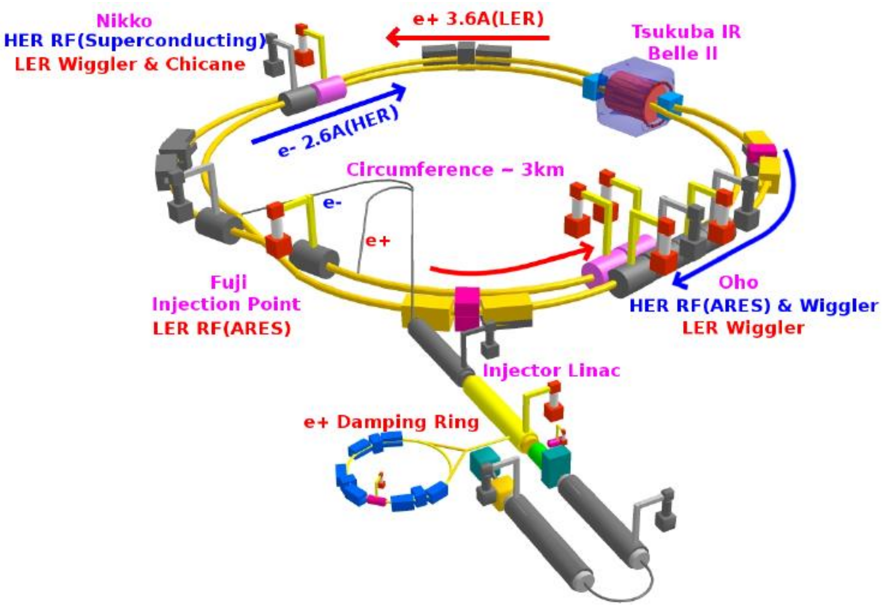
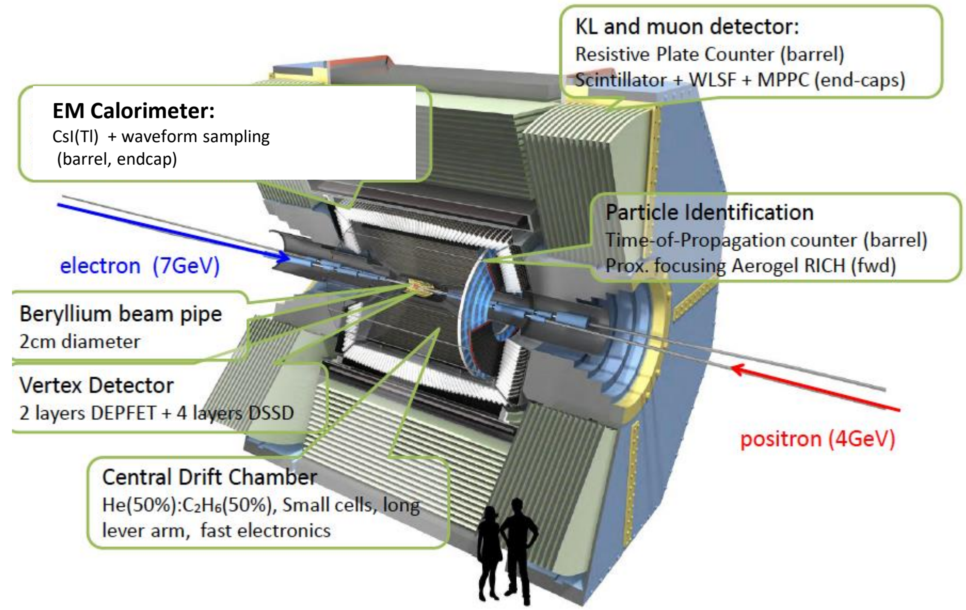
7GeV(e-), 4GeV(e-)





Belle2 beam background simulations and measurements

Hiroyuki Nakayama (KEK), on behalf of SuperKEKB/Belle II collaboration

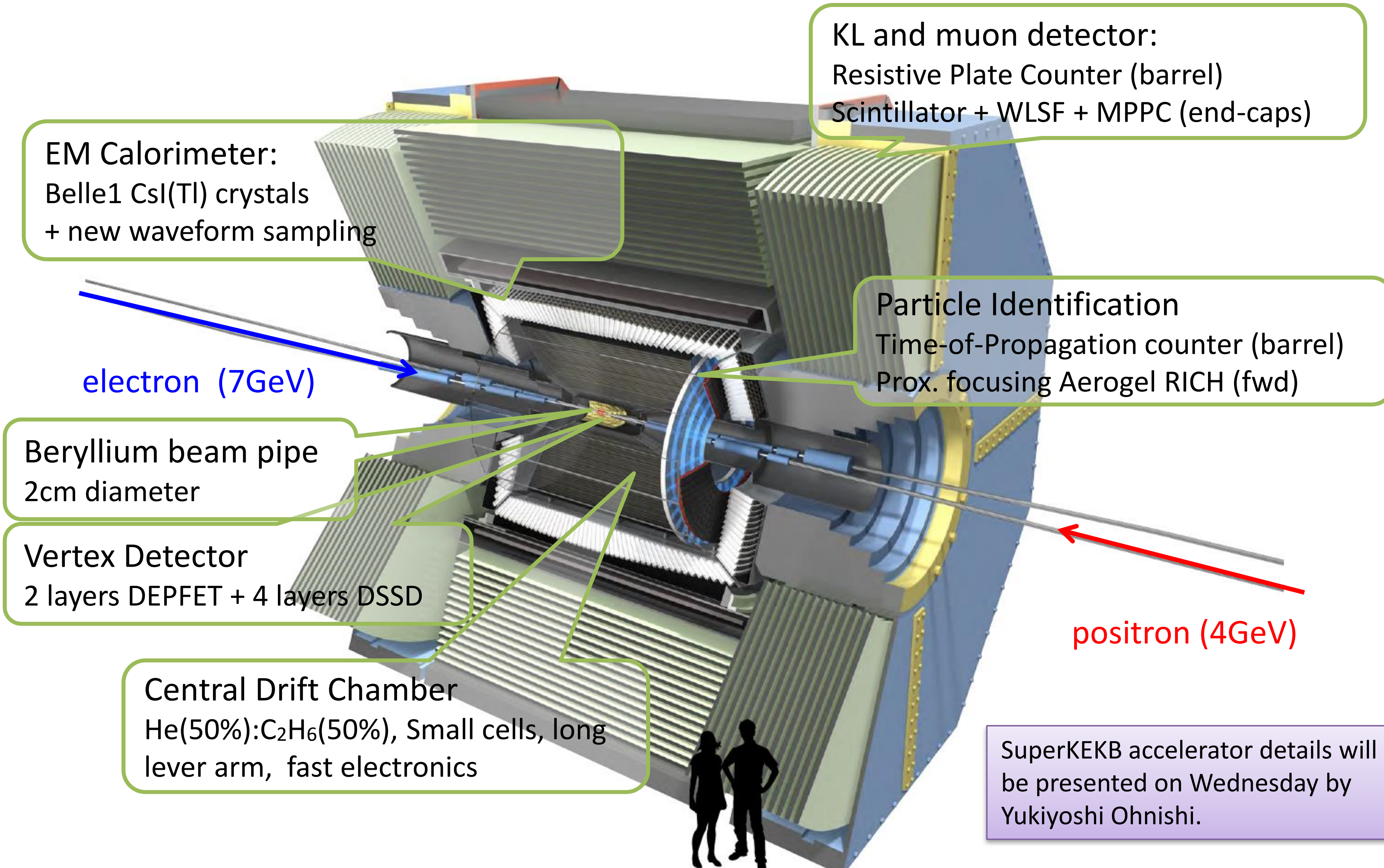
Dec. 4th, 2018
SCTF2018 workshop at LAL

SuperKEKB accelerator talk (by Y. Ohnishi) on Wednesday

Today's Contents

- **Beam background sources at SuperKEKB/Belle II**
  - Touschek scattering/Beam-gas scattering
    - Countermeasures: collimators and shield structures
  - Synchrotron radiation
  - Luminosity-dependent BG (radiative Bhabha, 2-photon process)
  - Background simulation tools
  - Latest numbers of BG rate simulation
- **Background measurement during SuperKEKB "Phase2" run**
  - Beam-size scan studies
  - Synchrotron radiations
  - Luminosity scan study
- **Summary**

Belle II Detector



SuperKEKB accelerator details will be presented on Wednesday by Yukiyoshi Ohnishi.

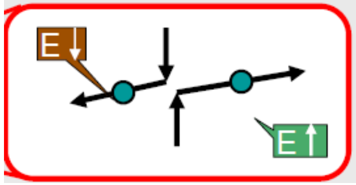
Beam background

- Beam-induced background at SuperKEKB accelerator can be dangerous for Belle II detector
- Beam BG determines survival time of Belle II sensor components and might lead to severe instantaneous damage
- Also increases sensor occupancy and irreducible analysis BG

SuperKEKB Beam BG sources

- *Single-beam BG:* Touschek, Beam-gas Coulomb/Brems, Synchrotron radiation, injection BG
- *Luminosity BG:* Radiative Bhabha, two-photon BG, etc..

1.Touschek scattering

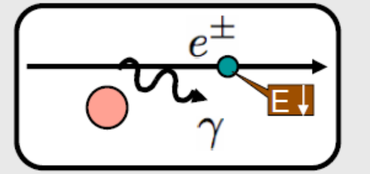


- Intra-bunch scattering : Rate∝(beam size)$^{-1}$,(E_{beam})$^{-3}$
- Touschek lifetime: should be >600sec (required by injector ability)

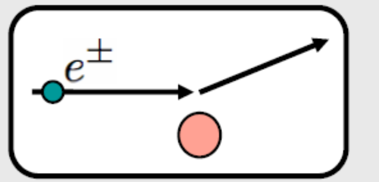
  → total beam loss: 375GHz (LER), 270GHz(HER)
- Horizontal collimators to reduce loss at IR (|s|<4m)
  - collimators added at 0~200m upstream IP are very effective
- Collimator width optimization
  - Initial values: $d_x = Max[d_{x\beta}, d_{x\eta}], \quad d_{x\beta} = n_x\sqrt{\varepsilon_x\beta_x}, \ d_{x\eta} = \eta_x(n_z\sigma_\delta)$
  - Further optimization to balance IR loss and beam lifetime
  - Smaller loss rate on the final collimators (~20m upstream IP) is preferred
- After careful optimization of collimators, simulated beam loss in the detector can be mitigated to few hundred Hz level
  - 3 orders of magnitude smaller than the loss without any collimators

2.Beam-gas scattering

Brems



Coulomb



- Scattering by remaining gas, Rate ∝ IxP
- Due to smaller beam pipe aperture and larger maximum βy, beam-gas Coulomb scattering could be more dangerous than in KEKB

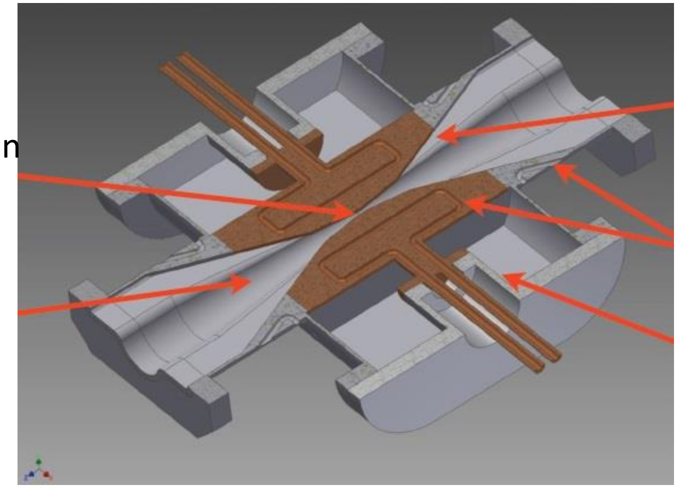
$$\frac{1}{\tau_R} = c n_G \langle \sigma_R \rangle = c n_G \frac{4\pi \sum Z^2 {r_e}^2}{\gamma^2} \left\langle \frac{1}{{\theta_c}^2} \right\rangle$$

	KEKB LER	SuperKEKB LER
QC1 beam pipe radius: r_{QC1}	35mm	***13.5mm***
Max. vertical beta (in QC1): $\beta_{y,QC1}$	600m	2900m
Averaged vertical beta: $<\beta_y>$	23m	50m
Min. scattering angle: θ_c	0.3mrad	0.036mrad
Beam-gas Coulomb lifetime	>10 hours	35 min

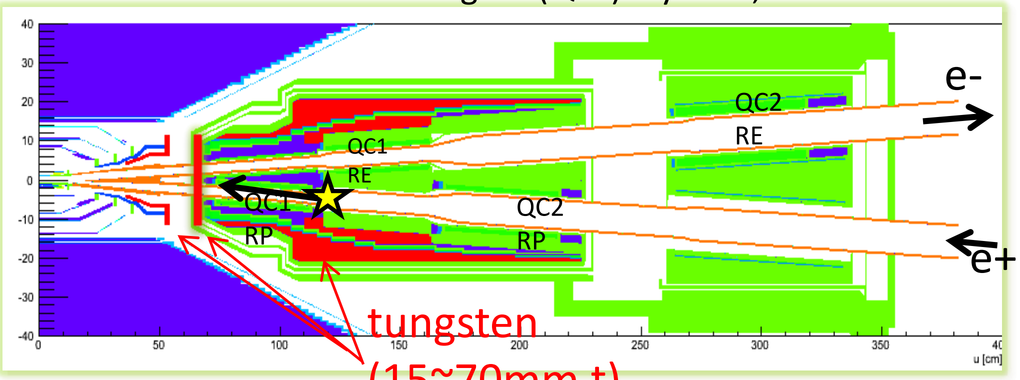
How to cope with beam BG?

- Movable collimators
  - Arc collimators and horizontal collimators near IP
  - Very narrow (d~2mm) vertical collimators
- Shielding structures
  - Thick tungsten structures inside Final Focus cryostat and vertex detector volume
  - Stops showers from beam loss "hot spot", at ~1m upstream from IP
  - Polyethylene shield to reduce neutrons

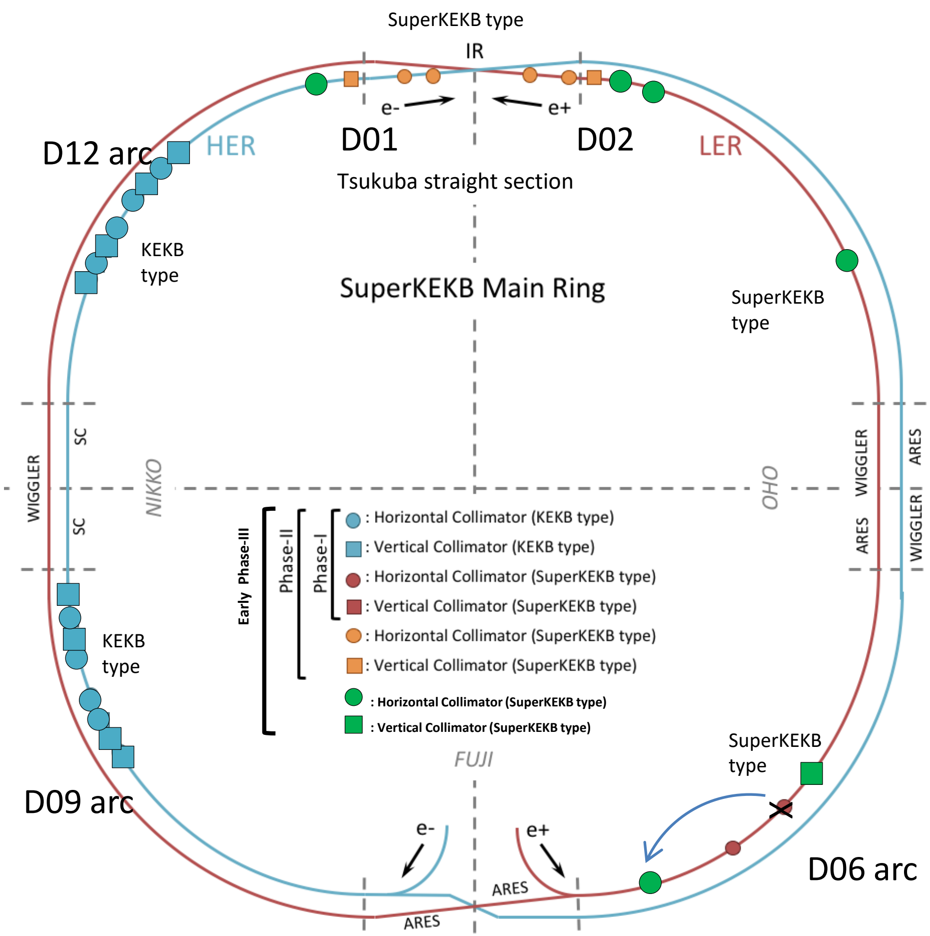
SuperKEKB horizontal collimator



Final focus magnet (QCS) cryostat, R-side



SuperKEKB Collimators



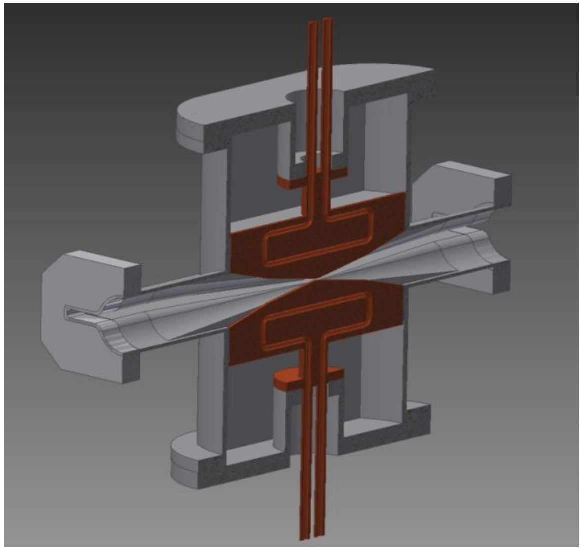
(*) D06H4 is moved to D06H1

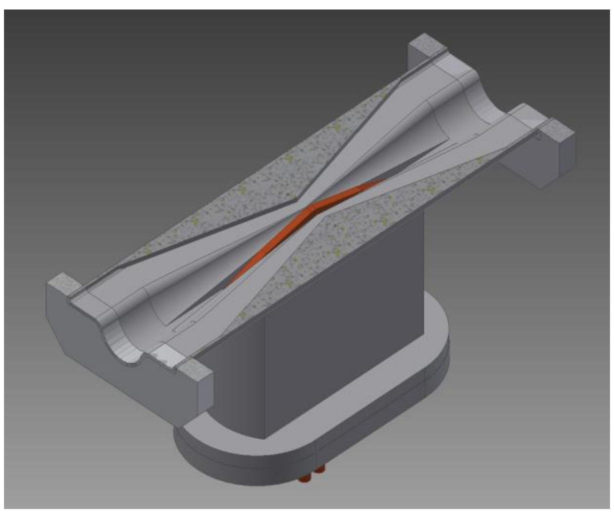
29 movable collimators in total (6 are being added after phase2, shown in green)

LER(9):
- 7 horizontal, 2 vertical “SuperKEKB type” collimators
  - horizontal: D06H1, D06H3, ~~D06H4(*)~~, D03H1 D02H1, D02H2, D02H3, D02H4
  - vertical: D06V2, D02V1

HER(20):
- 3 horizontal, 1 vertical “SuperKEKB type” collimators
  - horizontal: D01H3, D01H4, D1H5
  - vertical: D02V1
- 8 horizontal, 8 vertical “KEKB type” collimators
  - horizontal: D12{H1,H2,H3,H4},D09{H1,H2,H3,H4}
  - vertical: D12{V1, V2, V3, V4},D09{V1,V2,V3,V4}

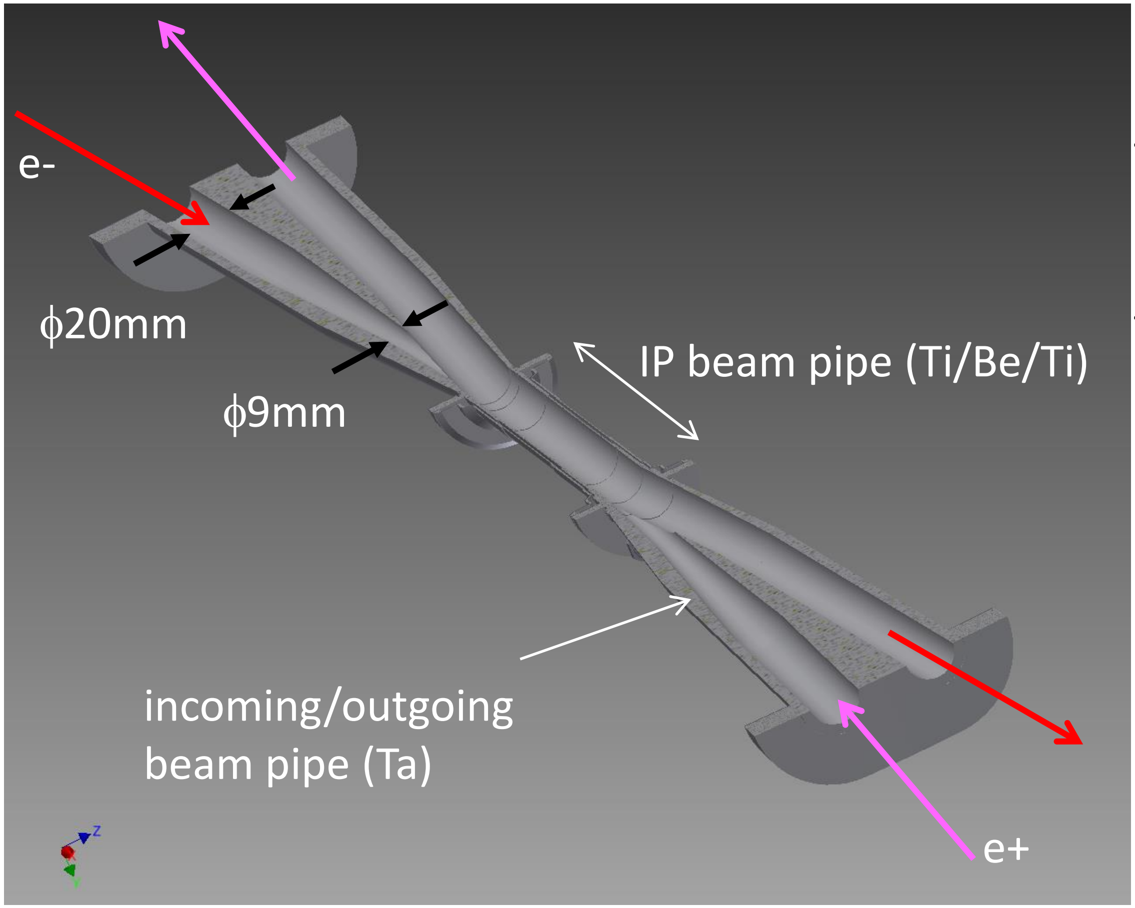
Vertical Collimators





- To reduce IR loss of beam-gas Coulomb BG, very narrow (~2mm half width) vertical collimator at βy=~100m is required
- TMC instability is an issue, low-impedance design of collimator head is important
- Only one collimator per ring, so precise (~50um) control of collimator width is important (otherwise IR loss rapidly increases)
- Should withstand ~100GHz loss (tungsten)
- Secondary shower (tip-scattering) study is important

3. Synchrotron radiation



Inner surface of Be pipe is coated with Au layer (10um)

- ϕ20mm→ϕ9mm collimation on incoming beam pipes (no collimation on outgoing pipes, HOM can escape from outgoing beam pipe)

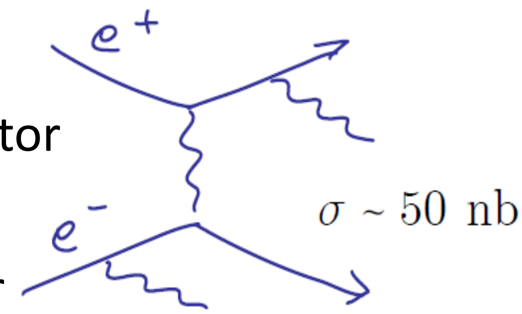
- Most of SR photons are stopped by the collimation on incoming pipe.
- Direct hits on IP beam pipe is negligible

- To hide IP beam pipe from reflected SR, "ridge" structure on inner surface of collimation part.

4. Luminosity-dependent background

Radiative Bhabha scattering

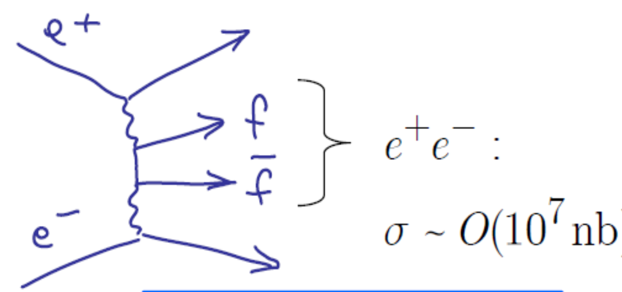
- Rate ∝ Luminosity (KEKBx40)
- Spent e+/e- with large ΔE could be lost inside detector (see next page)
- Emitted γ hit downstream magnet outside detector and generate neutrons via giant-dipole resonance



Bhabha scattering

2-photon process

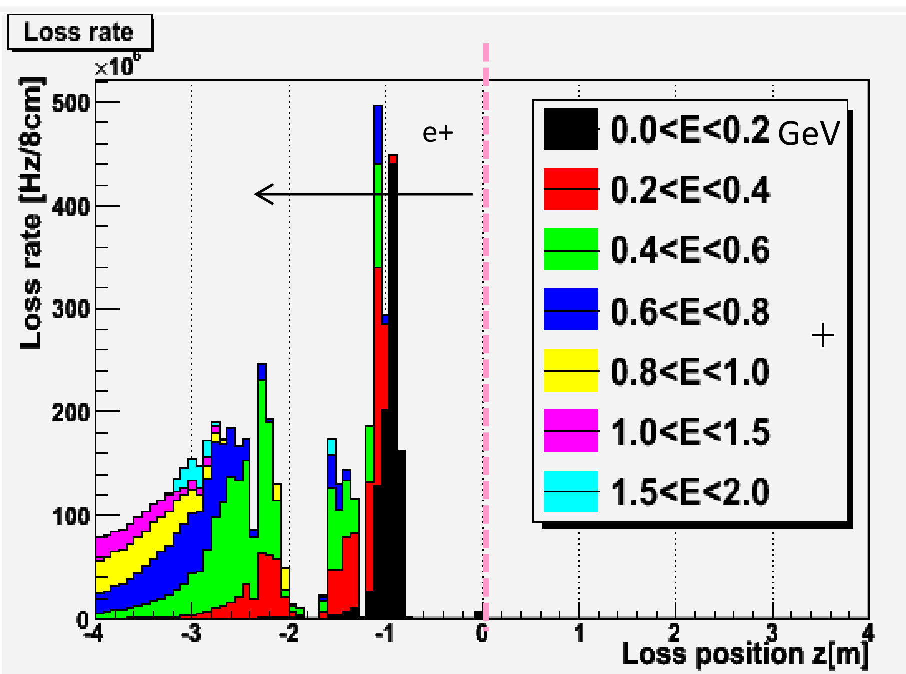
- Rate ∝ Luminosity (KEKBx40)
- e+ e- → e+ e- e+ e-
- Emitted e+e- pair curls by solenoid and might hit inner detectors multiple times



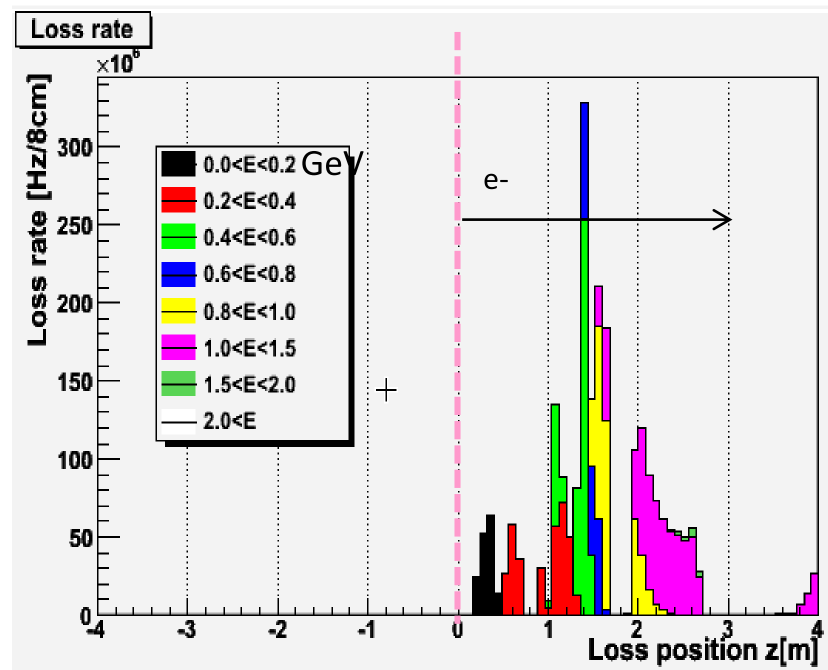
2-photon-processes

Spent e+/e- loss position after RBB scattering

LER(orig. 4GeV)



HER(orig. 7GeV)



If ΔE is large and e+/e- energy becomes <2GeV, they can be lost inside the detector (<4m from IP), due to kick by the 1.5T detector solenoid with large crossing angle(41.5mrad)

Background simulation tools

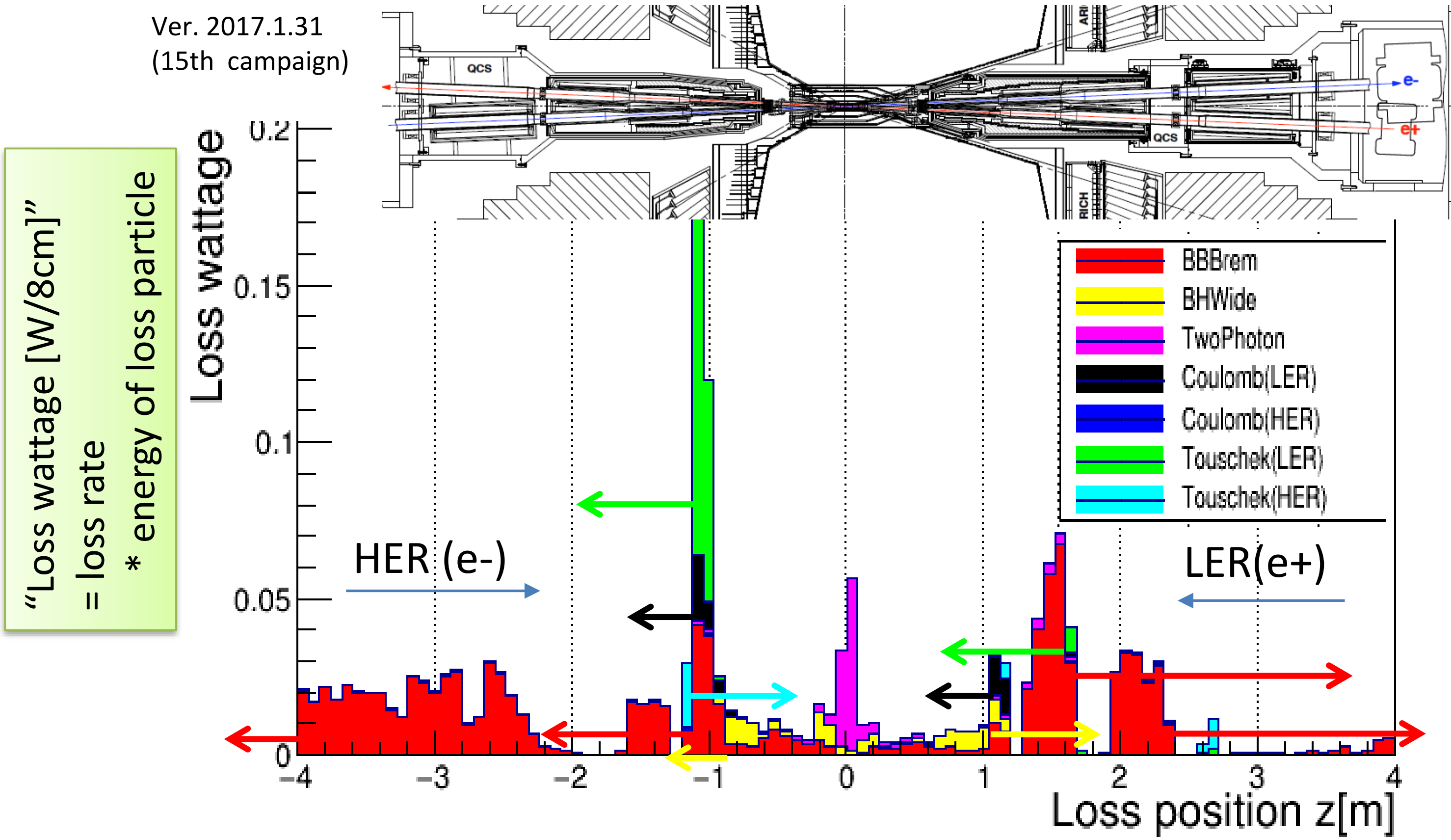
- Use SAD for multi-turn tracking in the entire rings
- Use GEANT4 for single-turn tracking within detector and full simulation

BG type	BG generator	Tracking (till hitting beam pipe)	Detector full simulation
Touschek/Beam-gas	Theoretical formulae [1]	SAD [2] (up to ~1000 turns)	GEANT4
Radiative Bhabha	BBBREM/BHWIDE	GEANT4 (multi-turn loss is small)	GEANT4
2-photon	AAFH	GEANT4 (multi-turn loss is small)	GEANT4
Synchrotron radiation	Physics model in GEANT4 (SynRad)	GEANT4	GEANT4

[1] Y. Ohnishi et al., PTEP **2013**, 03A011 (2013).
[2] SAD is a “Home-brew” tracking code by KEKB group, http://acc-physics.kek.jp/SAD/

Simulated BG loss distribution (design)

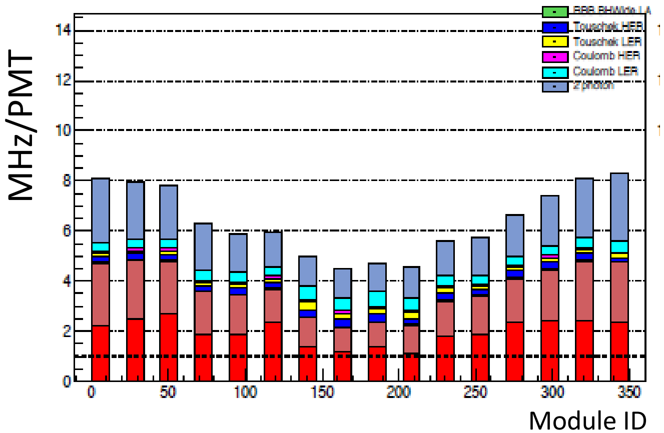
Ver. 2017.1.31
(15th campaign)



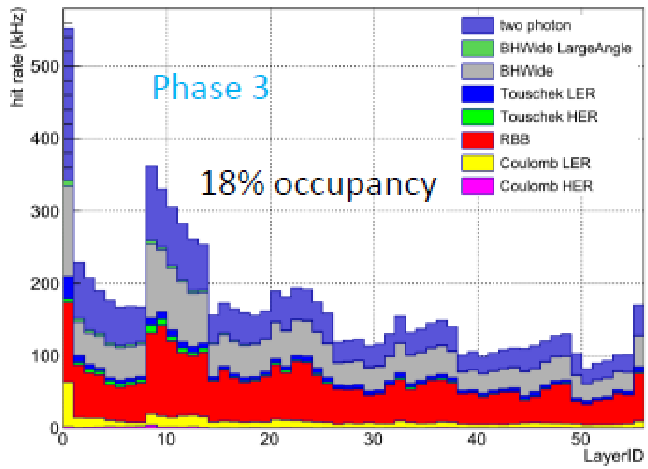
	LER (4GeV e+)	HER (7GeV e-)
Lumi-dependent BG	BBBrem: **1.08 W** (0.06 W in |z|<65cm) BHWide: 0.11 W (0.04 W), 2photon: 0.14 W(0.11W)	
Touschek	0.27 W (0.42GHz)	0.04 W (0.03GHz)
Coulomb	0.06 W (0. 10Hz)	0.00 W (0.002GHz)

Simulated Sub-Detector BG rates

TOP PMT rate



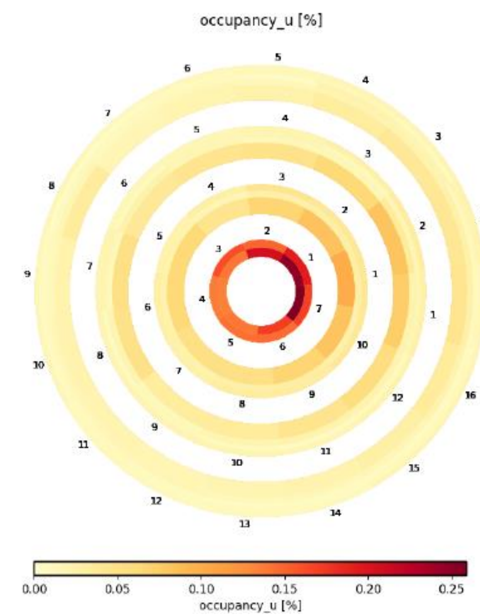
CDC wire rate



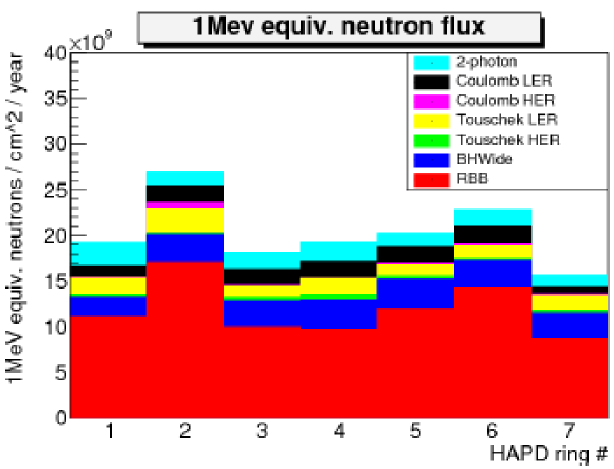
PXD occupancy

Layer #1
0.84 % occupancy
from 2-photon

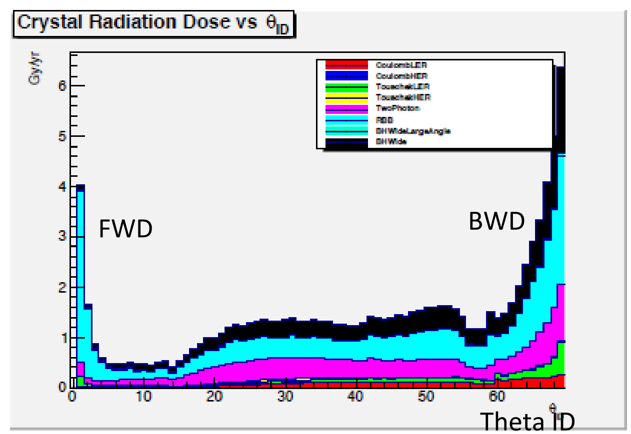
SVD occupancy



ARICH neutrons



ECL crystal dose



Sub-detectors can survive ~10 years at full luminosity (except TOP PMTs, which will be replaced in few years)

Simulated Sub-Detector BG rates

listing SF<5 only
SF=Safety Factor

	16th campaign result	limit	SF
PXD occupancy	2photon:0.8% , SR:~0.2% (10th)	< 3%	3
CDC wire hit rate	350kHz at layer#8	<200kHz	0.6 (*1)
CDC Elec.Borad n-flux* (averg.)	3.2	<1	0.3 (*2)
CDC Elec.Board dose	270 Gy/yr	<100 Gy/yr	0.3 (*3)
TOP PMT rate	5-8 MHz/PMT	<1 MHz/PMT (*3)	0.3
TOP PCB n-flux*	0.35	<0.5	3
ARICH HAPD n-flux*	0.3	<1	3
ECL crystal dose	6 Gy/yr in BWD	<10 Gy/yr	2
ECL diode n-flux*	?	<1	4
ECL pile-up noise	?	0.8 at Belle-I	?

KLMs studies are not included

(*1) effect on tracking performance is under study
(*2) more frequent SEUs and firmware reload
(*3) possible to replace electronics
(*4) ~40% of TOP PMTs have this lifetime. Other PMTs have longer lifetime

*neutron flux in unit of 10^{11} neutrons/cm2/yr, NIEL-damage weighted

BG estimation summary

- Collimators can mitigate Touschek/Beam-gas BG
- Radiative Bhabha spent e+/e- are dominant BG at full design luminosity
- Simulated BG rates on subdetectors at full luminosity are acceptable, but safety margins are small
  - Exception: 1/3 of TOP PMTs need replacement after few years of operation

→ <u>Simulation should be verified by machine studies</u>

Beam background measurement during SuperKEKB “Phase 2” runs

~ hot from the oven ~

3-phase SuperKEKB commissioning

DONE

Phase1 (2016 Feb-June)

- No final focus, no Belle II
- Vacuum baking, beam tuning

DONE

Phase2 (2018 Mar-July)

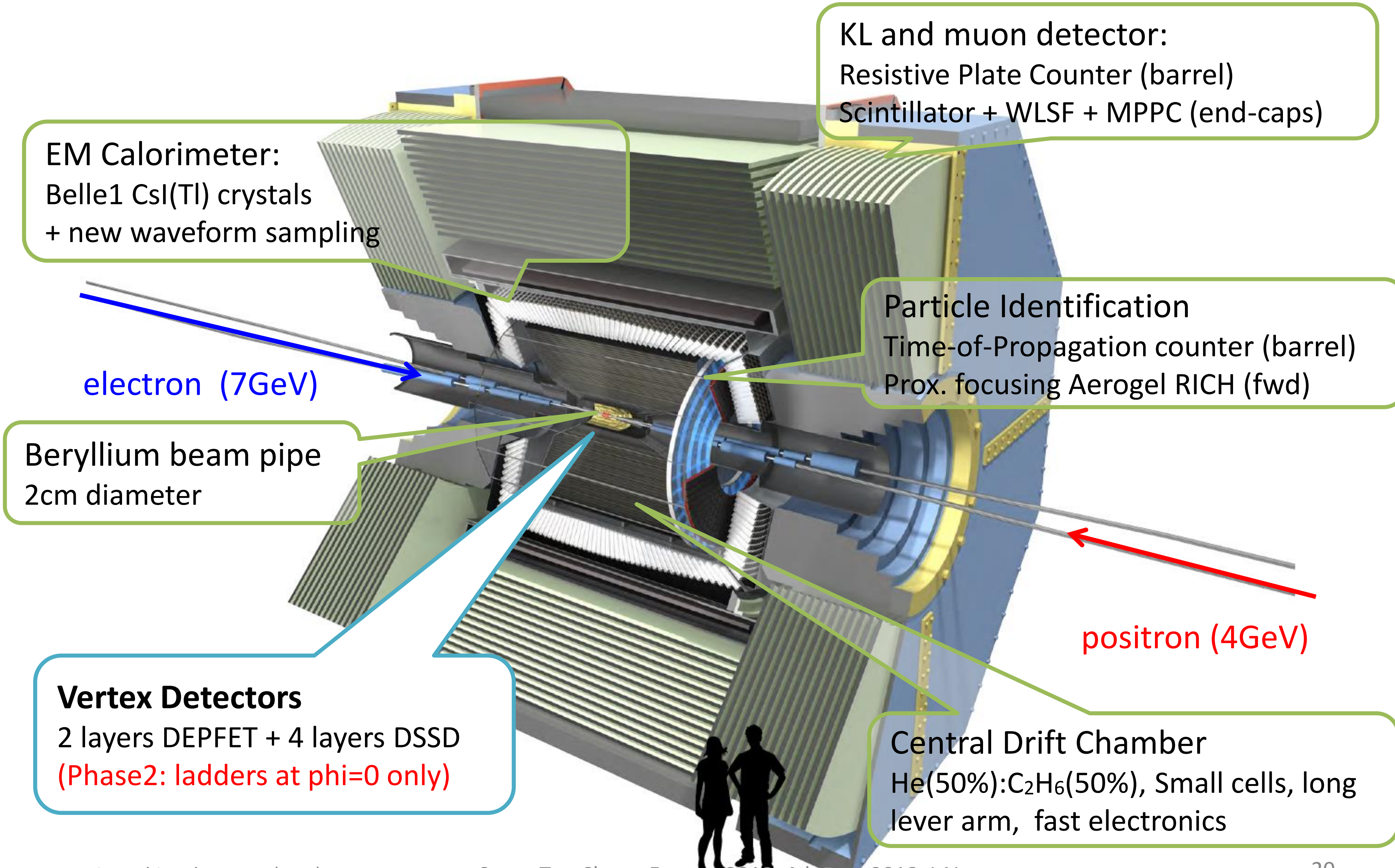
- Final focus installed, Belle II installed (partial inner detector)
- Collision tuning + early physics samples

Phase3 (2019 March-)

"Early Phase3": first several months dedicated for machine studies

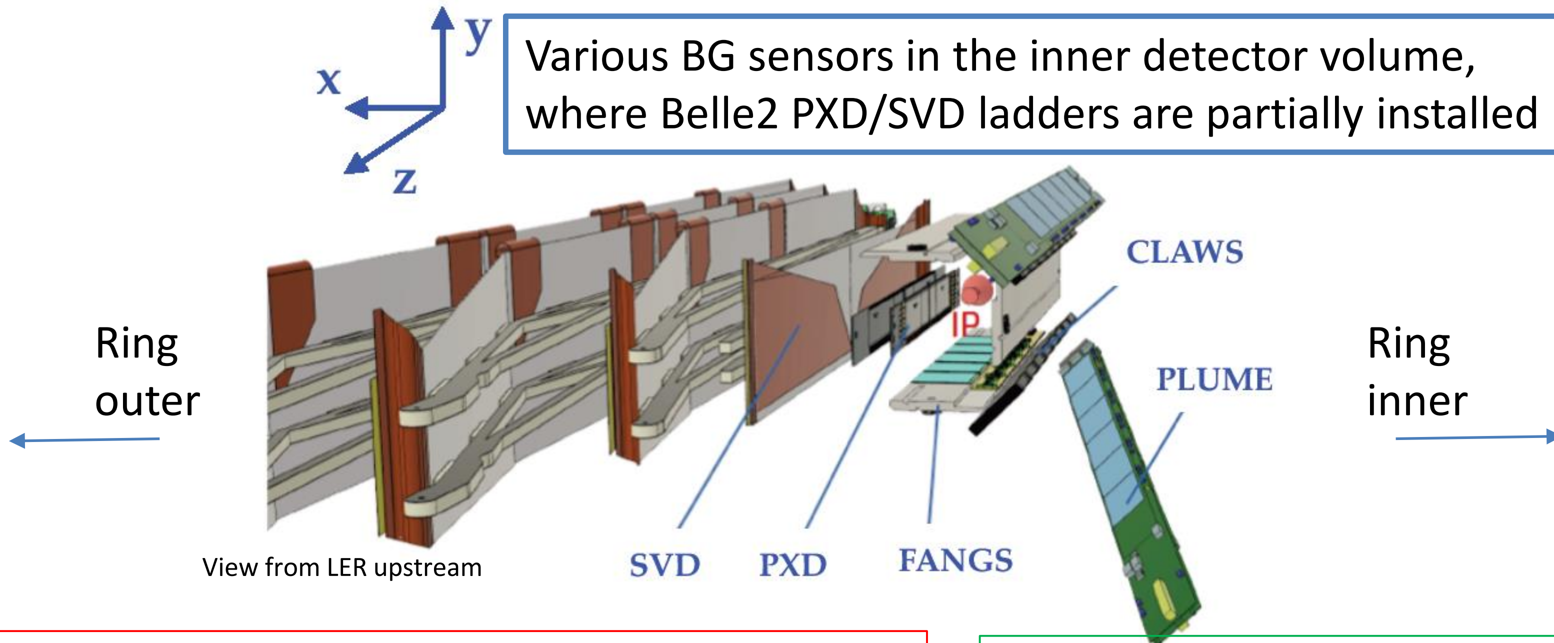
- All Belle2 installed -- "in full swing"
- Aim for L=8x10^{35} with further focused beams

Belle II Detector



Belle2/BEAST2 sensors in Phase 2

Various BG sensors in the inner detector volume, where Belle2 PXD/SVD ladders are partially installed



BEAST2 sensors at inner detector volume
- **FANGS** - hybrid silicon pixel detectors.
- **CLAWS** - plastic scintillators with SiPM readout.
- **PLUME** - double sided CMOS pixel sensors.
- **Diamond** sensors for ionizing radiation dose monitoring
- **PXD/SVD** ladders at phi=0 (ring outer) only

BEAST2 sensors in the "dock-box" area (inside endcap)
- **He3** tubes - for thermal neutron flux measurements.
- **TPC** detectors - for fast neutron flux and direction measurements.

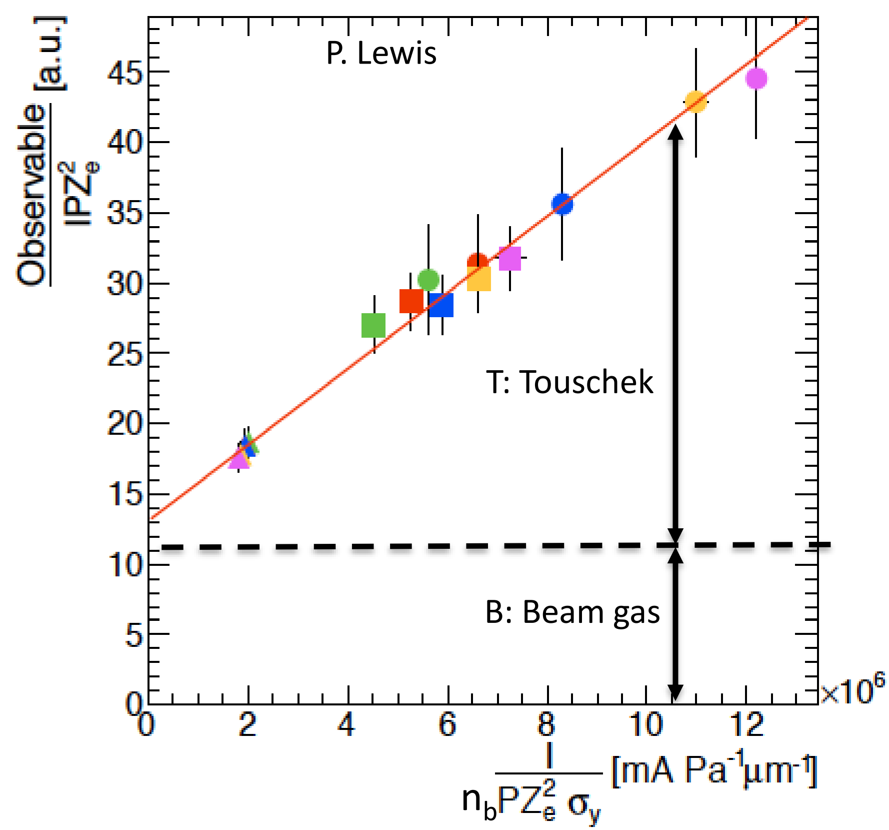
Belle2 outer sub-detectors (**CDC**,**TOP**,**ARICH**,**ECL**,**KLM**) were also functional during phase2

Estimating Beam-gas and Touschek: Beam size scans (single-beam)

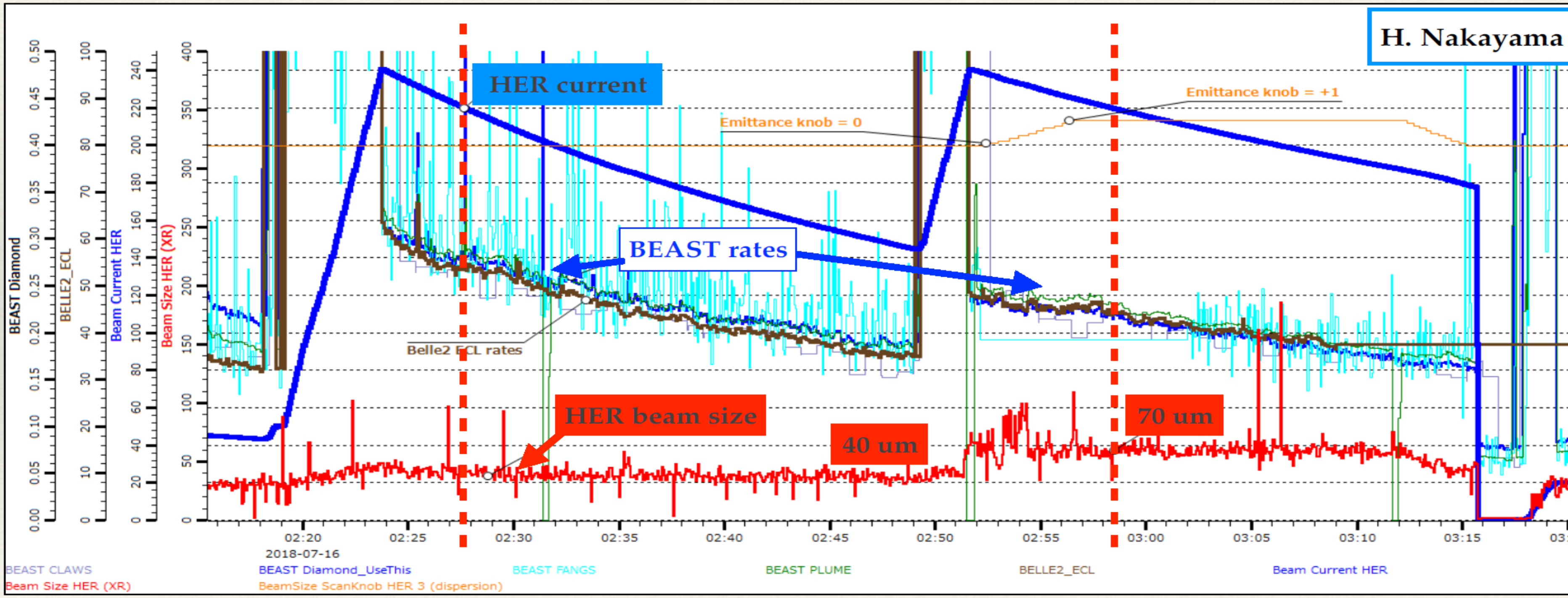
$$Rate = T\frac{I^2}{\sigma_y n_b} + BZ_e^2 IP$$

σ_y: vertical beam size, n_b: number of bunches
P: pressure, I: beam current
Z_e: effective atomic number of residual gas
T, B: Touschek/Beam-gas coefficient

- **Strategy: Fit for T and B coefficients and compare against MC**
- Scale to Phase 3 by assuming T_exp/T_MC and B_exp/B_MC remain constant
- We think this is the only reliable way to extrapolate backgrounds to Phase 3, properly takeing into account changes in beam optics, collimator settings, beam pipe gas pressure (vacuum scrubbing)
- T and B depend on detector and channel. Important to check many detector/channels to understand problems in simulation.
- Can check assumption that T_exp/T_MC and B_exp/B_MC are constant by performing multile BG studies at different optics



A snapshot from beam size scan studies

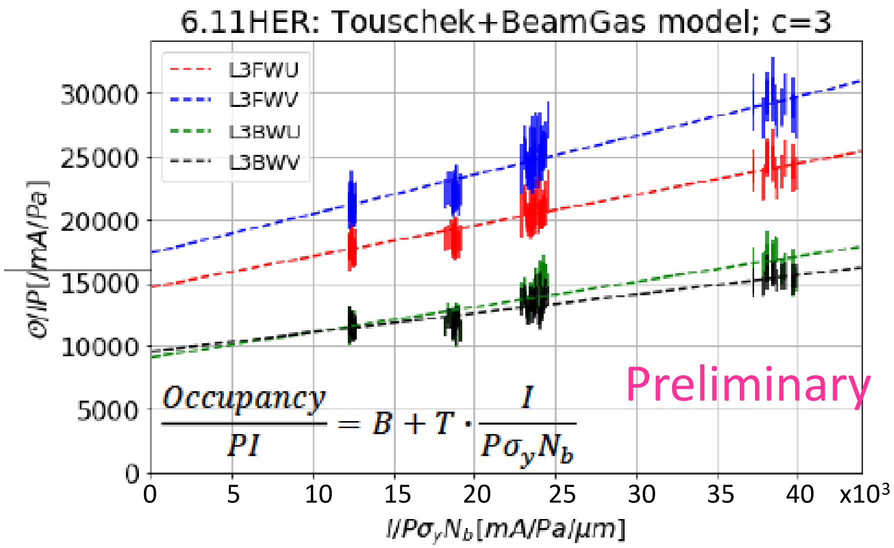


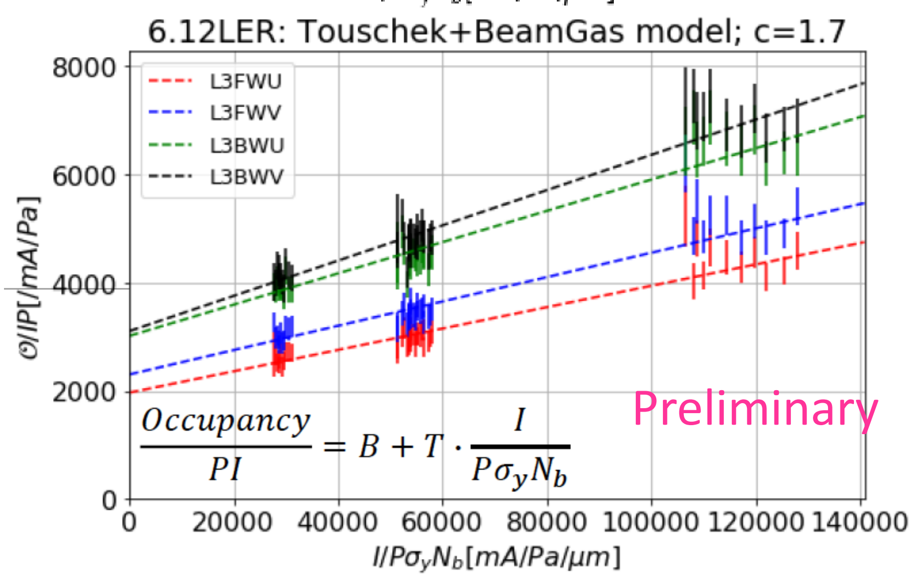
- With larger vertical beam size, BG gets smaller (due to Touschek decrease)
- Most of BEAST/Belle2 rates show similar dependence on beam current/size
- <u>Observed dependency are consistent with the “Touschek+ Beam-gas” model (no significant indication for other BG sources)</u>

- In some case, with even larger <u>HER</u> beam size, <u>BG gets larger(!)</u> although expected to get smaller. Vertex distribution obtained by tracking analysis shows additional HER beam loss positions with the large beam size. Should be further investigated at early Phase 3.

Hikaru Tanigawa

Measured BG rates at the beam size scan





- Extracted beam-gas and Touschek coefficients (to be used for extrapolation to Phase 3)

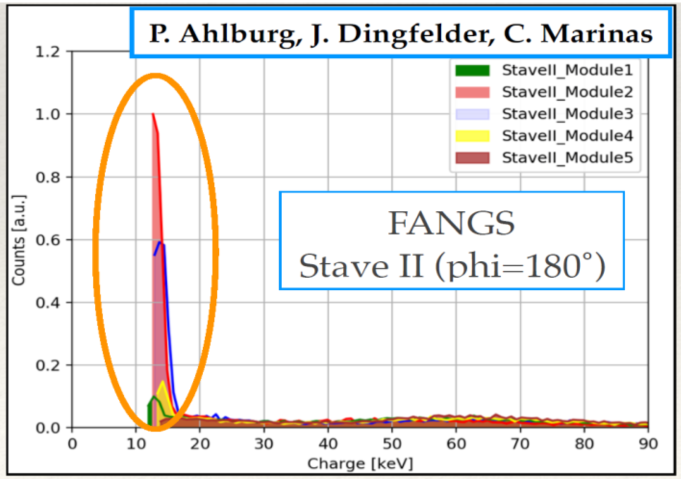
Data/MC for L3 sensors

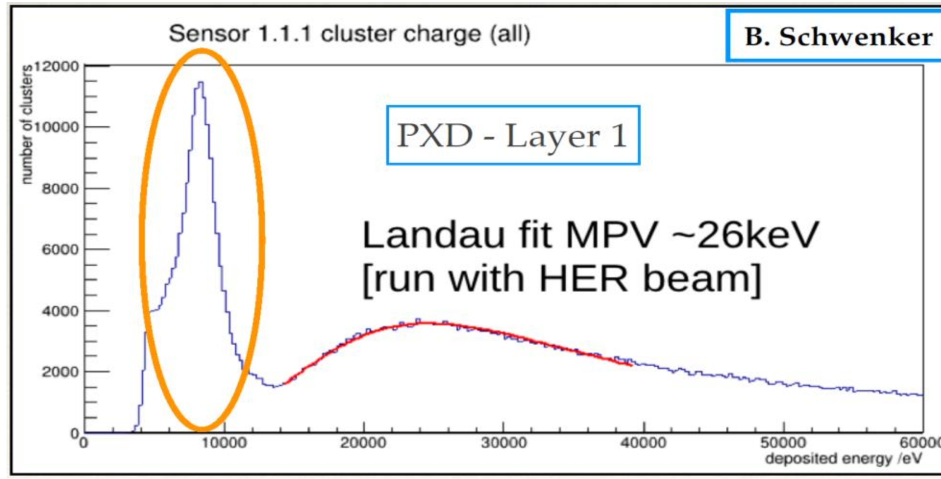
Preliminary

	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

Large discrepancies between Data and MC, especially in HER. Same/similar pattern in PXD. To be investigated further why we see such discrepancies (It is notable that our SAD loss rate in HER is much smaller than LER, almost zero)

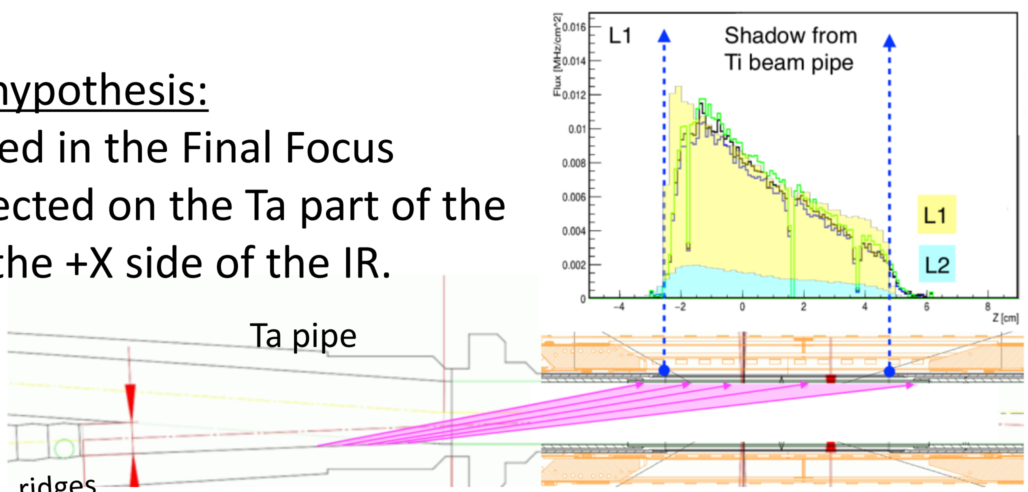
Synchrotron radiation





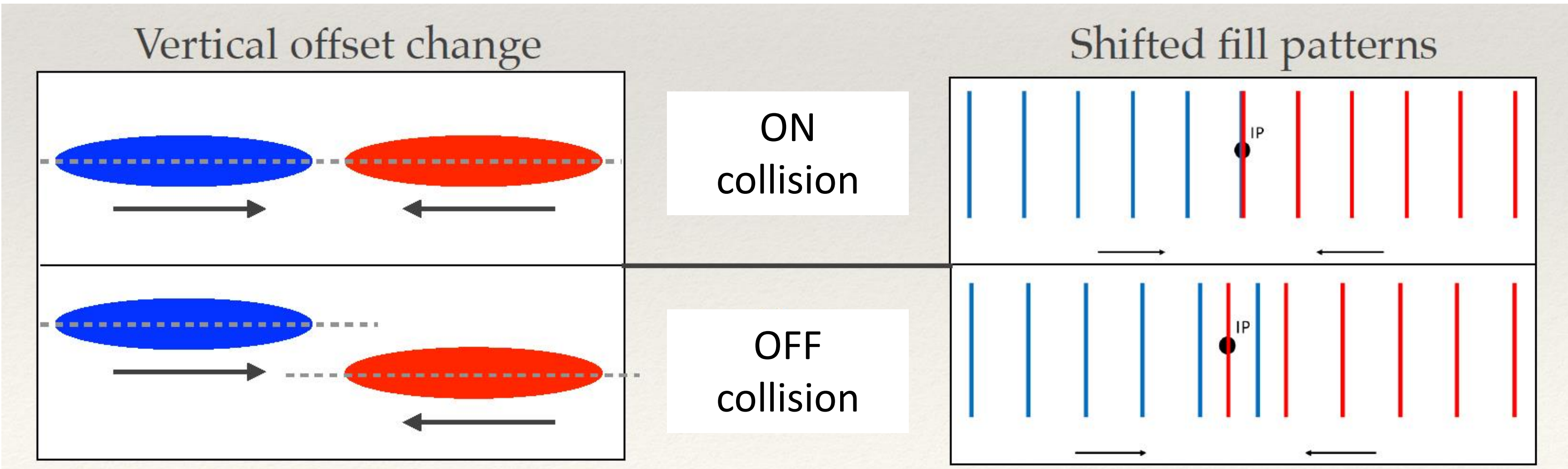
- PXD (ring outer side) and FANGS (ring inner side) see photon peak around 10keV
- Longitudinal distributions for HER and LER suggest same mechanism of SR generation

<u>Most probable hypothesis:</u>
Photons produced in the Final Focus magnet are reflected on the Ta part of the pipe and reach the +X side of the IR.



PXD rate of these photons are small and not dangerous

Estimating lumi-BG: luminosity scans (colliding beams)



- Two approaches to vary luminosity: "vertical offset" or "shifted fill patterns"
- In both cases, beam size also changes due to beam size blow up at collisions
- We need to subtract different Touschek/Beam-gas BG contribution with corresponding beam sizes at ON or OFF collision, using single-beam study result
- We took a luminosity scan data in Phase 2, but the analysis is challenging because the machine condition was unstable during the study, unfortunately
- Anyway, there are no visible lumi-BG contribution, which is consistent with small expected rate of lumi-BG at the small instantaneous luminosity during the Phase 2 study.

Summary of Phase2 measurement

- Touschek/Beam-gas BG are separately measured
  - Beam-size and N_{bunch} scan study
  - LER: <~10 x MC, HER: 100~1000 x MC
    (note that HER MC is very small)
- ~10keV photon peak are observed both in outer/inner ring sensors
- Lumi-BG in Phase2 are too small to be observed robustly, at the instantaneous luminosity reached in phase2

<u>Extrapolation to early phase3</u>

- Apply phase2 Data/MC ratio to the early phase3 simulation
- Belle II sensors will survive at least early Phase3 period (except TOP PMTs)

Overall summary

- Beam background at SuperKEKB can be dangerous and several countermeasures have been applied
- BG impact on Belle II detector is simulated
- BG measurements in Phase 2 provide scaling factors between data and MC, which should be applied on Phase3 estimation
- Further background mitigation campaigns during early Phase3 period

backup

Beam Background Status by Background Type

- 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 PXD, FANGS from both rings.
    New: SR *post*dicted after removing Geant4 low-energy cut
  - Dose: as predicted in diamonds. PXD suggests substantially 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, Beamgas versus run-specific simulation
    - LER: ~<10 x MC
    - **HER: ~1000 x MC in inner detectors, factor 100 in dock space, factor 10-20 in outer detector**
      - Leading hypothesis: caused by Geant4 QCS beam pipe shape discrepancy
    - When extrapolated to Phase 3, this predicts beam gas becomes similar to luminosity backgrounds

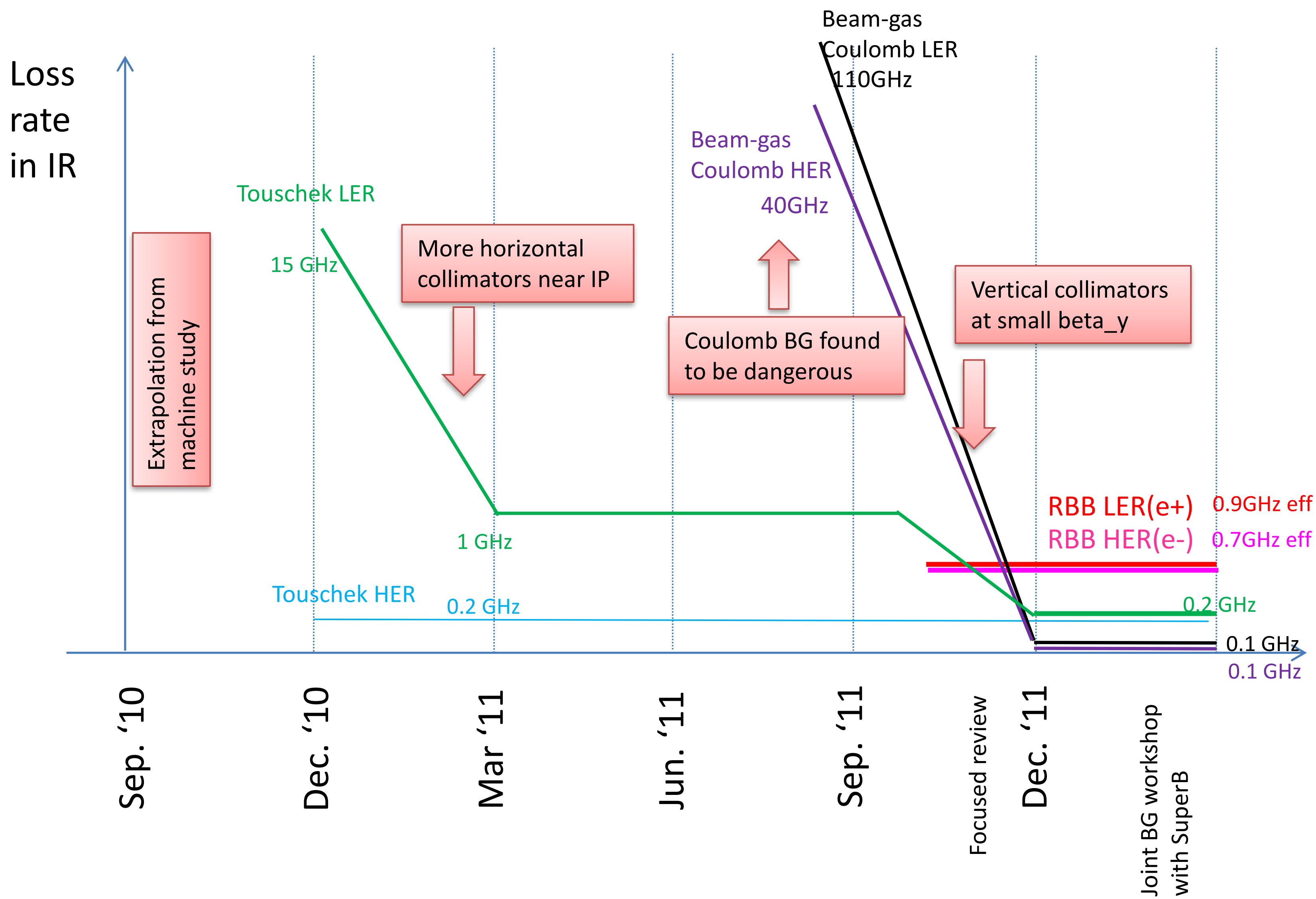
Executive Summary: phase 3 BG predictions

Preliminary

	Phase2 findings	Dangerous at early phase3?	Dangerous at final phase3?
SR	See ~10keV peaks in PXD/FANGS	+X side: OK(PXD) -X: side: FANGS analysis ongoing	Same as left
Integrated Dose	PXD, films see more than diamonds (as expected)	Rescaled MC: marginal (no injection BG included)	Rescaled MC: marginal for SVD, critical for PXD (7x reduction needed for HER BG)
PXD occupancy	See SR-like peak, but not dominant	Rescaled MC: marginal	Rescaled MC*: critical (2x more than DHP limit)
SVD occupancy	noise (or SR-like) peak at ~10keV, not dominant	Rescaled MC: marginal	Rescaled MC*: critical (10x more than limit)
CDC rates	"persistent current" is critical.	Pure MC: marginal Rescaled MC: not prepared yet	Pure MC: critical (5x than limit) Rescaled MC: not prepared yet
TOP rates	(clean) continuous injections are not a big problem for TOP	Rescaled MC: critical** (5x than limit) for short-life PMTs, which need to survive till 2020 summer	Rescaled MC: critical (2x more than limit) for ALD-type PMTs
ECL dose on crystals	-	Pure MC: OK Rescaled MC: not prepared yet	Pure MC: critical (2x than limit) Rescaled MC: not prepared yet
KLM	?	?	?
ARICH	?	?	?

*Rescaled MC for final phase3 = (final phase3 MC) * (phase2 data/MC).
Rescaled MC for early phase3 = (final phase3 MC) * (phase2 data/MC) * ¼, or (phase2 data)* (scaling with I^2) using phase2 collimators
**At early Phase 3, background improvement will be further pursued by tuning SuperKEKB parameters and the new collimators installed

Background reduction history



Where we should put the vertical collimators?

Collimator <u>aperture</u> should be narrower than QC1 aperture.

$$d/\sqrt{\varepsilon\beta} < r_{QC1}/\sqrt{\varepsilon\beta_{QC1}} \Rightarrow d_{max} \propto \beta^{1/2}$$

<u>TMC instability</u> should be avoided.

<u>T</u>ransverse <u>M</u>ode <u>C</u>oupling instability

<u>Assuming following two formulae</u>:

$$I_{thresh} = \frac{C_1 f_s E/e}{\sum_i \beta_i k_{\perp i}(\sigma_z)} > 1.44 \text{ mA/bunch (LER)}$$

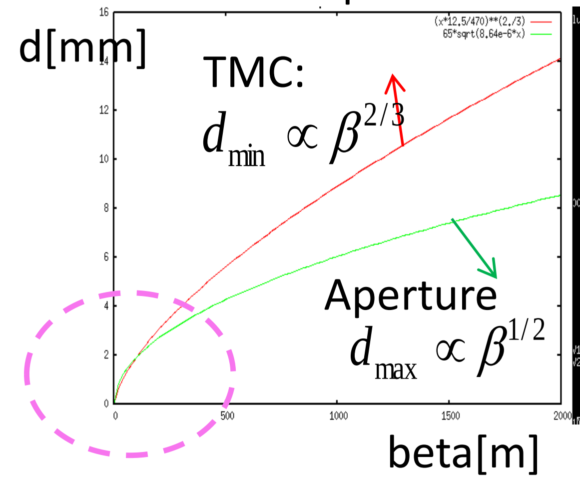
taken from "Handbook of accelerator physics and engineering, p.121"

Kick factor $k_\perp = 0.215 A Z_0 c \sqrt{\frac{\theta}{\sigma_z d^3}}$

(in case of rectangular collimator window)

$$\Rightarrow d_{min} \propto \beta^{2/3}$$

Collimator position



We should put collimator where beta_y is rather <u>SMALL!</u>

For more details, please check out following paper:

H. Nakayama et al, "Small-Beta Collimation at SuperKEKB to Stop Beam-Gas Scattered Particles and to Avoid Transverse Mode Coupling Instability", Conf. Proc. C **1205201**, 1104 (2012)

IR loss is quite sensitive to vertical collimator width

ler1604, V1=LLB3R downstream

V1 width[mm]	IR loss [GHz]	Total loss[GHz]	Coulomb life[sec]
2.40	**0.04**	153.9	1469.8
2.50	**0.05**	141.8	1594.8
2.60	**0.09**	131.0	1724.9
2.70	**0.24**	121.4	1860.2
2.80	**1.65**	111.4	2000.5
2.90	**11.48**	100.8	2014.3
3.00	**21.98**	90.3	2014.3

her5365,V1=LTLB2 downstream

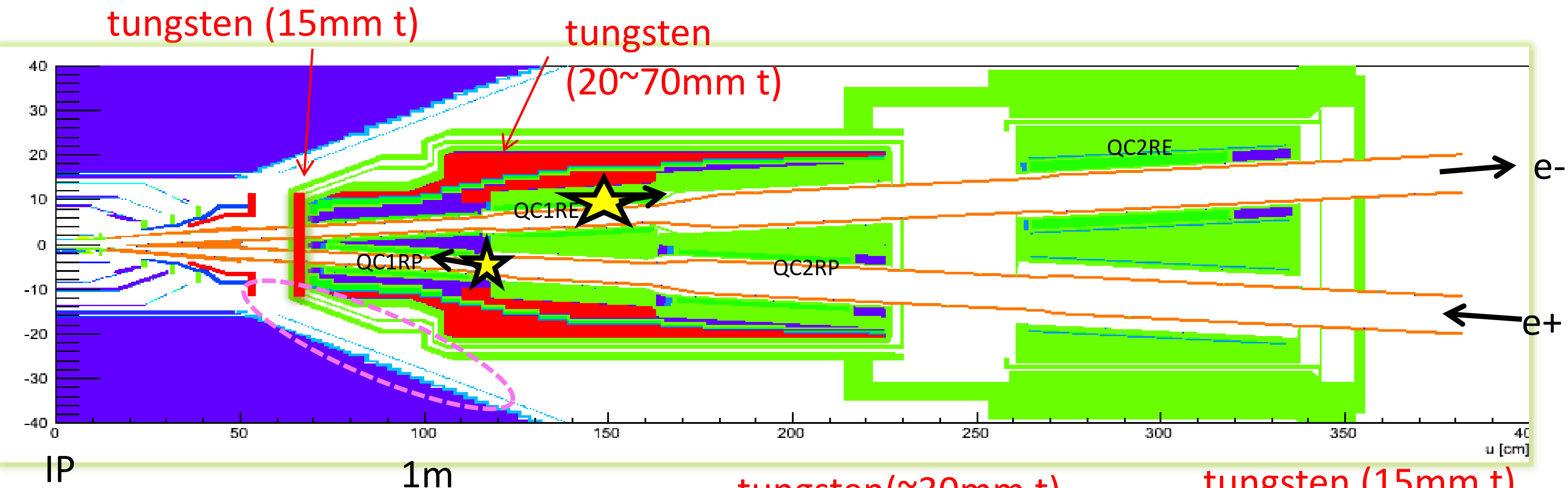
V1 width[mm]	IR loss [GHz]	Total loss[GHz]	Coulomb life[sec]
2.10	**0.0007**	49.6	3294.0
2.20	**0.001**	45.2	3615.2
2.30	**0.357**	41.0	3951.3
2.40	**7.99**	33.0	3985.9
2.50	**13.1**	27.9	3985.9

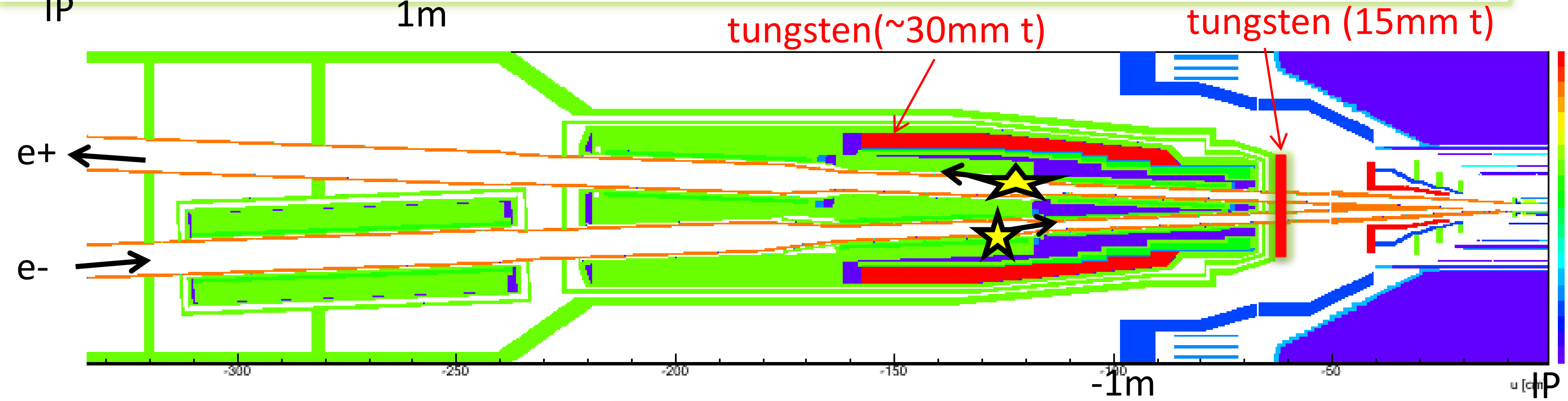
Based on element-by-element simulation, taking into account the causality and the phase difference, up to 100 turns (Nakayama)

Just a few hundreds micron wider setting of vertical collimator width can lead to significant increase on IR loss. Quite dangerous!

Typical orbit deviation at V1 : +-0.12mm (by iBump V-angle: +-0.5mrad@IP)

Tungsten shields inside Final Focus cryostat

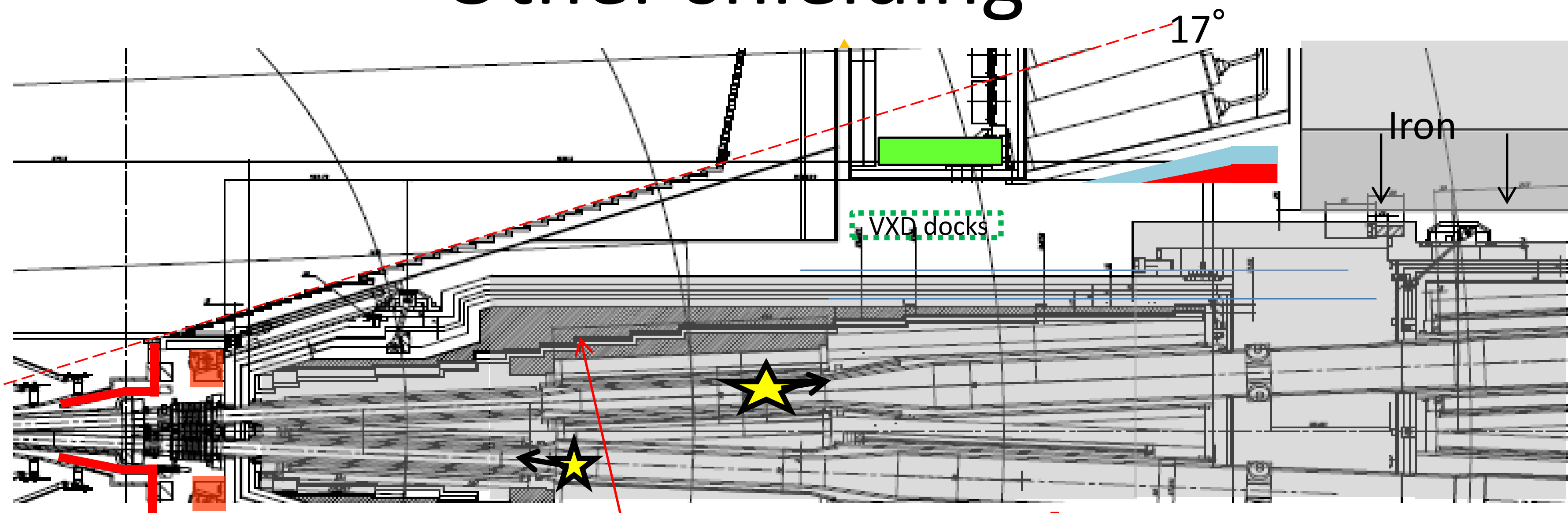




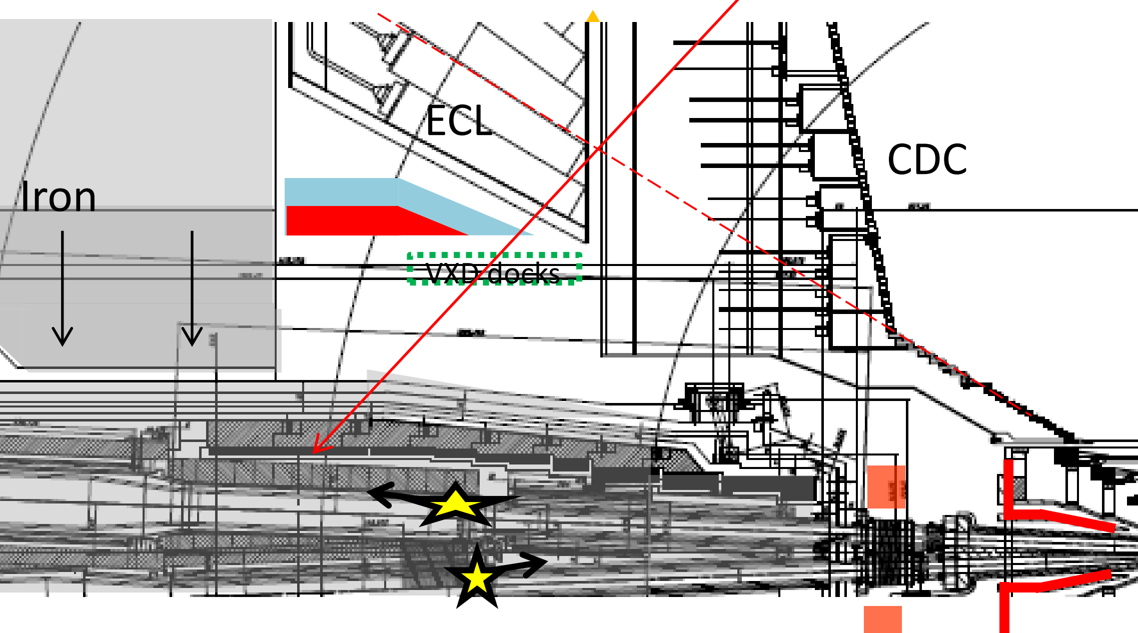
Major beam loss position by Touschek or Beam-gas

Thick tungsten shields can significantly stop background showers originated from |s|>65cm.

Other shielding



Thick tungsten layers inside cryostat



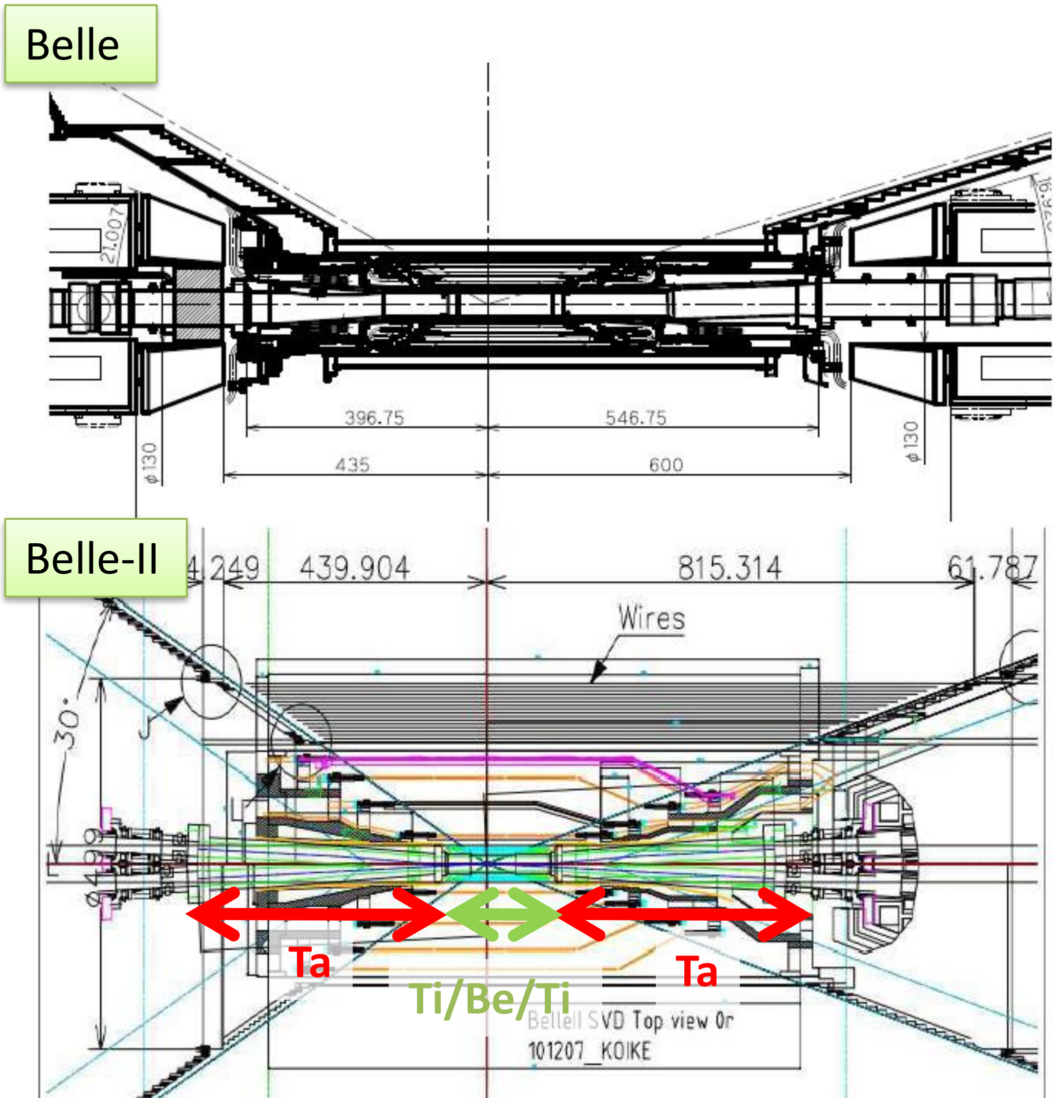
Heavy metal shields to protect VXD from showers generated in cryostat

Neutron shield to protect HAPDs in ARICH (Boron-doped Polyethylene)

ECL shield, for included for (Lead + Polyethylene)

Remote Vacuum Connection structure in front of QCS reduces showers from RBB loss at |s|~60cm (6cm-thick SUS)

Interaction region

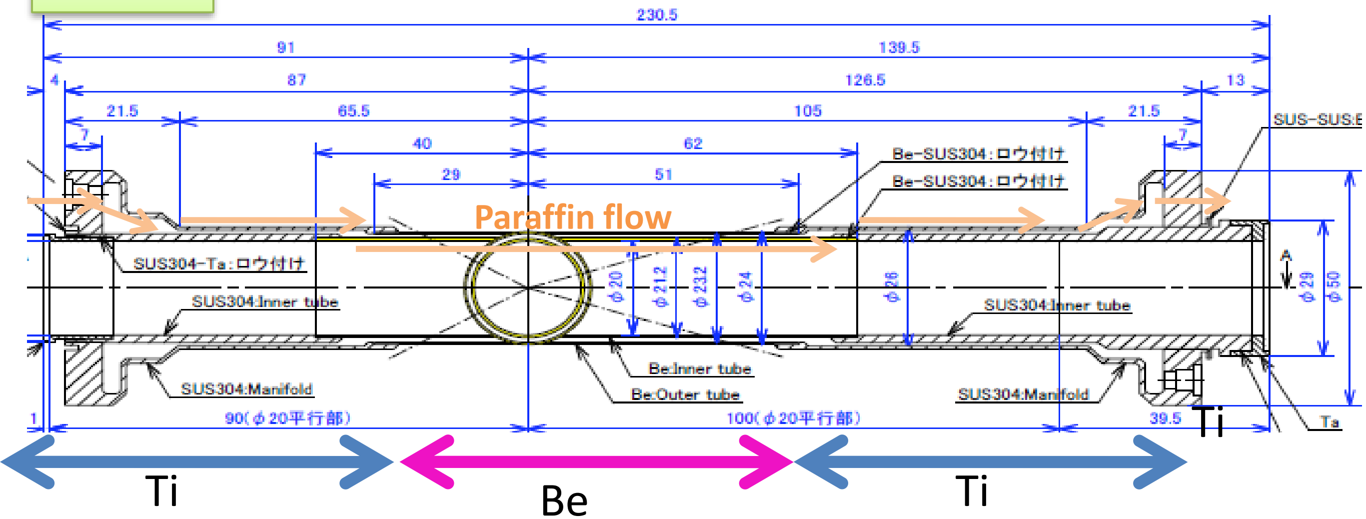


<Belle-II>

- Smaller IP beam pipe radius (r=15mm⇒10mm)
- Wider beam crossing angle (22mrad⇒83mrad)
- Crotch part: Ta pipe
- Pipe crotch starts from closer to IP, complicated structure
- New detector: PXD (more cables should go out)

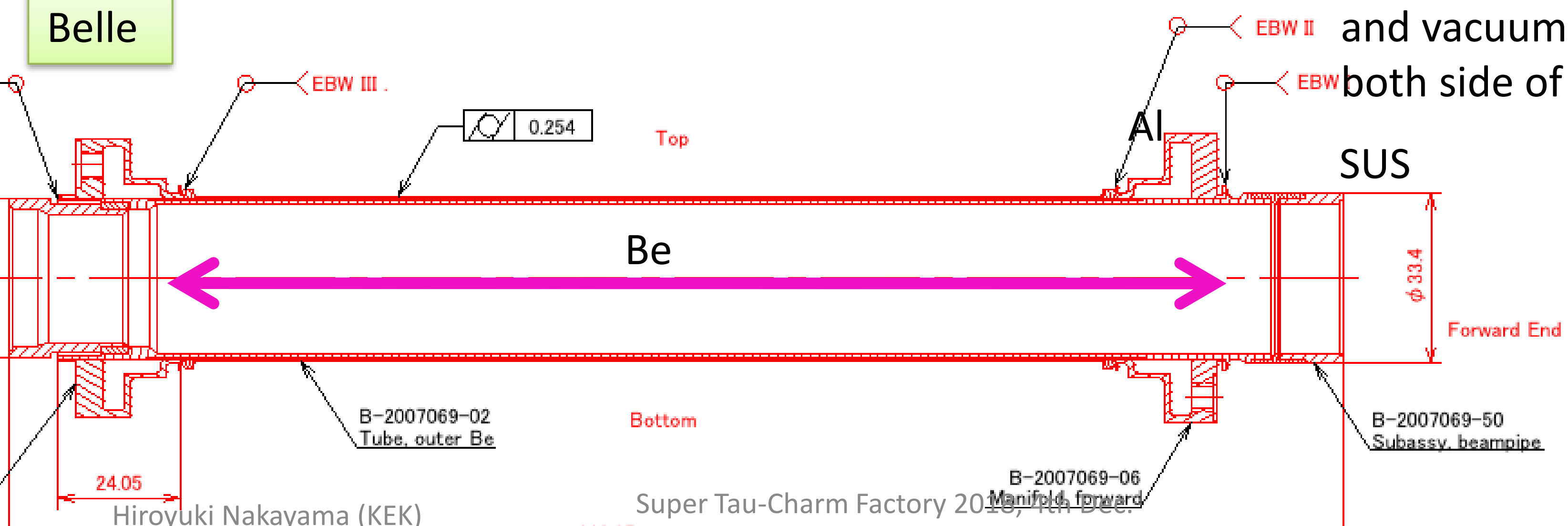
IP beam pipe

Belle-II

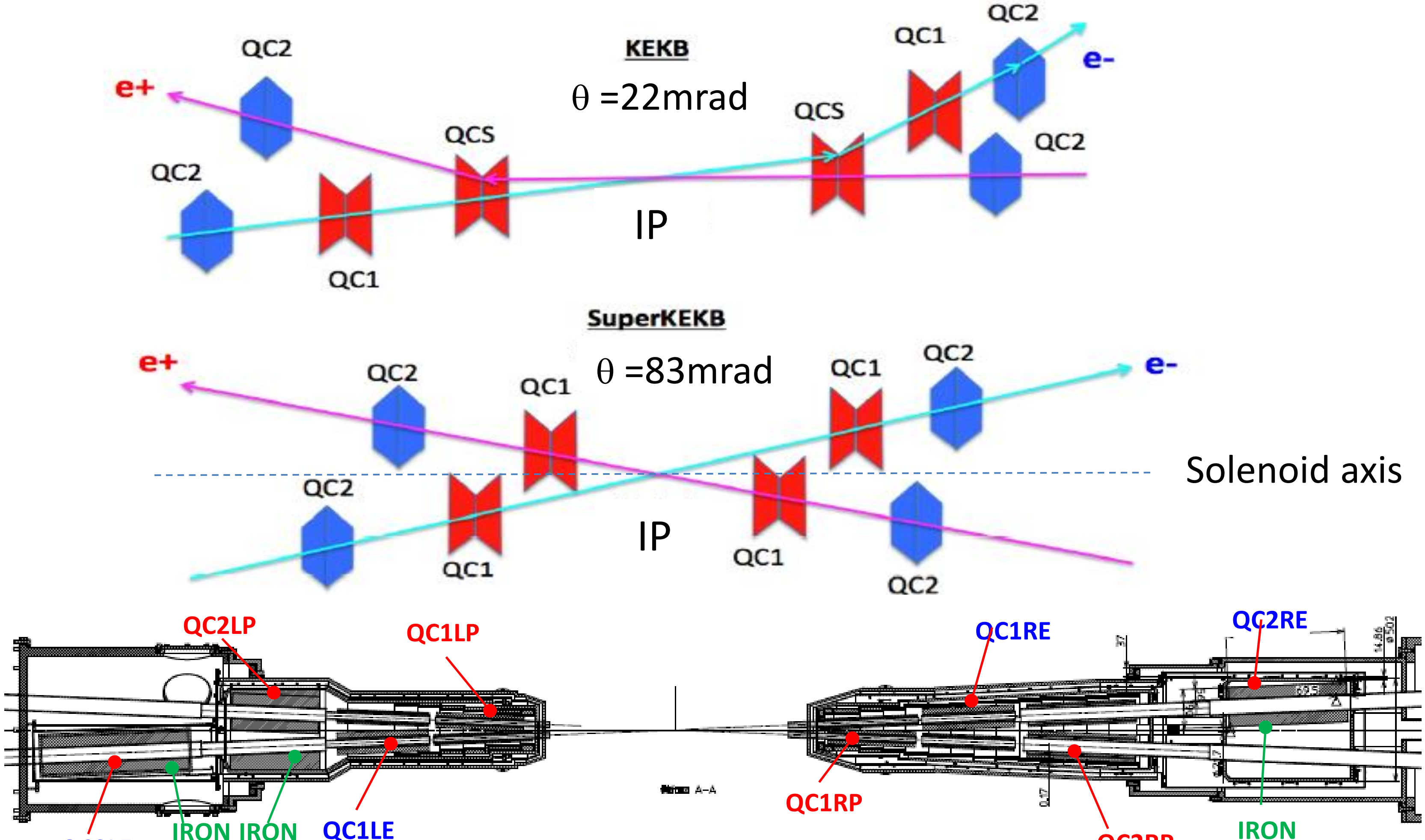


- Light material (Be) inside detector acceptance
- Paraffin ($C_{10}H_{22}$)flow to remove heat from mirror current (~80W)
- Gold plating (~10um) on inner wall to stop SR
- Much simpler Be shape (also much cheaper) since we allow Paraffin and vacuum to attach both side of welding

Belle

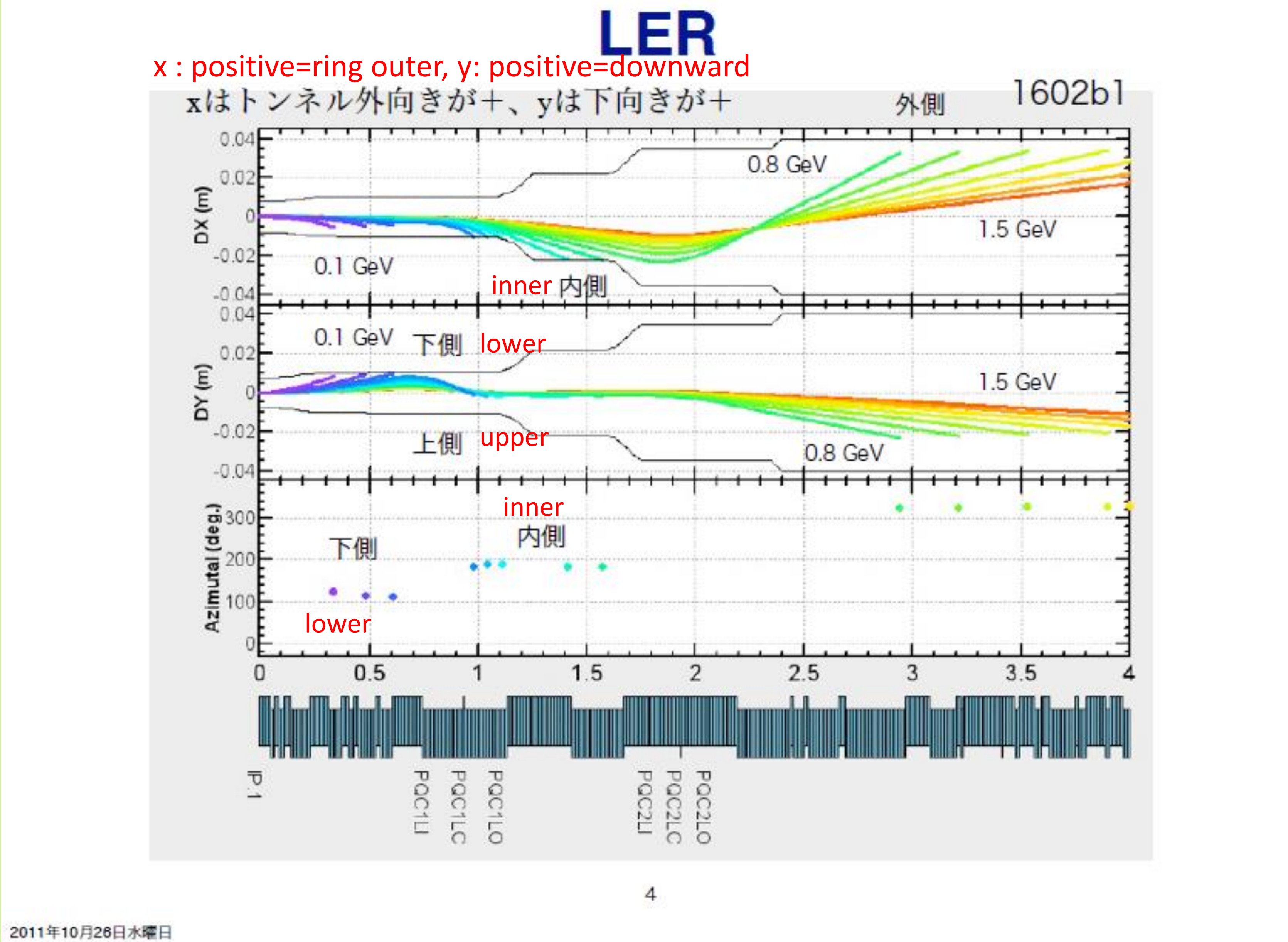


Final focusing magnets



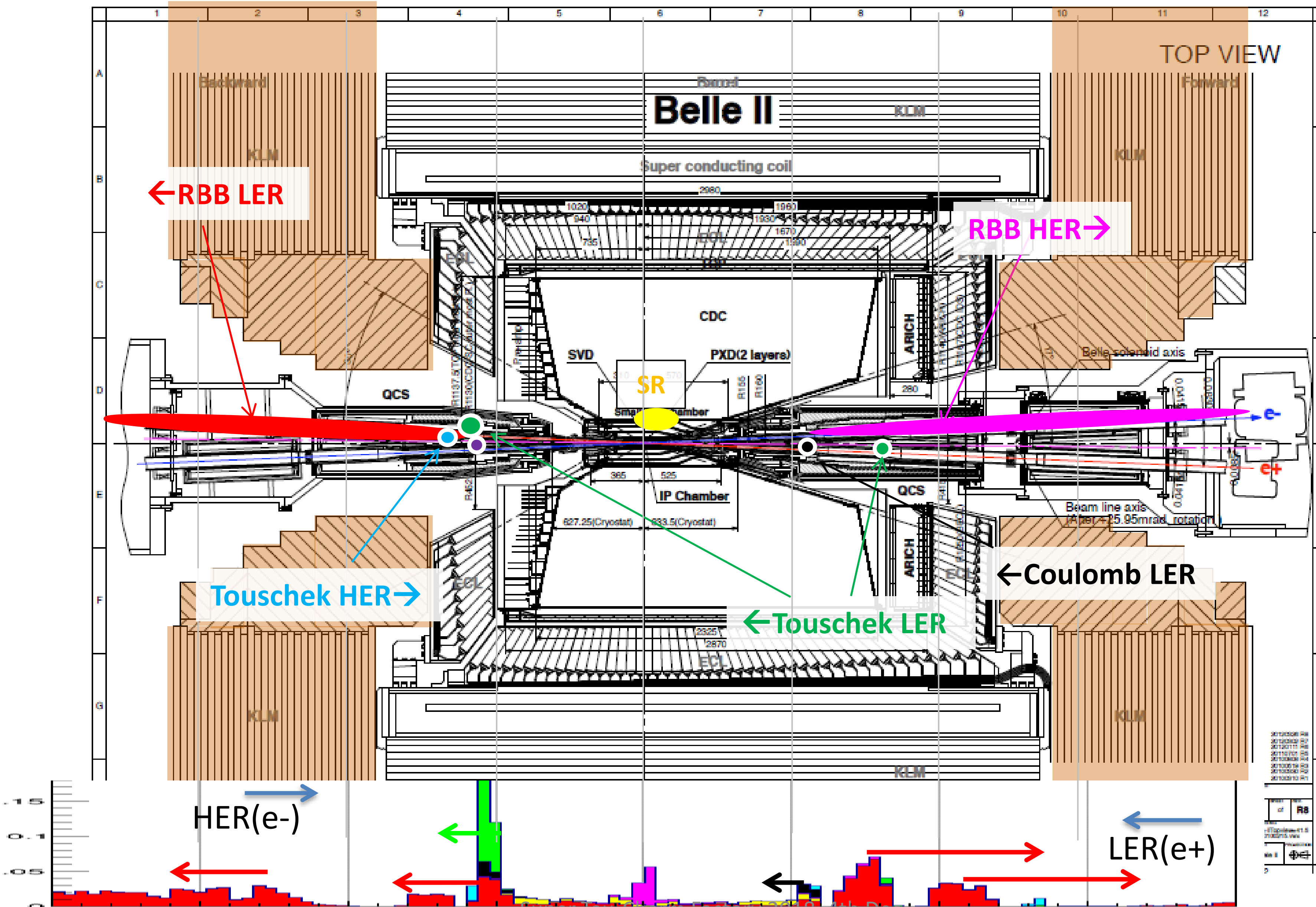
- Larger crossing angle θ
- Final Q for each ring→ more flexible optics design
- No bend near IP→ less emittance, less background from spent particles

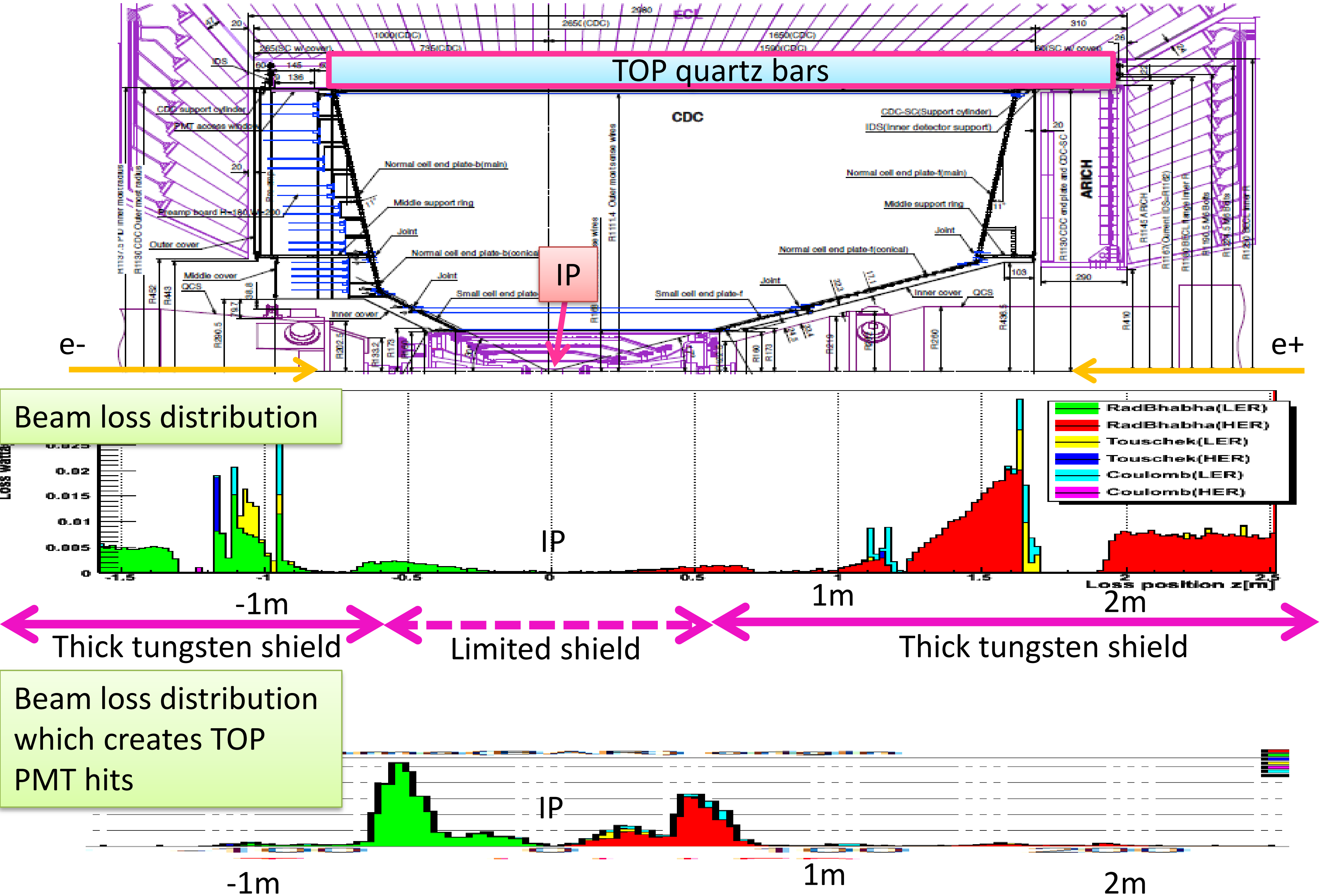
Beam orbit after RBB scattering



Background Global picture

Ver. 2017.1.31

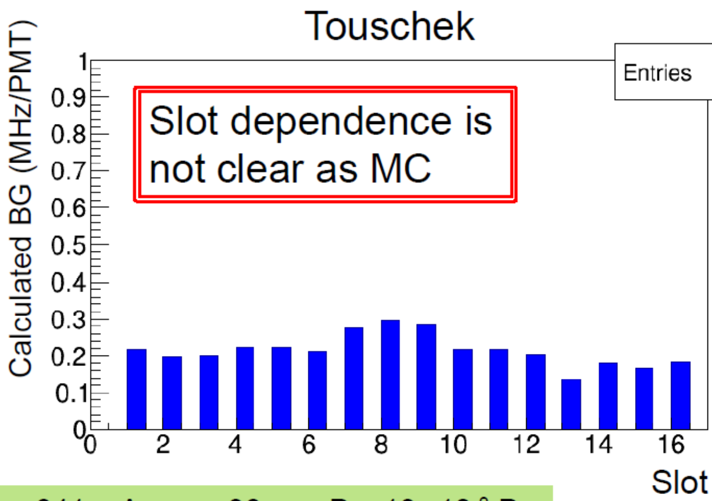


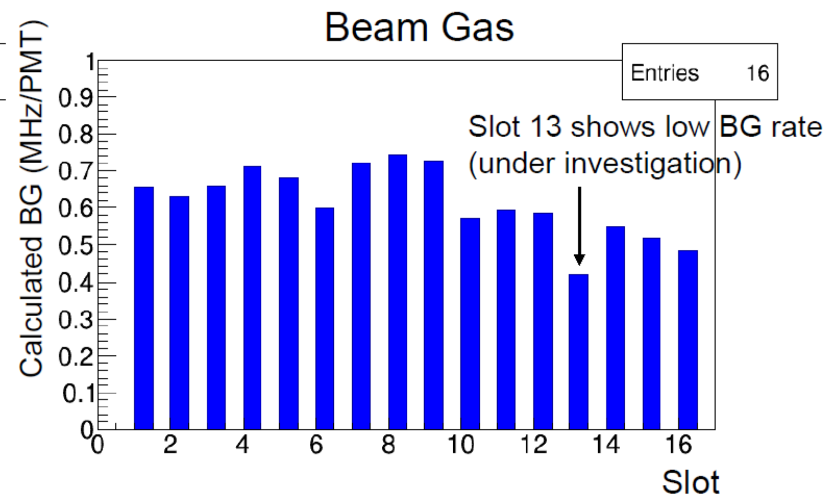


TOP quartz bars
CDC
ARICH
ECL
IP
e-
e+
Beam loss distribution
RadBhabha(LER)
RadBhabha(HER)
Touschek(LER)
Touschek(HER)
Coulomb(LER)
Coulomb(HER)
Loss position z[m]
-1m
1m
2m
Thick tungsten shield
Limited shield
Thick tungsten shield
Beam loss distribution which creates TOP PMT hits
IP
-1m
1m
2m

TOP background in June 2018 runs

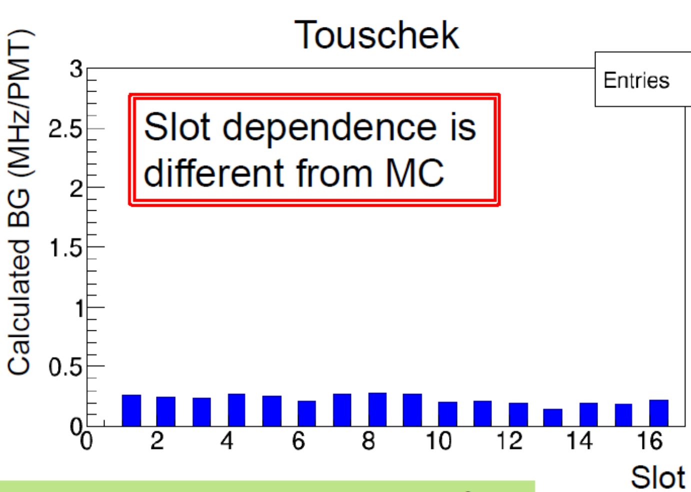
LER

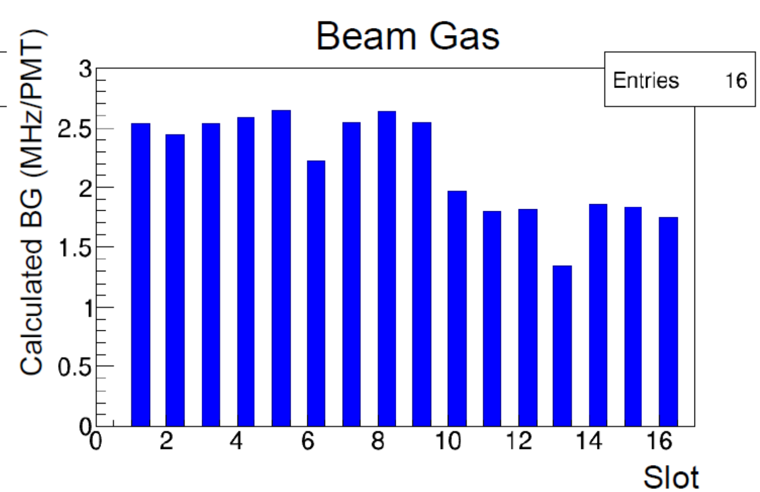




I = 341 mA, σ_y = 38 um, P = 13×10^{-8} Pa

HER





I = 287 mA, σ_y = 36 um, P = 13×10^{-8} Pa

Hikaru Tanigawa

Fit with beam lifetime

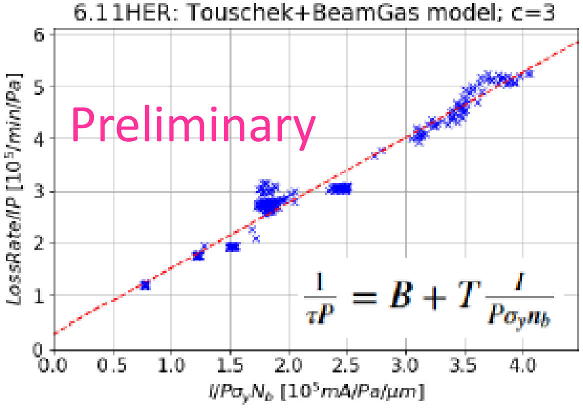
Beam lifetime

1. Lifetime is separated into BeamGas and Touschek.
   - Beam loss rate = (beam current)/lifetime can be decomposed like other BG rates.

$$\frac{I}{\tau} = BPI + T\frac{I^2}{\sigma_y n_b} = \frac{I}{\tau_B} + \frac{I}{\tau_T}$$

   - Data are fitted to this function to determine BeamGas/Touschek lifetime.

2. Lifetime in data is compared with the lifetime in MC calculated by Antonio.
   - Data/MC factor of lifetime will help understanding why the discrepancy of data and MC.



Result:
- Not all the data are well fitted to the model.
- HER(LER) Touschek lifetime in data is 2-5(1.5-3) times shorter than MC.
- BeamGas lifetime was not compared due to less sensitivity.

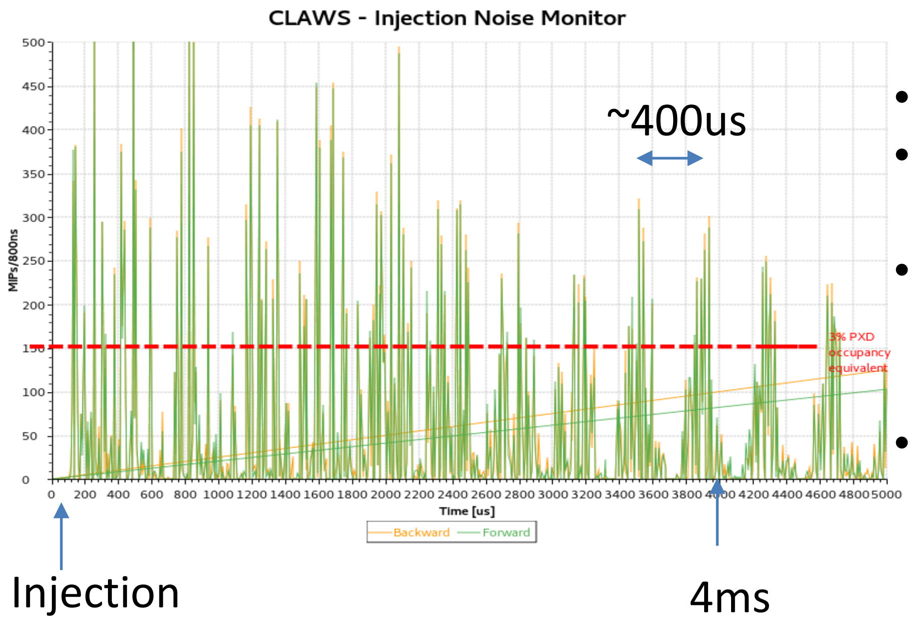
Preliminary

Touschek Life	Data [min]	MC [min]	MC/Data
6.11HER	79	165	2
7.13HER	22	No MC	-
7.16HER	~28	145	~5
6.12LER	9-15	30	2-3
7.16LER	12-22	33	1.5-3

Touschek dominant (6.11HER, 7.13HER); inexplicable (7.16HER, 6.12LER, 7.16LER)

2018/10/13 HIKARU TANIGAWA 7

Injection BG

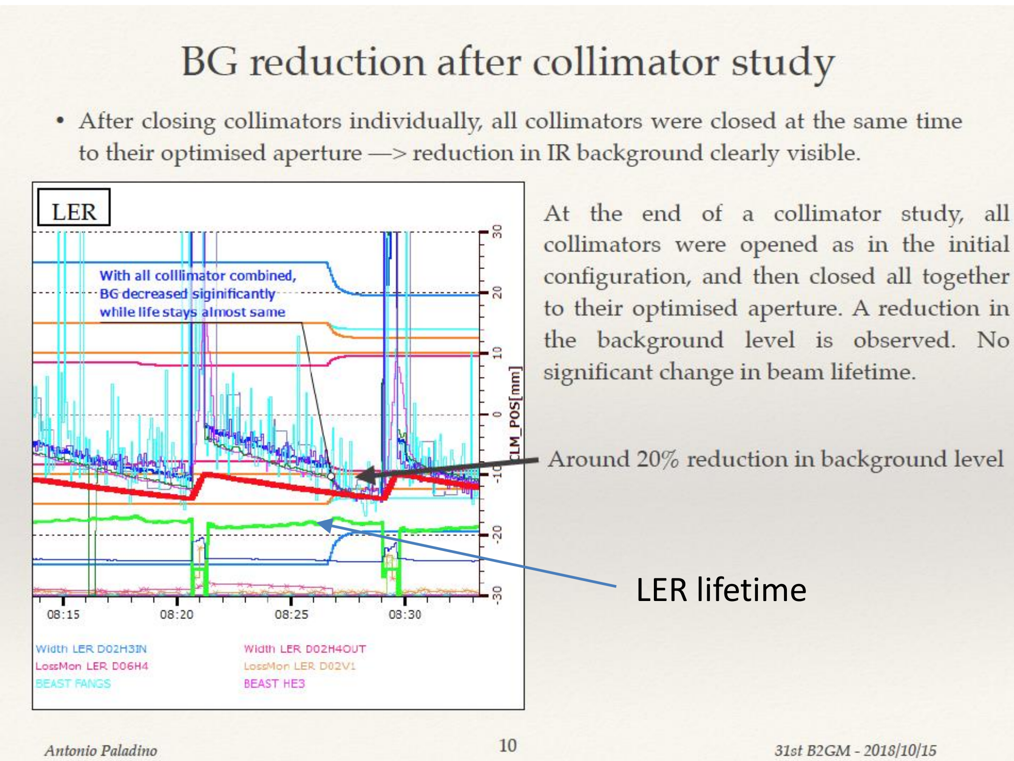


- Belle2 trigger veto after each injections
- Veto window width is defined by BG measurement by CLAWS/PXD
- It is important to keep injection BG amount to be small and the duration to be short
- Stable and safe operation with continuous injections is essential in Phase 3

Phase2 CLAWS measurement on injections
Structure of ~400us intervals: betatron tune?

Collimator Optimization: First look at measurement vs Simulation

Antonio Paladino



- During phase2, “quick” collimator adjustments were done continually, to follow optics changes or to reduce injection backgrounds
- The systematic collimator optimization was conducted in July
- Strategy:
  - Start from “open” collimator settings
  - Reduce IR background levels by closing each collimator
  - Keep closing till beam life start to decrease, or reach collimator loss monitor abort limit
  - Repeat it for all collimators

<u>Comparison with simulation</u>

- LER
  - MC: IR loss rate reduction ~ 5% (fullsim study is ongoing)
  - Measured BG reduction: ~20%.
- HER
  - MC: IR loss rate reduction ~ factor 3
  - Measured BG reduction: ~ factor 2