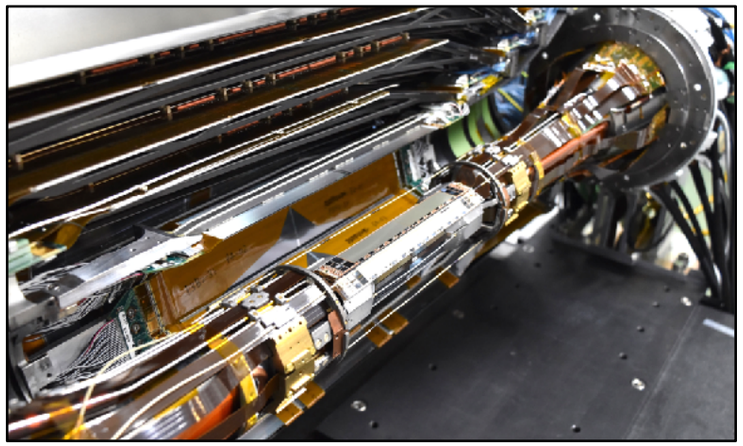


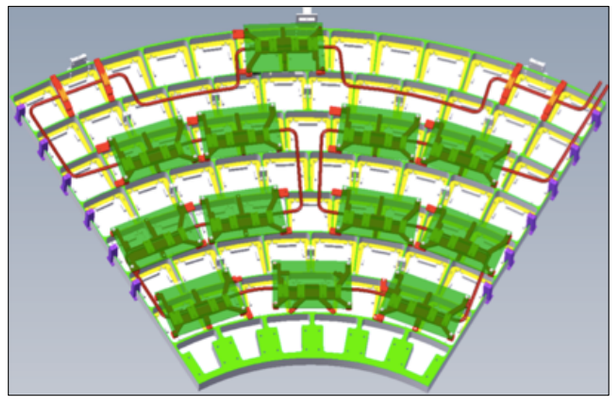


Installed detectors worked, although some fixes were necessary.

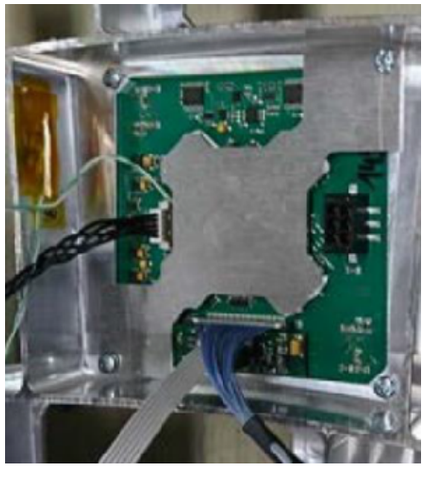
Preparation for Phase 3

Vertex detector (instead of background monitors) is installed

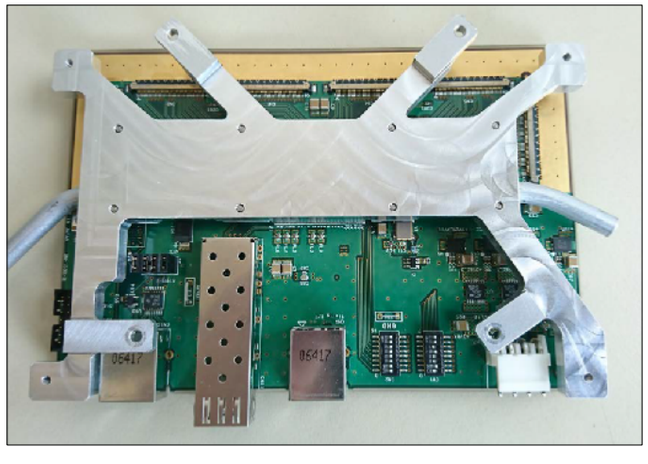




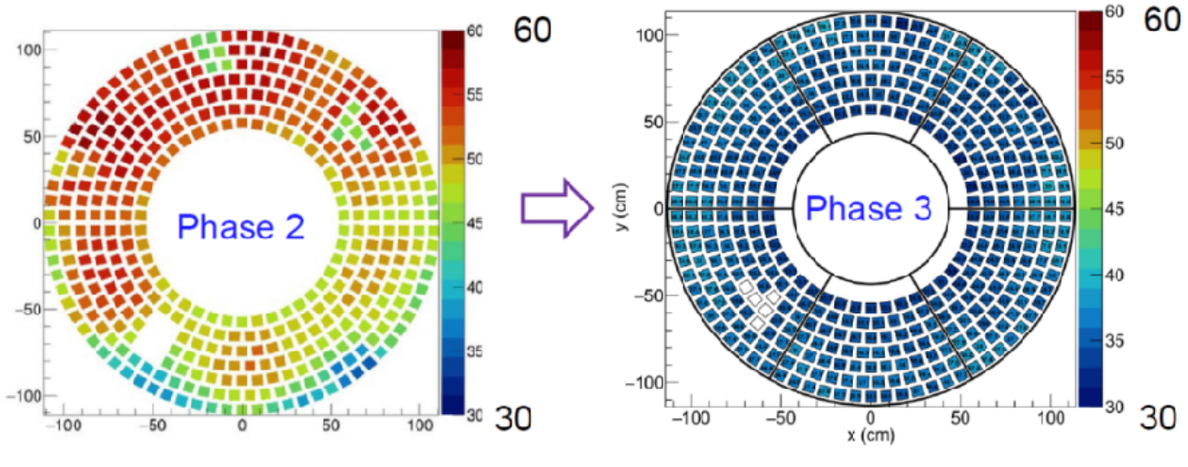
ARICH cooling reinforced



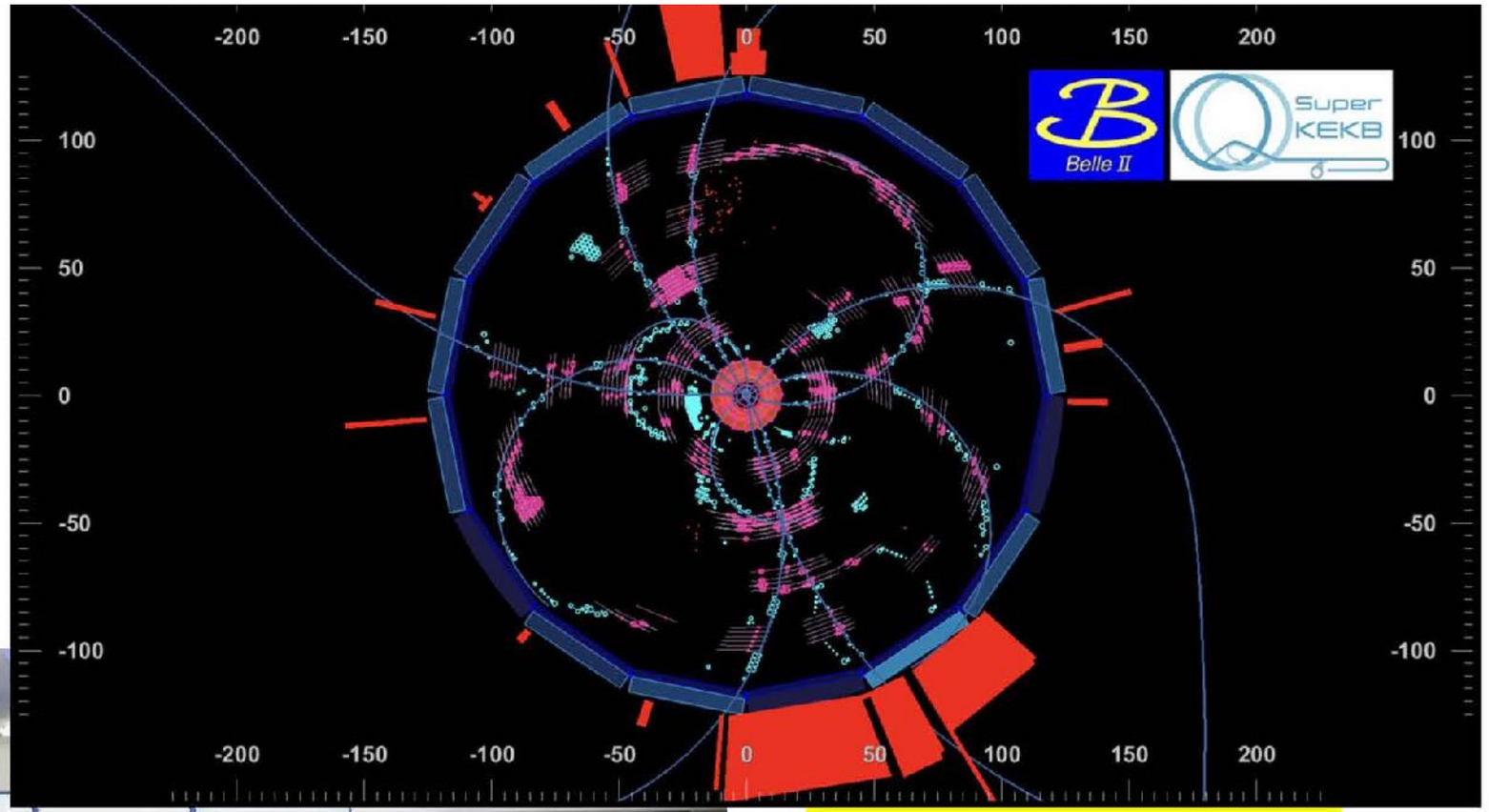
2018/9/5



FEB temperatures (after installing inside Belle II)

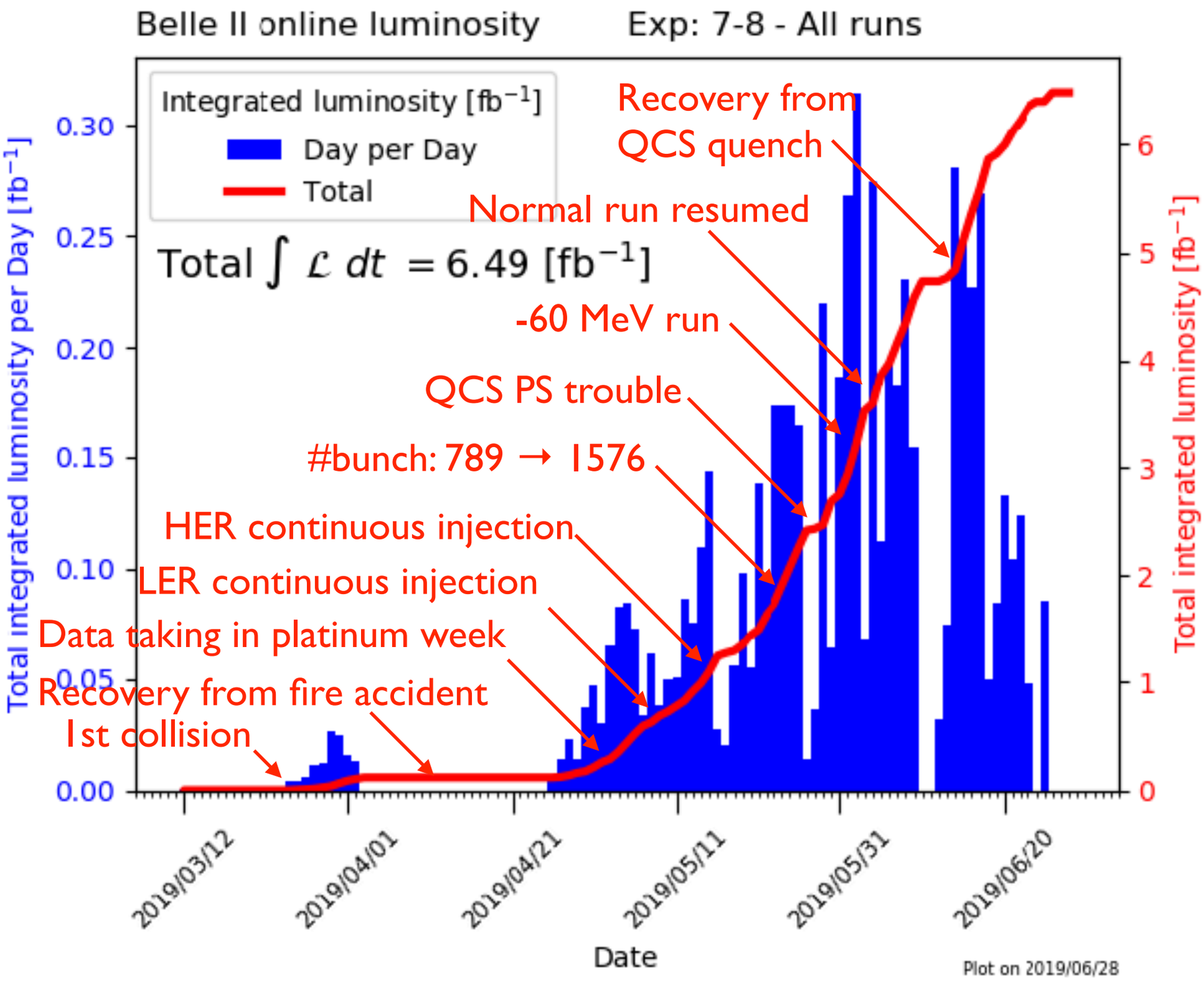


Start of the Phase 3 Run



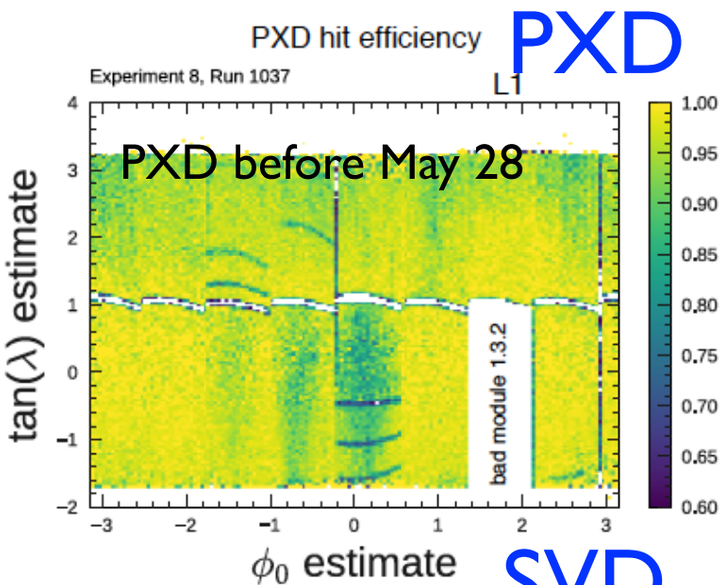
25/March/2019

Status of physics run

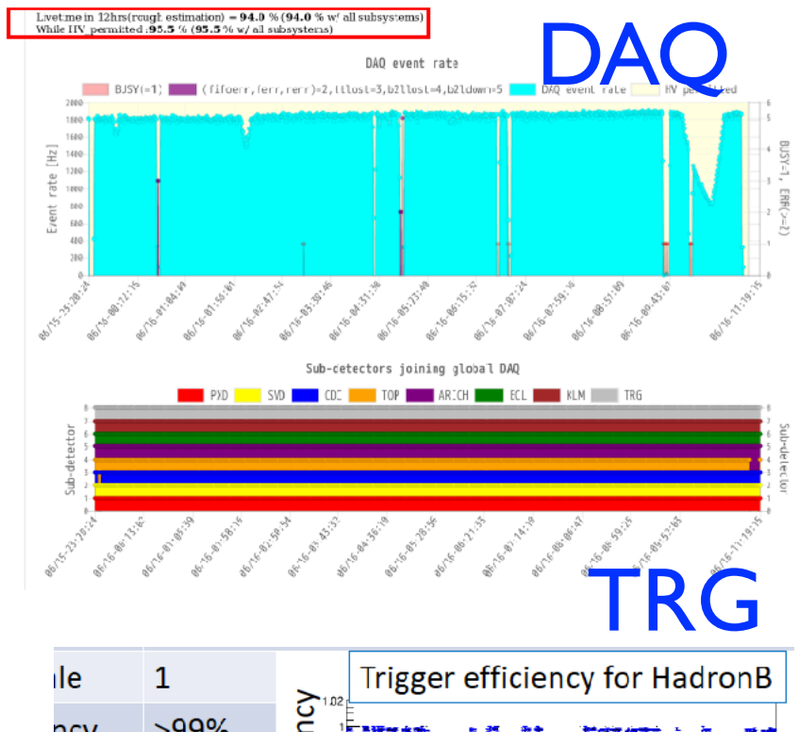


Belle II is working "basically"

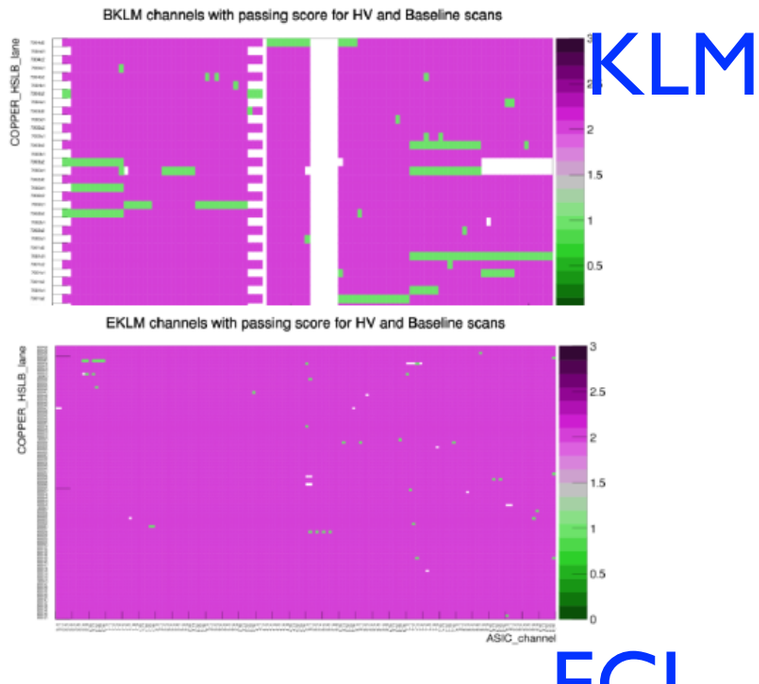
PXD



DAQ



KLM



SVD

efficiency	u/P	v/N
layer3	(99.72 ± 0.04)%	(98.47 ± 0.06)%
layer4	(99.66 ± 0.04)%	(99.34 ± 0.09)%
layer5	(99.61 ± 0.08)%	(99.4 ± 0.1)%
layer6	(99.2 ± 0.2)%	(99.3 ± 0.2)%

Slightly lower due to masked APV chip

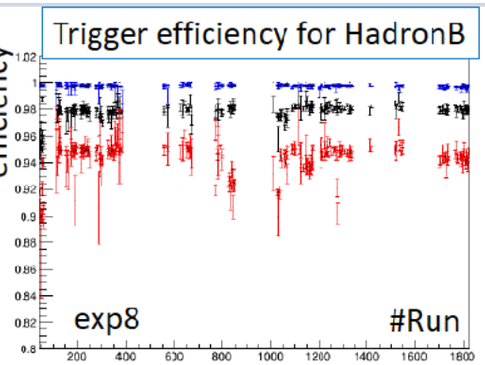
TRG

ıle	1
ıncy	>99%

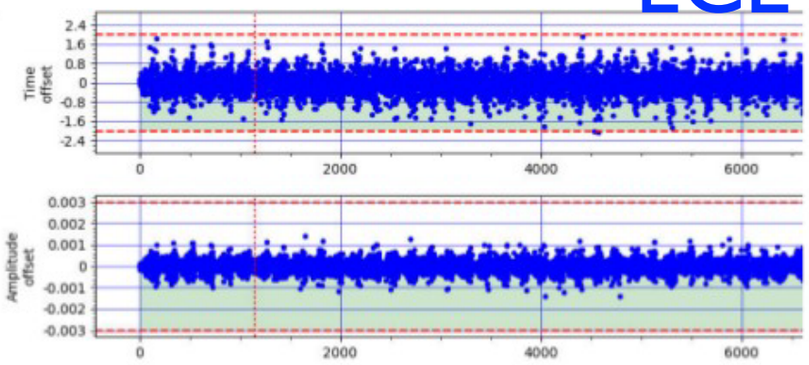
-ECL cluster (c4|hie)

-two 2D track with opening angle (ffo)

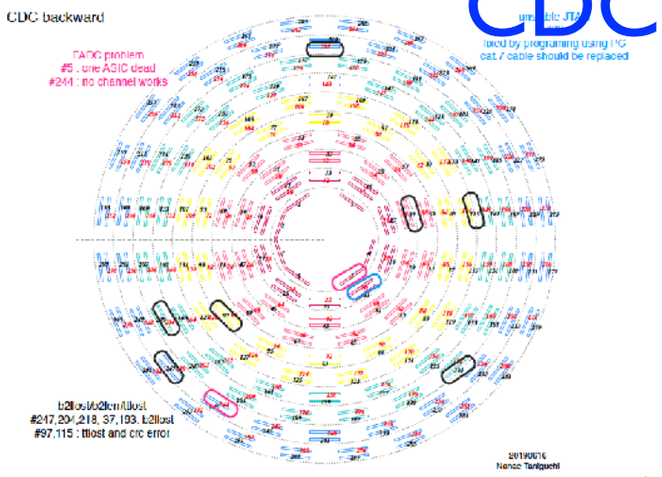
-three 2D tracks (fff)



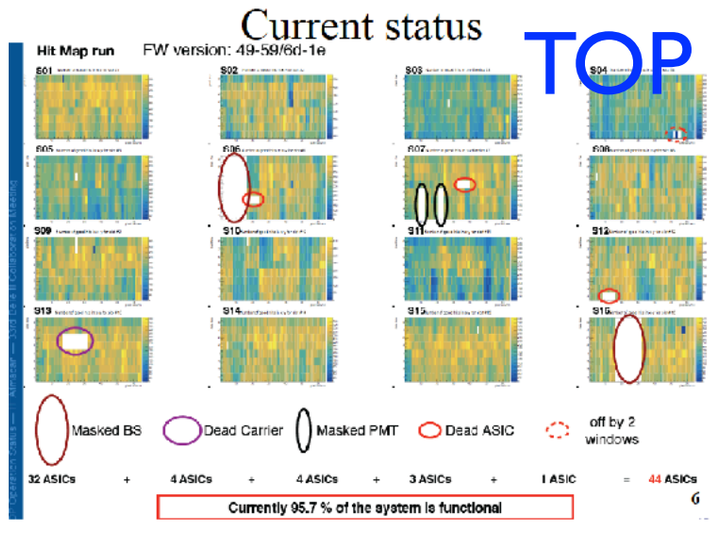
ECL



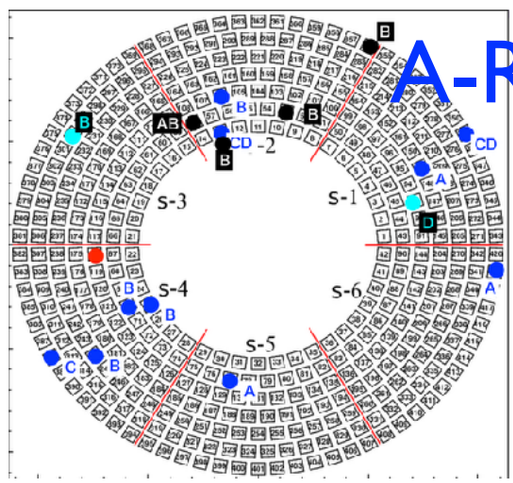
CDC



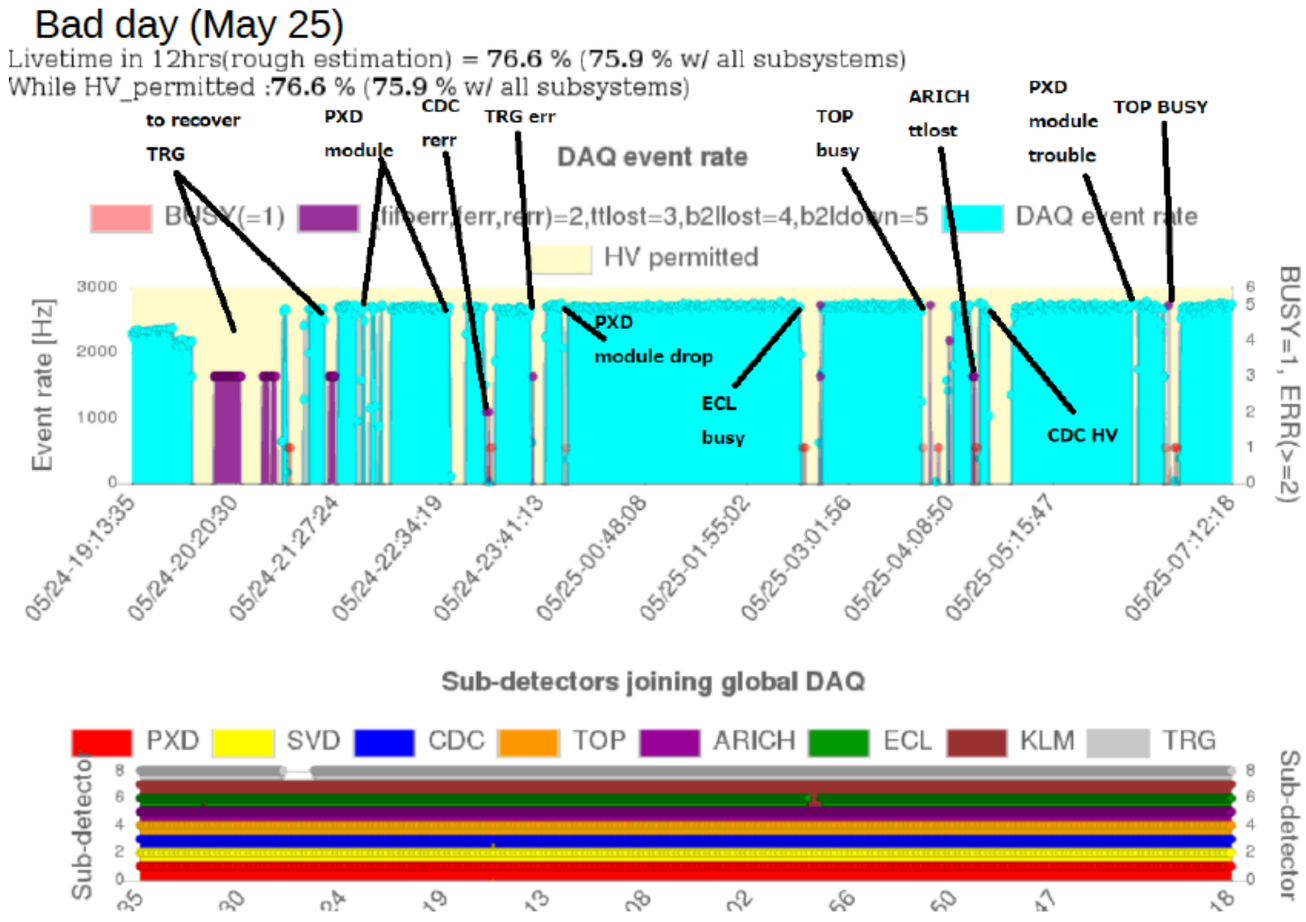
TOP



A-RICH



But, not always …



PXD BUSY

SALS !

CDC ttlost/b2ldown

TOP BUSY

ECL BUSY

TRG BUSY/ttlost

HV TRIP !

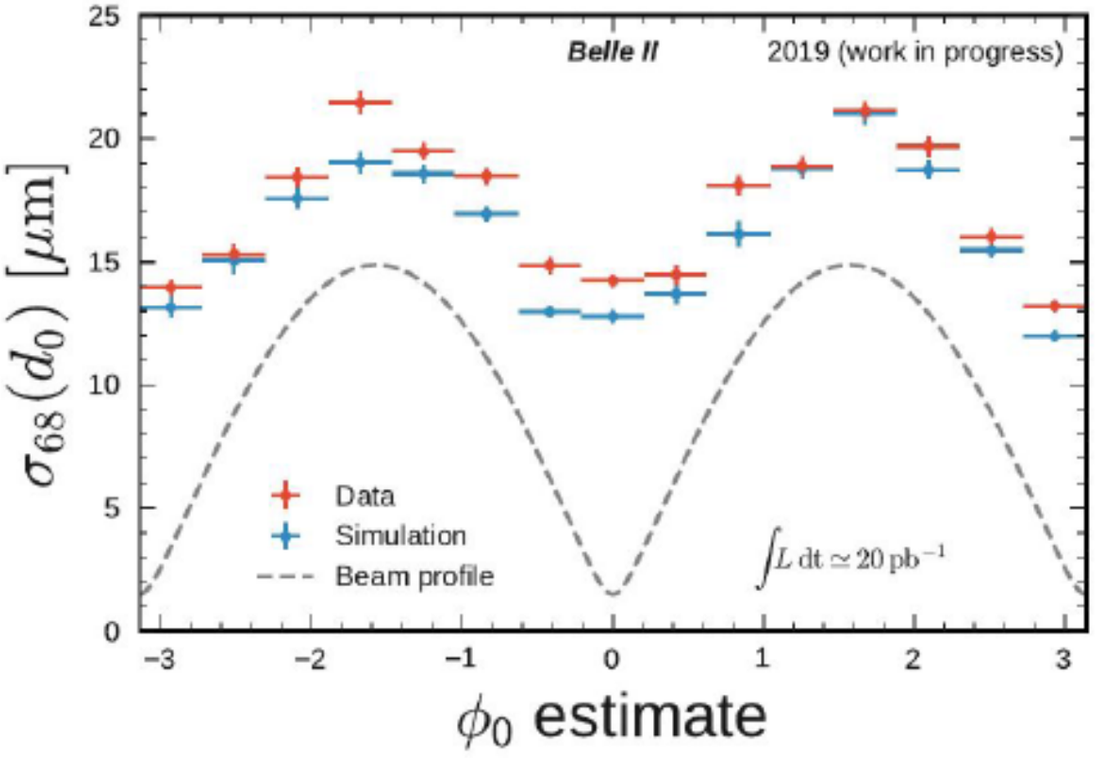
Belle II is still in learning stage, and need get more matured.

- More debugging
- More sustainable operation (slow control, HLT, …)
- More people at Gemba
- Data quality assurance
- Documentation

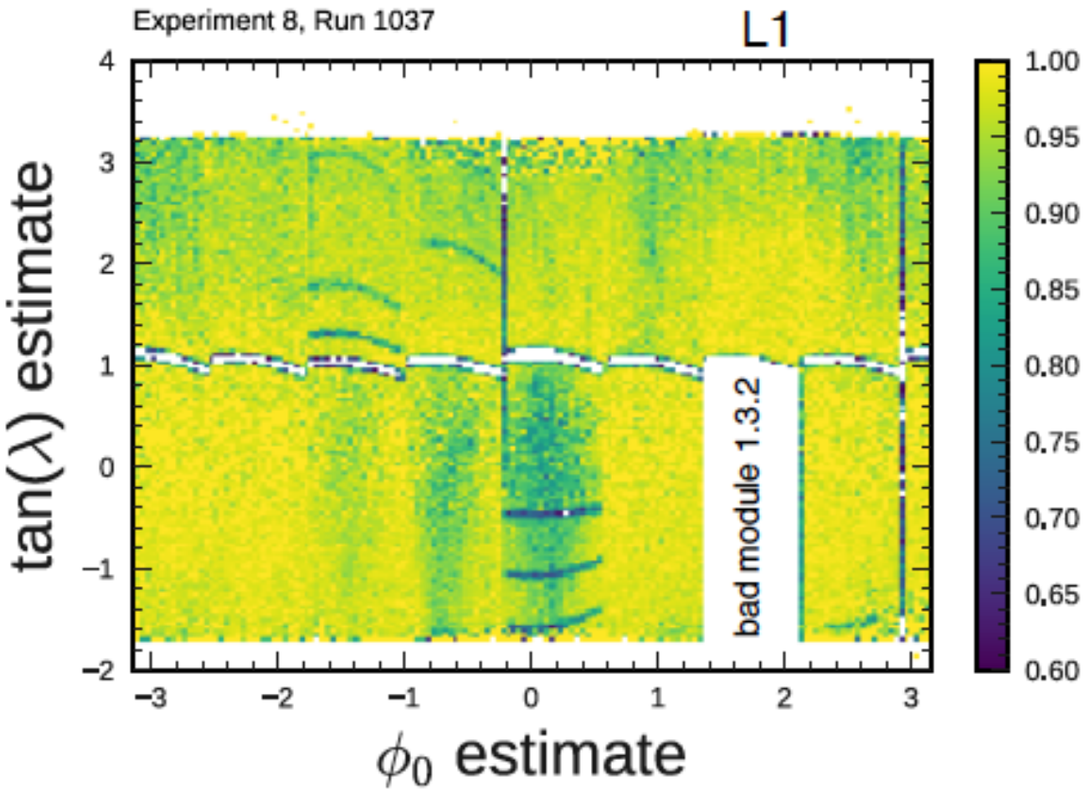
Yet a child ?

PXD (before May 28)

Transverse impact parameter resolution



PXD hit efficiency



- PXD regularly participating in luminosity runs
  - initial data taking instabilities solved with new DHH firmware versions
  - occupancy in general way below 3% limit
- Impact parameter resolution approaching MC expectations
  - remaining inconsistencies in alignment results in different data sets ⇒ field-on/off cosmic run July 1-2
  - MC studies under different background assumptions for 2020-2021 underway to assess impact of L2
- Efficiency in general high, but further fine tuning of several modules required

Carsten Niebuhr

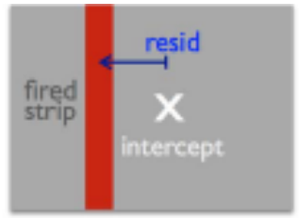
SVD in Phase 3

- SVD operation has been very smooth and stable. No major issue has been encountered.
- Excellent performance: cluster efficiency above 99% in L3-L6 and on n/p- side.
- Occupancy
  - Current offline occupancy is ≦ 0.3%
    - Extrapolation: 1.6% (2020), 2.6% (2021)

      ⟷ limit for good tracking (2-3%)
    - Online data rate will be also OK up to 2021 (w/ possible improvements for bandwidth limitations)

Cluster efficiency

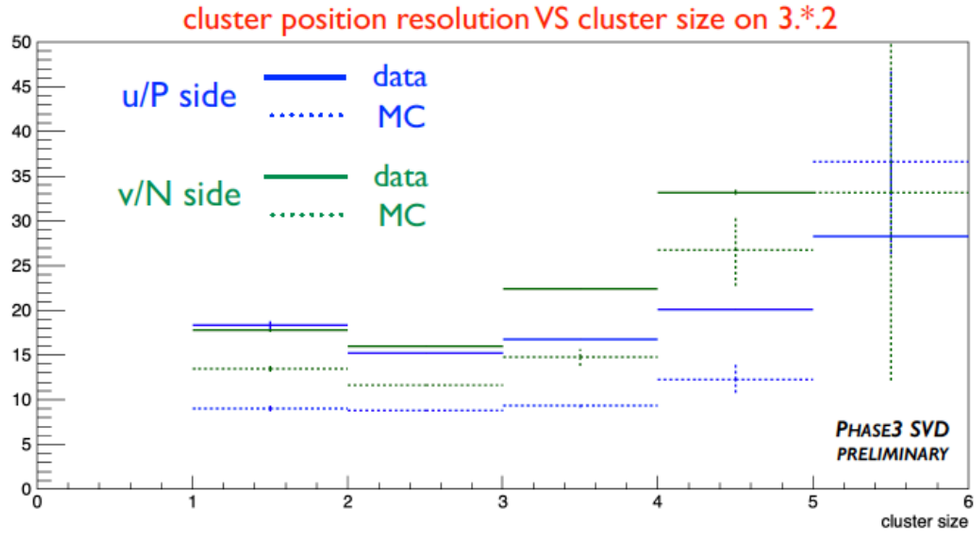
fraction of times a cluster is found within ±0.5mm from extrapolation



efficiency	u/P	v/N
layer3	(99.72 ± 0.04)%	(98.47 ± 0.06)%
layer4	(99.66 ± 0.04)%	(99.34 ± 0.09)%
layer5	(99.61 ± 0.08)%	(99.4 ± 0.1)%
layer6	(99.2 ± 0.2)%	(99.3 ± 0.2)%

Slightly lower due to masked APV chip (see next slide)

Cluster position resolution

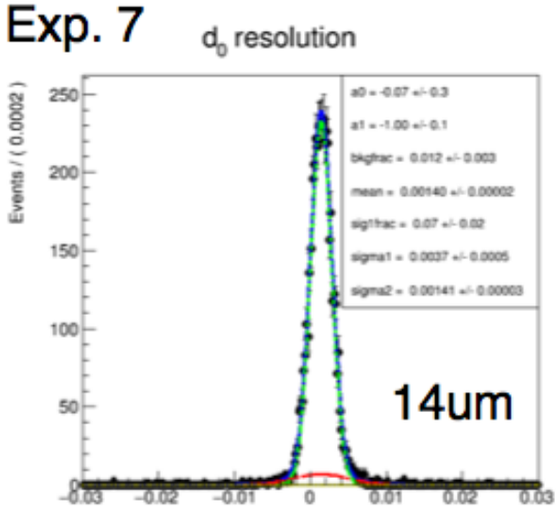


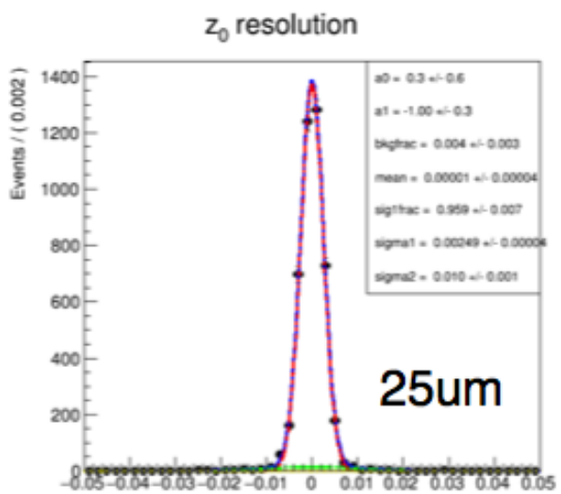
CDC in Phase 3

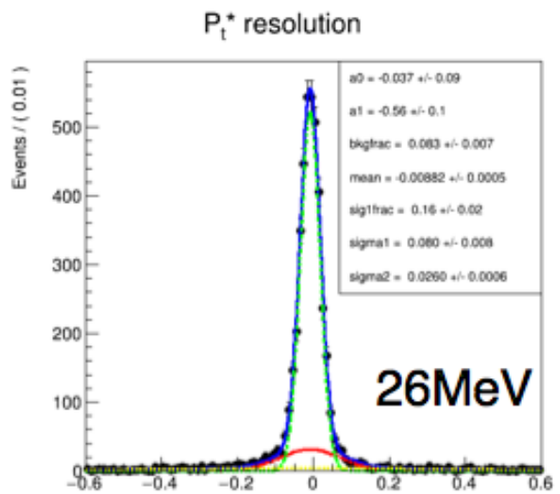
performance check using mumu event

M. Uchida and cdc software group

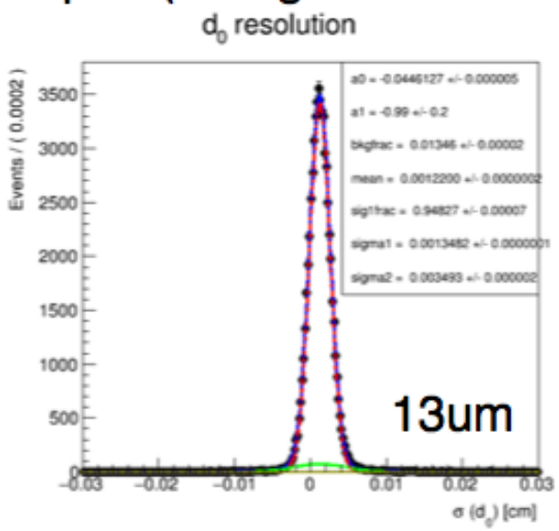
Exp. 7

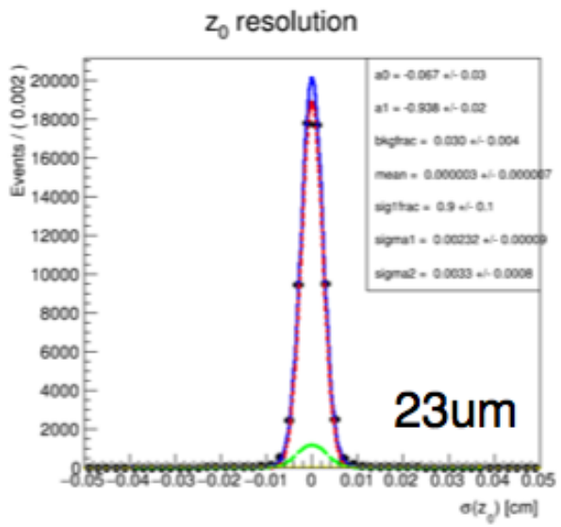


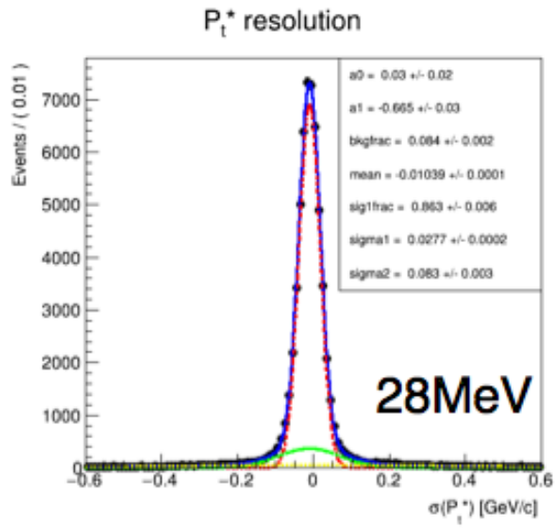




Exp. 8 (w/ higher threshold)





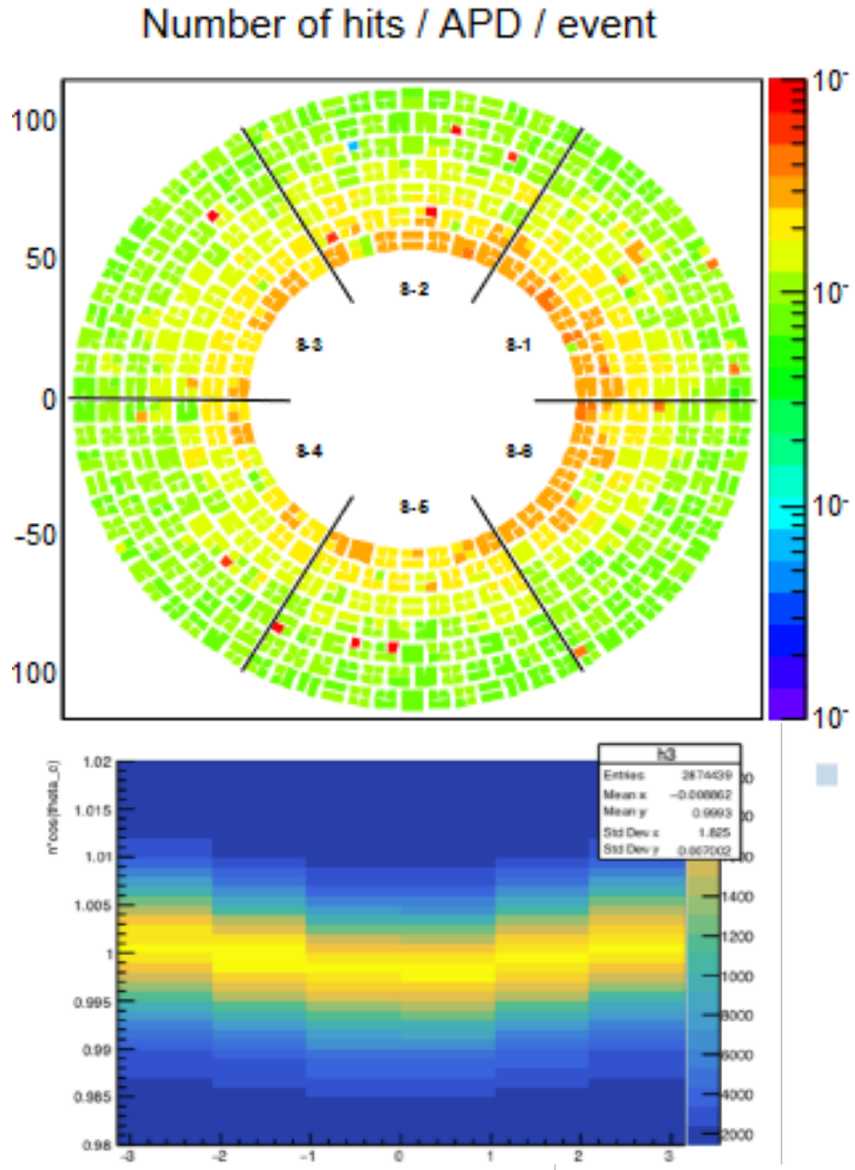


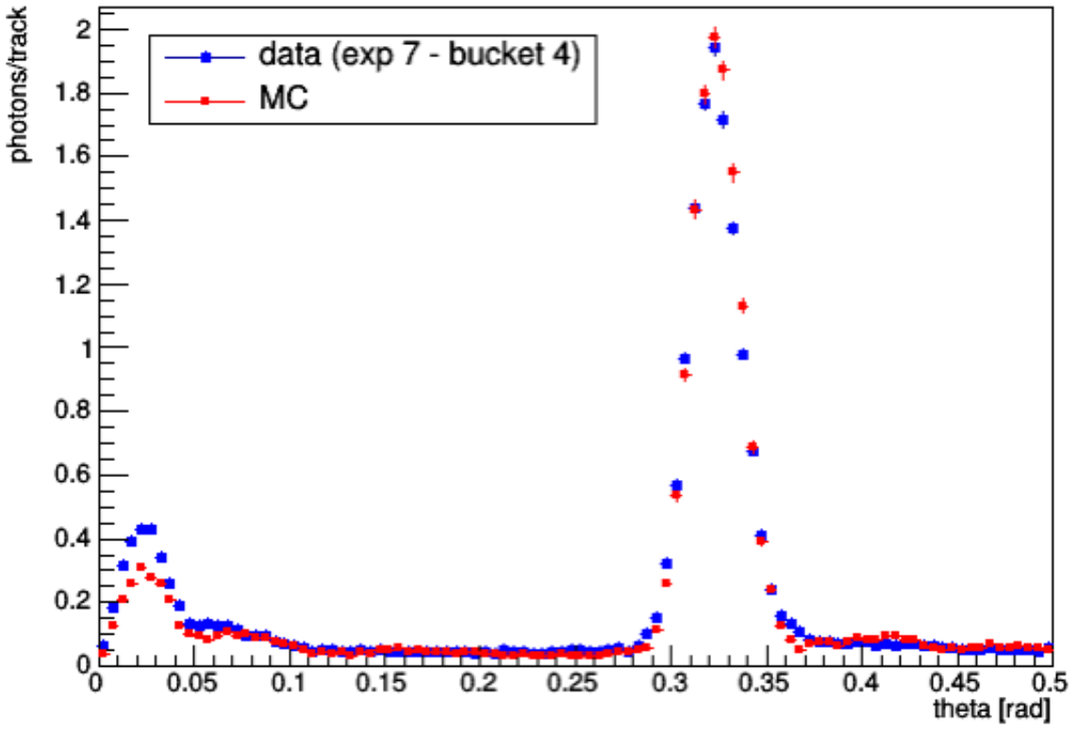
thanks to efforts of calibration and alignment,
competitive performance is obtained.

J. Kumar et al (CMU) verified that dE/dx is unchanged

ARICH in Phase 3

- ARICH operation is stable.
  - ✓ No major problems in DAQ and robust against beam background.
  - ✓ No major concerns in the near future.
- ARICH data is generally has better quality compared to Phase 2 (full operation, better threshold settings etc.).
  - ✓ #(photons) is 20% larger than in Phase 2, consistent with MC.
- Alignment and calibration are on-going.





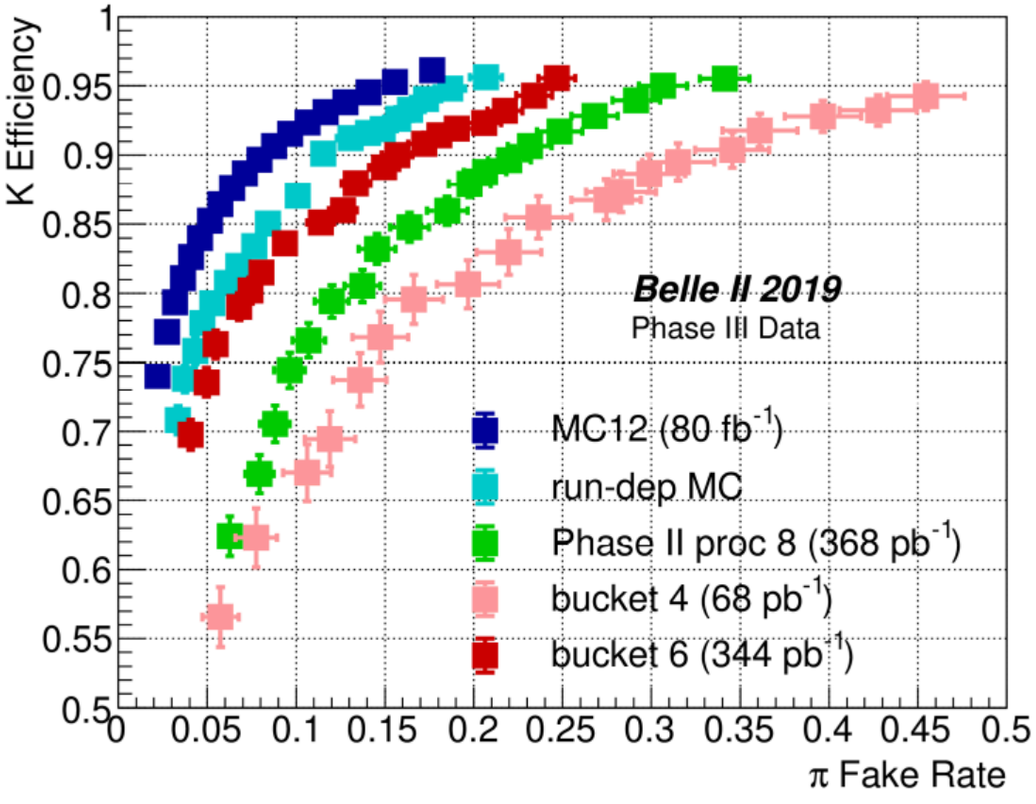
S. Nishida, S. Korpar et al.

Charged Hadron ID

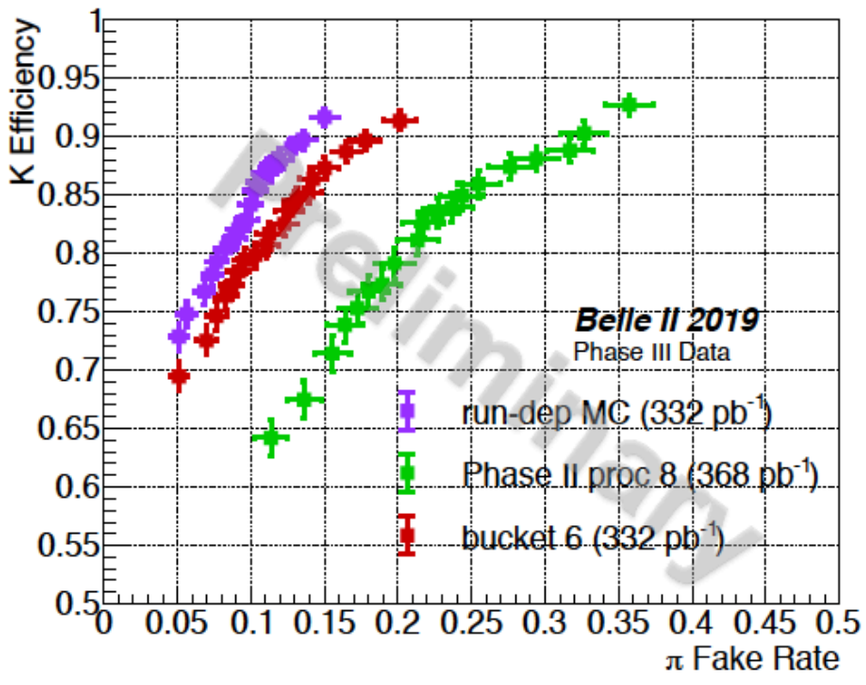
- Charged hadron ID is made by combining information from CDC(dE/dx), TOP and ARICH.
- Significant improvement in Data/MC agreement in recent calibrated Phase 3 data.

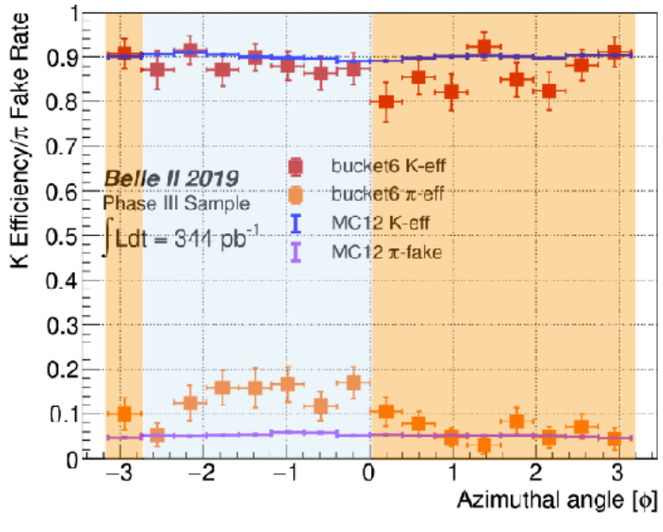
K eff. vs π fake w/ K/π tracks from D* decays

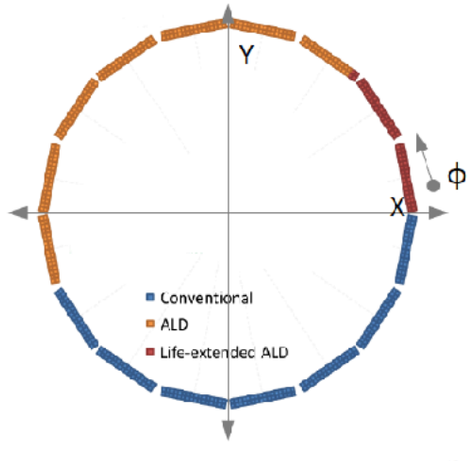
Combined PID



TOP only



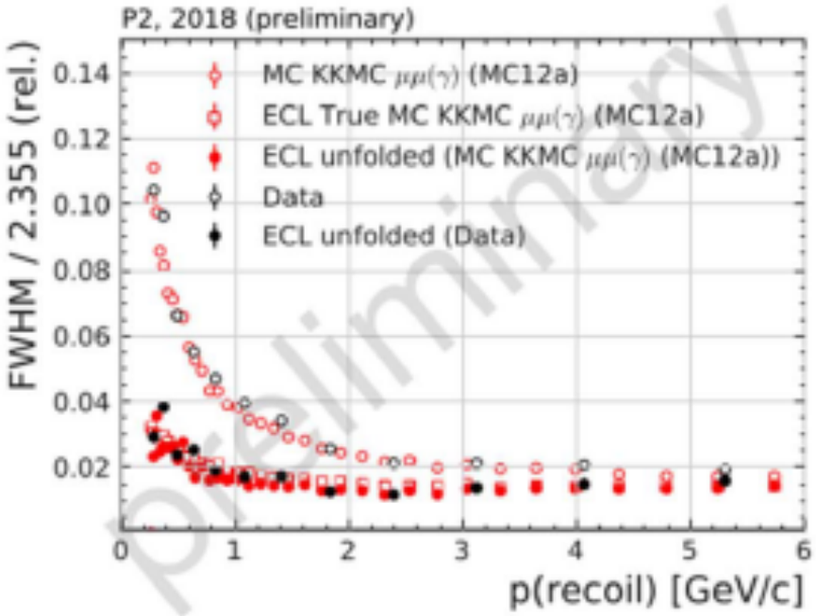


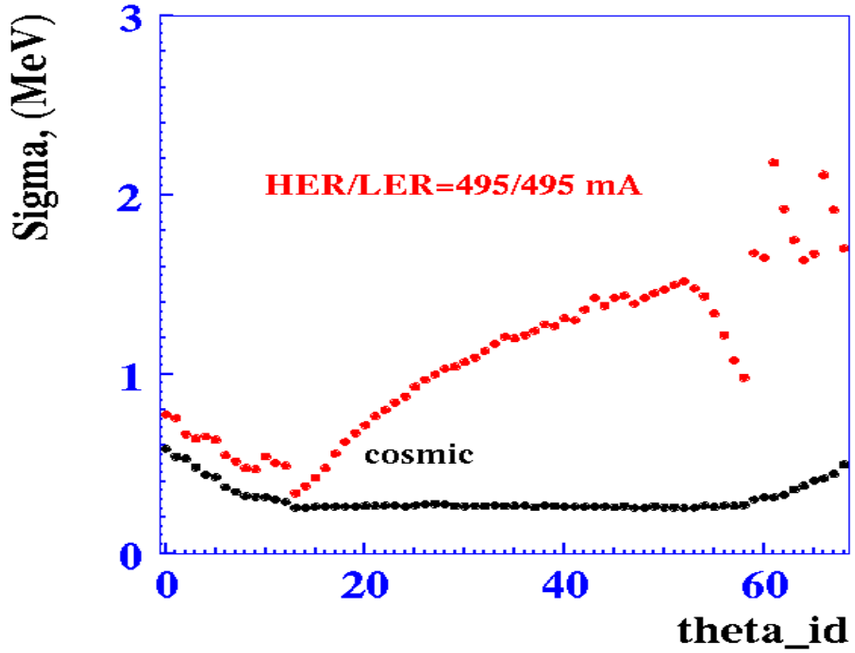


Need more studies to understand difference between the two Φ angle regions (conventional vs. other types of MCP-PMTs)

ECL

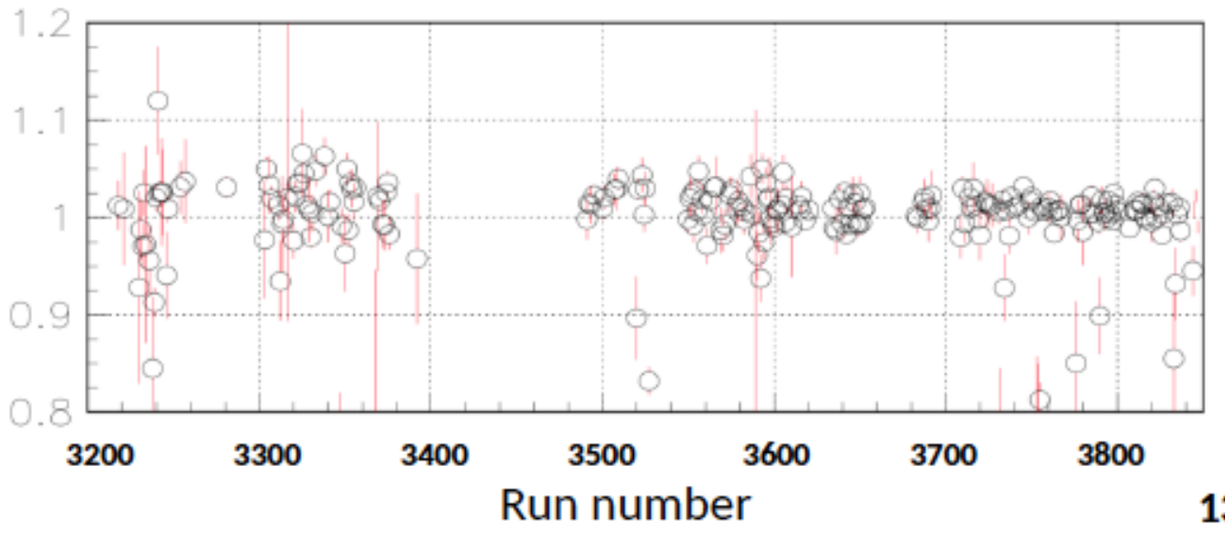
- Electromagnetic Calorimeter (ECL) works stably. All counters are working
- Pile-up noise is monitored by the width of pedestals.
- No extra noise from continuous injection with a proper veto applied.
- Pile-up noise still large in the barrel and backward escape regions.





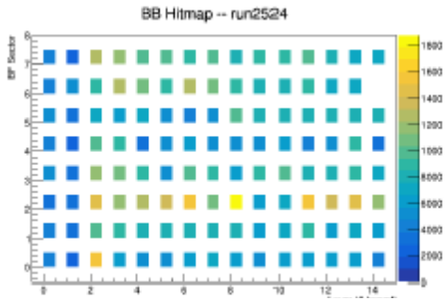
- ECL provides accurate luminosity measurements in real time.
- Accuracy of the online luminosity measurements is estimated to be 1.87%.

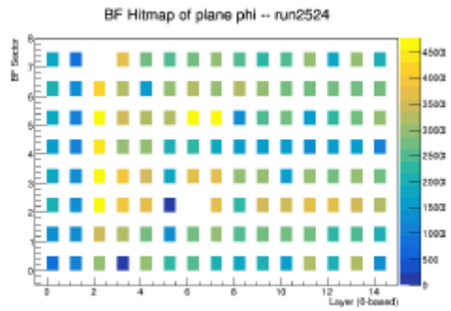
L_{off}/L_{on}

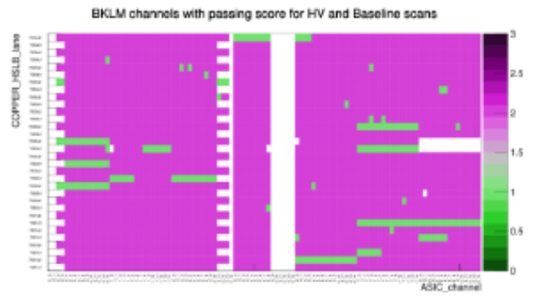


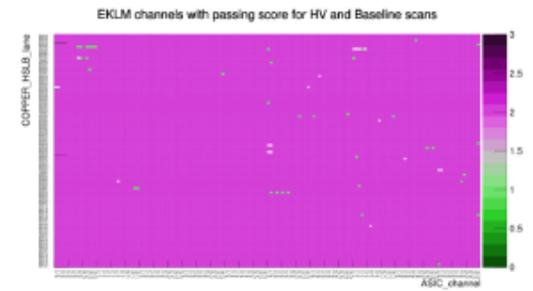
KLM (MuID)

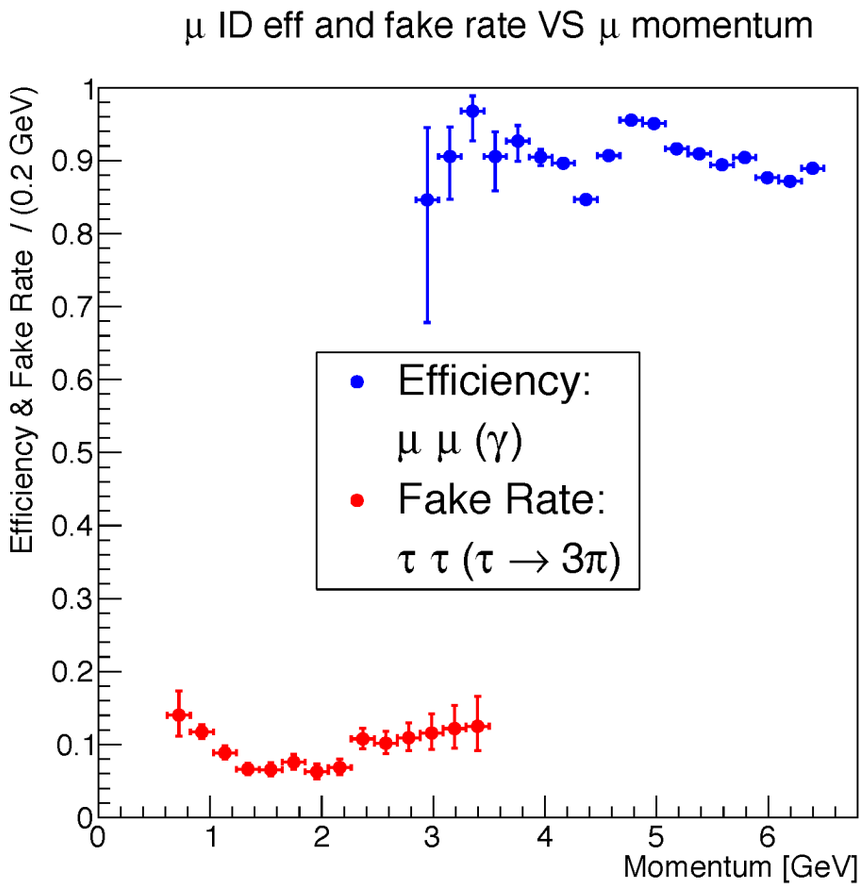
- KLM DAQ stable, all sectors included, muons seen;
- Barrel RPC, 1.5% nonoperational channels
  - one layer (BB6 outermost) disconnected;
  - no phi hits in BF2, layer 6, and BF7, layer 2 (broken cable headers disconnected?)
- Barrel scintillators: 6.5% of channels fail calibration
- Endcap scintillators: 0.5% of channels fail calibration





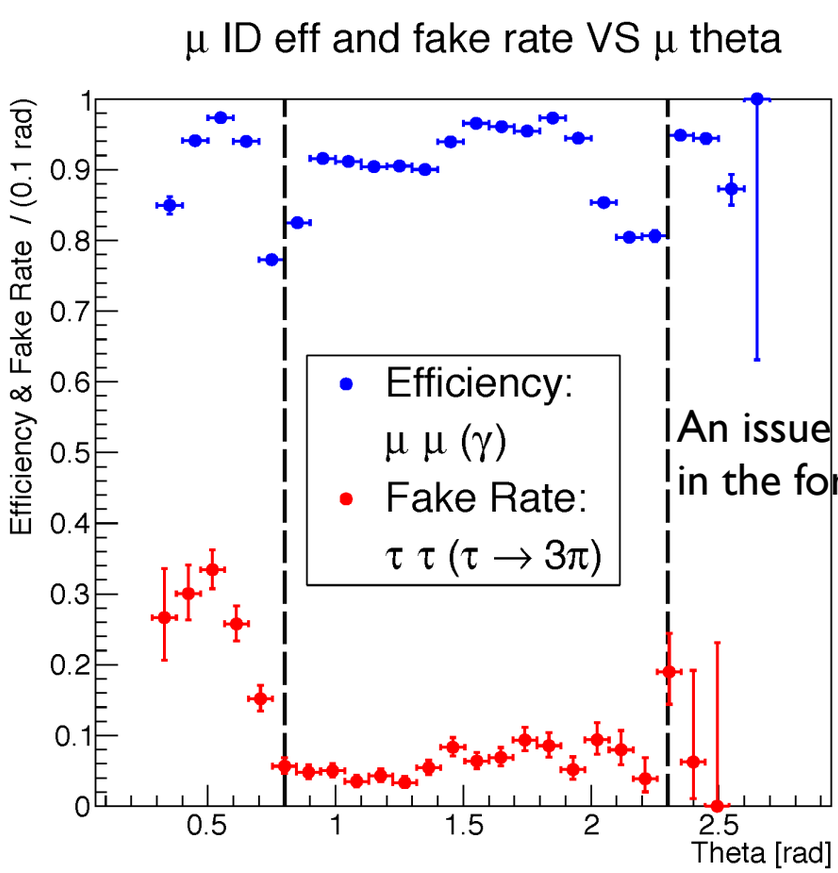






Need a sample of tagged muons in the lower momentum region such as J/Ψ's in hadronic events

A. Martini et al (Roma Tre)



An issue (software?) in the forward endcap.

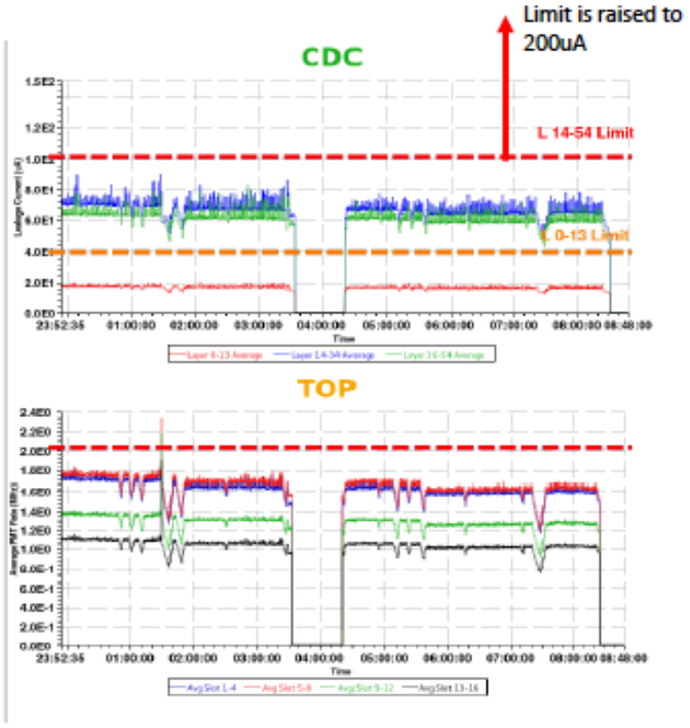
Beam background issues

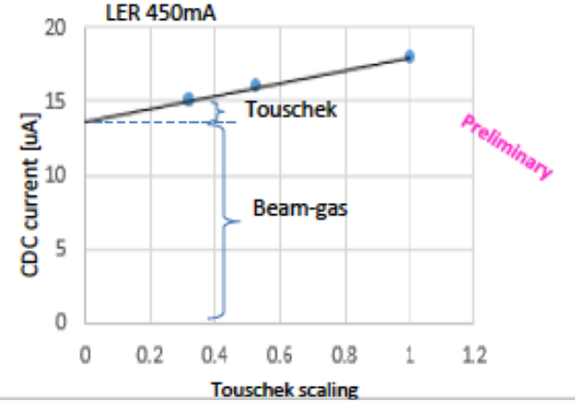
Beam Background "big picture"

(as of mid. June 2019)

- Machine parameters
  - beta_y*=3mm, 1576bunch, 650+650mA, L~0.5*10^{34}
- Our bottle-neck is CDC (and TOP)
  - CDC HV trips with large BG (storage + injection)
  - TOP PMT photocathode lifetime get shorter
- Dominant source: LER beam-gas BG
  - Touschek BG is small enough, thanks to newly-installed horizontal collimators after phase2
- <u>Keep good injection condition</u> is very important
  - To avoid CDC HV trip
  - To avoid loss monitor aborts at collimators (and allow us to close the collimators even narrower)

After moving to beta_y*=2mm, Belle2 was turned ON only at ~300mA.
When L~1.2*10^{34} is achieved with 800mA, BG was x3 higher to turn on Belle2.
Note that we didn't have enough time for collimator optimization with 2mm optics



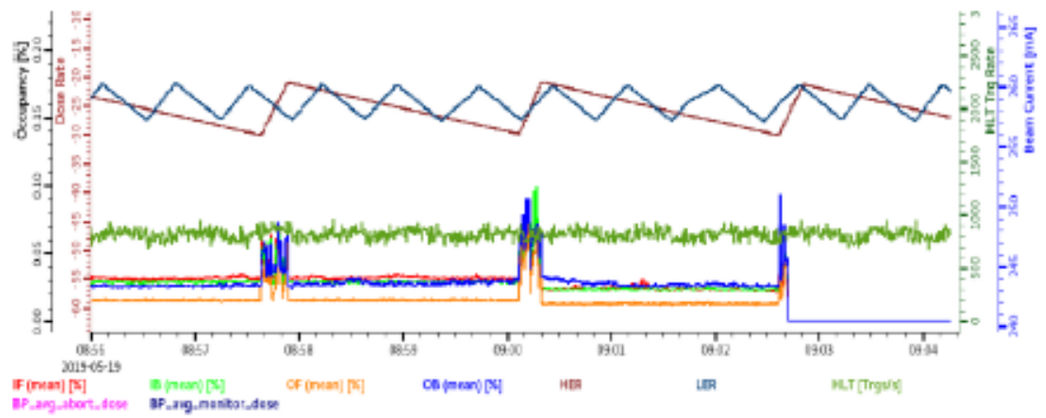


Listen to Nakayama-san's talk !

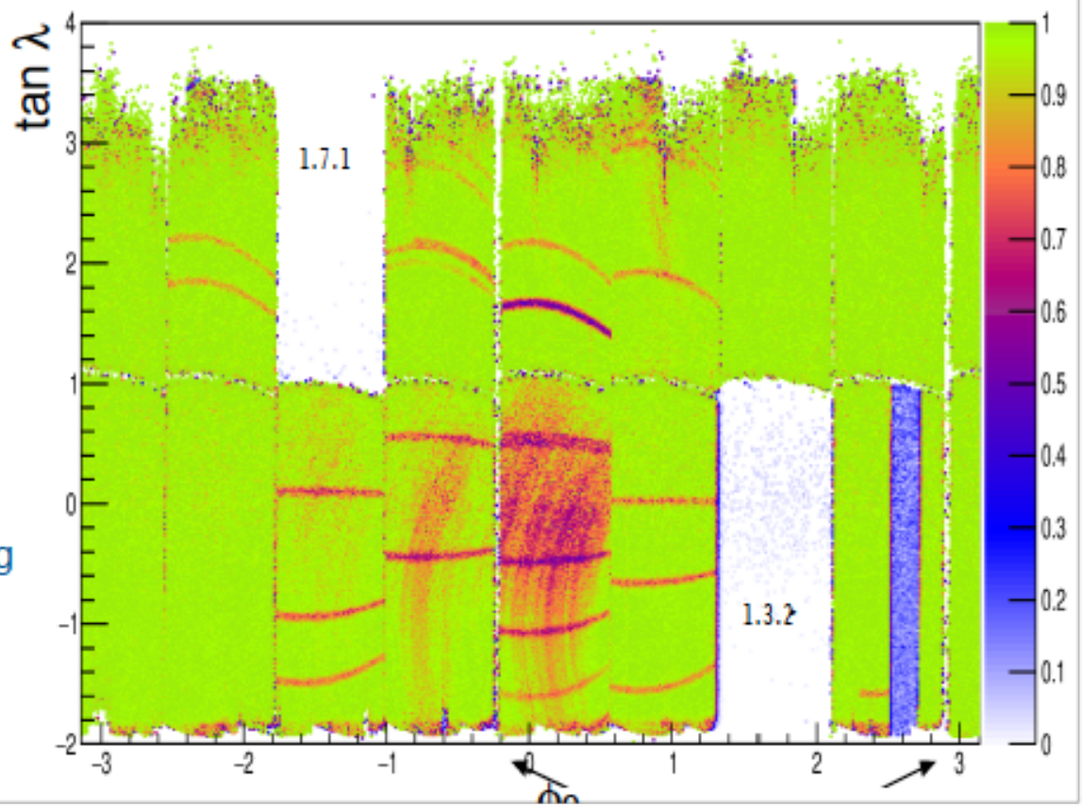
Recent PXD issues (I)

- Data loss during HER continuous injection
  - high occupancy and high rate lead to loss of synchronisation between DHP and DHE
  - lab tests ongoing to find origin of the problem
  - short term mitigation: increased length of veto period
  - mid term solution: Gated mode and/or reset during run => Gated mode tests planned for this week
- Beginning of June lost one (out of four) optical links in module 1042 → check connection in summer
- Severe impact of recent beam incidents
  - 28.5. QCS power supply failure (HER)
    - diamonds saturated ⇒ no estimate of integrated dose
    - 9 modules on +x side affected - since then significantly higher clear currents in all of them
    - combination of TID and latch-up in switcher circuit?
  - 9.6. beam loss due to dust particle (LER)
    - accumulated dose: >3000 mrad in 40μs after abort signal
    - working point of modules shifted further ⇒ needs retuning
    - very high clear current in module 1081 ⇒ presently off
    - many additional noisy or dead gates

PXD data rate drops after loss of synchronisation



PXD L1 efficiency after beam loss on May 28



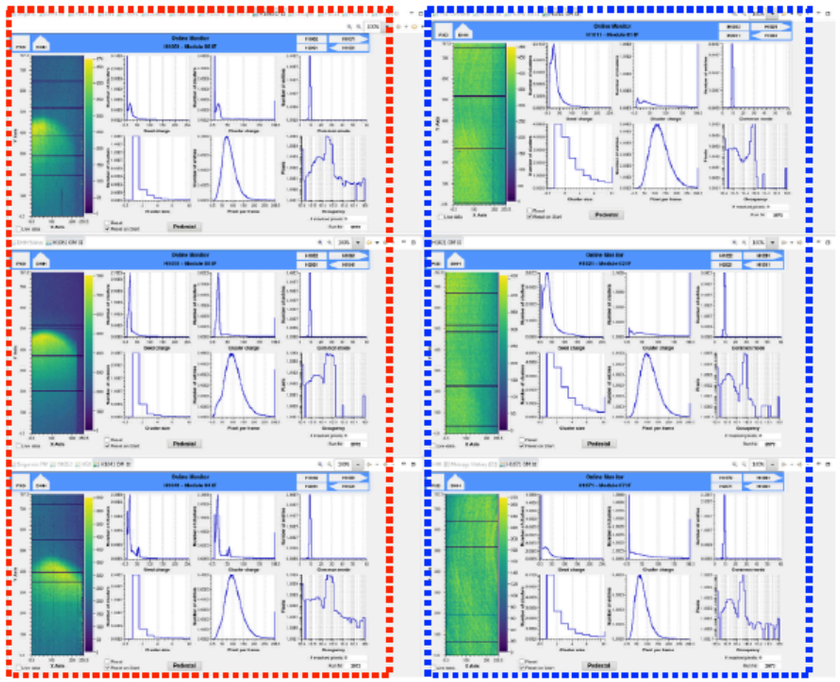
Carsten Niebuhr

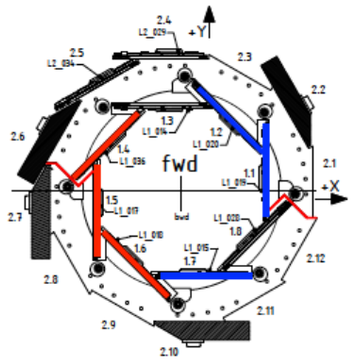
Recent PXD issues (II)

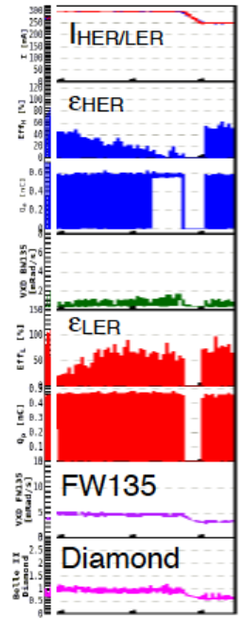
SR background was observed during $\beta_y^* = 2$mm operation

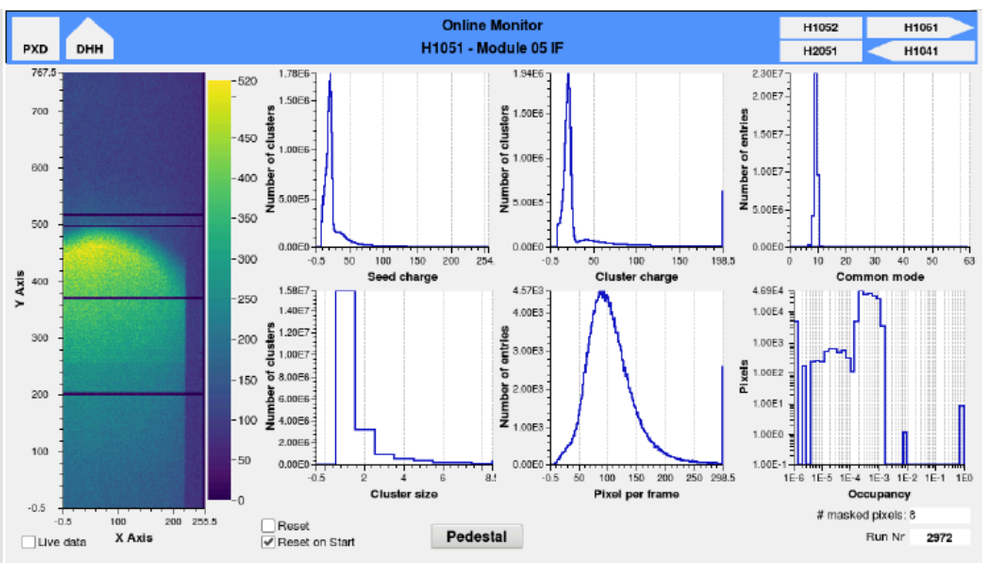
Interlude: Synchrotron Radiation Background on June 23

L1 Forward Modules

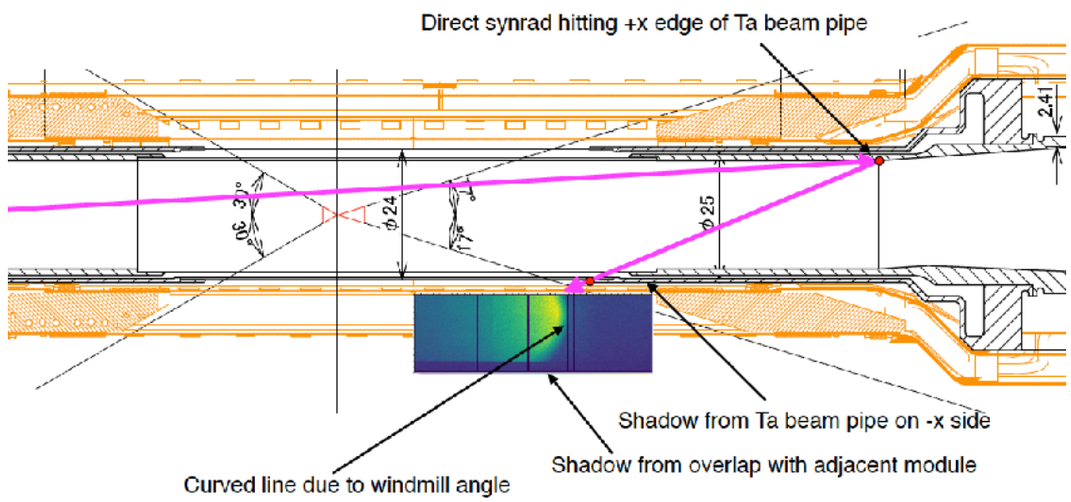








Interlude: Synchrotron Radiation Background on June 23



Physics Targets at LP2019

Goals (5-10 fb^{-1}) for Lepton Photon (August 5-10)

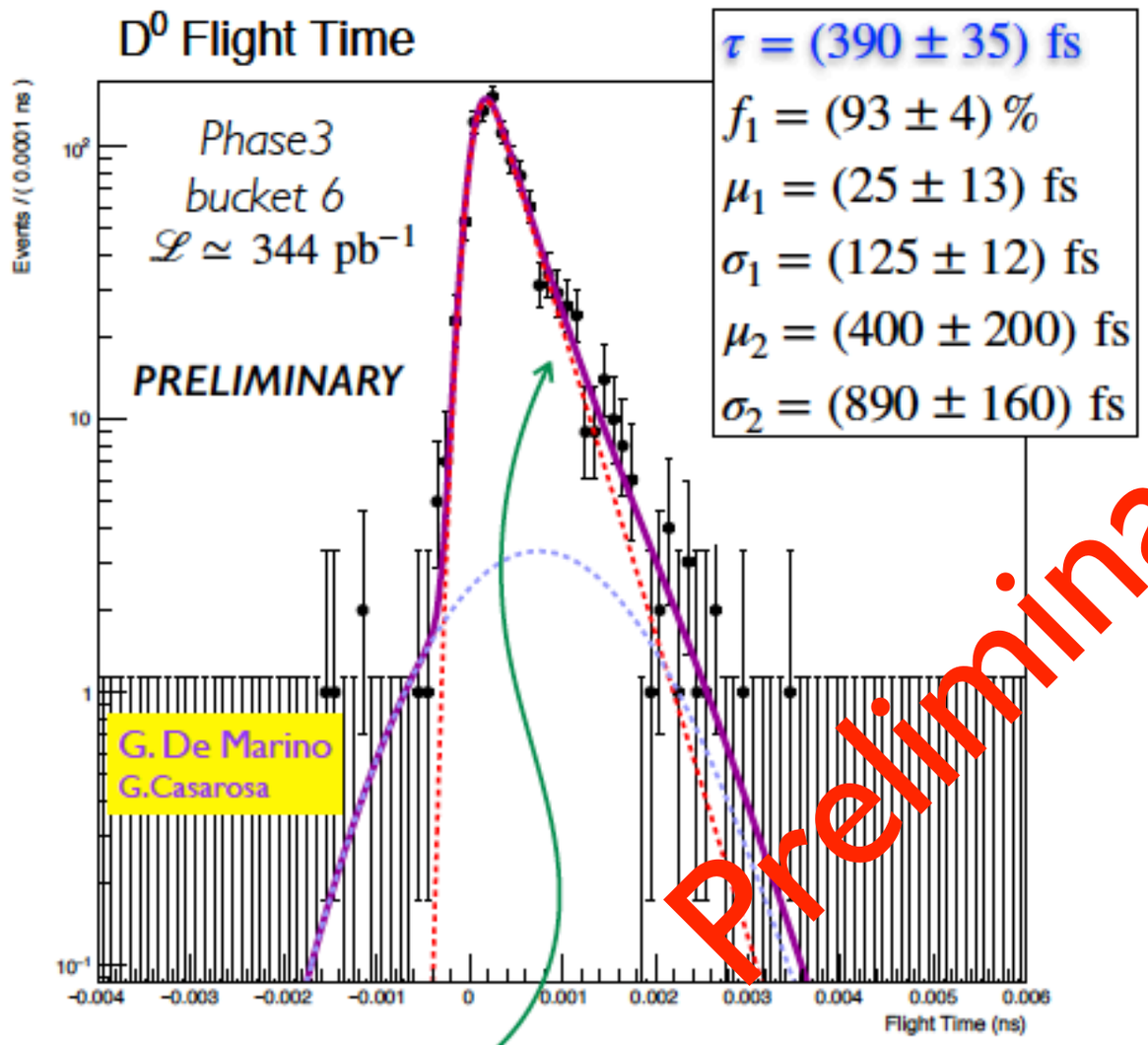
- **Physics analyses & rediscovery targets.**
  - Data analyses presented on almost all topics at this B2GM.

Semileptonic and leptonic	$B \to X\, l\, \nu$ ($B \to X_u\, l\, \nu$ endpoint)
	$B \to D^*\, l\, \nu$
	$B \to \pi\, l\, \nu, \rho\, l\, \nu$
	FEI calibration
EWP	$B \to K^*\, \gamma$
	$B \to X_s\, \gamma$ ΣExclusives
TDCPV	Mixing time independent
	B lifetimes and time dependent mixing
	$B \to J/\psi\, X$
B→Charm(less) hadronic	$B \to D^{(*)}\pi^{\pm}/\rho/K$
	$B \to K\pi$
Charm	D lifetimes
	CF & CS hadronic, DCS hadronic, Baryons
T (observation)	Mass in 1P3P, BR of 1P and 3P decays
T (new searches)	$\tau \to \alpha\, l$
	$\nu\tau$ mass limit / heavy ν
Dark/Low multiplicity	$ee \to \mu\mu Z'$(invisible)
	$ee \to \gamma a'(\gamma\gamma)$
	$ee \to \gamma A'$(invisible)
	$ee \to e\mu Z'$(invisible)

- **Performance with benchmark modes.**
  - Sizeable yields of **J/ψ, D*** accumulated.
  - Efficiency & resolution characterisation needed timely for phase 3 physics: particularly BR and lifetime studies.

Tracking	Efficiencies with $ee \to \tau\tau$, $ee(\gamma)$
	IP studies with 2-track events
Neutrals	Efficiencies and resolution with $ee \to \mu\mu(\gamma)$
	π^0, η resolutions
Hadron ID	K/π separation with $D^* \to D^0(K\pi)\,\pi$
	p/π separation with $\Lambda \to p\pi$
Lepton ID	e/π separation with $ee \to llee$, $ee \to ee(\gamma)$, $J/\psi \to ee$, $K_S \to \pi\pi$
	μ/π separation with $ee \to llee$, $ee \to \mu\mu(\gamma)$, $J/\psi \to ee$, $ee \to \tau(1P)\tau(hhh\nu)$
Trigger	Efficiencies with $ee \to \tau\tau$
	Efficiencies with $ee \to ee(\gamma)$, $\mu\mu(\gamma)$
Combined	Mass, Vertex resolutions, Yields of narrow resonances
Luminosity	$ee \to ee(\gamma)$, $\gamma\gamma(\gamma)$

First Evidence of the D^0 lifetime



$\tau = (390 \pm 35)$ fs
$f_1 = (93 \pm 4)\,\%$
$\mu_1 = (25 \pm 13)$ fs
$\sigma_1 = (125 \pm 12)$ fs
$\mu_2 = (400 \pm 200)$ fs
$\sigma_2 = (890 \pm 160)$ fs

clear exponential decay confirming the excellent resolution achieved with the Belle II VXD!

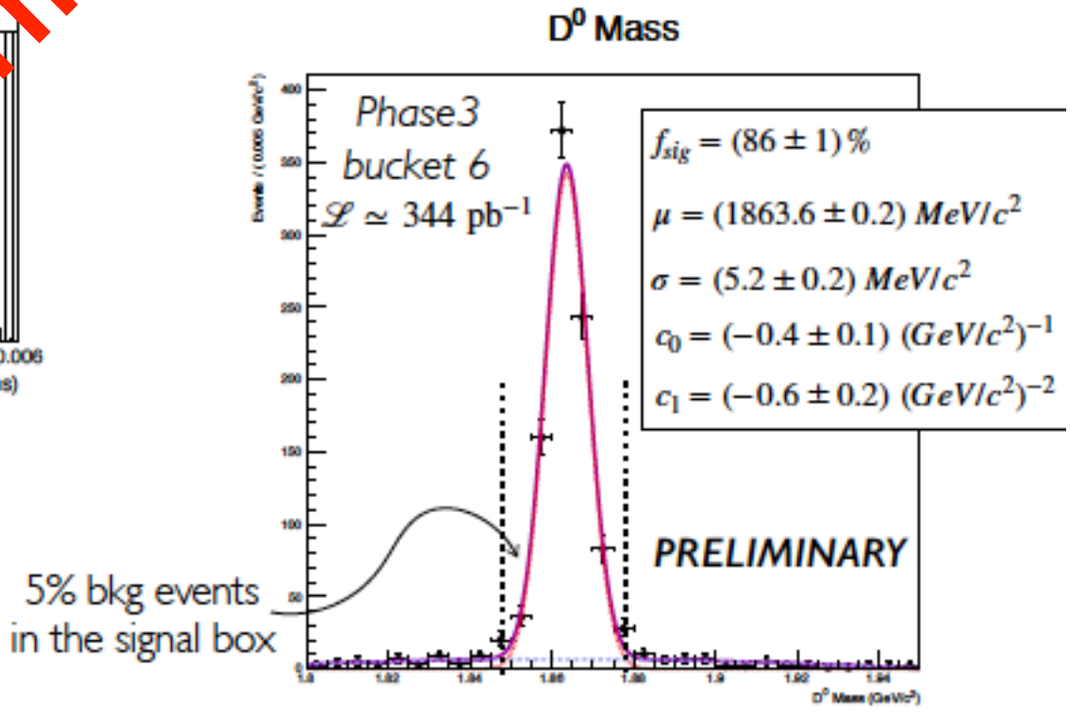
$\tau_{PDG} = (410.1 \pm 1.5)$ fs

*) *PR under review to allow the IP constraint on data*

$D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+$

- *D^* calibration monitoring skim*
- *tracks from IP*
- *PID > 0.2 for D^0 daughters*
- *at least one PXD hit on both D^0 daughters*
- *$p_{CM}(D^*) > 2.5$ GeV/c²*
- *TreeFitter with measured IP(*) and $m(D^0)$ constraints*
- *signal region:* $m_{D^0} \in [1.848, 1.878]\ GeV/c^2$, $Q \in [4.54, 7.18]\ MeV/c^2$

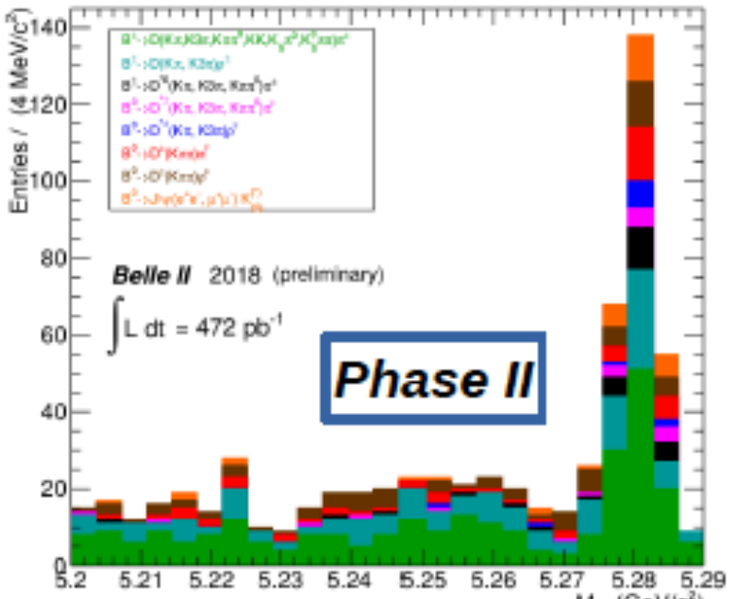
Preliminary!

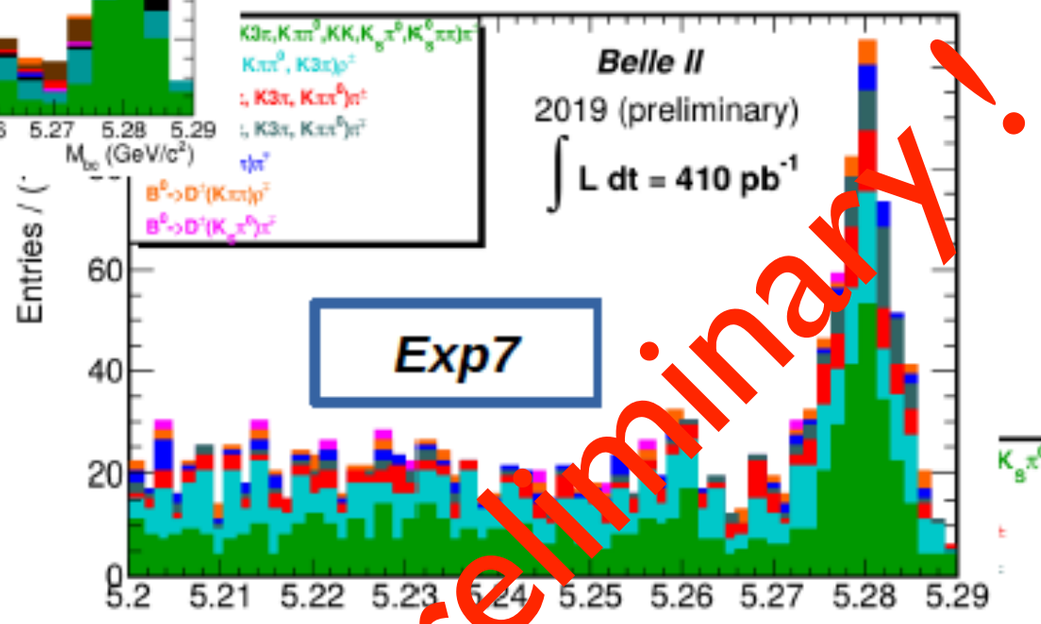


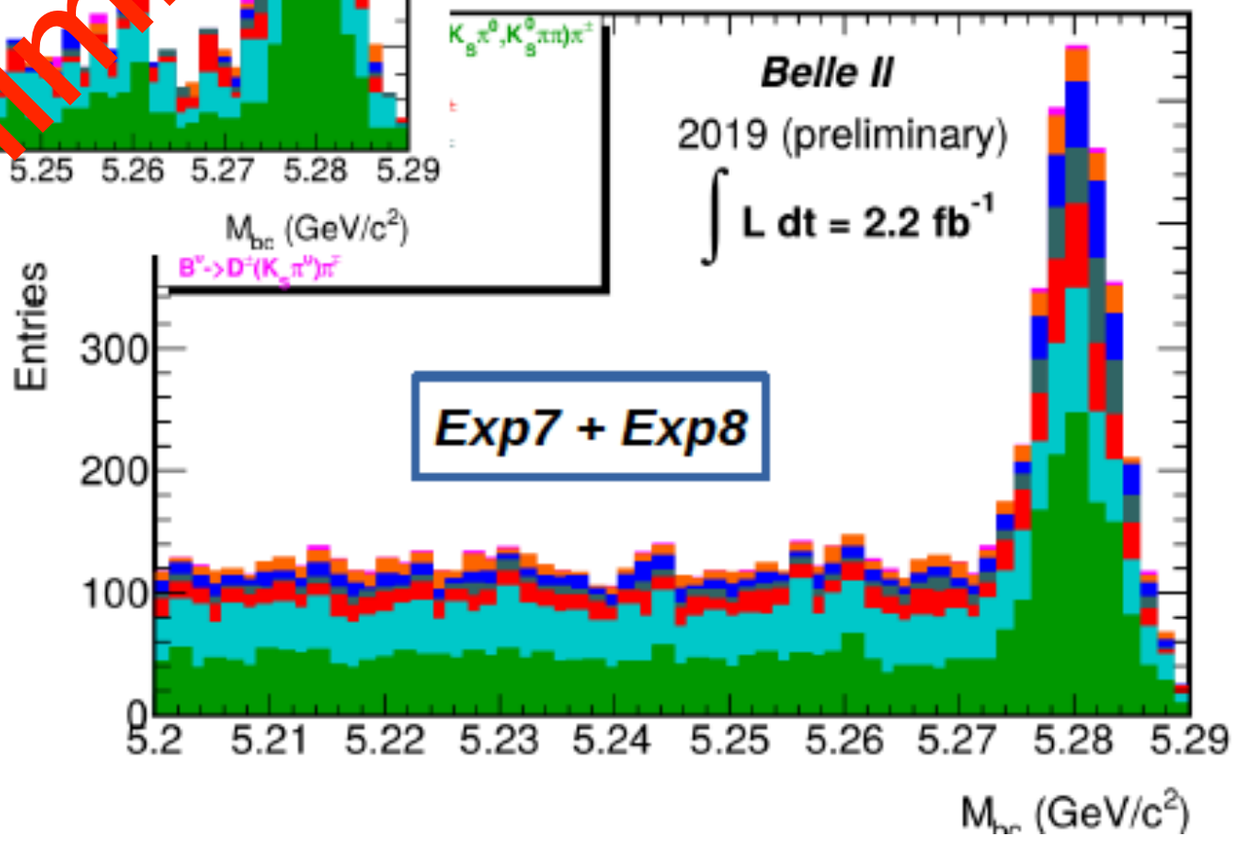
Guilia Casarosa, Gaetano de Marino

$B \to D^{(*)}h$

N. Rout, E. Ganiev

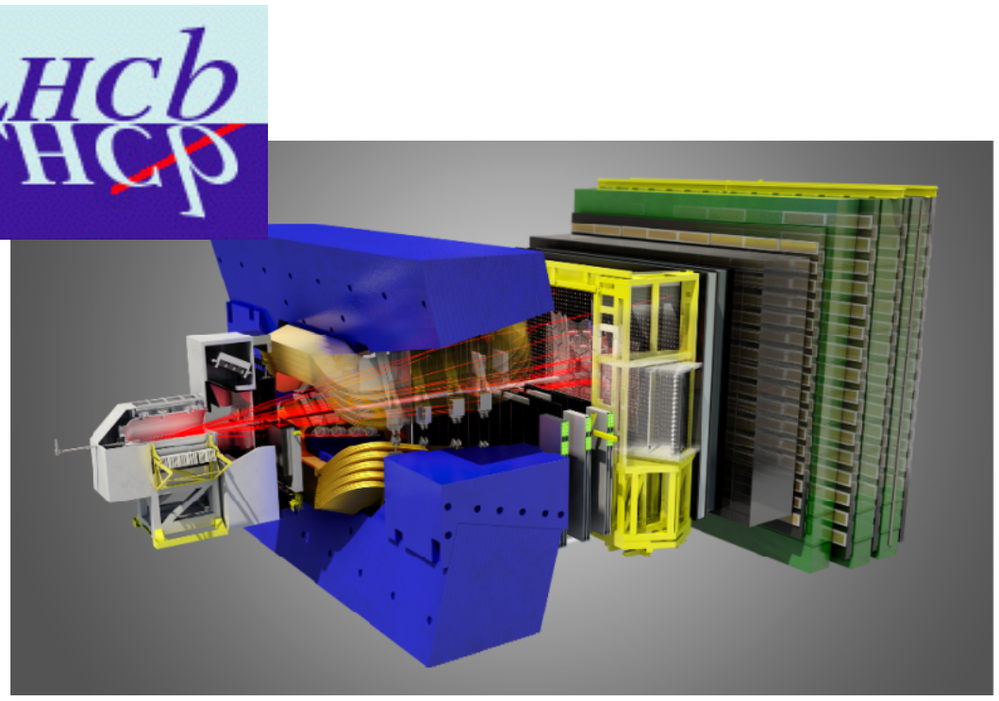


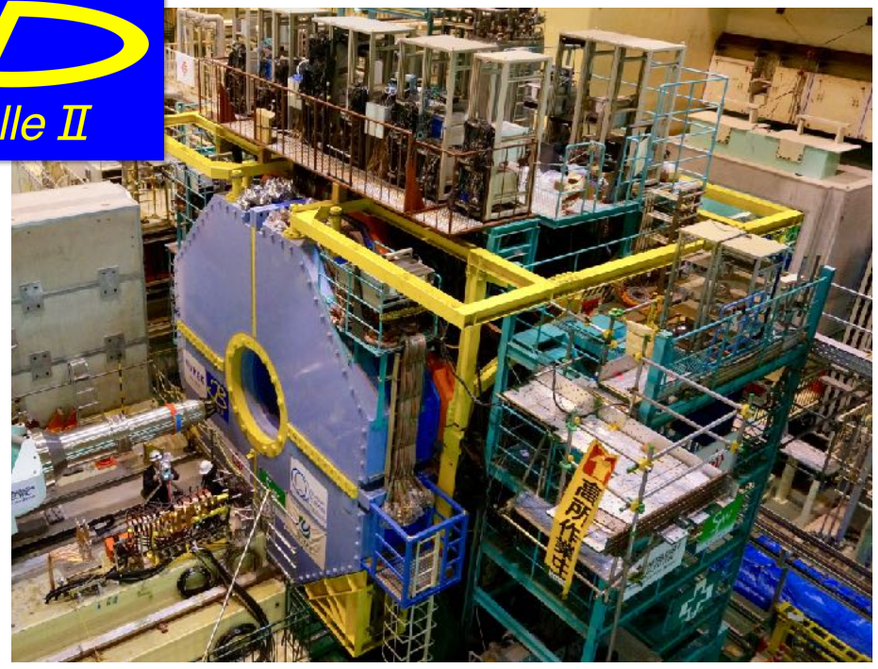




Toward 2020, 2021

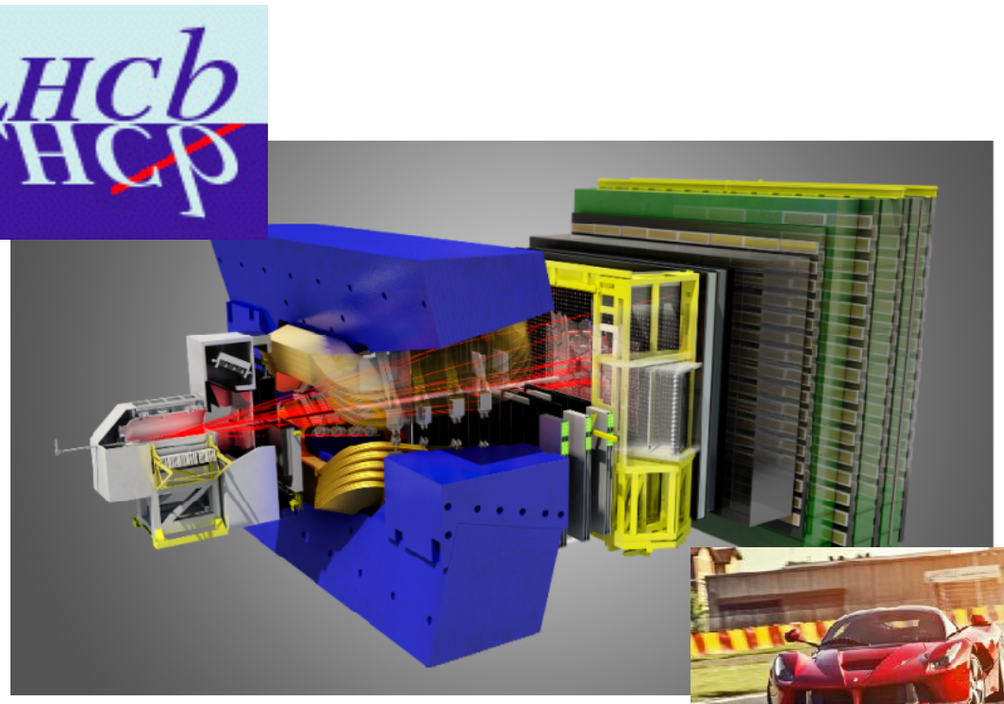
Competition with LHCb will be tough !

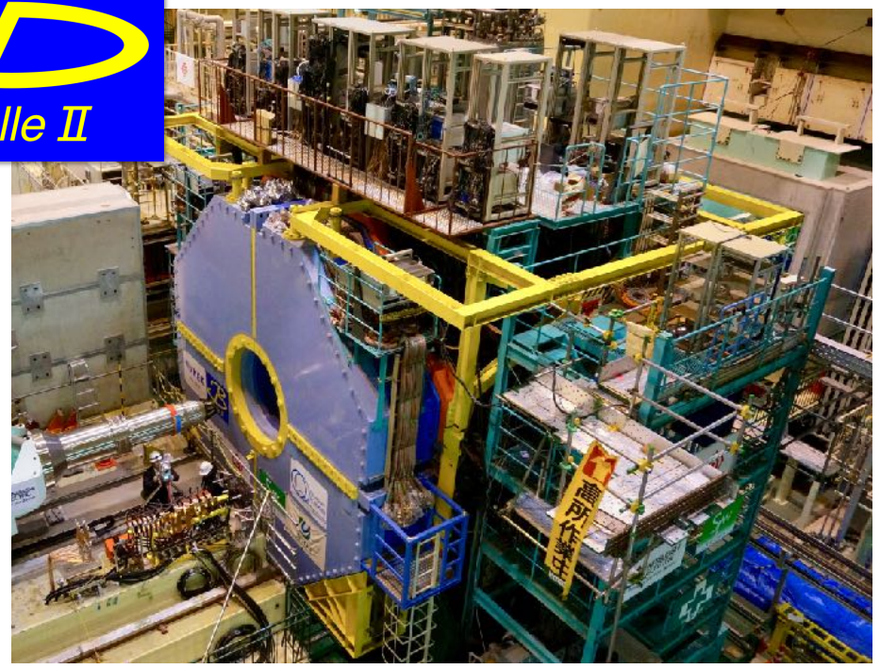




Toward 2020, 2021

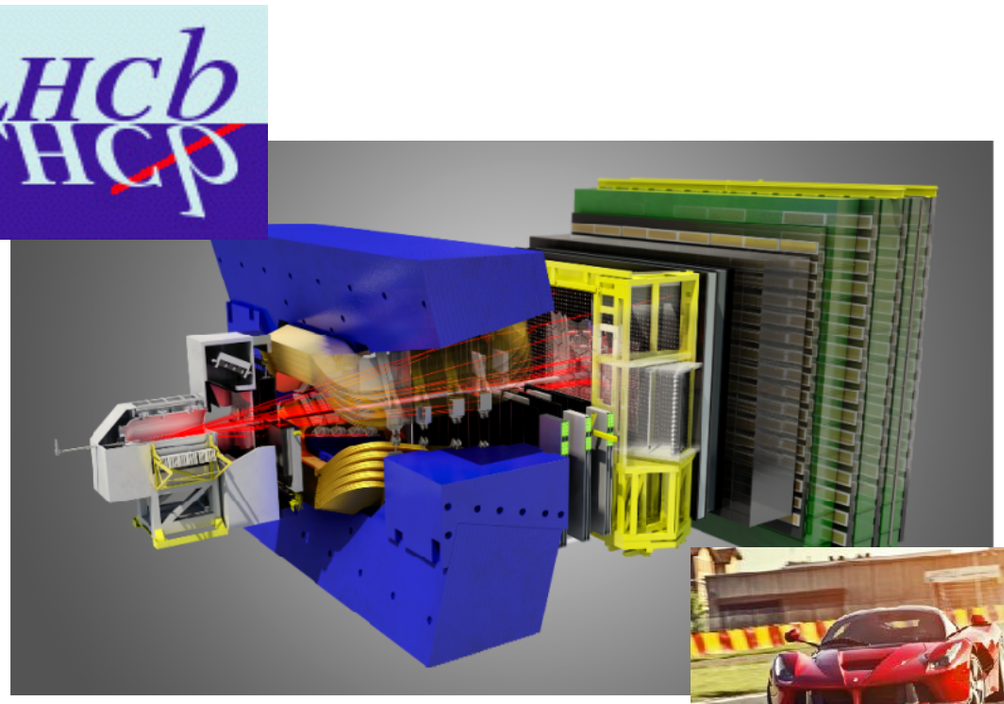
Competition with LHCb will be tough !

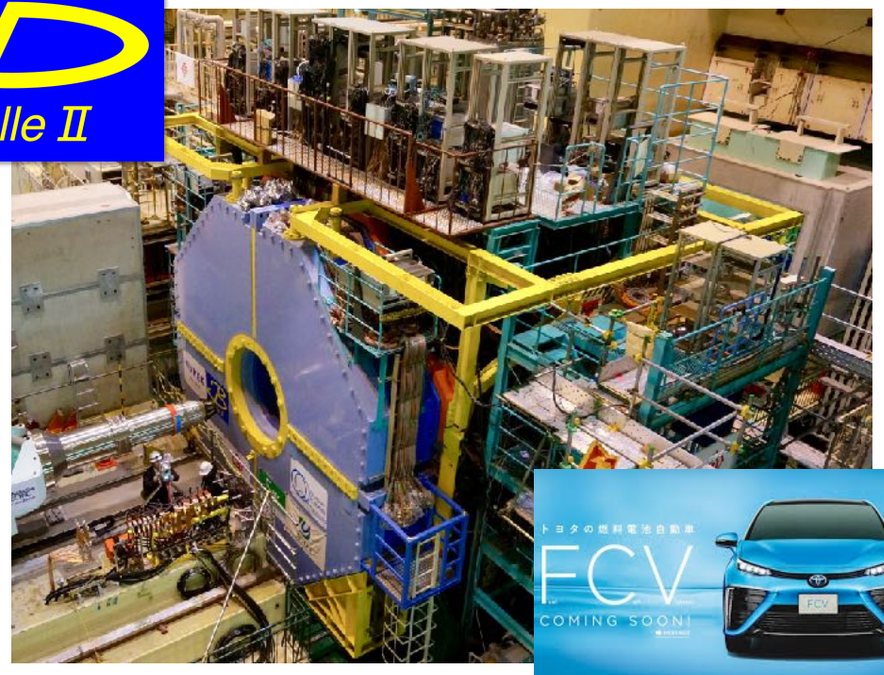




Toward 2020, 2021

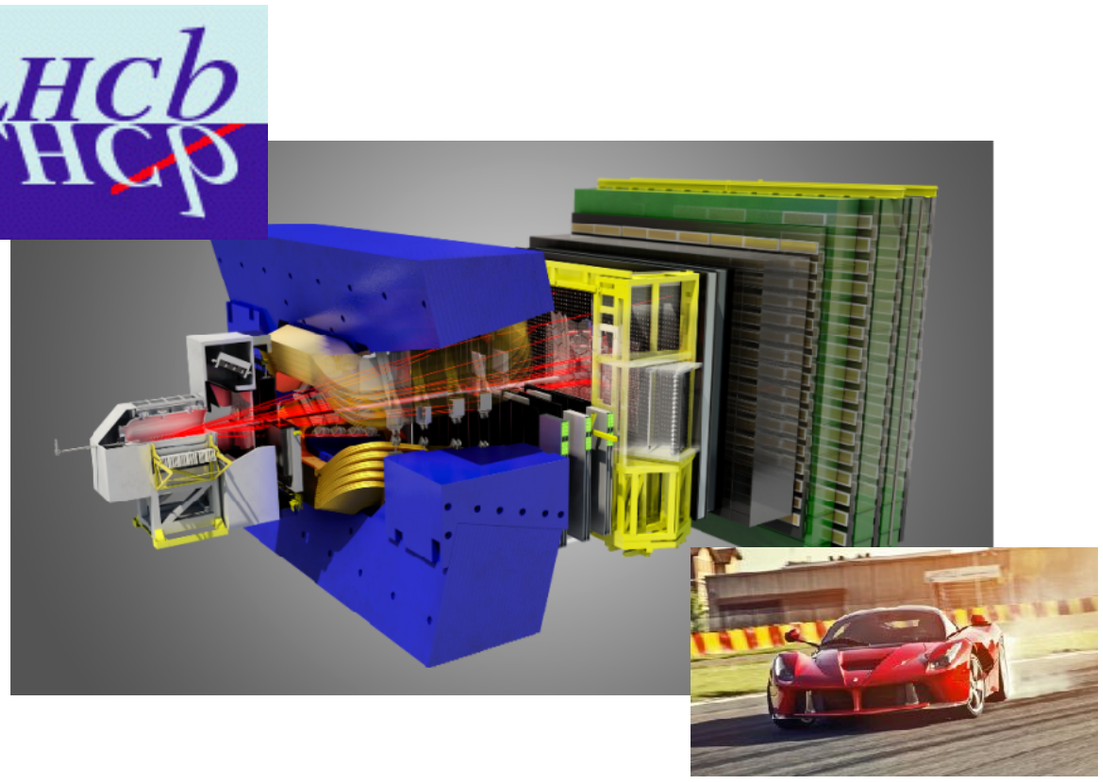
Competition with LHCb will be tough !





Toward 2020, 2021

Competition with LHCb will be tough !

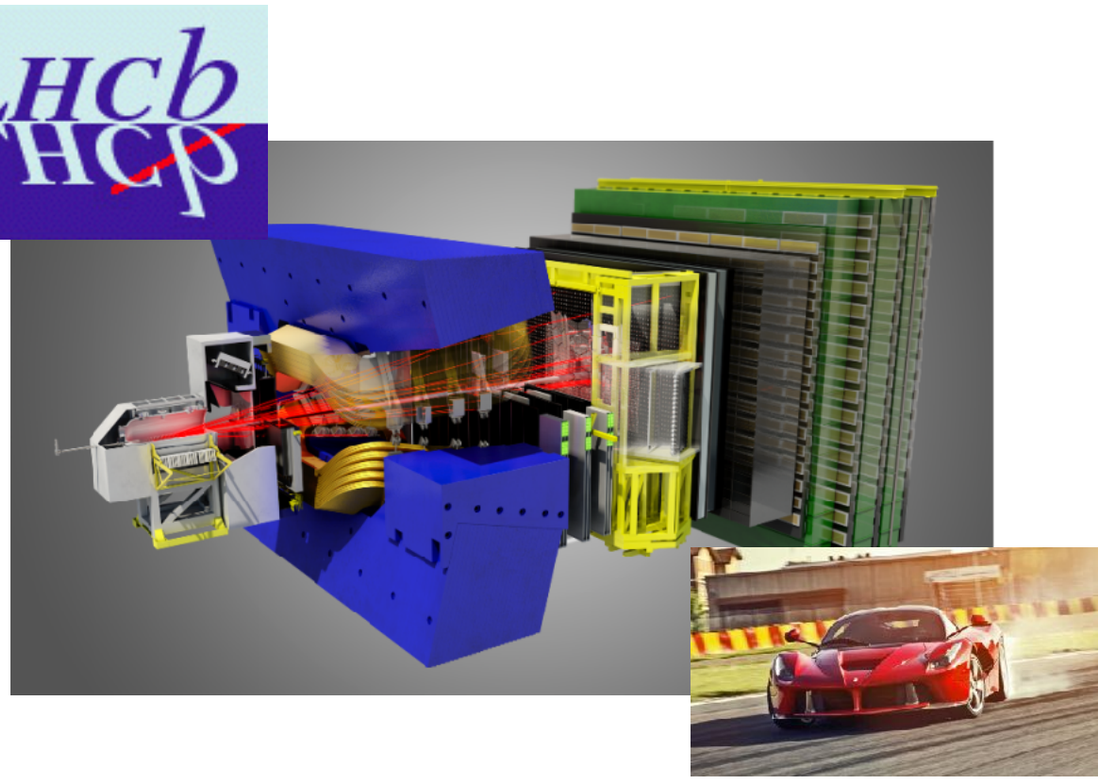


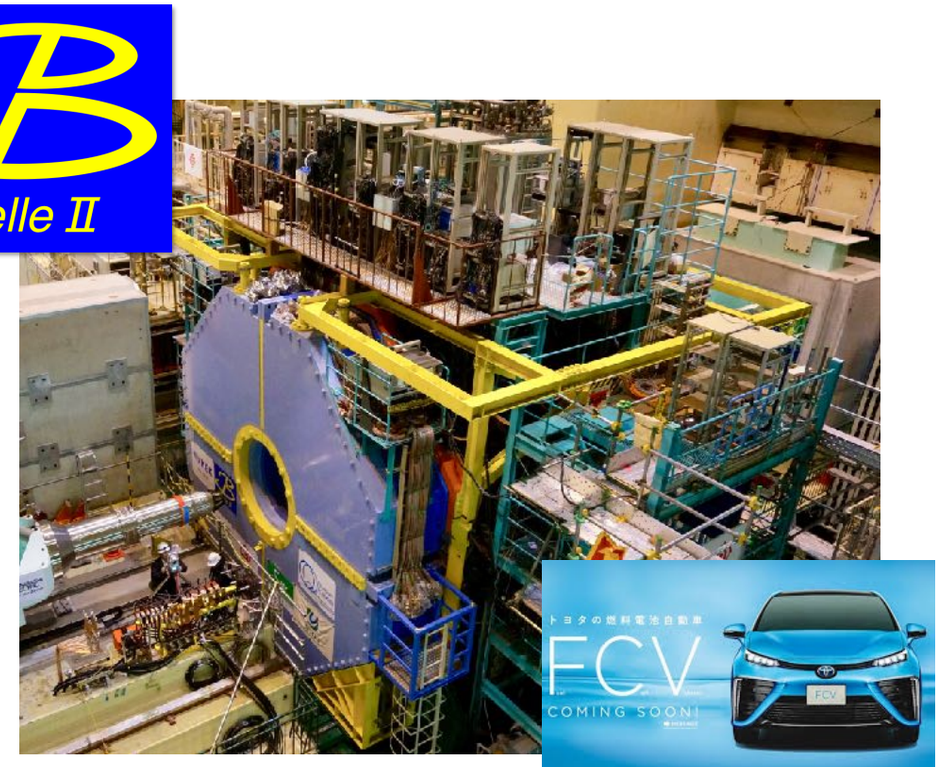
Before they resume in 2021, we want

- demonstrate performance (quality) of Belle II $\gtrapprox$ Belle
- catch up LHCb (and also Belle, BaBar)

Toward 2020, 2021

Competition with LHCb will be tough !





Before they resume in 2021, we want

- demonstrate performance (quality) of Belle II $\gtrapprox$ Belle
- catch up LHCb (and also Belle, BaBar)

We want 200 - 400 fb^{-1} by 2020 summer

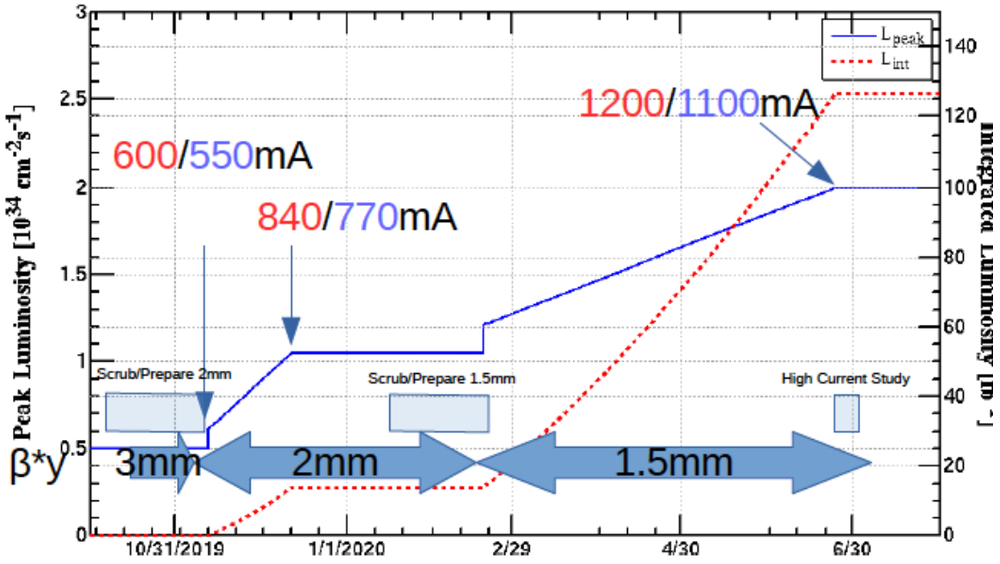
Luminosity Projection

Shown by Morita-san at B2GM

ASSUMPTIONS
(*risky* ⟺ *realistic*)

- Integral Efficiency (~65%)
  - Integration Time Efficiency ~90%
    - 8H maintenance & 4H startup / 2weeks
    - 12H linac study / week
  - SuperKEKB Availability 85%
  - Belle2 Availability 85%
    - Availability @ 2019-06-02 is 89.6%.
- Luminosity Performance
  - Baseline: 0.5 x 10^{34} @ 600/550mA(n_b=1576, β*y=3mm)
  - No beam-beam parameter improvement
  - β*y staging: 2mm @ 2019-11 → 1.5mm @ 2020-02
  - Improvement by squeezing β*y: 1/√β*y → 1/β*y during operation period
    - Assuming detector background independence with β*y.
  - Beam current limit improvement: x√2 @ 2019-12-12 → x2 @ 2020-06-24
    - Assuming factor 2 improvement of CDC current limit until next summer.
    - Assuming no current limit for protecting detector.
- Machine Study
  - ***No future beam development time is counted.***

Integral Luminosity
13.9 fb^{-1} (2019-10 ~ 2019-12)
112.8 fb^{-1} (2020-01 ~ 2020-07)



Note: L=1.2x$10^{34}$$cm^{-2}s^{-1}$
@ βy* = 2mm
already (w/o Belle II)

Can we have more aggressive plan ?

Assumption

- No machine study time for future beam development

- Detector background independent of βy*
- x2 improvement of CDC current limit
- No current limit for protecting detector

Need continuous efforts to reduce background on Belle II side.

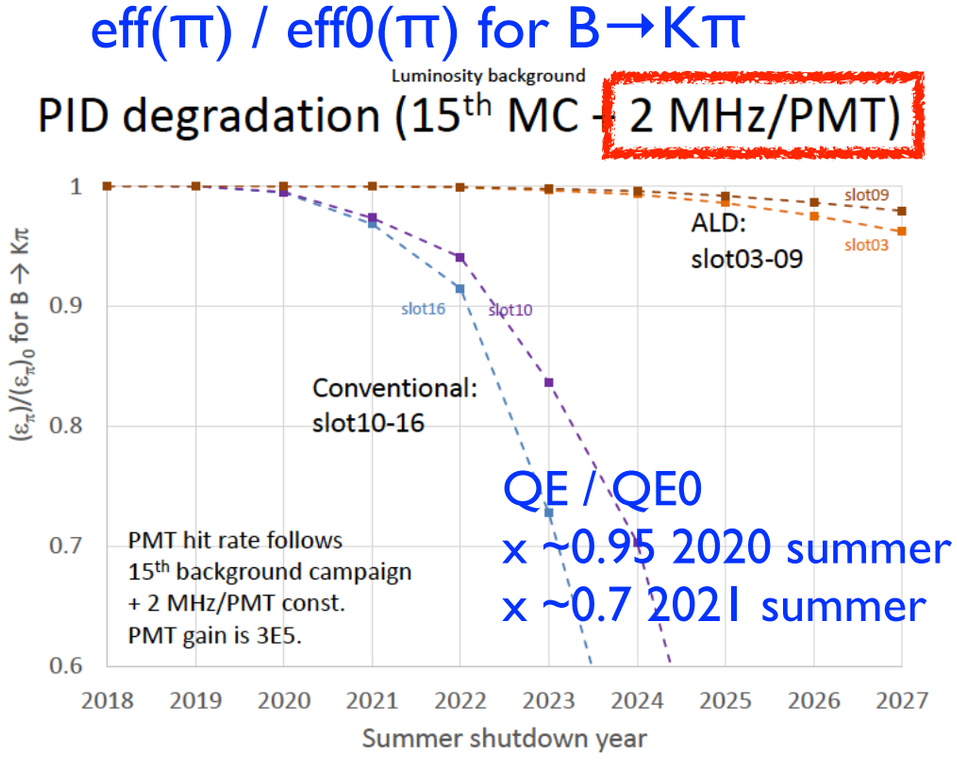
Belle II work in 2020 or 2021

- Installation of full PXD
- Replacement of TOP "conventional" MCP-PMT
- Required time for replacement:
  - 4 months for TOP MCP-PMT replacement alone.
  - 9 months for PXD replacement and PXD+TOP MCP-PMT
- We preparer detectors as early as possible, and install them as late as possible.
- The earliest possible shutdown in 2021 spring. Decision ti be made in June 2020.

PXD2020 Executive Summary

- PXD2020 preparations
  - sensor production well on track - very good yield
  - improved ladder assembly procedure ⇒ resume L2 assembly as soon as review committee gives green light
  - new switcher SW2.2 not functional ⇒ use existing SW2.1 that were still available from AMS for new L1 modules
  - ⇒ still possible to have L2 and L1 modules ready by the end of this year, but schedule very tight
- Replacing / repairing PXD is a major enterprise
  - cannot afford to do this multiple times (risk to damage something, shutdown length, experts, …)
  - **should only be done once all weak points in the protection system against beam incidents are eliminated**
  - extrapolated performance of present detector under realistic background conditions in 2020/21 still acceptable (as far as we can tell now …)
- ⇒ **Current baseline plan is to replace PXD in 2021**

BPAC, June 2019: PXD/2020 Status 13 carsten.niebuhr@desy.de



In terms of the efficiency (while keeping the fake rate), the replacement could be deferred until 2021 summer in this case.

Summary

- Belle II has started taking data with full detector (except for part of PXD) since March 25, 2019.
- Belle II runs smoothly, although we still need improve for more stable and sustainable running.
- Belle II has accumulated >6 fb^{-1}, which will produce some first physics papers.
- It is essential to improve detector background (CDC and TOP) to ramp up the peak and integrated luminosity.
  - Protection of Belle II against QCS quench etc. is also important.

Tough competition with LHCb

- We are happy to discuss with SuperKEKB colleagues how to optimize the future run plan.

Backup

Belle II work in summer shutdown

Belle II work at IR

	Work item	Remarks
PXD	Cable connector check	FWD/BWD
SVD	Junction box cable/connector check	BWD
TOP	Fiber inspection at slot6	BWD
ECL	Fix noisy channels Improve grounding	BWD
PXD/SVD/ CDC/TOP	Space confirmation for MCP-PMT replacement	BWD

Work around the Belle II detector structure such as KLM VME crate replacement are planned.