Belle-II background overview

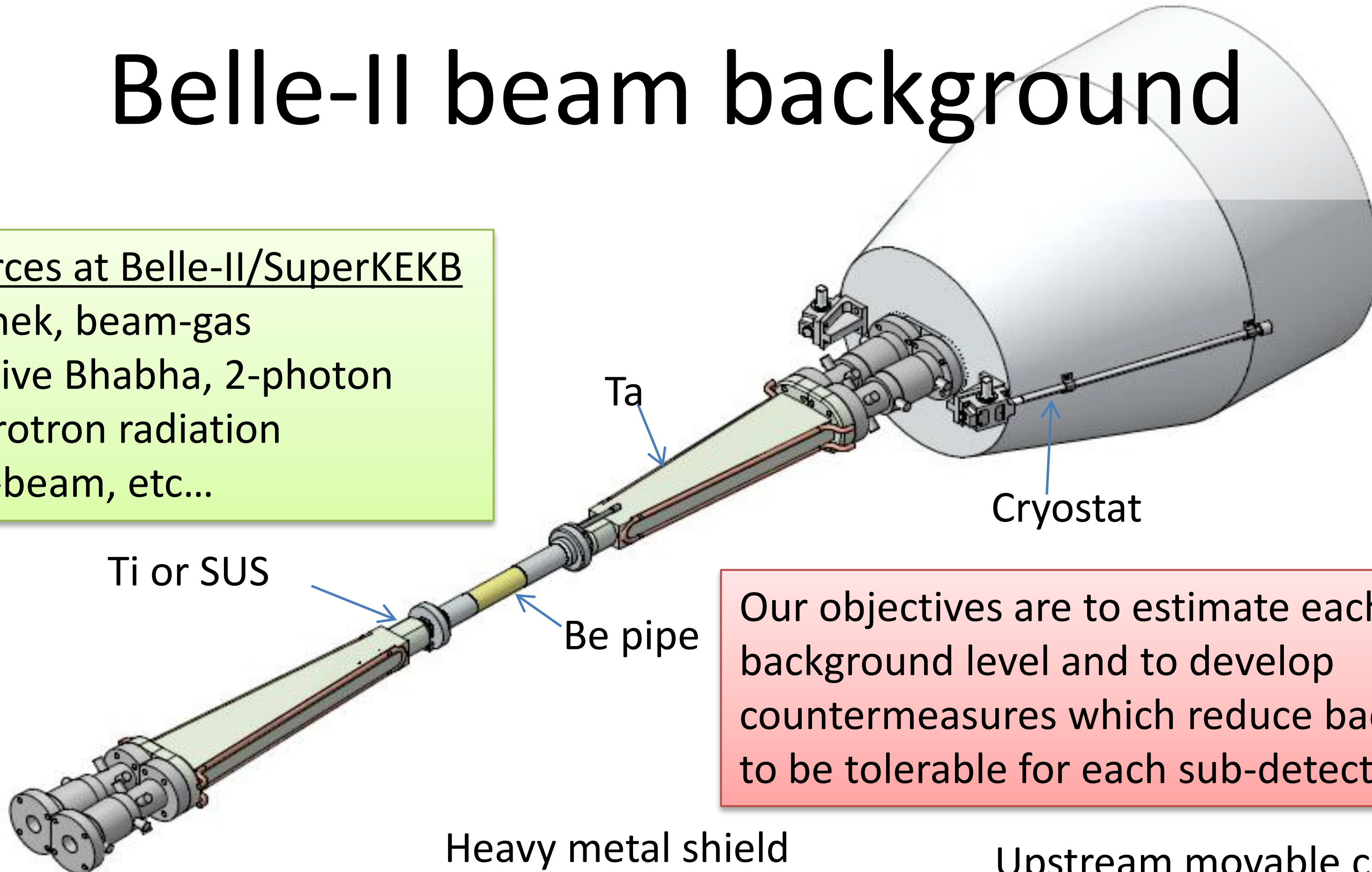
- Touschek BG, beam-gas BG
  - Vertical collimators and beam instability
- Radiative Bhabha BG
- Synchrotron radiation BG
- 2-photon BG
- Full-detector GEANT4 simulation

Hiroyuki NAKAYAMA (KEK)

Belle-II/SuperB Joint BG meeting (Feb. 9-10, 2012)

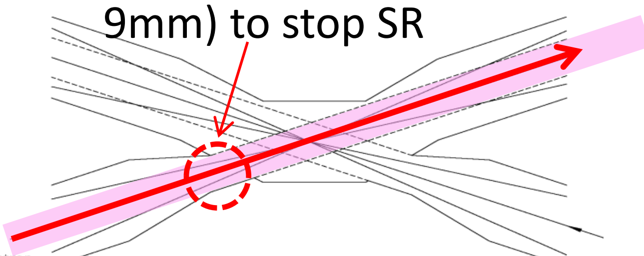
Belle-II beam background

BG sources at Belle-II/SuperKEKB
- Touschek, beam-gas
- Radiative Bhabha, 2-photon
- Synchrotron radiation
- beam-beam, etc…

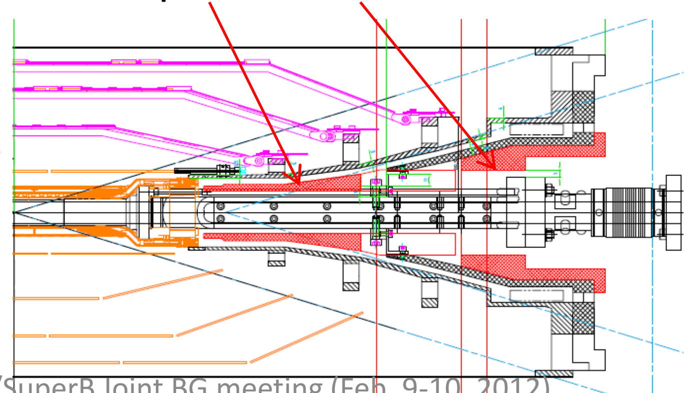


Our objectives are to estimate each background level and to develop countermeasures which reduce background to be tolerable for each sub-detectors.

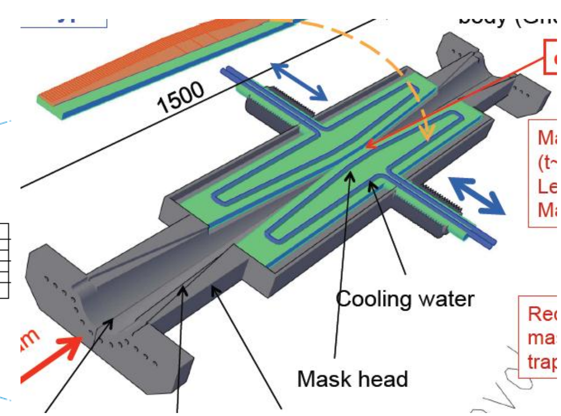
Collimation (20mm-> 9mm) to stop SR



Heavy metal shield to stop BG showers



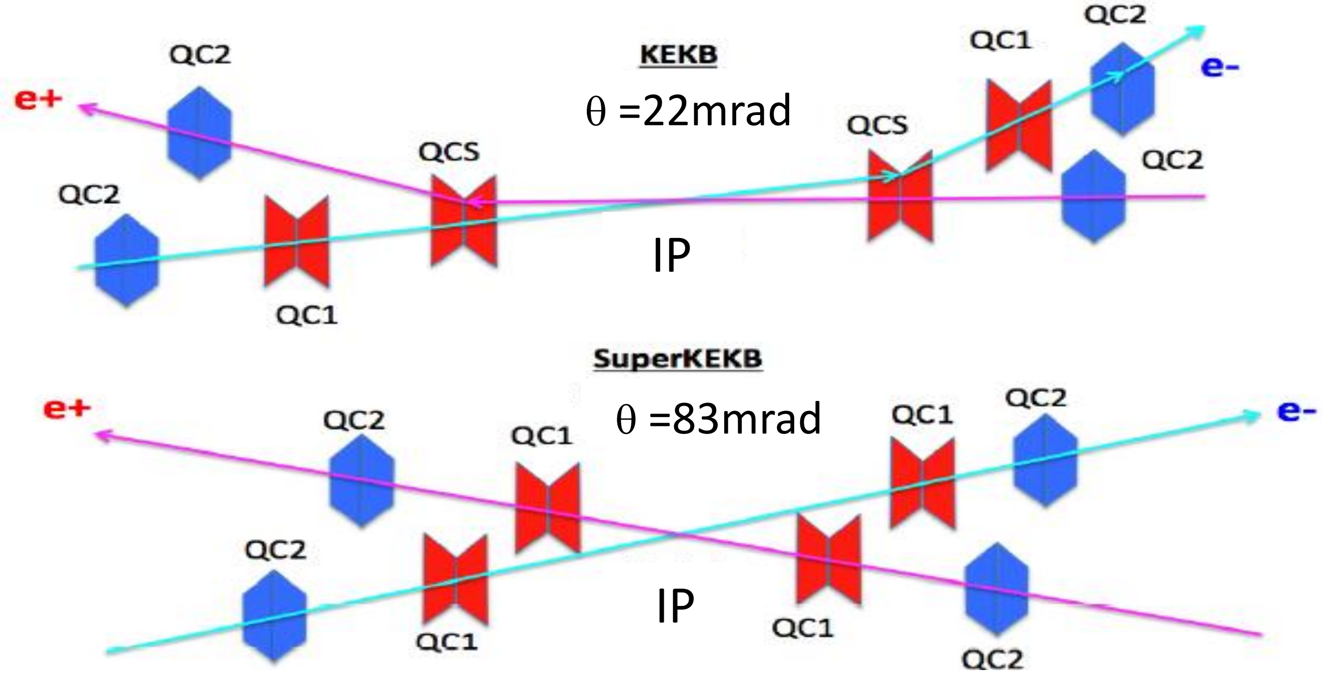
Upstream movable collimators



Expected change on BG from KEKB to SuperKEKB

- x20 smaller beam size
  → Touschek scattering rate increases drastically. Need special care.
- x2 more beam current
  → Touschek/Beam-gas scattering rate increases.
- x40 higher luminosity
  → Radiative Bhabha/2-photon scattering rate increases drastically.
- Smaller IR beam pipe aperture
  → scattered particles are more likely to be lost in IR, not in the tunnel.
- Final focusing scheme
  → Back-scattering SR and over-bent radiative Bhabha can benefit from it

Final focusing scheme

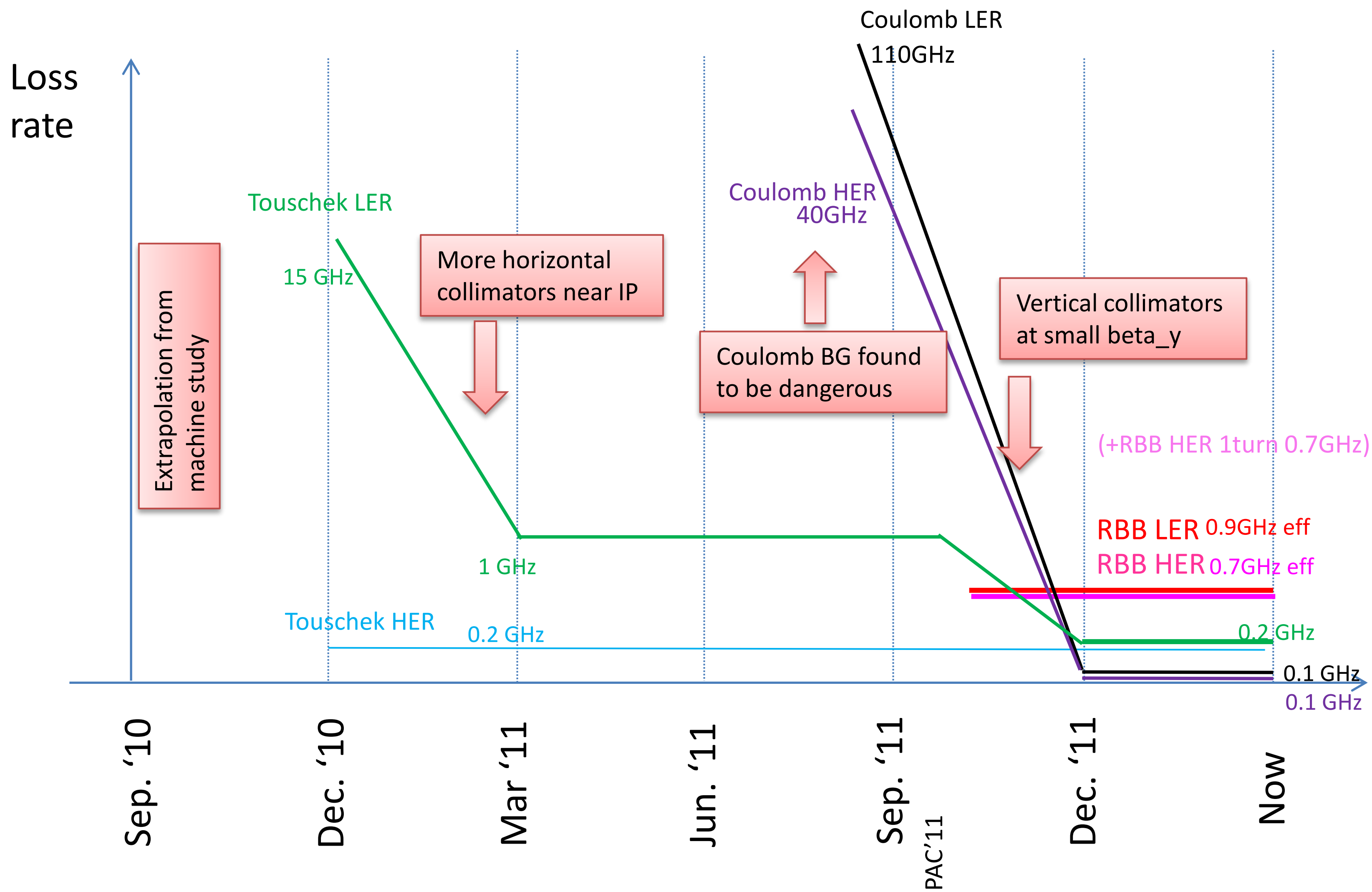


In Belle-II, thanks to the independent final Q magnets for each ring, downstream orbits pass through the center of Q magnets, which results in less dispersion and therefore less back-scattering SR BG and less over-bent radiative Bhabha background.

Estimation status of each BG

- **Touschek BG**
  - Reduced down to ~0.2GHz(LER/HER) thanks to horizontal/vertical collimators (Apr. 2011)
- **Beam-gas BG**
  - Reduced down to ~0.1GHz(LER/HER) thanks to vertical collimators. (Nov. 2011)
- **Synchrotron BG**
  - Reduced down to few order smaller than PXD requirement thanks to collimation on incoming beam pipe (Jul. 2010, toy study) Full detector simulation has just started. . (Jan. 2012)
- **Radiative Bhabha**
  - Most of spent electrons/positrons are lost outside detector thanks to independent final Q magnet (Aug. 2010). But few GHz are still lost in |s|<4m (Nov. 2011).
- **2-photon process**
  - Small enough according to KoralW simulation, which is confirmed with BELLE-I machine study (Nov. 2010).
- (Beam-beam)
  - Computational study ongoing by accelerator group

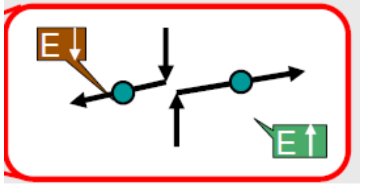
History



Loss rate
Coulomb LER
110GHz
Coulomb HER
40GHz
Touschek LER
15 GHz
More horizontal collimators near IP
Coulomb BG found to be dangerous
Vertical collimators at small beta_y
Extrapolation from machine study
(+RBB HER 1turn 0.7GHz)
RBB LER 0.9GHz eff
RBB HER 0.7GHz eff
1 GHz
Touschek HER
0.2 GHz
0.2 GHz
0.1 GHz
0.1 GHz
Sep. '10
Dec. '10
Mar '11
Jun. '11
Sep. '11
IPAC'11
Dec. '11
Now

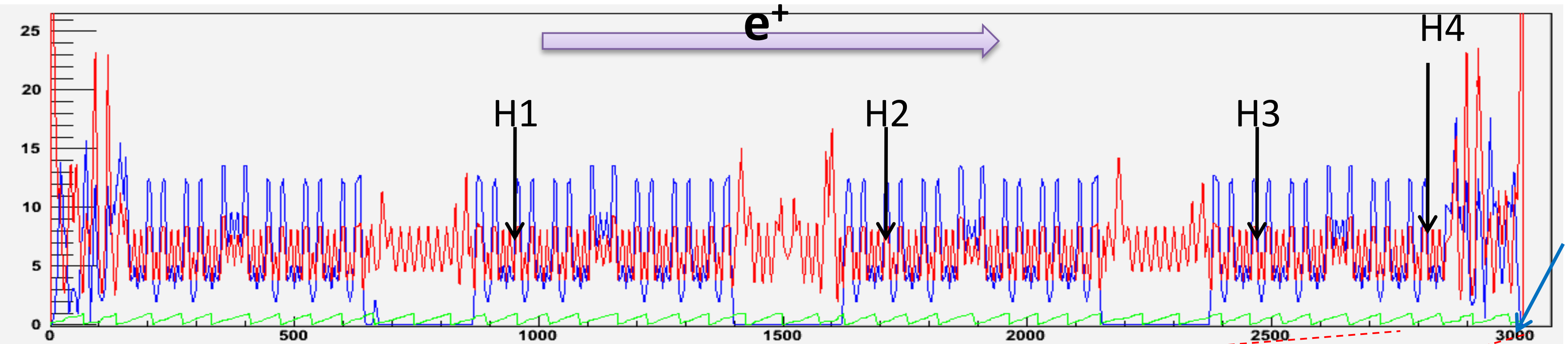
Y. Ohnishi
H. Nakayama

Touschek background

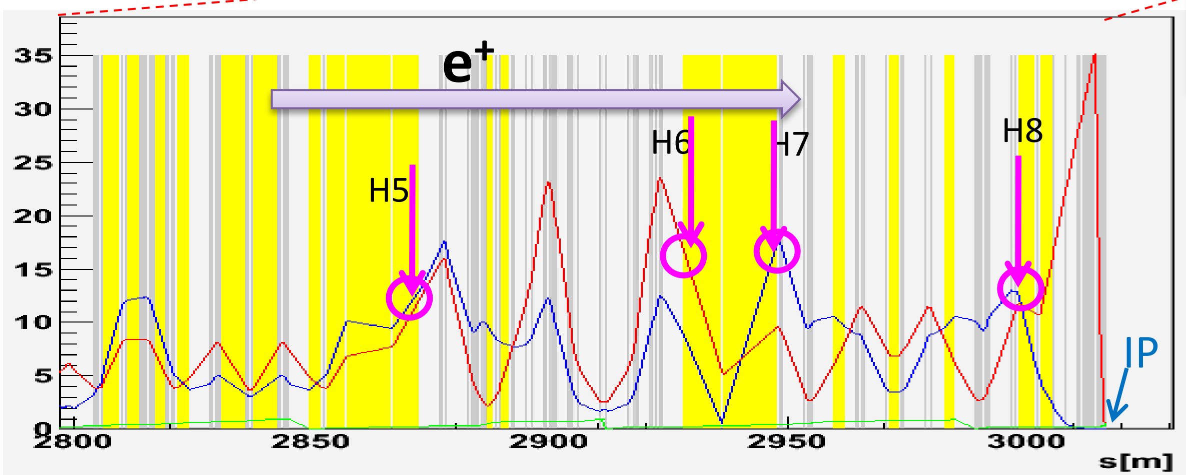


Intra-bunch scattering, Rate∝(beam size)$^{-1}$,$(E_{beam})^{-3}$
More dangerous in LER

LER horizontal collimators



β_x or η_x converted to collimator width (mm)



Collimator width: 10~15mm

$$d_x = Max[d_{x\beta}, d_{x\eta}, d'_{x\beta}]$$

$$d_{x\beta} = n_x \sqrt{\varepsilon_x \beta_x}$$

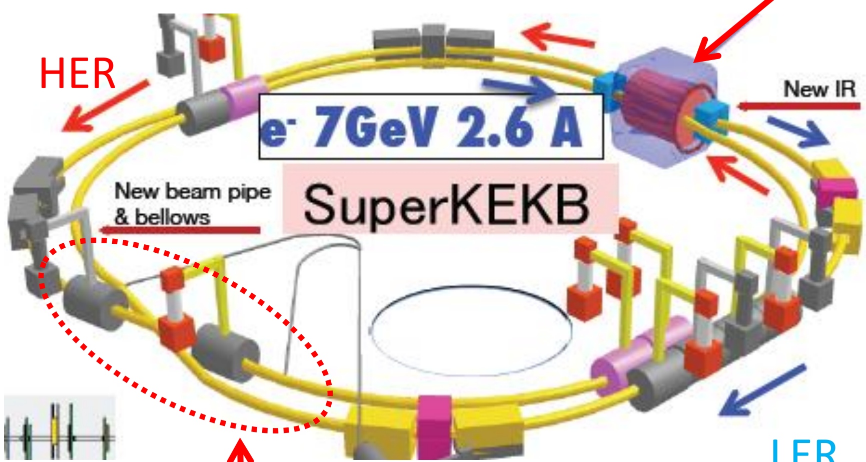
$$d_{x\eta} = \eta_x (n_z \sigma_\delta)$$

$$d'_{x\beta} = \sqrt{\frac{\beta_{x,\text{mask}}}{\beta_{x,\text{QC2}}}} r_{\text{QC2}}$$

Compared to KEKB, we add more collimators (H5-H8) just before IP (-200m~-18m).
Collimators are located where beta function or dispersion is large.

Vertically oscillating Touschek BG

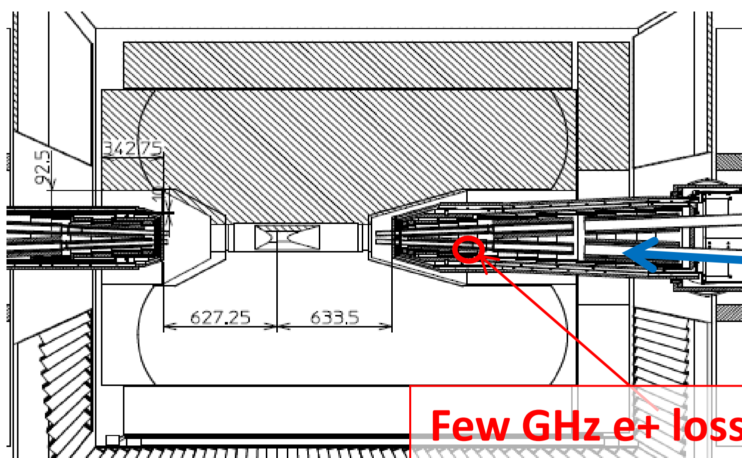
Belle detector



Touschek scattered particles scattered at Fuji-area (where vertical dispersion exists) start vertical oscillation and are eventually lost in IR QC1 where βy is large.

Vertical collimator narrower than QC1 can reduce such Touschek loss. Beam instability caused by such collimator is an issue.

In Fuji area, LER ring bends vertically , to pass under HER ring

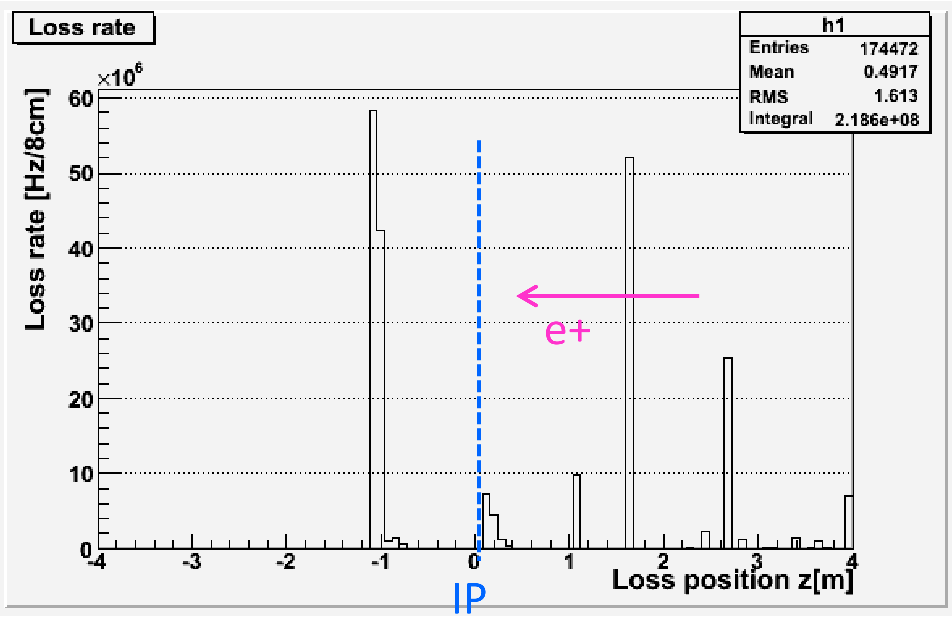


Vertical collimator width: few mm

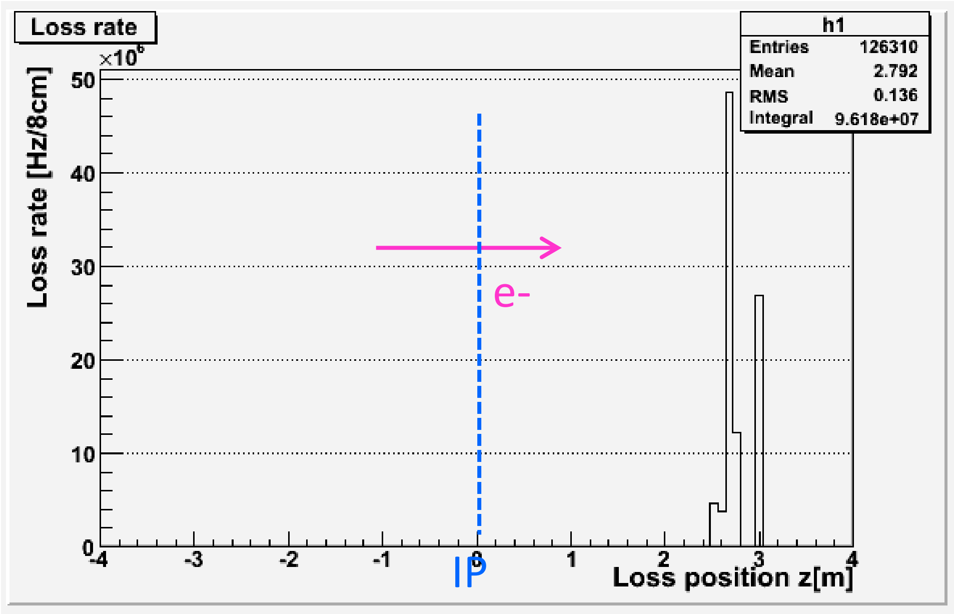
Few GHz e+ loss w/o vertical collimator

Final Touschek loss in IR

LER



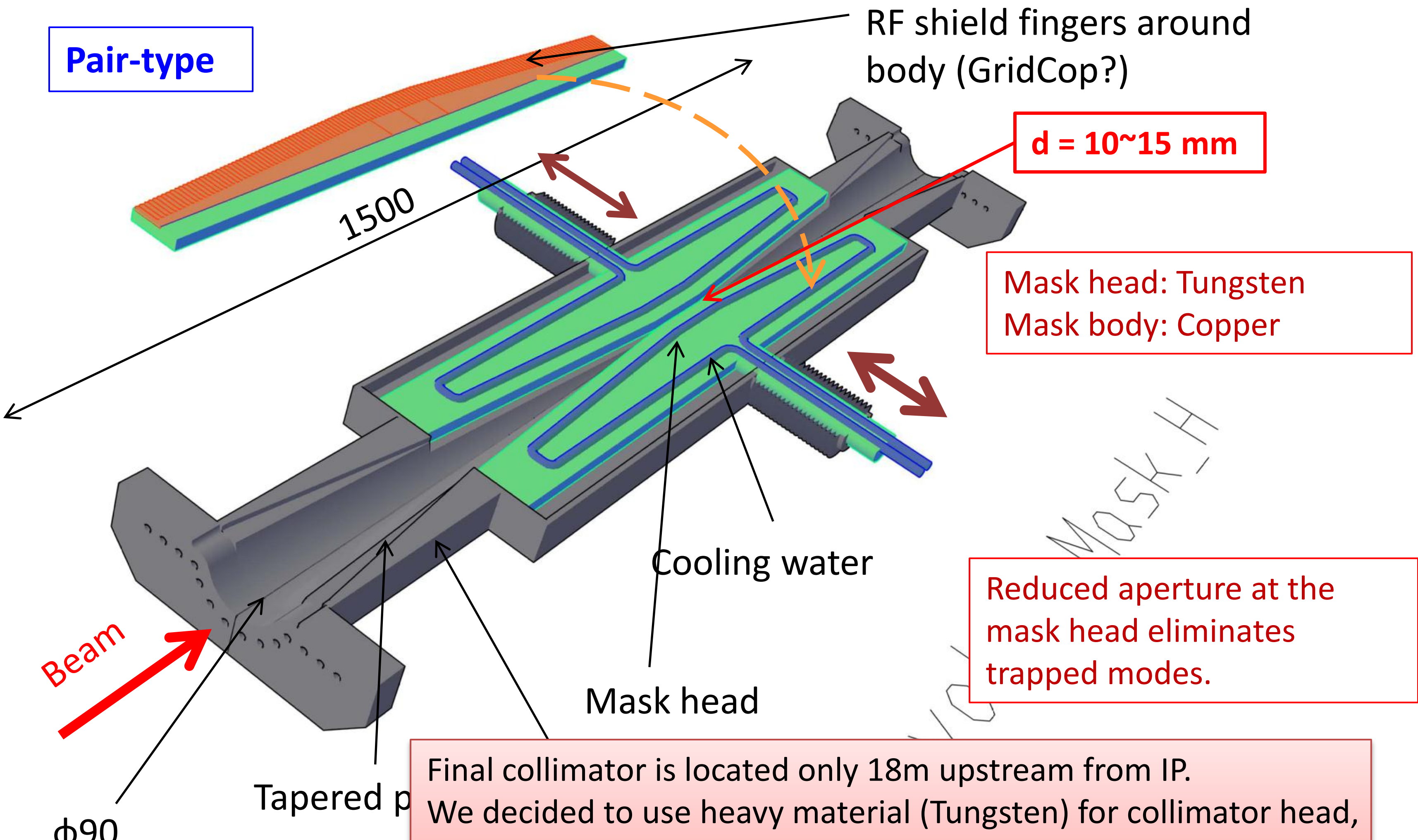
HER



Within |z|<4m,
- loss rate: 0.22 GHz
- loss wattage: 0.14 W

Within |z|<4m,
- loss rate: 0.10 GHz
- loss wattage: 0.10 W

Concept of horizontal collimators



Final collimator is located only 18m upstream from IP.
We decided to use heavy material (Tungsten) for collimator head, according to the secondary simulation. Beam particles should deposit enough energy to be lost before reaching IR.

H. Nakayama
K. Kanazawa
Y. Funakoshi

Beam-gas background

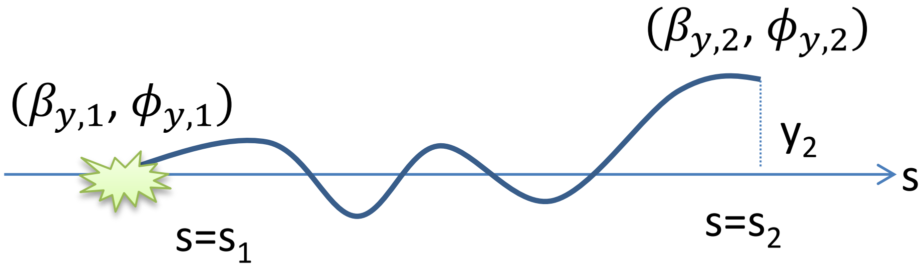
Coulomb>> bremsstrahlung

Coulomb BG is naively proportional to P x I.
Also depends on beta function over the ring and IR physical aperture.

P = 10^{-7}Pa is assumed

H. Nakano
K. Kanazawa

Beam-gas Coulomb lifetime



θ: Scattering angle

$$y_2 = \theta \sqrt{\beta_{y,1} \cdot \beta_{y,2}} \sin(\phi_{y,2} - \phi_{y,1})$$

The minimum scattering angle θ_c to hit QC1 beam pipe

$$\theta_c = r_{QC1} / \sqrt{\langle \beta_y \rangle \cdot \beta_{y,QC1}}$$

Beam lifetime τ_R is proportional to $\theta_c{}^2$

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

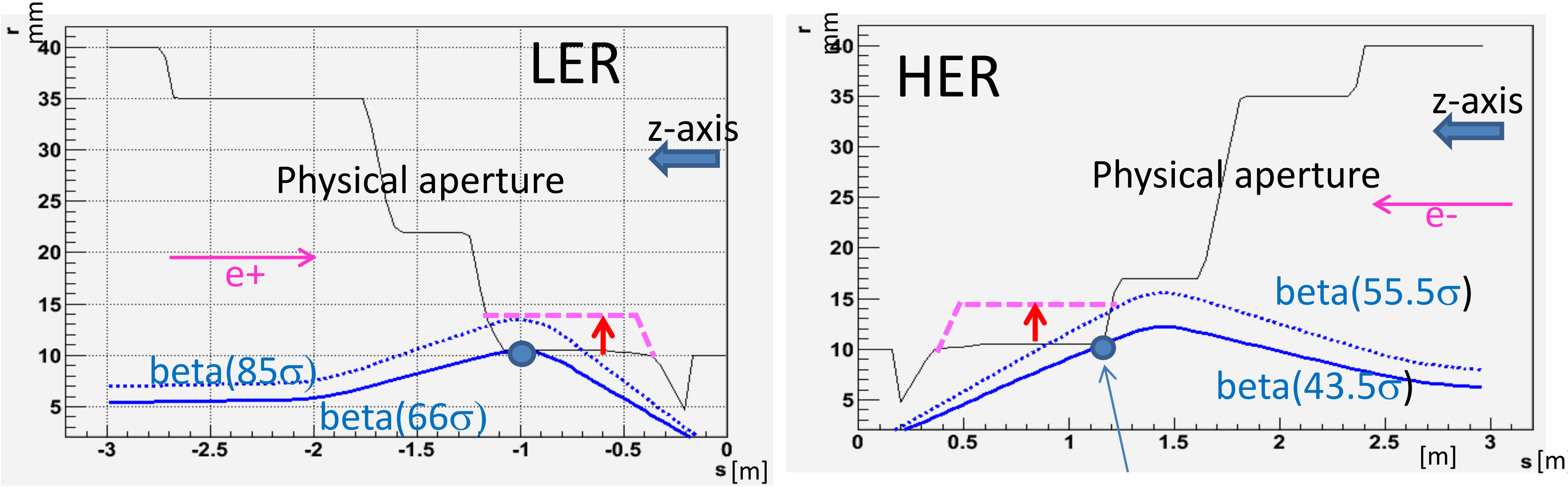
	KEKB LER	SuperKEKB LER
QC1 beam pipe radius: r_{QC1}	35mm	13.5mm
Max. vertical beta (in QC1): $\beta_{y,QC1}$	600m	2900m
Averaged vertical beta: $<\beta_y>$	23m	48m
Min. scattering angle: θ_c	0.3mrad	0.036mrad
Beam-gas Coulomb lifetime	>10 hours	2200sec

Rate $\propto$ P x I x $<\beta>$
x β_{QC1} / $r_{QC1}{}^2$

Beam-gas lifetime is only x1/100 of KEKB, due to larger vertical beta in QC1 and narrower QC1 physical aperture

Strategy to reduce Coulomb BG

- Larger QC1 physical aperture (r=10.5mm→13.5mm)



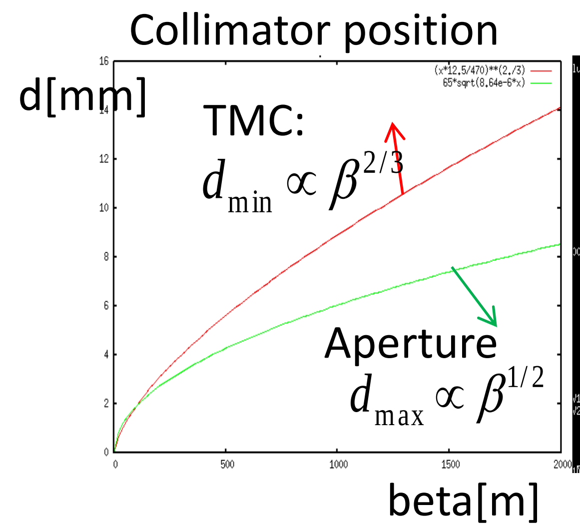
We widened QC1 aperture without major change in QCS design.
Coulomb lifetime improved (LER: 1360→2240sec, HER: 2100→3260sec)

- Vertical collimators!
  - QC1 aperture should not be narrowest over the ring
  - Collimator aperture should be narrower than QC1 aperture
  - Beam instability? (collimators should be very close(few mm) to the beam)

Where we should put vertical collimator?

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

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



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

<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"

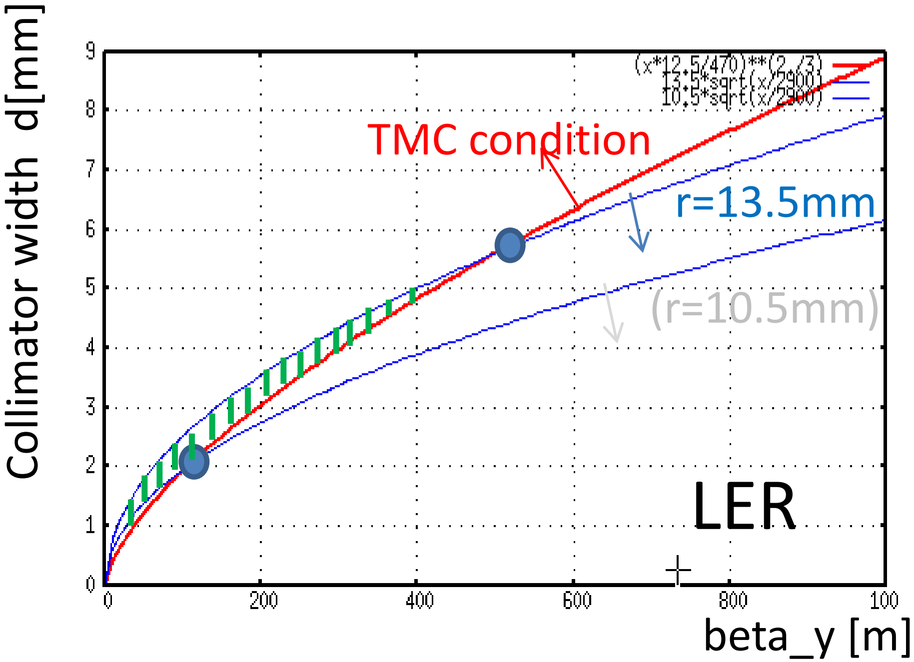
Kick factor $k_{\perp} = 0.215 A Z_0 c \sqrt{\frac{\theta}{\sigma_z d^3}}$

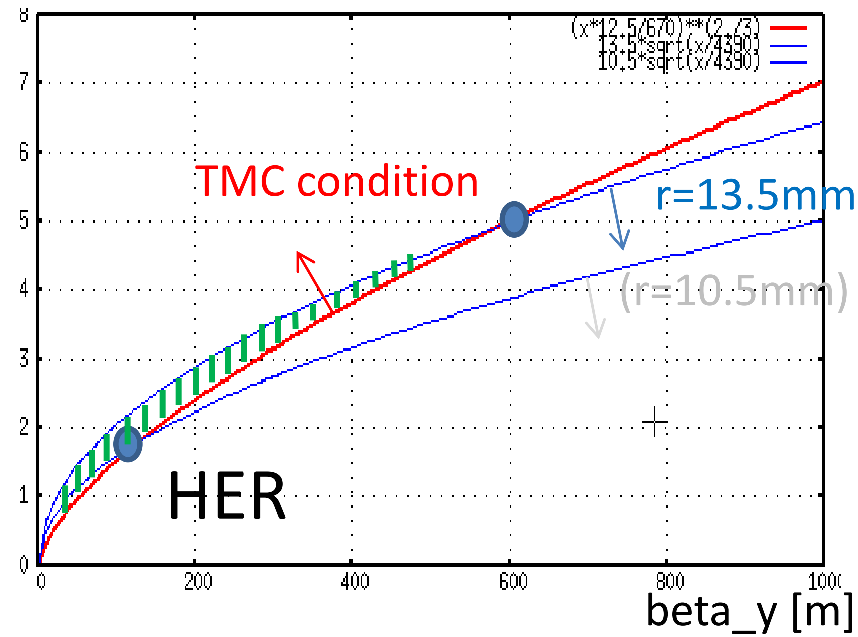
(in case of rectangular collimator window)

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

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

Candidate collimator locations





lerfqlc_1604

V1 collimator @ LLB3R (downstream)
(s=-90→-82m, βy=30→146m)
βy=125m, 2.23mm<d<2.81mm

herfqlc5605

V1 collimator @ LTLB2 (downstream)
(s=-63→-61m, βy=81→187m)
βy=123m, 1.74mm<d<2.26mm

Collimator position should satisfy beta_y condition above,
need space(at least 1.5m), and the phase should be close to IP

Vertical collimator width vs. Coulomb loss rate, Coulomb life time

ler1604, V1=LLB3R downstream

V1 width[mm]	IR loss [GHz]	Total loss[GHz]	Coulomb life[sec]
2.40	0.04	149.5	1513.3
2.50	0.05	137.8	1642.0
2.60	0.09	127.4	1776.0
2.70	0.24	118.1	1915.2
2.80	0.81	110.0	2057.2
2.90	8.48	109.3	2069.6
3.00	18.98	109.3	2069.6

her5365,V1=LTLB2 downstream

V1 width[mm]	IR loss [GHz]	Total loss[GHz]	Coulomb life[sec]
2.10	0.001	48.4	3379.4
2.20	0.001	44.1	3709.0
2.30	0.357	40.0	4053.8
2.40	6.862	33.0	4099.1
2.50	12.004	27.9	4099.1

Based on element-by-element simulation considering causality the phase difference (by Nakayama)

IR loss rate is VERY sensitive to the vertical collimator width.
(Once V1 aperture>QC1 aperture, all beam loss goes from V1 to IR

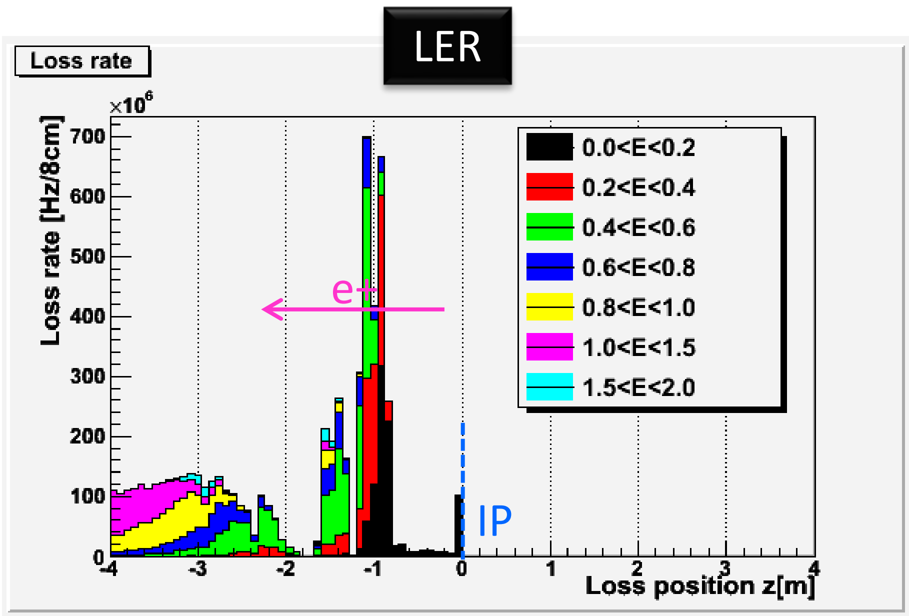
Typical orbit deviation at V1 : +-0.12mm (by iBump V-angle: +-0.5mrad@IP)

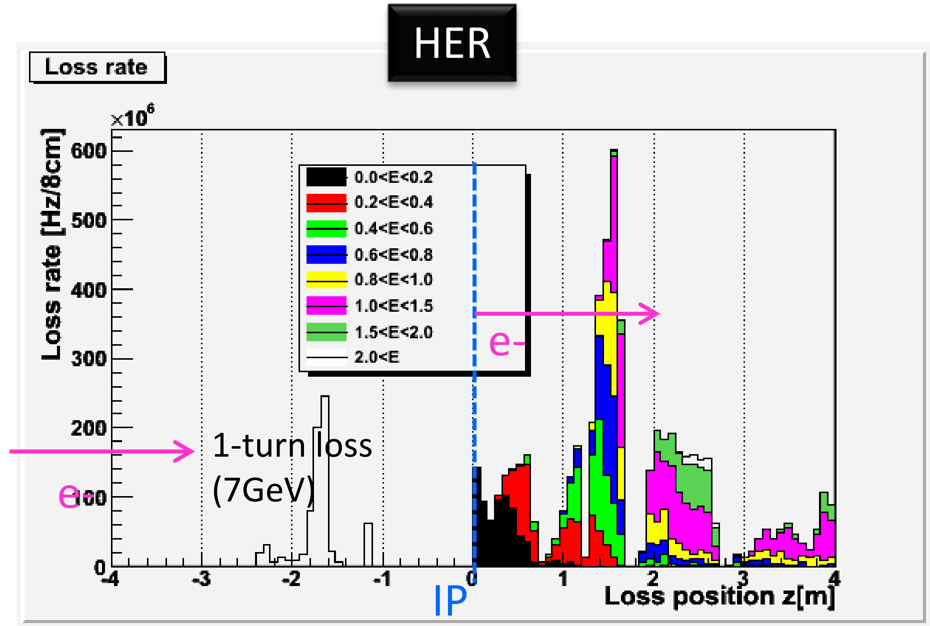
Y. Funakoshi

Radiative Bhabha background

- Spent e+/e- loss in downstream
  Dominant loss position is very far (~10m) from IP, but little fraction with large ΔE (still dangerous with Lx40) can be lost inside detector.
- Gamma emitted from IP
  They hit downstream (~10m) beam pipe/magnet and generate neutrons by giant dipole resonance. Neutron shielding inside tunnel will be increased

Radiative Bhabha BG



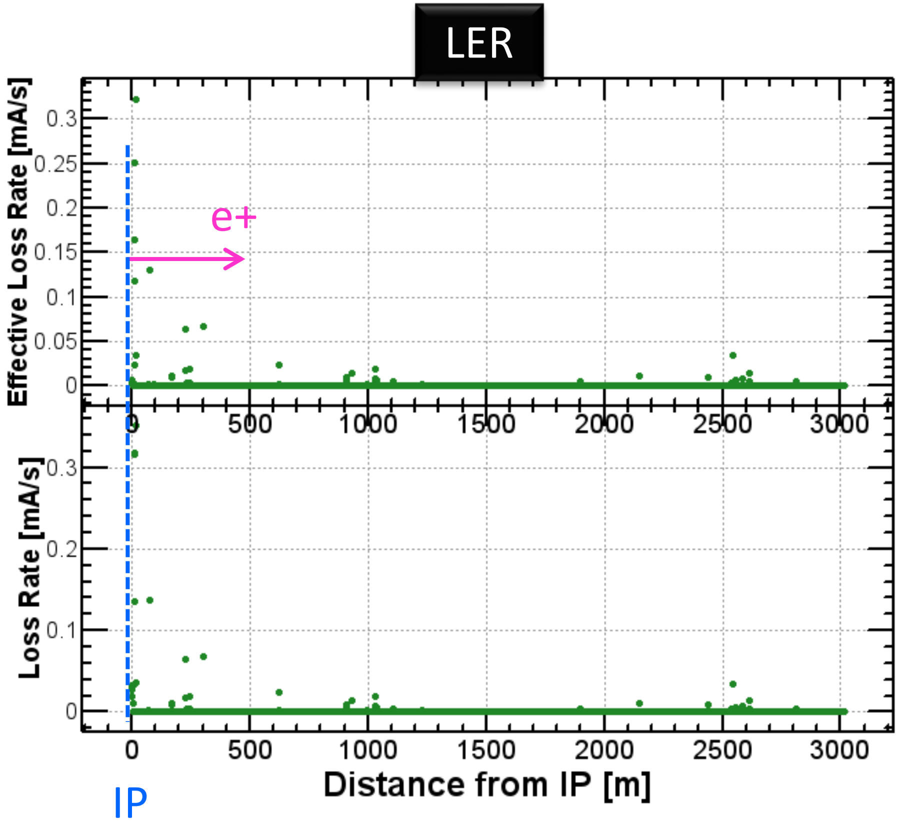


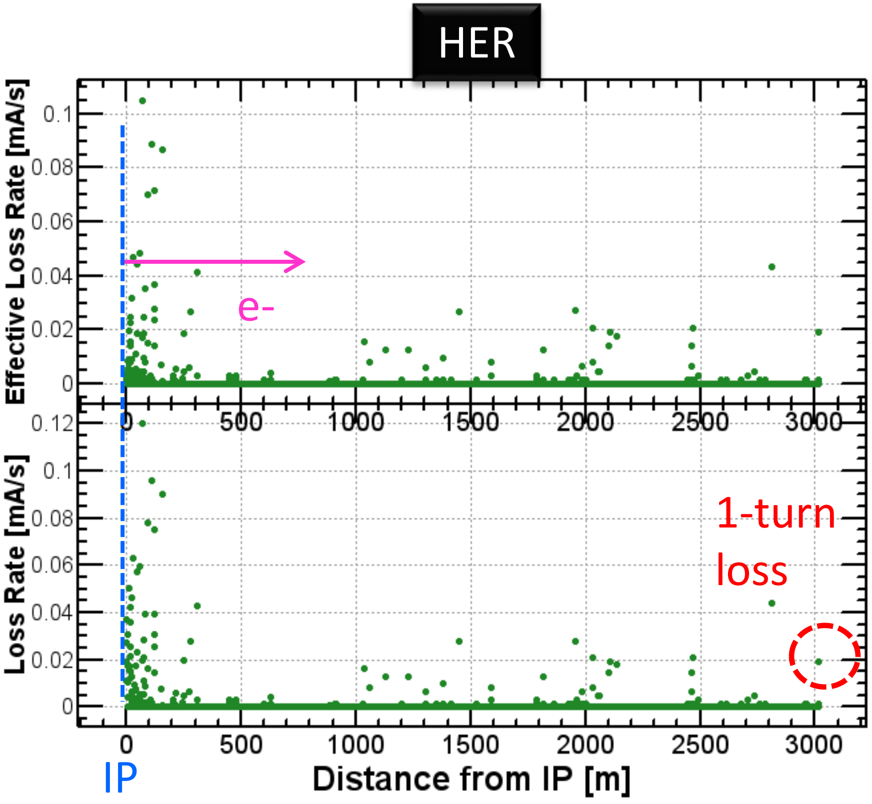
Within |z|<4m,
loss rate: 6.8 GHz(0~1.4GeV)
loss wattage: 0.55 W
(Equivalent to 0.86GHz of 4GeV e-)

Within |z|<4m,
loss rate: 5.8 GHz(0~2GeV)
loss wattage: 0.75 W
(Equivalent to 0.68GHz of 7GeV e-)

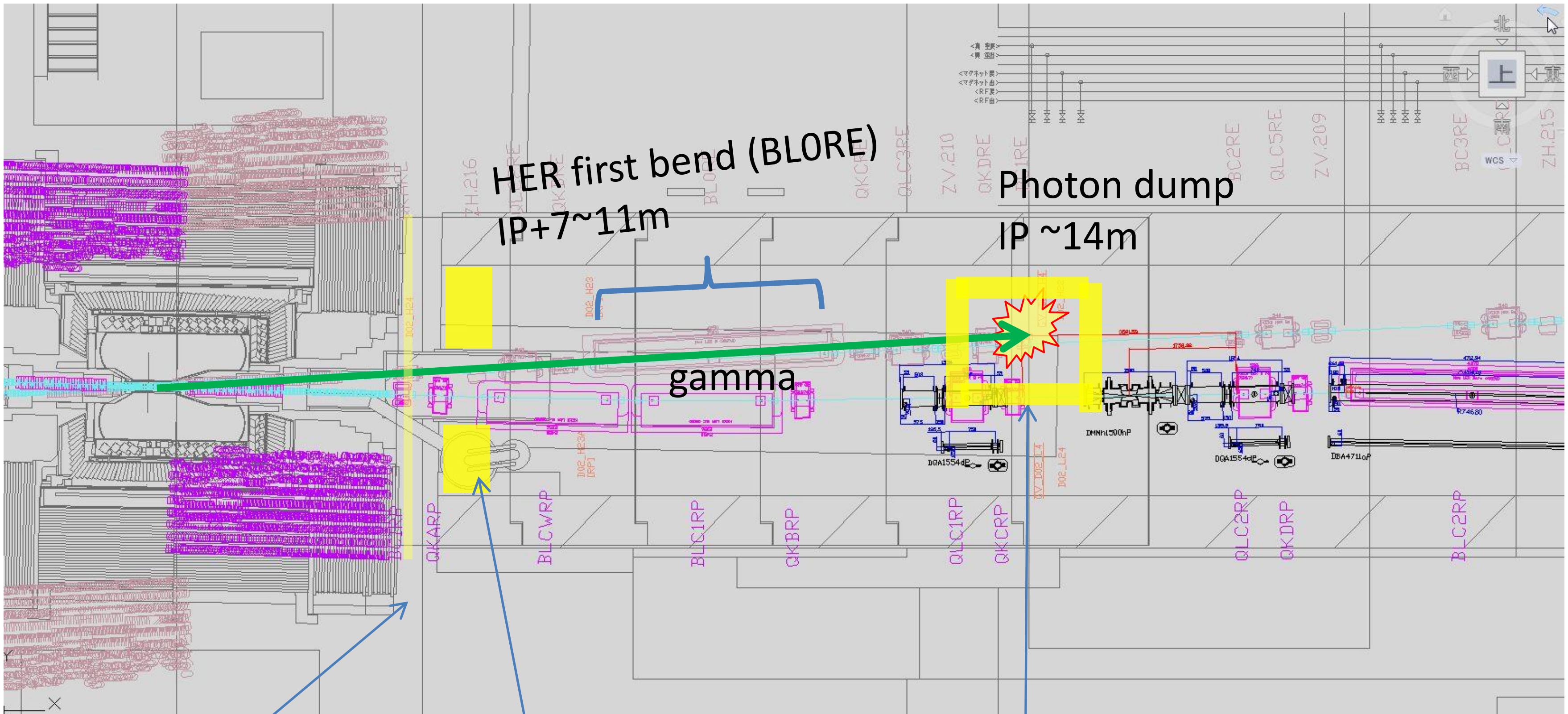
+ 0.80W of 1-turn loss at z=-1.8m

RBB loss rate in the total ring





Additional shields in tunnel

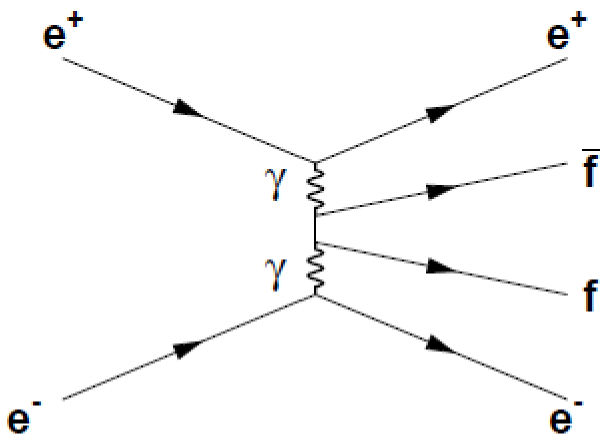


Polyethylene shield (10cm) at KEKB

Additional concrete shield at tunnel exit

Additional neutron shield around gamma dump

2-photon BG



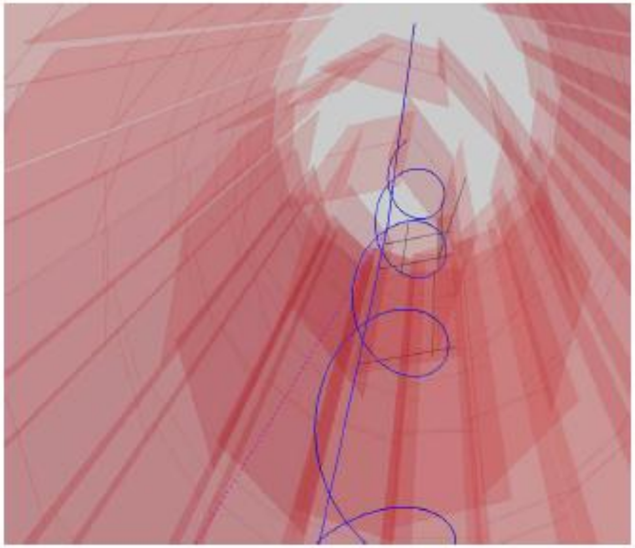


Figure 6.3: Event display of the two-photon KoralW events in the SVD

C. Kiesling, S. Koblitz
E. Nedelkovska

2-photon BG

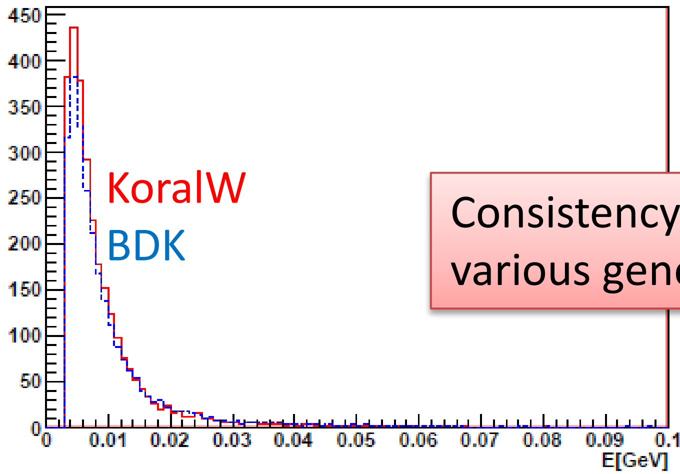
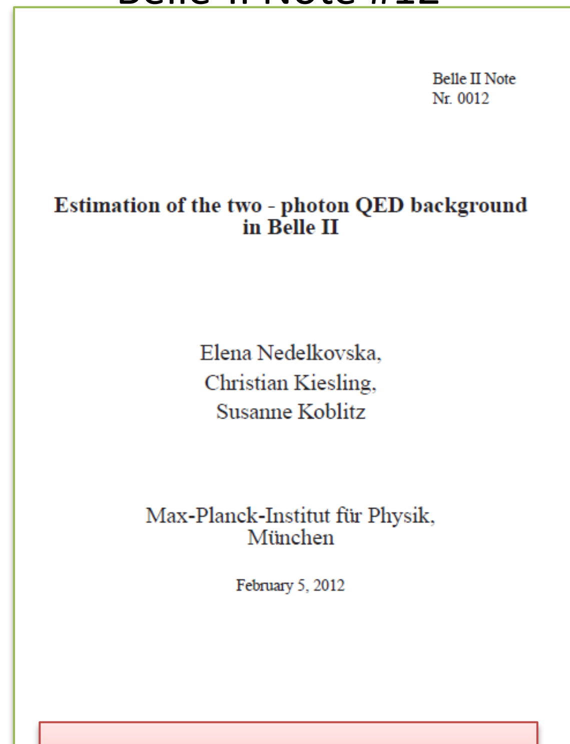


Figure 2.4: KoralW(dashed blue) and BDK(solid red) simulation

Consistency among the various generator s

Belle-II Note #12


Belle II Note
Nr. 0012

Estimation of the two - photon QED background in Belle II

Elena Nedelkovska,
Christian Kiesling,
Susanne Koblitz

Max-Planck-Institut für Physik,
München

February 5, 2012

Documentation now available

Experiment	SVD layers	Hits	QED hits	KoralW	SuperB(BDK)
Belle	1	~ 100	13.3 ± 2.6	11.31	62.2
	2 - 4	~ 45	-2.9 ± 2.1	2.38	13.1
Belle II	Occupancy (1st PXD)			0.7%	4.0%

Table 6.1: Comparison between data and Monte Carlo

KEKB machine study in 2010 is consistent with our generator, and inconsistent with SuperB numbers

Synchrotron BG

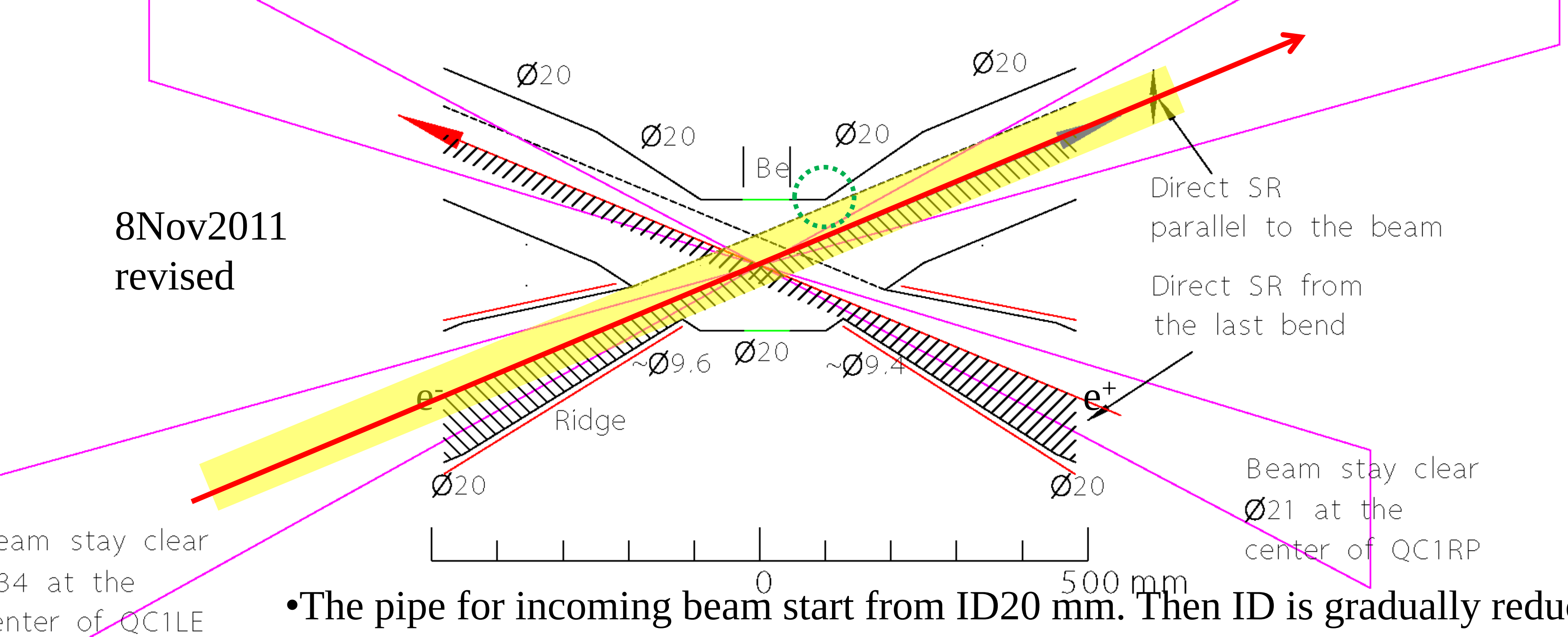
mainly from HER

IR Beam pipe design for SR

•Minimize the creation and the trap of HOM.

•The central part and the branch for out going beam constitute a bent pipe of ID20mm.

8Nov2011
revised

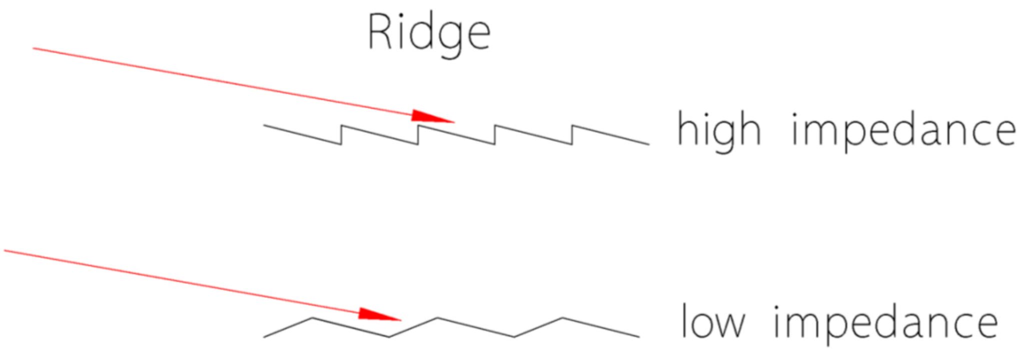


•The pipe for incoming beam start from ID20 mm. Then ID is gradually reduced to about 9 mm to stop direct SR.

•The inner surface of a pipe for incoming beam has ridges to prevent scattered light from hitting the central part.

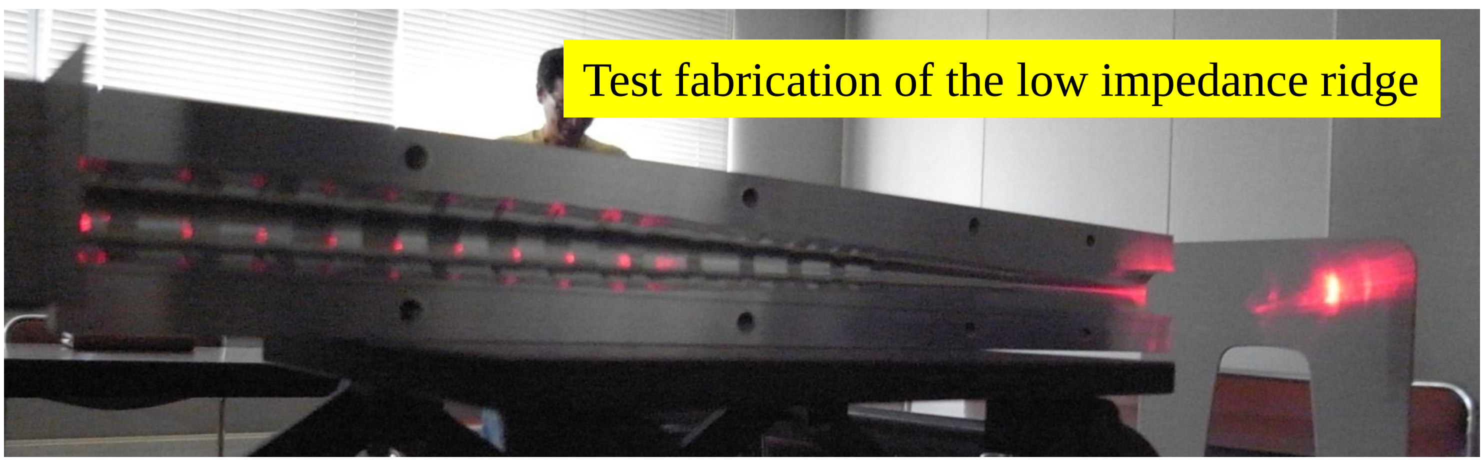
“Ridge” structure on incoming beam pipe

Reflected SR cannot see the straight part of Beam pipe



Low risk for multiply scattered photon to escape forward

Risk for multiply scattered photon to escape forward

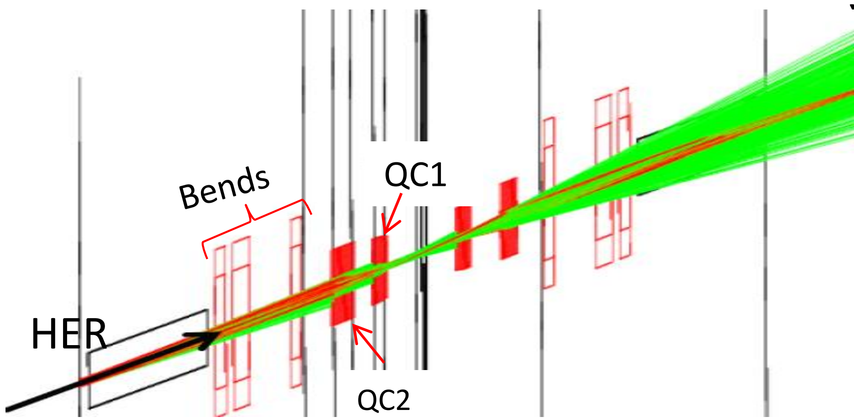


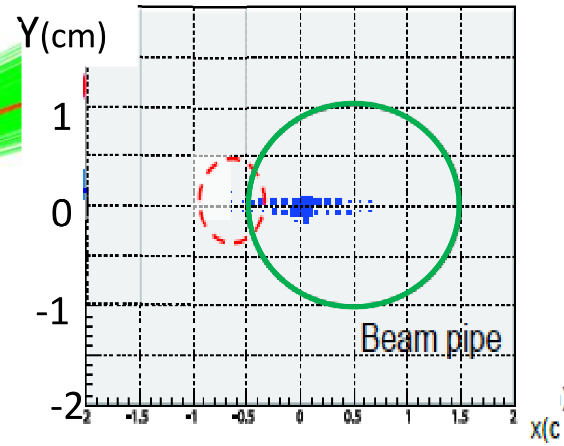
Test fabrication of the low impedance ridge

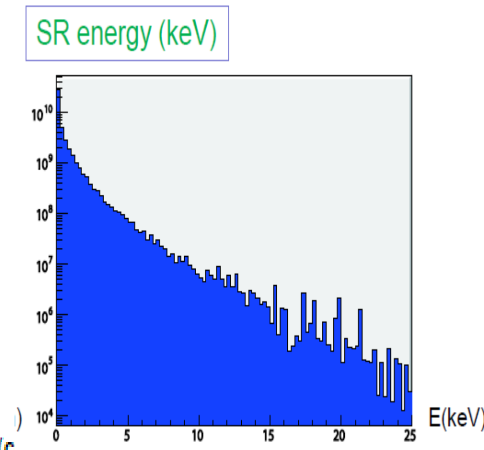
Final decision on the shape of the ridge depends on the estimated impedance (loss factor).

M.Iwasaki

SR simulation results in 2010

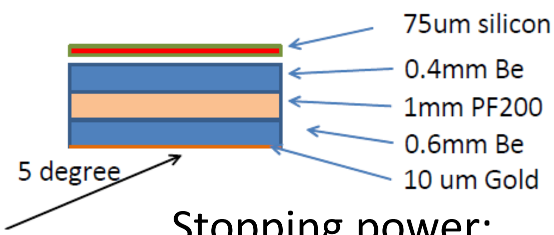






- Simplified geometry, no SR scattering/reflection considered
- Bending magnets, solenoids, Q magnets, Q leak field implemented
- Gaussian beam with tail cutoff of 20σ

~200/bunch (>5keV) photons hit straight part of beam pipe, which is 3-4 order below PXD requirements.

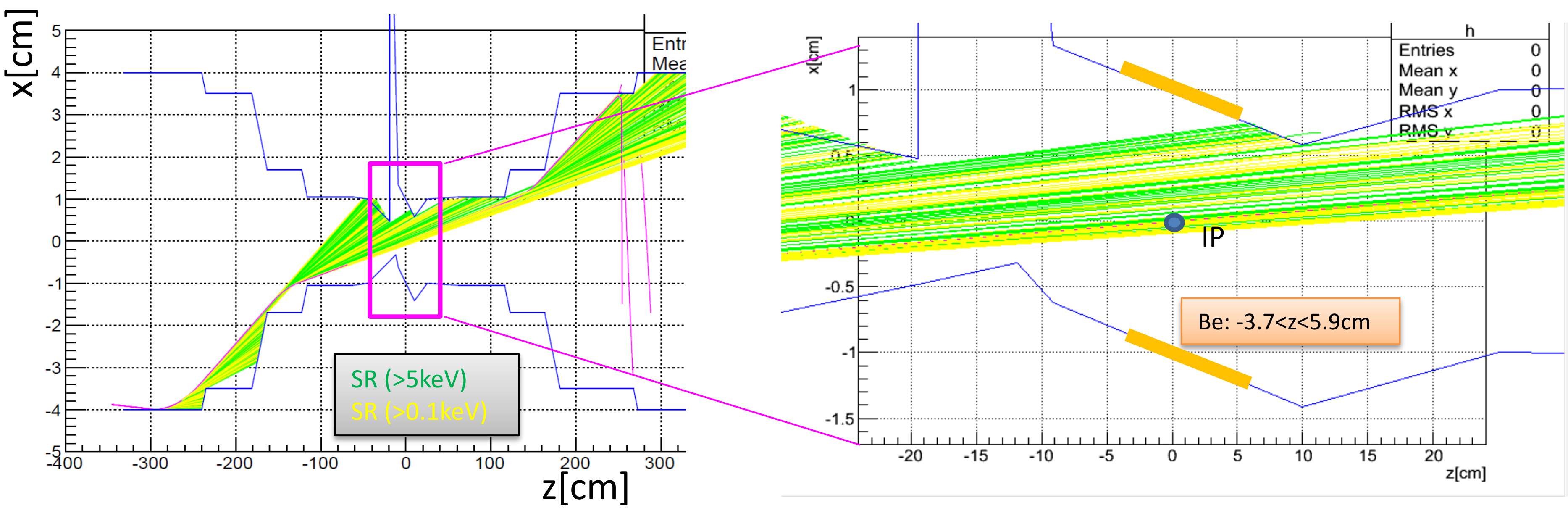


Stopping power: O(~10^{-6}) for <20KeV

H. Nakayama
K. Itagaki

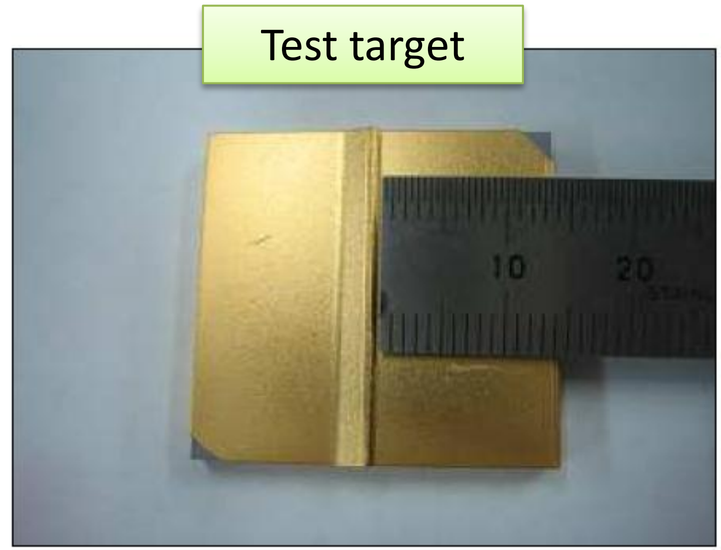
Detailed SR simulation

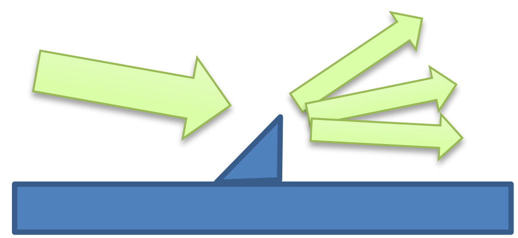
- Just started in our full-detector GEANT4 framework
- Detailed beam pipe geometry implemented, only QC1/2 so far
- Waiting for correct solenoid field based on 3D ANSYS calculation
  - Currently using 2D "cylindrical" solenoid field which gives wrong orbit
- Consider reflection/scattering on Au coating of beam pipe
- Test-beam study to implement home-made "tip-scattering" model



J. Murakami
S. Tanaka

X-ray beam test



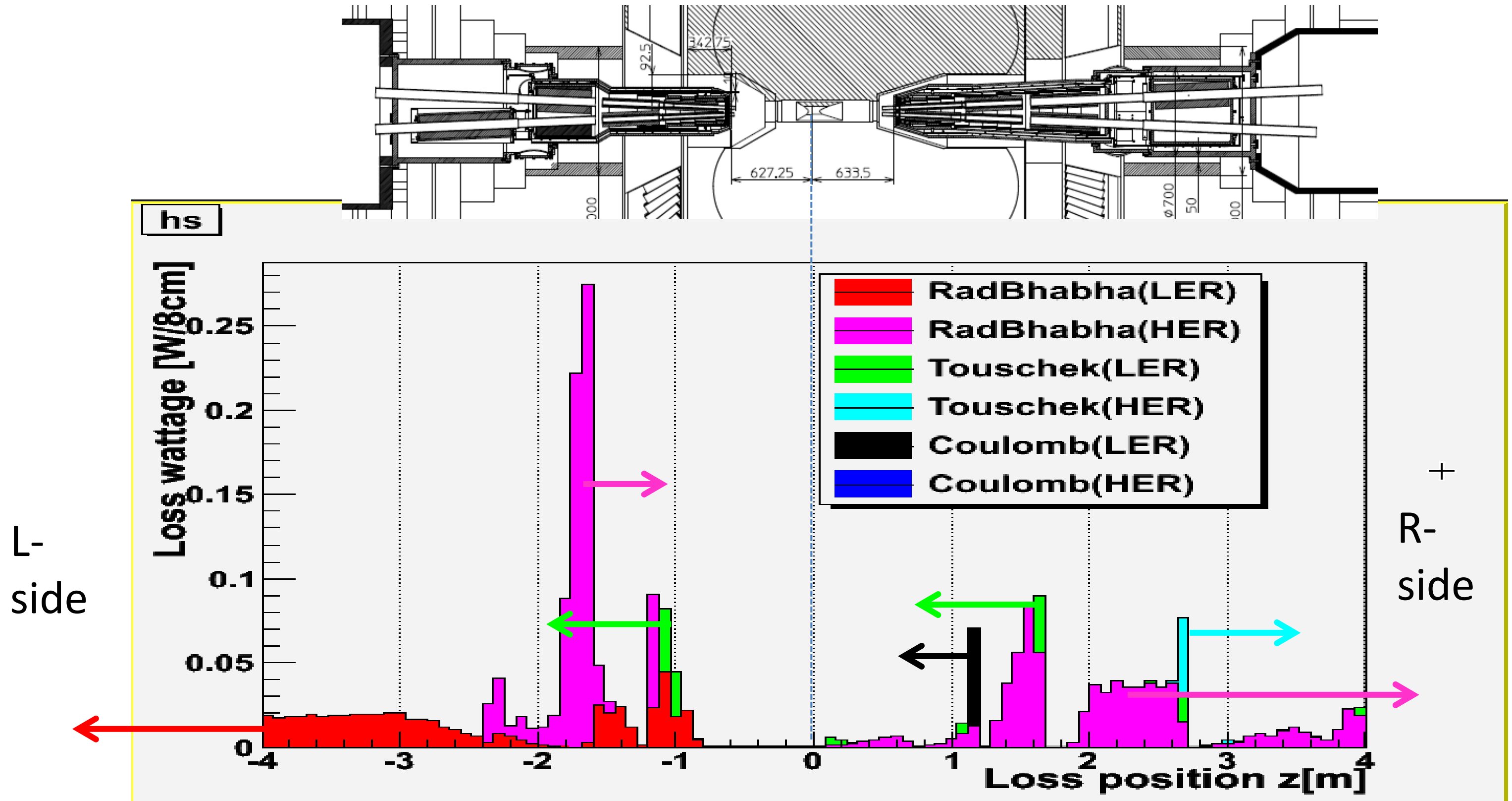


Measure scattering angle distribution

Irradiate X-rays onto Ta tip plated with gold and measure angle distribution of scattered flux.

Analysis ongoing

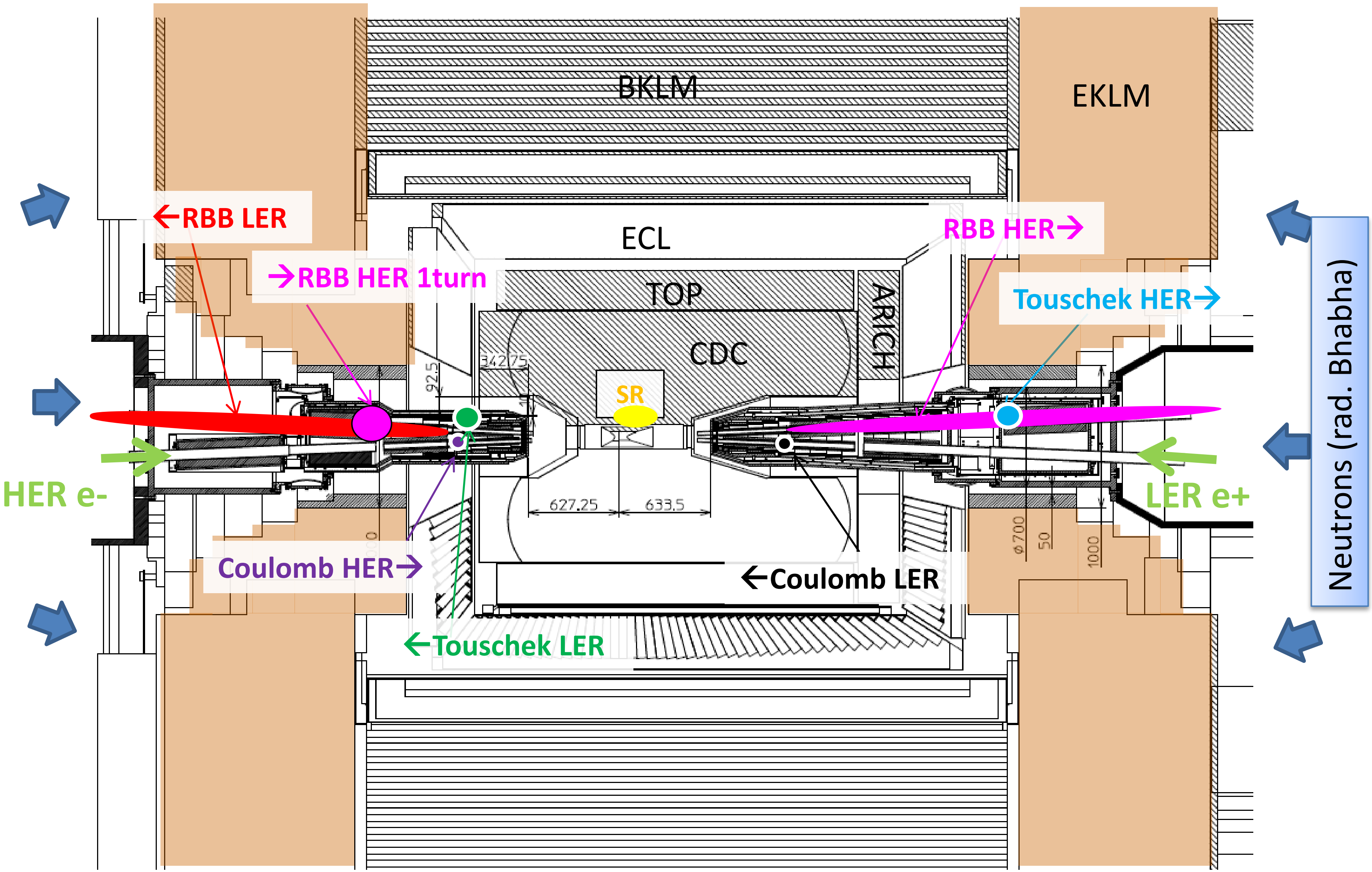
Total BG



	LER (4GeV e+)	HER (7GeV e-)
Rad. Bhabha	0.55 W (eff. 0.9GHz)	1.60W (eff. 1.4GHz)
Touschek	0.10 W (0.16GHz)	0.05 W (0.05GHz)
Coulomb	0.06 W (0.09GHz)	0.001W (0.001GHz)

1GeV ,1GHz
= 0.16W

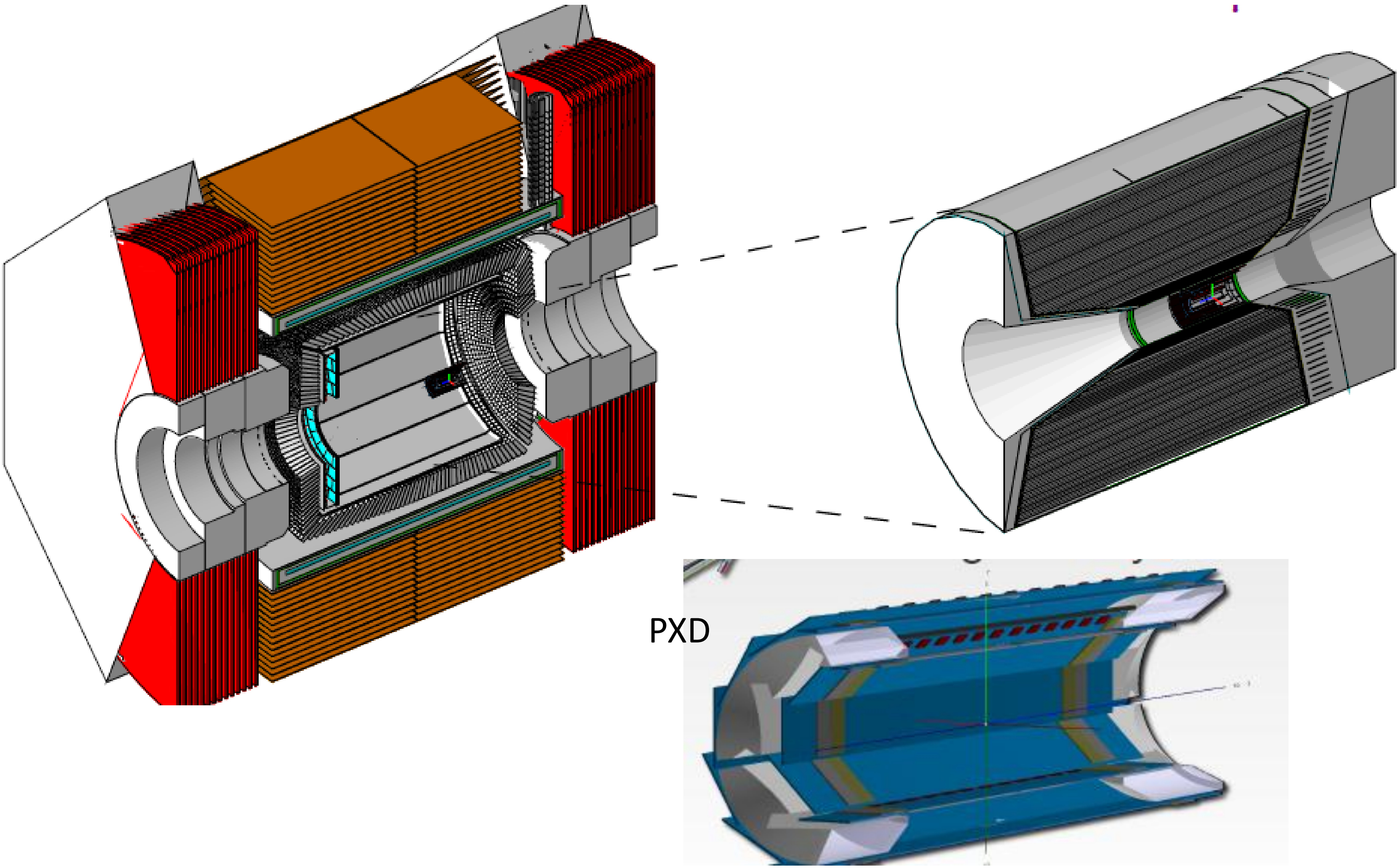
Background picture at Belle-II



Full-detector simulation

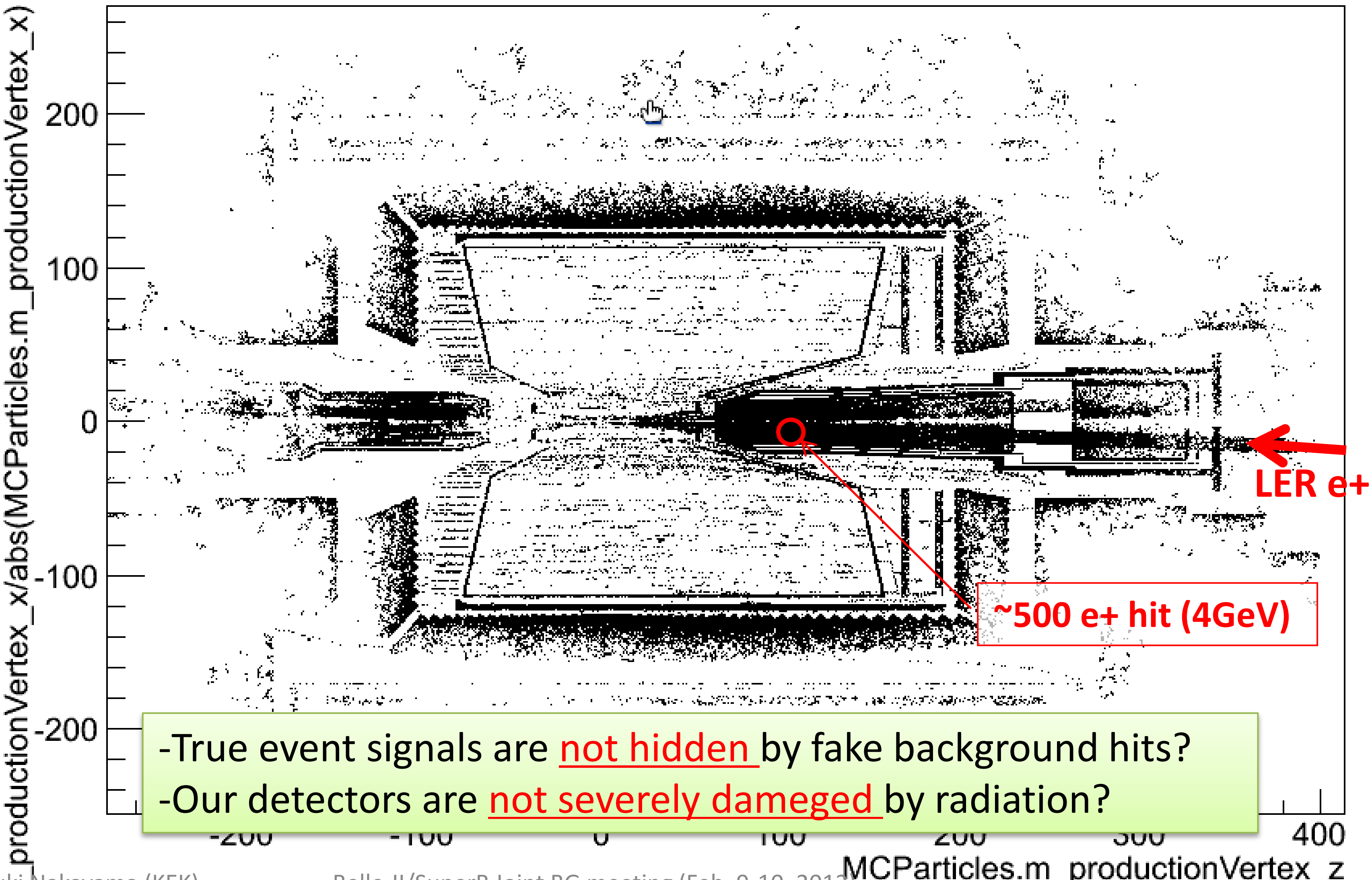
- First campaign in Dec. 2011
  - 0.9GHz Touschek LER / 2photon
- Second campaign in Feb. 2012 (coming soon)
  - Touschek/Beam-gas/Rad. Bhabha/ 2photon

Whole geometry ready in GEANT4



Full-detector simulation

Generated vertex of all MC particles

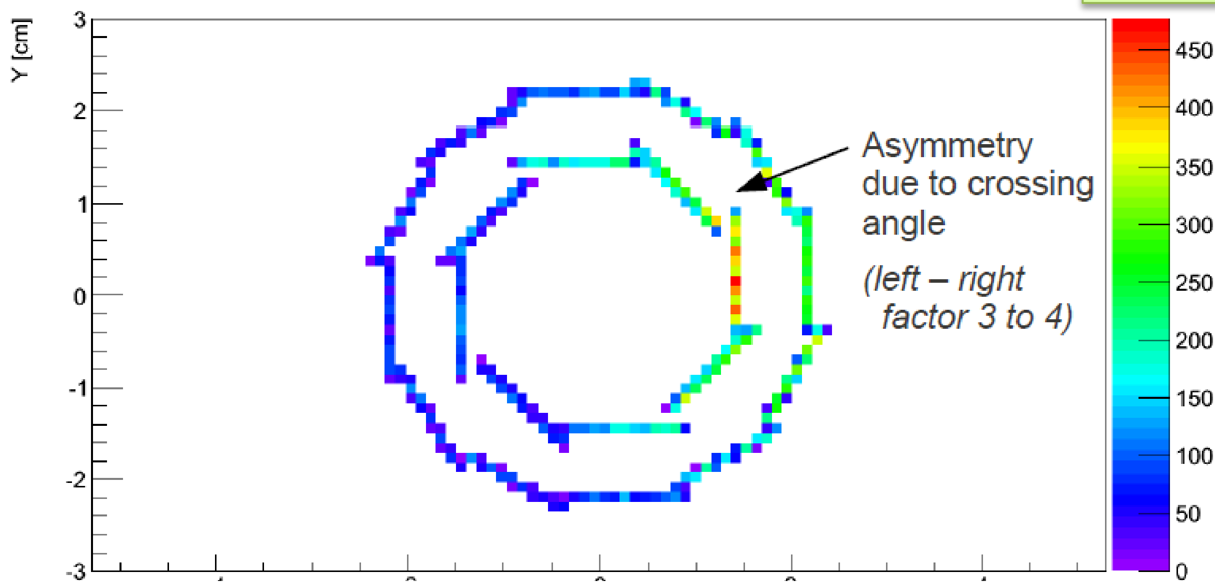


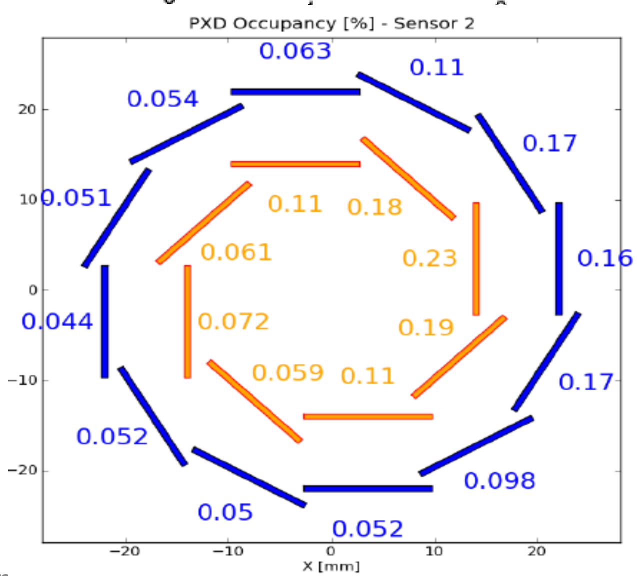
-True event signals are not hidden by fake background hits?
-Our detectors are not severely dameged by radiation?

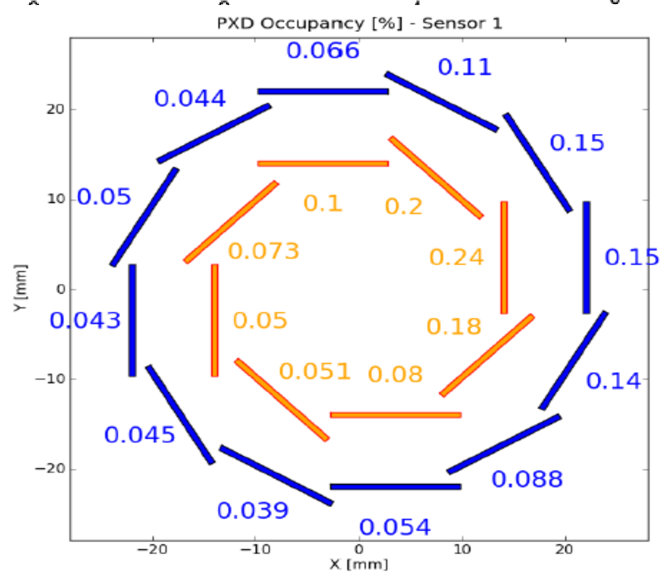
A. Moll

PXD

2nd campaign
(0.2GHz LER Touschek)





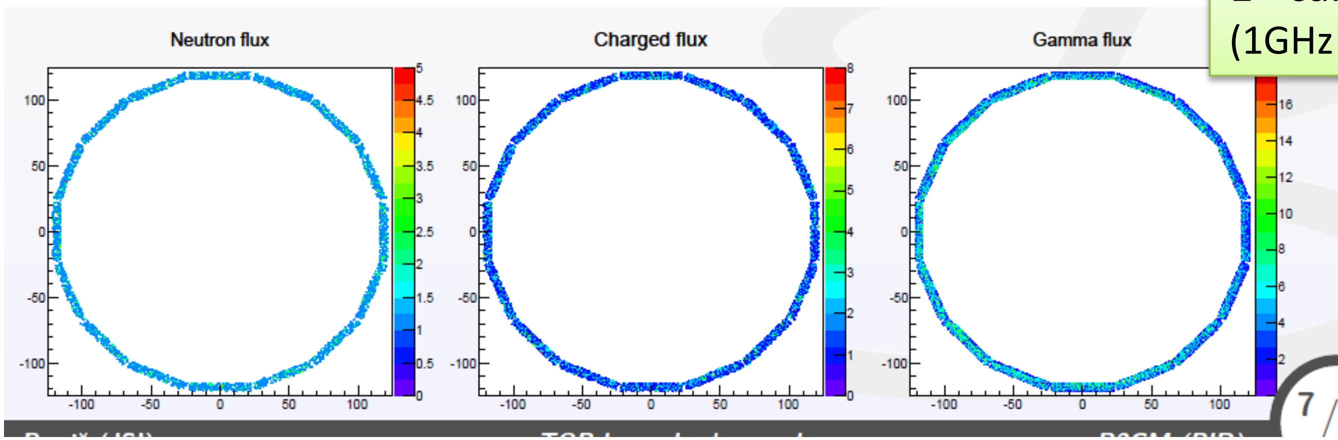


M.Petric, L. Santej

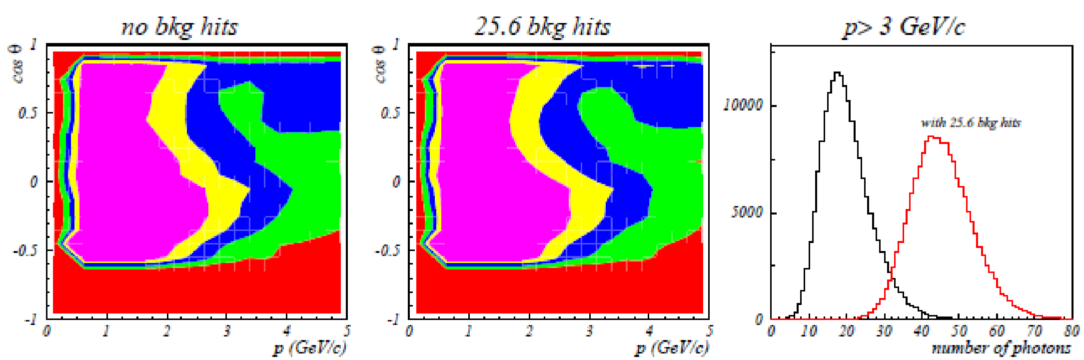
TOP/ARICH

1st campaign
(1GHz LER Touschek)

TOP

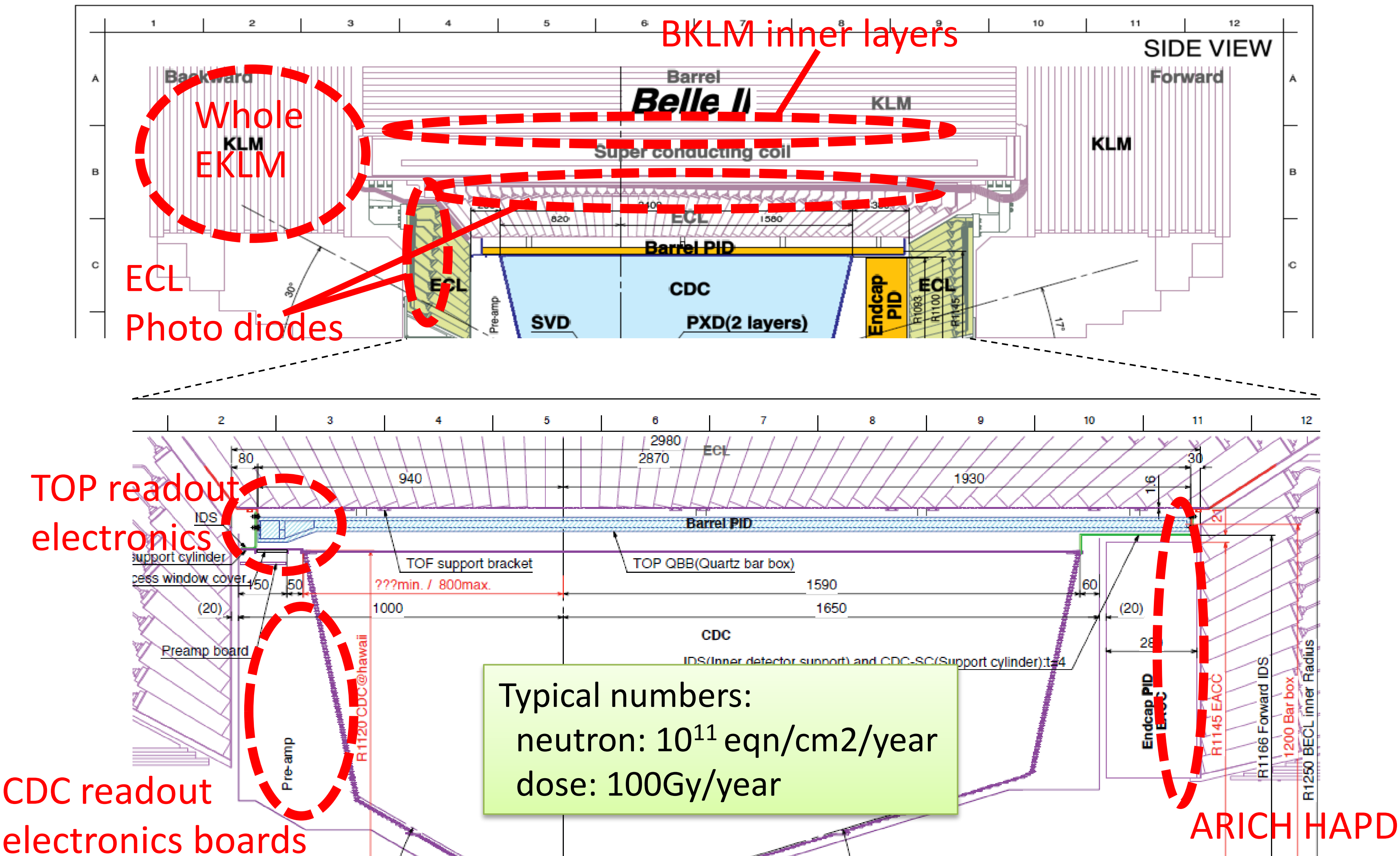


ARICH



	$B^0 \to \pi^+\pi^-$		$B^0 \to \rho\gamma$		$D^0 \to K^-\pi^+$	
	π effi	K fake	π effi	K fake	K effi	π fake
no background	92.1	6.8	98.3	1.4	96.7	2.8
16 MHz/PMT	90.8	7.6	97.5	1.9	96.4	3.5

neutron damage /radiation dose



Typical numbers:
neutron: 10^{11} eqn/cm2/year
dose: 100Gy/year

Summary

- Touschek, beam-gas have been reduced, now radiative Bhabha dominates. (Same as SuperB!)
- I hope we can understand the 2-photon number discrepancy today
- SR simulation in full simulation started recently
- Full detector simulation campaign ongoing

Limitation

- Touschek:
  - scattering at beam center only, perfect collimation assumed
- Beam-gas
  - scattering at beam center only, perfect collimation assumed
- RBB, 2-photon: OK
- SR
  - unrelalistic SR angular distribution, no sextapole or higher multi-pole
- Fullsim
  - loss at $|z|>4$m are not included