Beam-induced Background

Hiroyuki NAKAYAMA (KEK)

ARC(Mar. 3rd, 2014)

Topics reported last year

- Beam loss simulation:
  - Touschek/Beam-gas: SAD-based (Ohnishi, Funakoshi)
  - Radiatibe Bhabha: BBBREM generator
  - 2-photon: “BDK” generator
  - SR: Geant4 SR physics model
- Full-detector simulation (5th campaign)
  - PXD occupancy 2~3%: close to limit
  - TOP PMT lifetime: new PMTs are OK, still ~x2 reduction needed for old PMTs (lifetime: ~1C/cm2)
- Injection BG study

What's new in this review

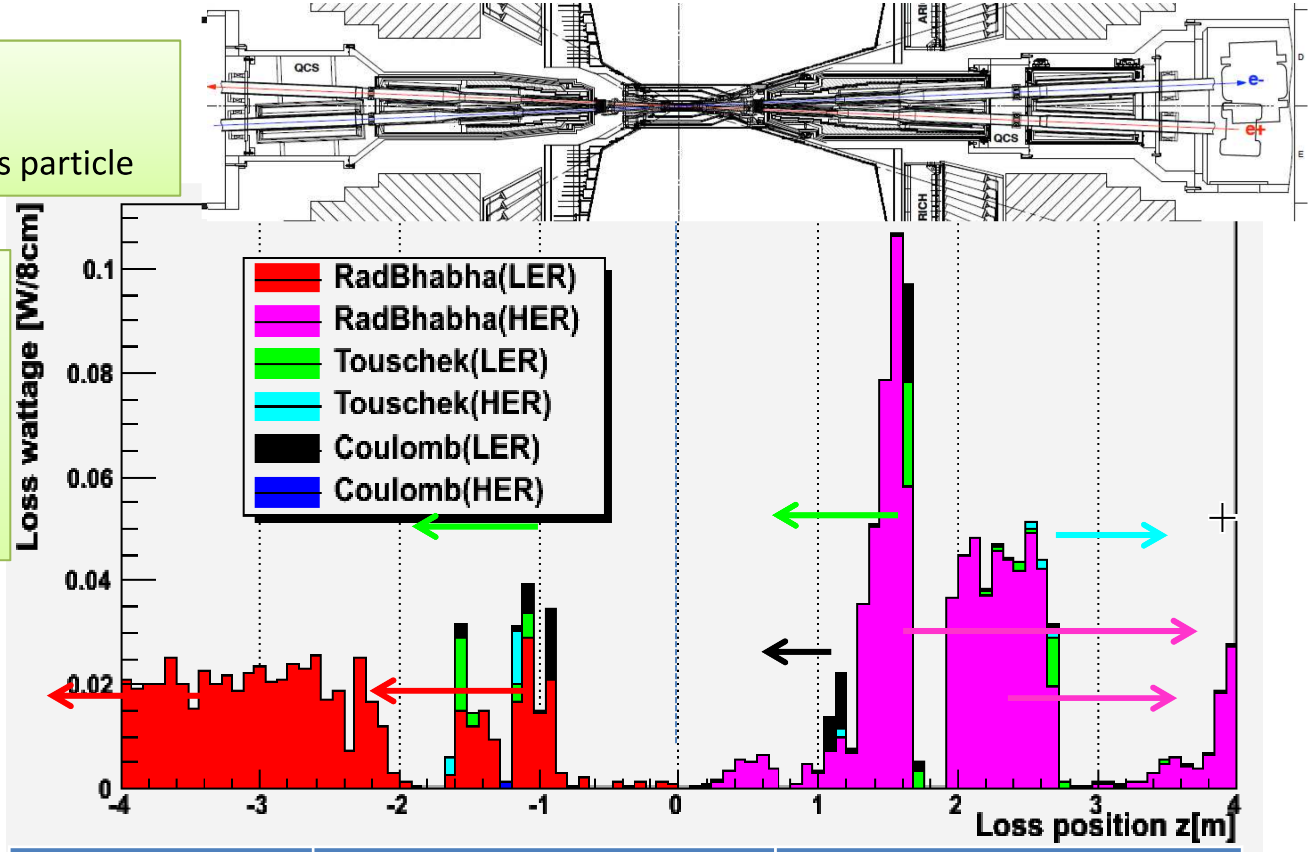
- RBB cross section update
  - Less cross section due to "beam size effect"
- Full detector simulation (8^{th} campaign)
  - Detector performance, radiation dose, neutron flux with the updated loss distribution
  - New shielding ideas (near ARICH/ECL)
  - Forward QCS design
- Monitor DAQ diagram
  - Beam abort, collimator control

Ver. 2013.6.12
(6th campaign)

BG loss distribution

Loss wattage
= loss rate
* energy of loss particle

For 7th/8th campaign we scale RBB components By x0.8



LER
(e+)

1GeV ,1GHz
= 0.16W

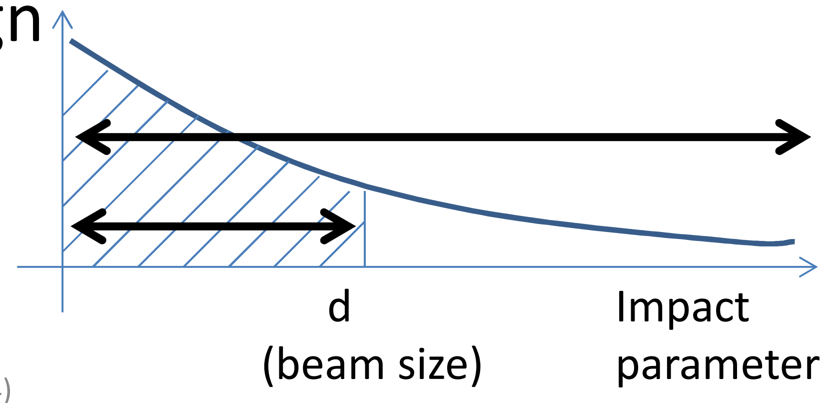
	LER (4GeV e+)	HER (7GeV e-)
Rad. Bhabha	0.63 W (eff. 0.98GHz)	0.88W (eff. 0.78GHz)
Touschek	0.07 W (0.11GHz)	0.02 W (0.02 GHz)
Coulomb	0.07 W (0.10GHz)	0.001W (0.001GHz)

Rad. Bhabha cross section:
“beam size effect”

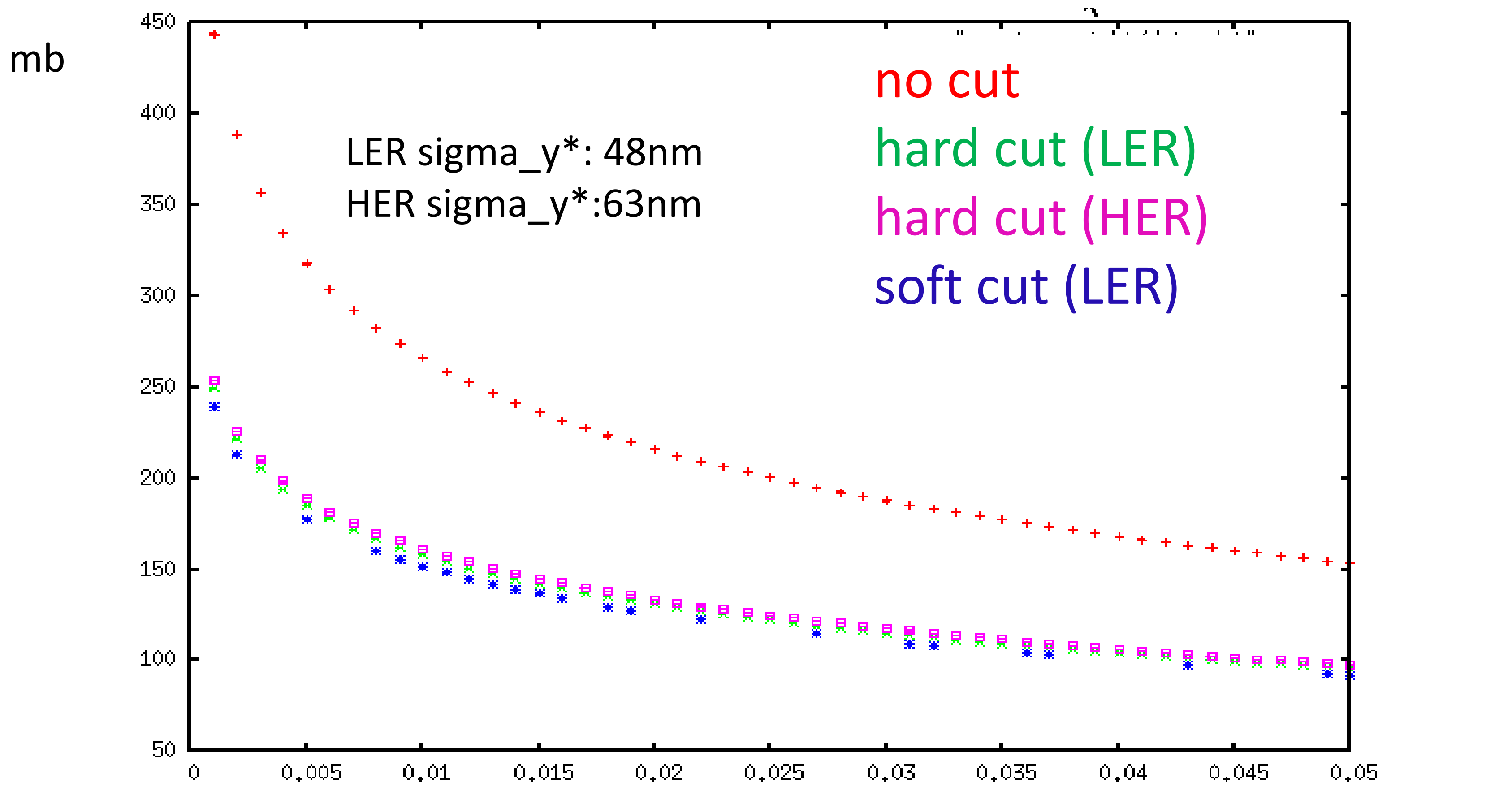
Rad.Bhabha: beam size effect

BBBREM paper: R. Kleiss, H. Burkhardt arXiv:hep-ph/9401333

- Theoretically calculated RBB cross section is larger than measured cross section at machine.
- This is explained by assuming only “impact parameter < beam size” range contributes to the measured cross section, while the theoretical calculation assume infinite impact parameter range.
- This effect was not included in default BBBREM which is used for 6th campaign



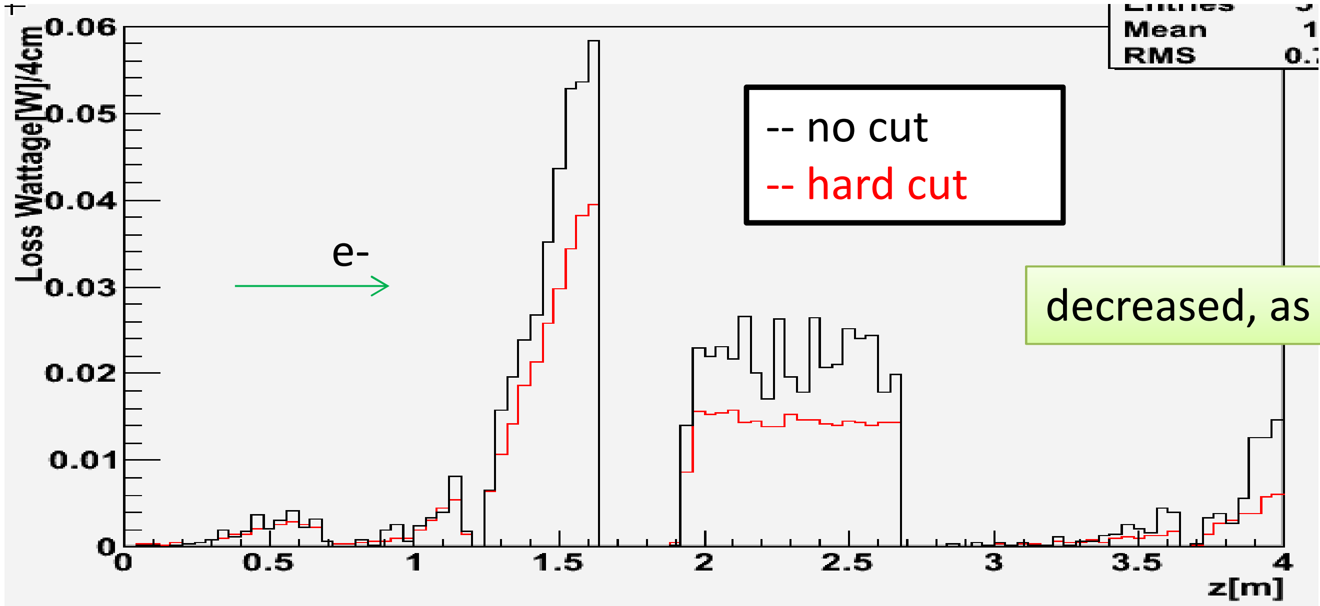
BBBREM cross section



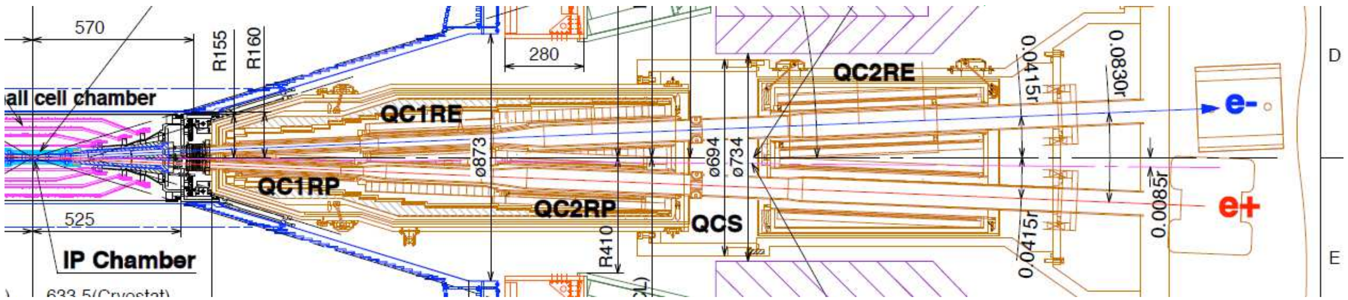
Min frac	1e-6	1%	2%	5%
no cut	1077 mb	266 mb	215 mb	153 mb
hard cut	521 mb	161 mb	131 mb	96 mb
soft cut	501 mb	152 mb	125 mb	92 mb

RBB HER loss distribution

Tracking by SAD



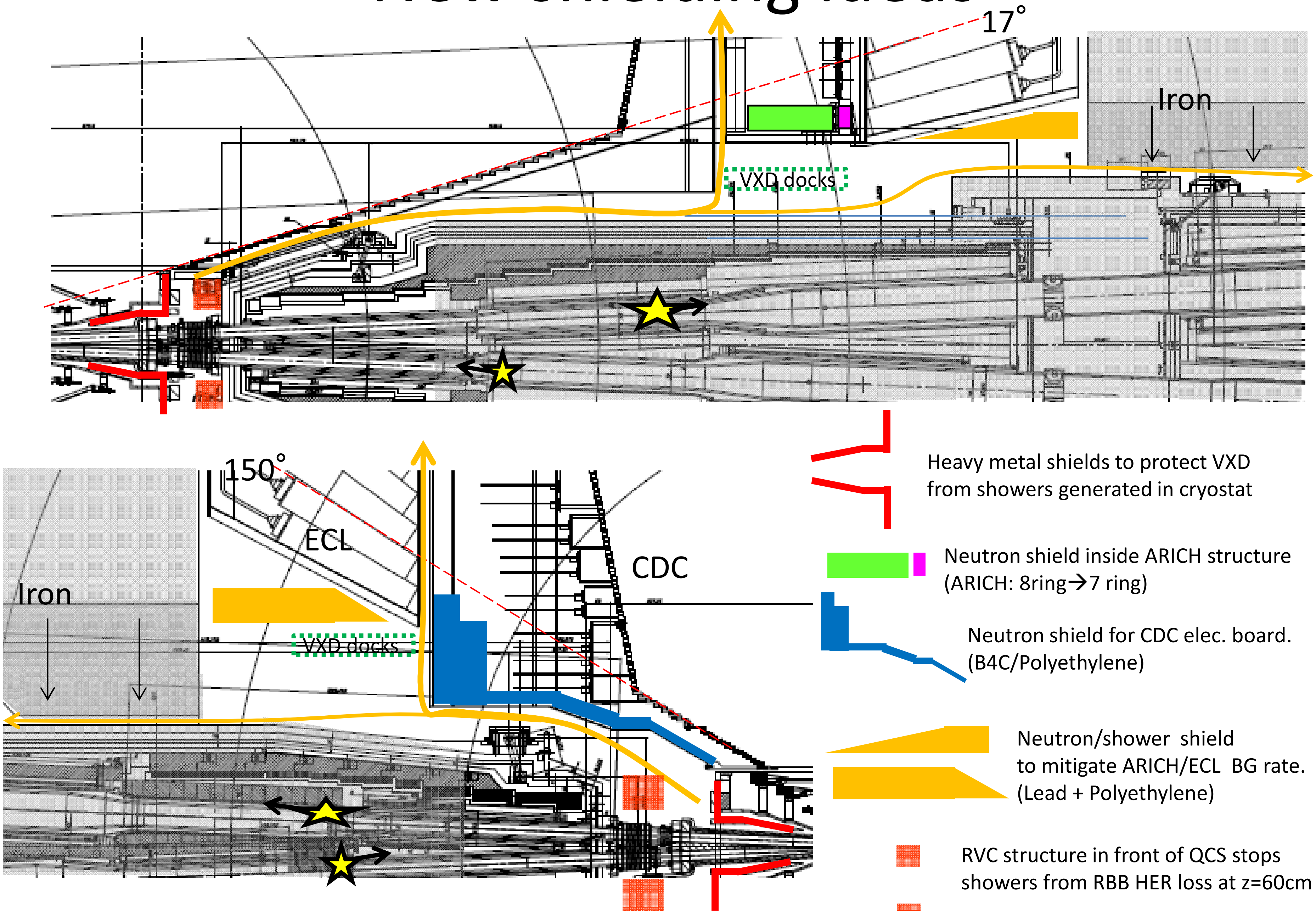
decreased, as expected



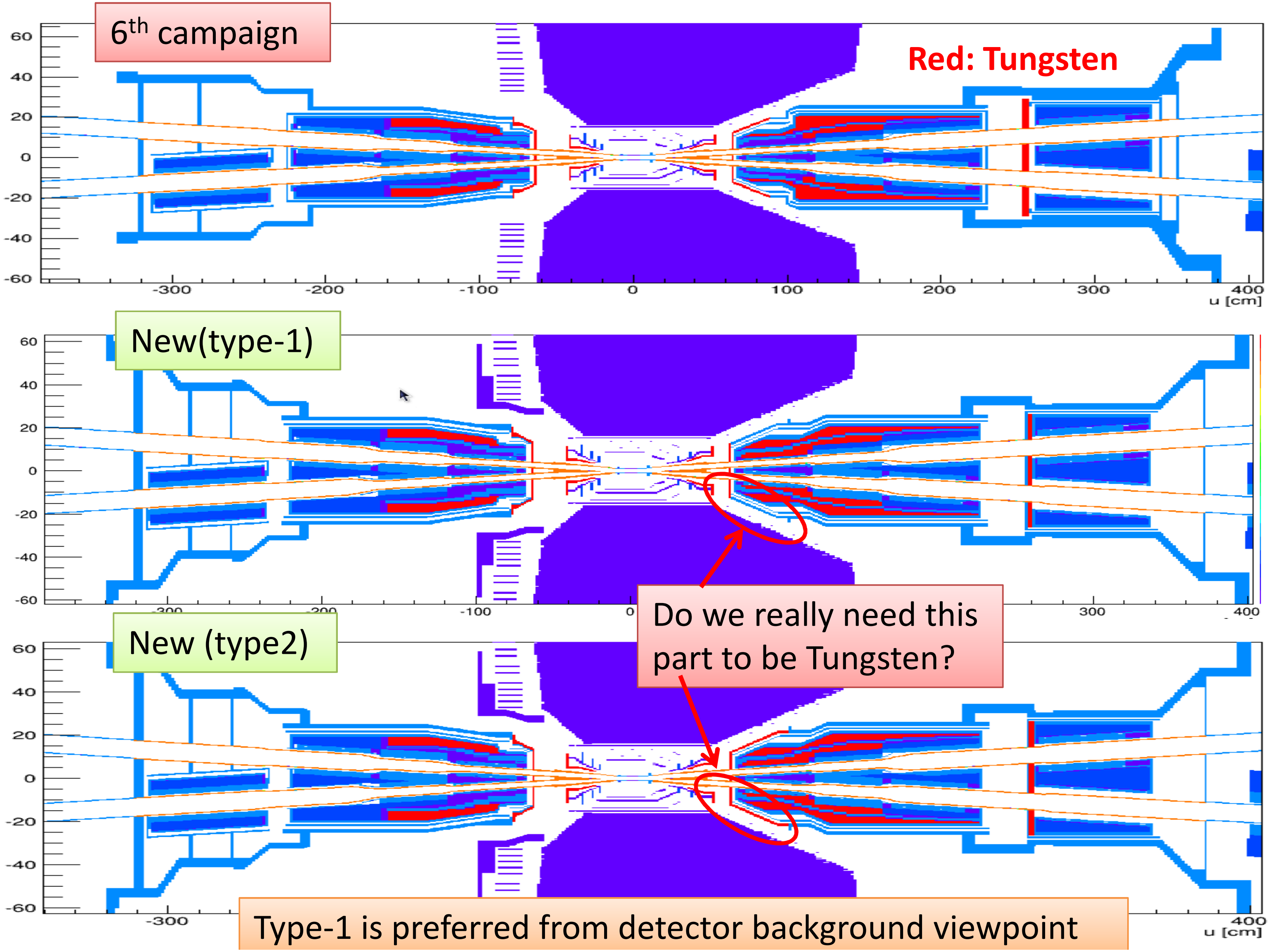
IP

Full-detector simulation

New shielding ideas



Forward QCS cryostat design



Full-detector simulation summary

- Full simulation(8th campaign)
  - PXD occupancy: 2-photon:0.8%, SR~0.1%
  - TOP: old PMTs killed in few years w/ full lumi.
  - CDC/ARICH neutron rate: suppressed by shields
- We prefer type2 (more tungsten)
  - slightly less BG in most of sub-dets
  - slight increase in CDC rate, but it can be handled anyway

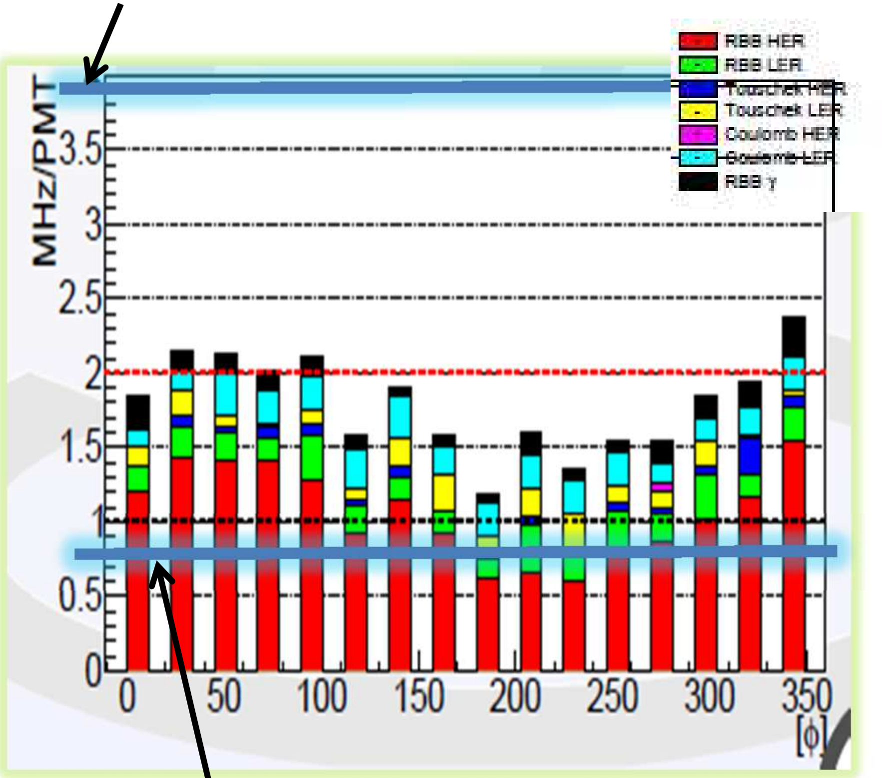
See each sub-detector report at this B2GM
http://kds.kek.jp/conferenceTimeTable.py?confId=14531#20140206

TOP

Tara Natut (7^{th} campaign)

TOP PMT rates

New PMTs(7C/cm2), half gain, 80/ab



Old PMTs(1C/cm2), half gain, 80/ab

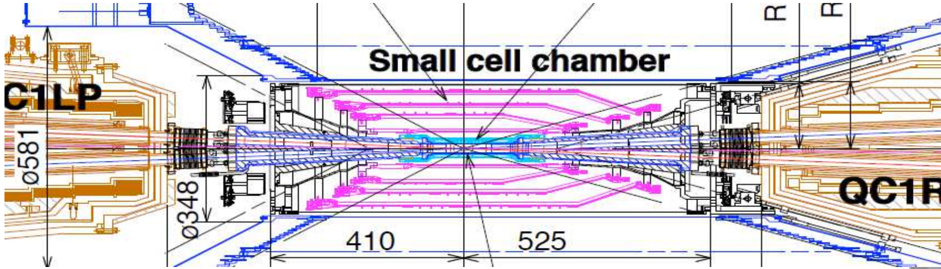
2MHz/PMT, 50/ab
→ 4C/cm2 (full-gain)
→ 2C/cm2 (half-gain)

2MHz/PMT, 80/ab
→ 6.4C/cm2 (full-gain)
→ 3.2C/cm2 (half-gain)

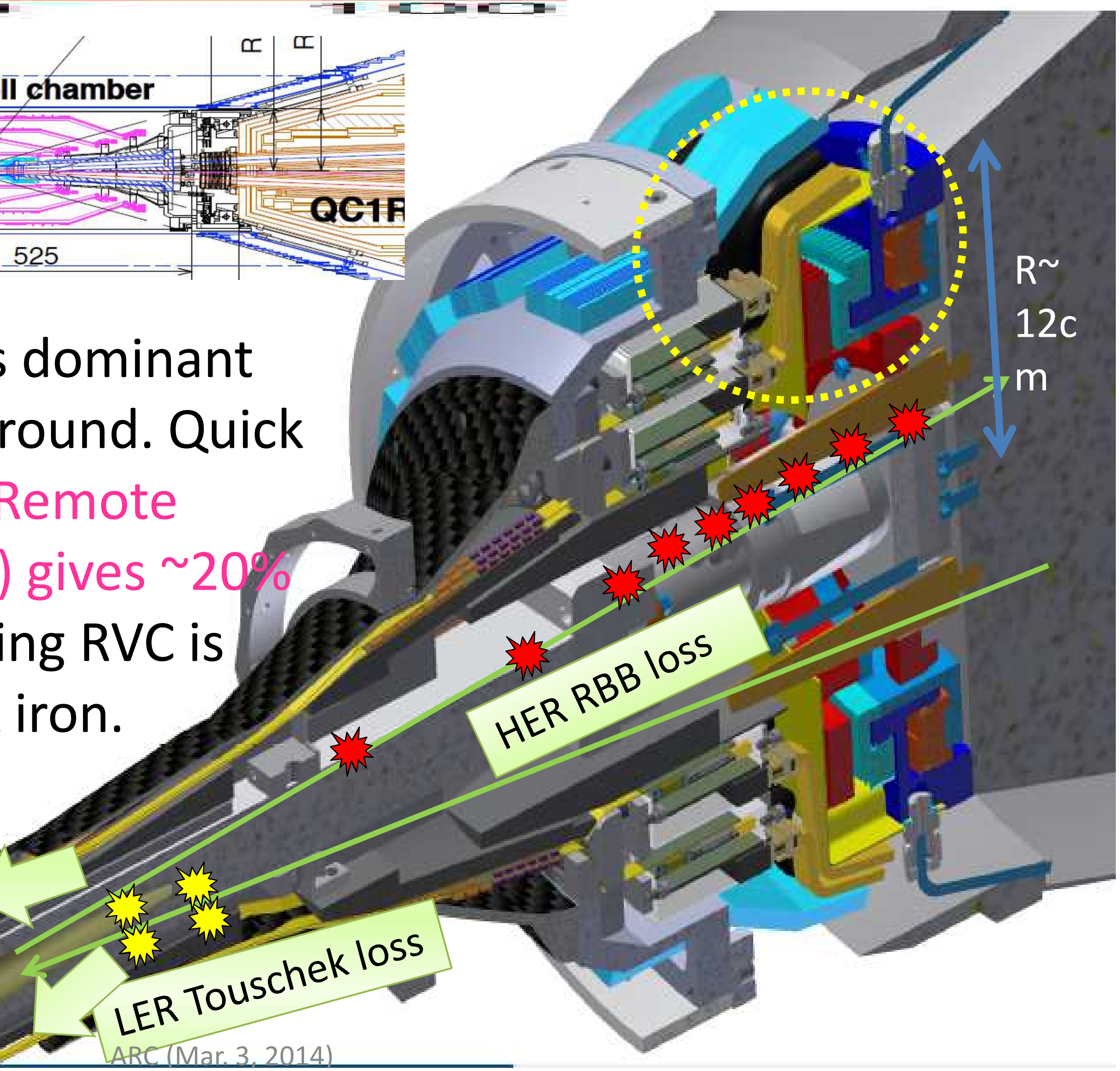
We assume
10 years x full lumi.

Measured photocathode lifetime
-New PMTs: 7C/cm2
-Old PMTs : 1.5C/cm2 (best)
1C/cm2 (ave.)

New PMTs with half-gain survives 80/ab (with x2 margin)
Old PMTs with half-gain can only survive 3years x full-lumi.



HER RBB loss at z=60cm is dominant source of TOP PMT background. Quick study shows material for Remote Vacuum Connection (RVC) gives ~20% TOP BG reduction, assuming RVC is equivalent to 60mm thick iron.

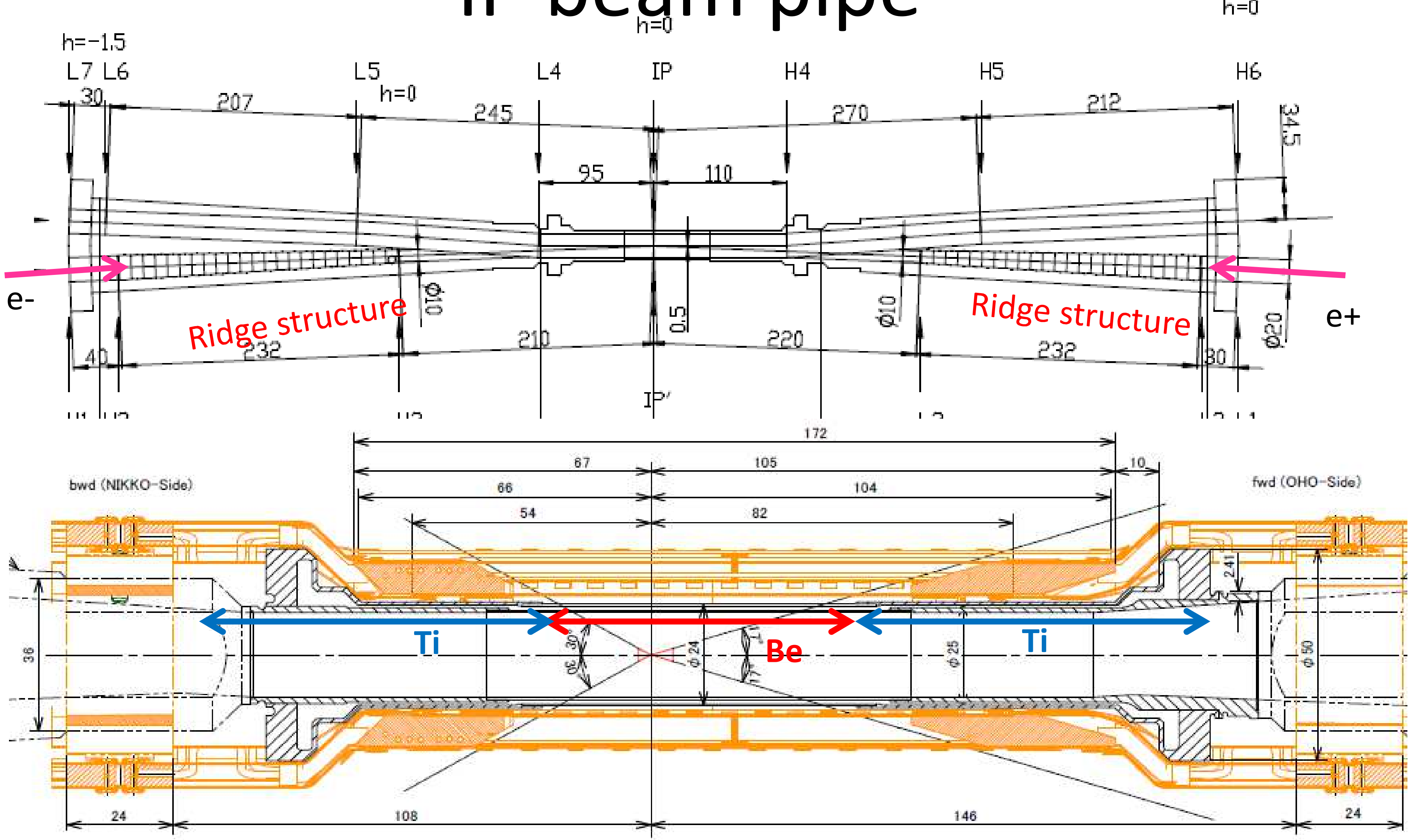


Recent news on RBB

Preliminary

- We used a wrong lattice file for beam loss simulation for RBB_LER
  - Dipole component of solenoid field was artificially switched off in that lattice file
- Beam loss at z=-50cm was underestimated, where shield thickness is limited
- Impact on TOP PMT BG is now under detailed investigation (increase x2?)

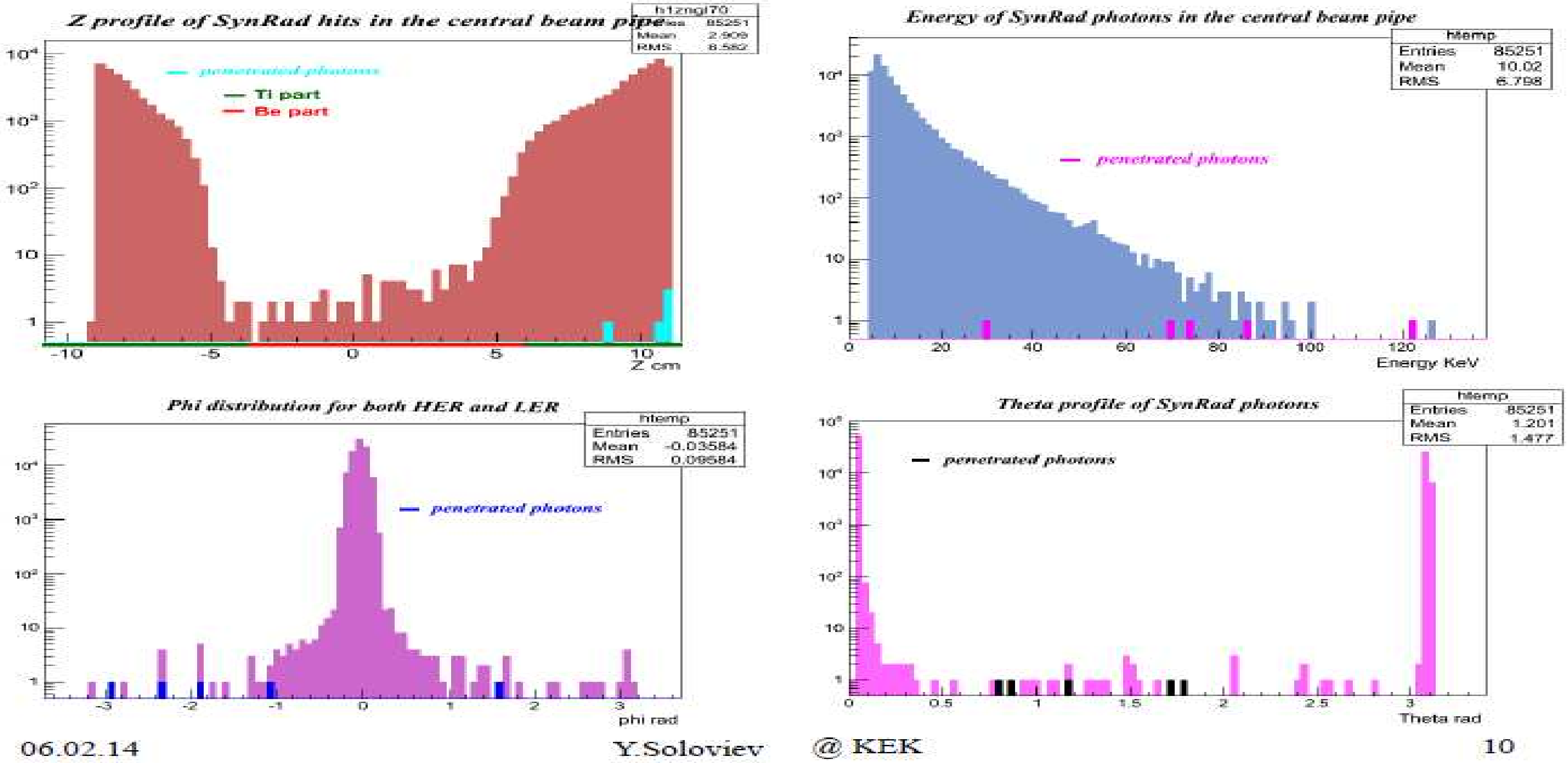
IP beam pipe



10um Au plating on inner surface of Be/Ti pipe

Latest SR simulation

Y. Soloviev
(DESY)



LER (per bunch crossing)

Ti part - 8.3e+4 ± 500 , Be part - 15 ± 6

No photons penetrated beam pipe observed.

Occupancy < 1ppm (1e-4%)

HER (per bunch crossing)

Ti part - 1.3e+5 ± 600 , Be part - 1400 ± 100

number of photons penetrated beam pipe wall = 13 ± 6

number of photons in PXD1 = 0

Occupancy ~ 0.003%

Also need to study halo/misalignment effect

Summary for 8th campaign

* Not including halo , mis-alignment effect

SF=Safety Factor

	8th campaign result	limit	SF
PXD occupancy	2photon:0.8% (from 7th), SR:~0.1%*	< 3%	<3
CDC wire hit rate	~100kHz	<200kHz	2
CDC Elec.Borad n-flux*	0.8	<1	1
CDC Elec.Board dose	~20Gy/yr	<100 Gy/yr	5
TOP PMT rate	2MHz/PMT	<1 MHz/PMT	0.5
TOP PCB n-flux*	0.5	<1	2
ARICH HAPD n-flux*	0.65	<1	1
ECL crystal dose	13Gy/yr	<10 Gy/yr	1
ECL diode n-flux*	1.2	<1	1
ECL pile-up noise	5/1MeV	0.8/0.2MeV at Belle-I	?

KLMs are not included
showing SF<5 only
(SVD is not shown 'cause it's very save)

With "combined" shield inside ECL

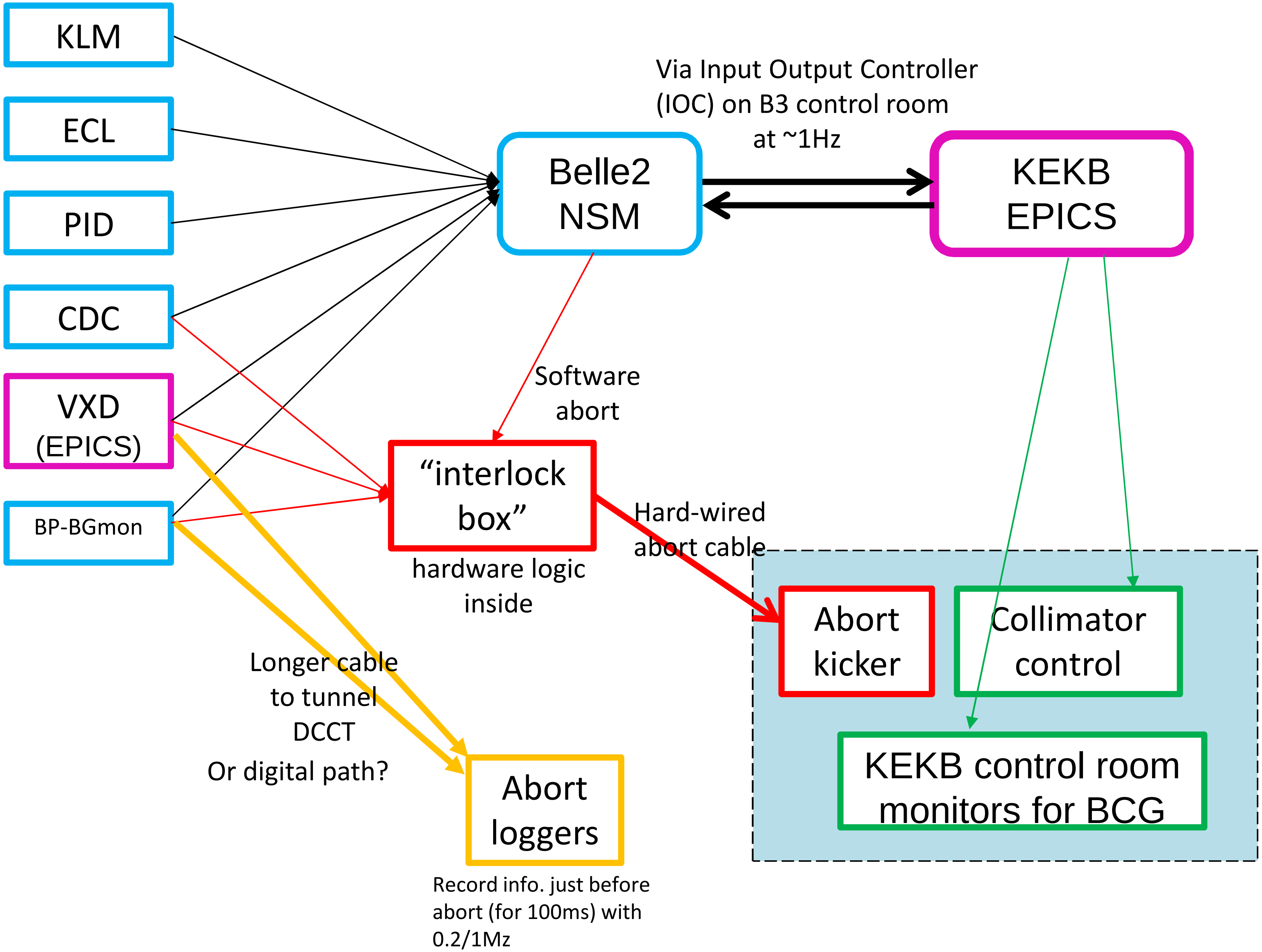
*neutron flux in unit of 10^{11} neutrons/cm2/yr, NIEL-damage weighted

Belle2-SuperKEKB DAQ interface

Beam abort,
Collimator control, etc..

Monitor DAQ diagram

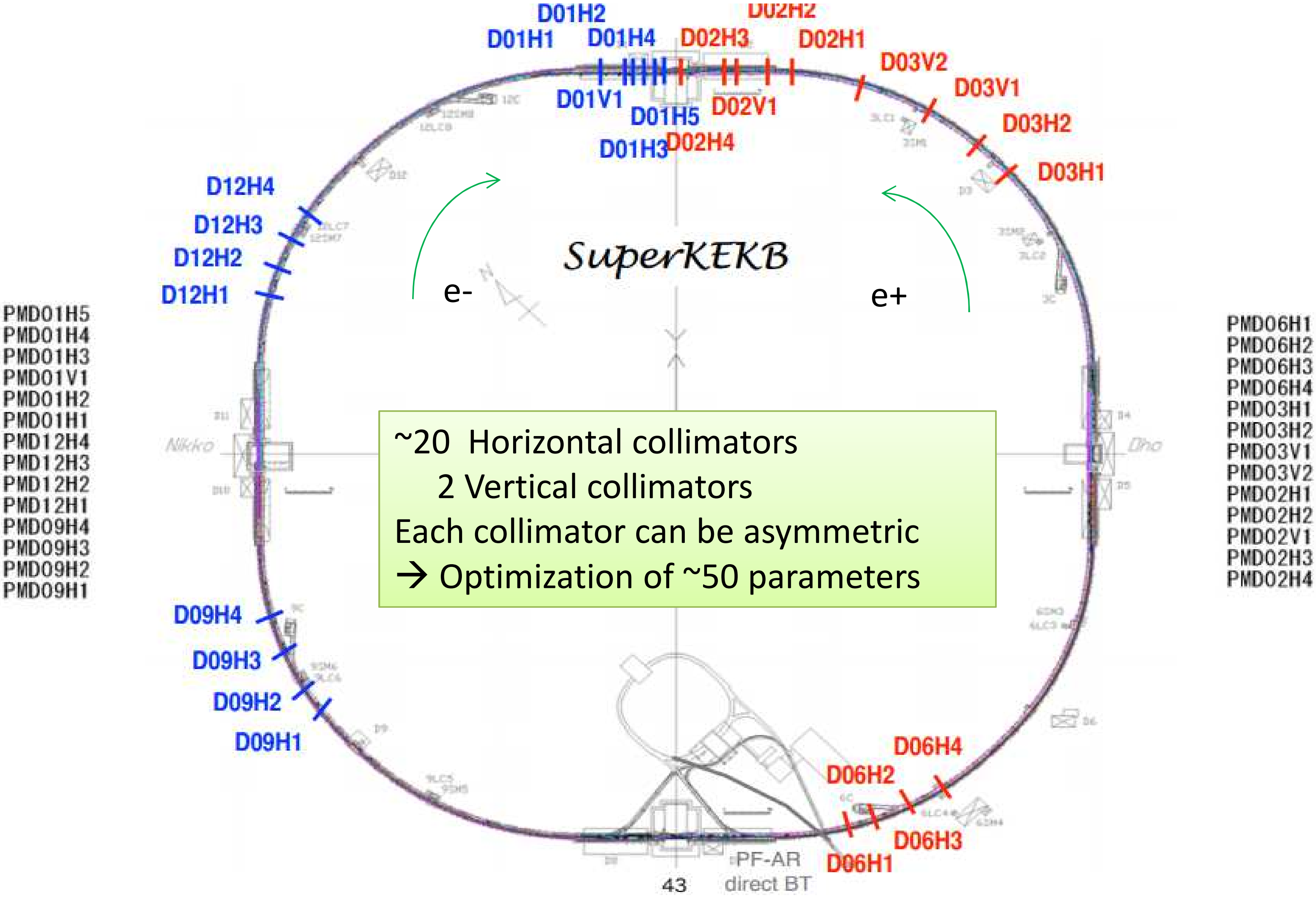
Proposed by Nakayama



Collimator control systems

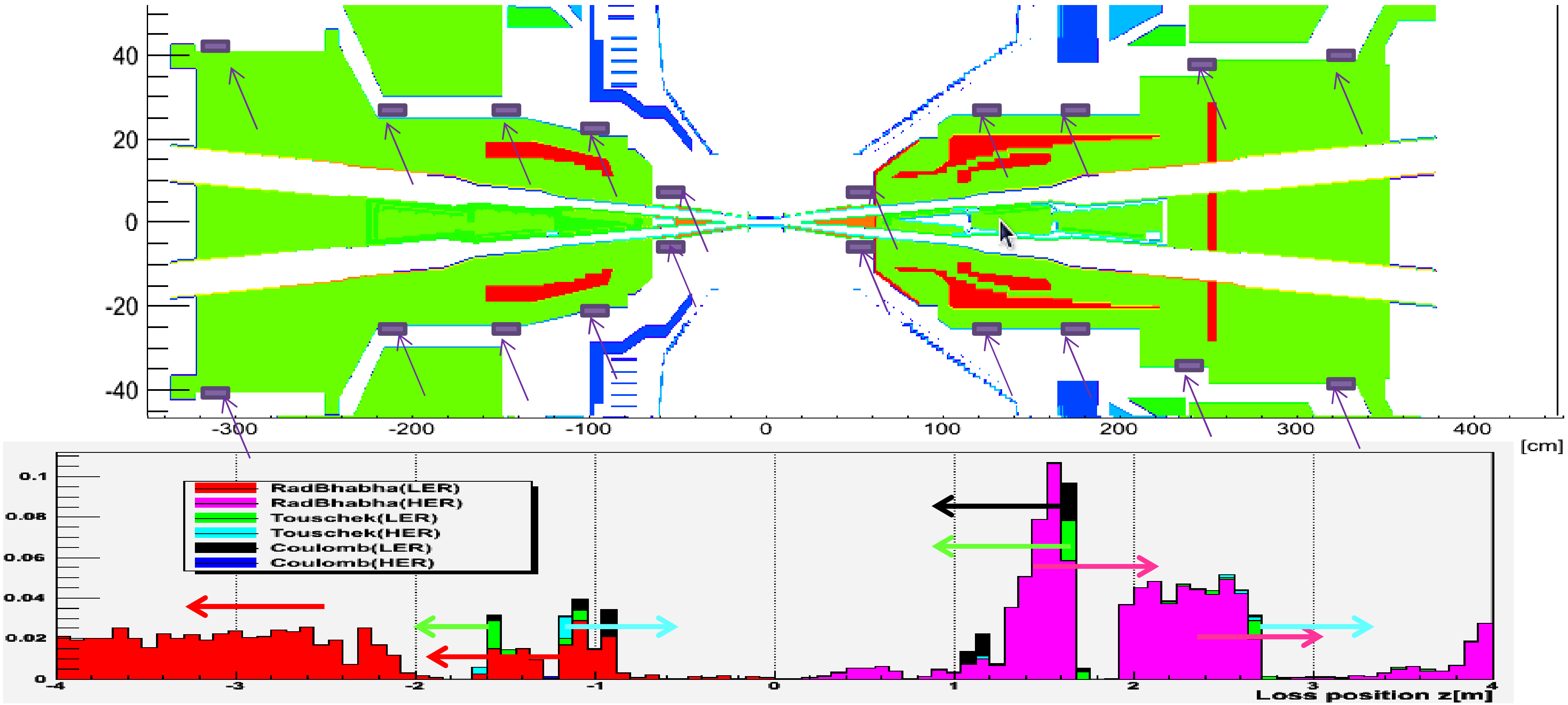
- Careful operation is important at SuperKEKB/Belle-II
  - Keep IR loss <1GHz, while total collimator loss >600GHz
  - Miss-operation of collimator(espc. vertical ones) easily results in x10 or even x100 detector background level
  - Aim to develop semi-automatic control algorithm
- Input information:
  - beam lifetime, loss rates at collimators, sub-detector BG levels, injection efficiency, and IR loss distributions, etc..
- IR loss rate distribution gives insight on which BG source and therefore which collimator we should adjust
- IR loss monitor R&D has started

SuperKEKB collimators



~20 Horizontal collimators
2 Vertical collimators
Each collimator can be asymmetric
→ Optimization of ~50 parameters

IR loss monitors around cryostat



- For example, loss at z=+1.2m is strongly correlated with Touschek/Coulomb
- 6 or 8 sensors in phi direction at each z positions
- Type of sensor is under discussion
    - PIN diodes? Diamonds? Thin plastic scintillators to issue veto? Neutron sensors?
    - Should be prepared before summer '14 and tested at BEAST phase-1
    - Collaboration with BEAST group !!

Summary

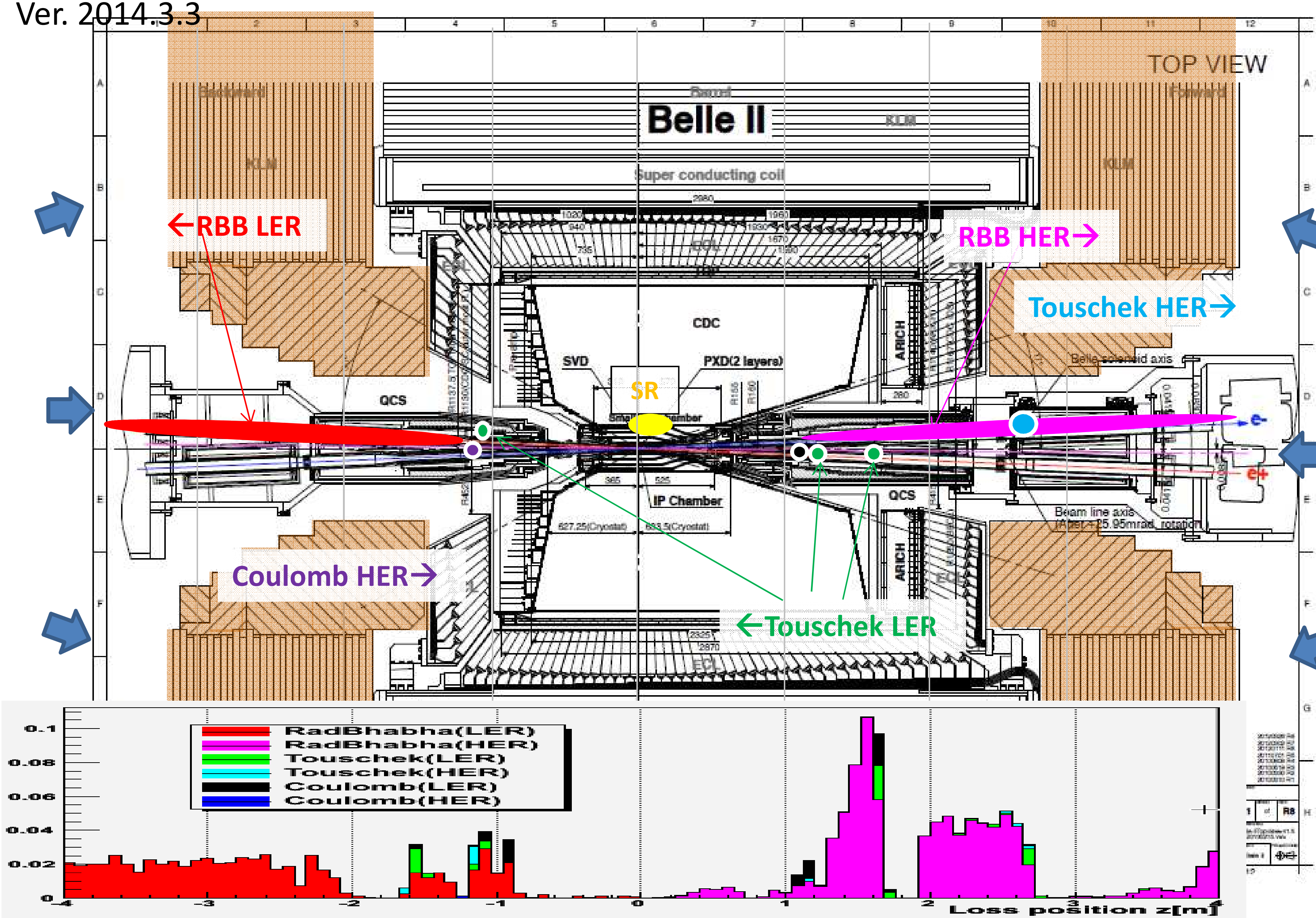
- Detector simulations are updated every 4 month
- New shielding ideas confirmed to be effective, now start realistic design
- TOP PMT lifetime is still the biggest concern

- Propose to develop semi-automatic collimator control
  - Vertical collimator is very sensitive to IR background level
  - Detector BG information should be provided to the collimator control algorithm

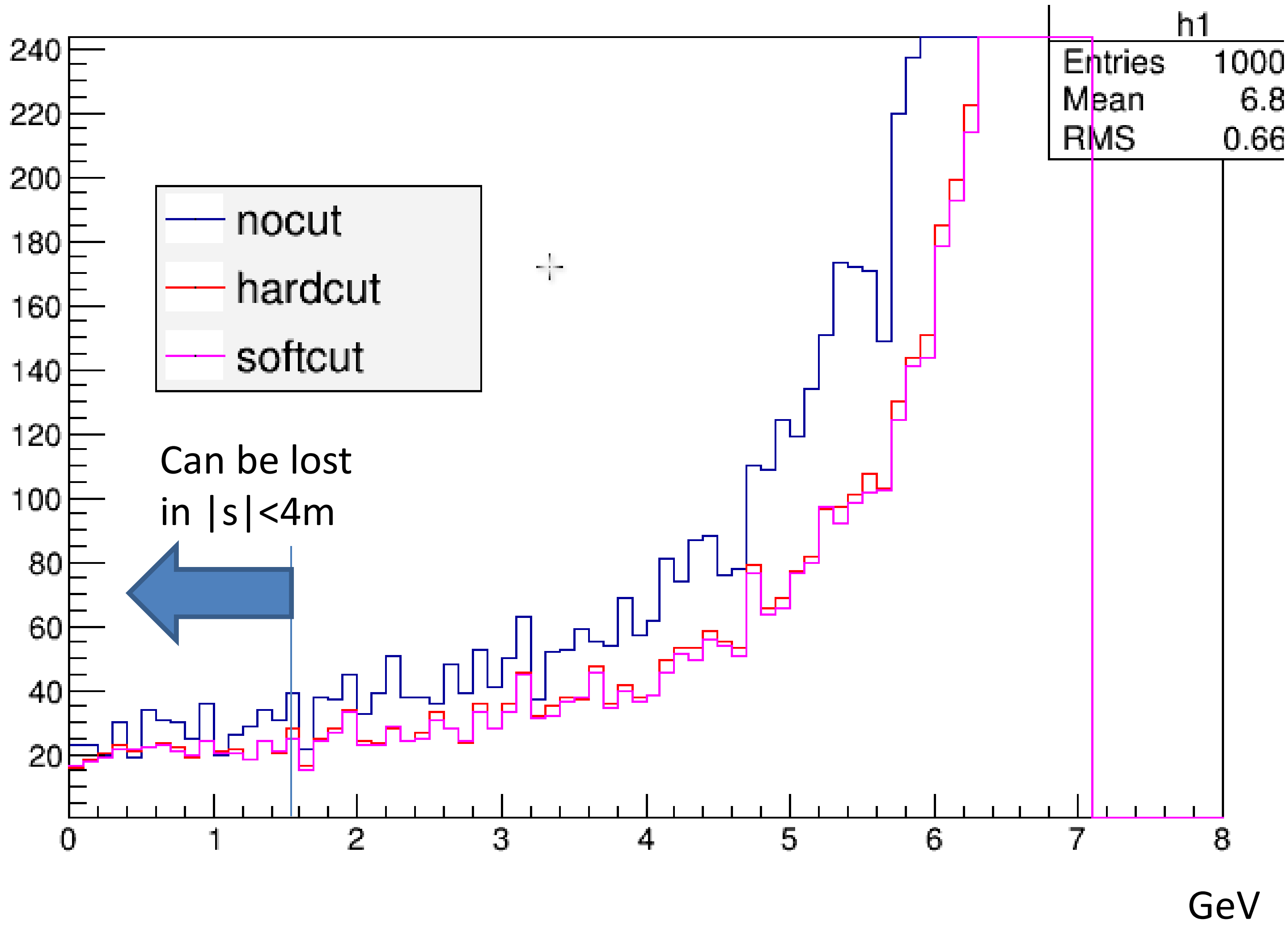
Backup

Background picture

Ver. 2014.3.3



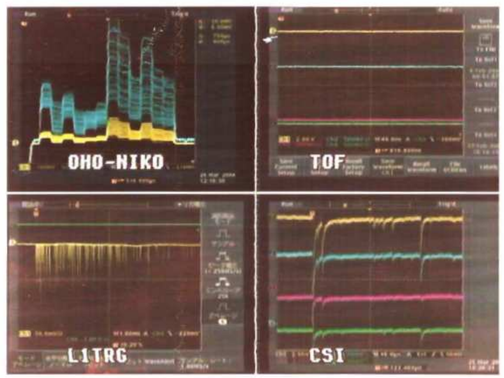
Electron energy (lab)



Items omitted in the DAQ diagram

to keep it simple

- Belle solenoid field, power outage should also issue beam abort
- "injection_inhibit" signal to tell accelerator that BG level is uncomfortable, but not so bad to abort beam
- Analog path for real time monitoring by shifters
  - CDC leak current limiter (beep sound in KEKB control room at Belle1)
  - ECL BG level / TOP rate/ Injection veto timing measured by oscilloscope (send display image by CATV line)
  - We need similar ones for Belle2, also in digitized way to give to collimator semi-automatic control algorithm
- Timing signals from/to KEKB
- ZDLMs
  - Need much faster path for bunch-by-bunch feedback



Detail to do lists

- QED spent e+/e- could contribute to CDC?
- Secondary showers from collimator
- Shield around collimators/beam loss positions
- SR emitted at |s|>4m (final bending magnet)
  - Speed up mag-field calculation in simulation
- Feasibility study for IR loss monitors to feedback collimator control
- Realistic injection background (need e- gun group involved)
- Tunnel neutron BG on BKLM edges
  - Polyethylene shield thickness requirement attached to end-yoke
- Dose estimation on QCS components
- CDC neutron shield design (by CDC group)
- etc..

BG levels at each sub-detectors

7th/8th campaign

Disclaimer:
- We assume 10 Snow-Mass years of operation with the design luminosity.
- Neutron flux are normalized to 1MeV-equivalent neutron rate using NIEL-damage.

Safety margin>2

Safety margin>1

Safety margin<1

PXD

Pit Vanhoefer

BKG	Occu. Layer 1 (%)	Occu. Layer 2 (%)
BDK	0.8	0.3
Touschek (6th MCC)	< 0.03	< 0.03
RBB (6th MCC)	< 0.13	< 0.13
Coulomb (6th MCC)	< 0.01	< 0.01
Total	**< 1**	**< 0.5**

SR: ~0.1% at one half (+z) ladder in #1 layer
need to see halo/miss-alignment impact with latest results (were <1% previously)

Yuri Soloviev

Close to limit (3%)

SVD

Peter Kvasnicka (7th campaign)

Source	Typical, z (%)	Change wrt. prev. campaign
Coulomb LER	0.02 ± 0.01	n.a.
RBB HER	0.04 ± 0.02	-0.01
RBB LER	0.06 ± 0.02	-0.02
Touschek LER	0.75 ± 0.63	n.a.
2-photon (BDK)	0.13 ± 0.07	0.13
Total	**1.1 ± 0.6**	**+0.10**

Source	Typical, r-phi (%)	Change wrt. prev. campaign
Coulomb LER	0.01 ± 0.01	n.a.
RBB HER	0.08 ± 0.01	- 0.02
RBB LER	0.06 ± 0.03	- 0.01
Touschek LER	1.07 ± 1.0	n.a.
2-photon (BDK)	0.27 ± 0.15	0.27
Total	**1.5 ± 1.0**	**+0,25**

Well below 10%. OK

CDC

Don van Thanh(7^{th} campaign)

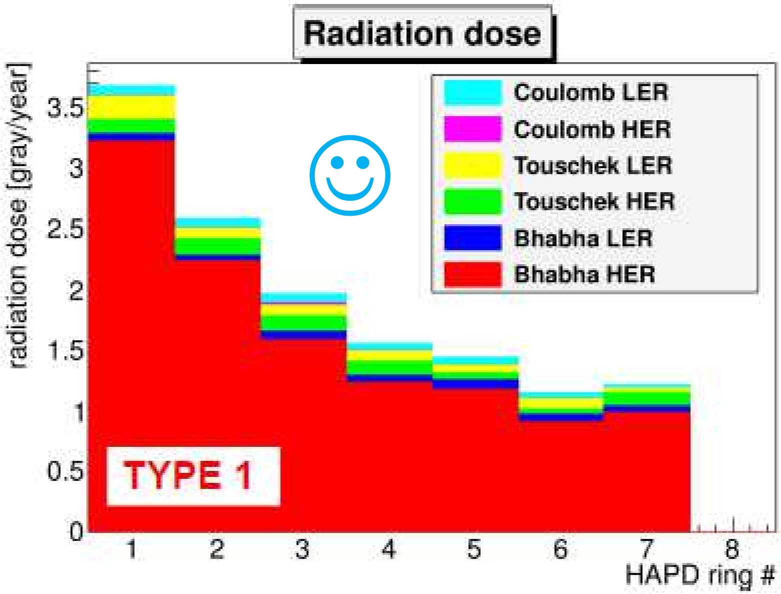
	6^{th} campaign	7^{th} campaign	Hardware requirement	Status
CDC hitrate	<120kHz/wire	<100kHz/wire	<200kHz/wire	ok
Total Dose	<21Gy/year	<18 Gy/year	<100Gy/year	ok
Neutron flux	$<2.2\ 10^{11}$ $n/cm^2/year$	$<0.84*10^{11}$ $n/cm^2/year$	$<1.0*10^{11}$ $n/cm^2/year$	ok

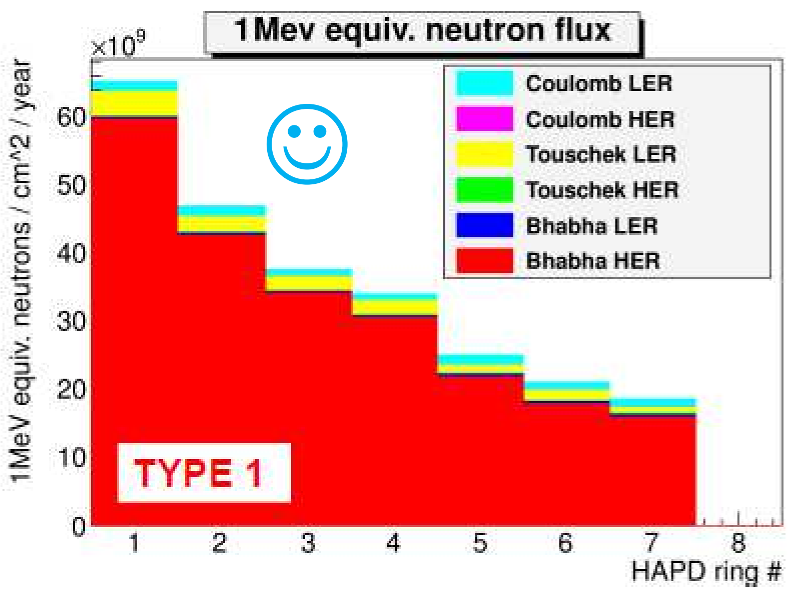
With this rate, "unrecoverable error" happens every ~7hours in one of FPGAs and we need to stop the data-taking to download FPGA firmware. It is still acceptable but less neutrons rate is desired.

ARICH

Removed innermost ring
8 rings → 7 rings

Luka Santelj





Rad. Dose: 3.5 gray / year

7^{Th} campaign: 5 gray / year

Neutron flux: 0.6 x 10^11 n/cm2/year

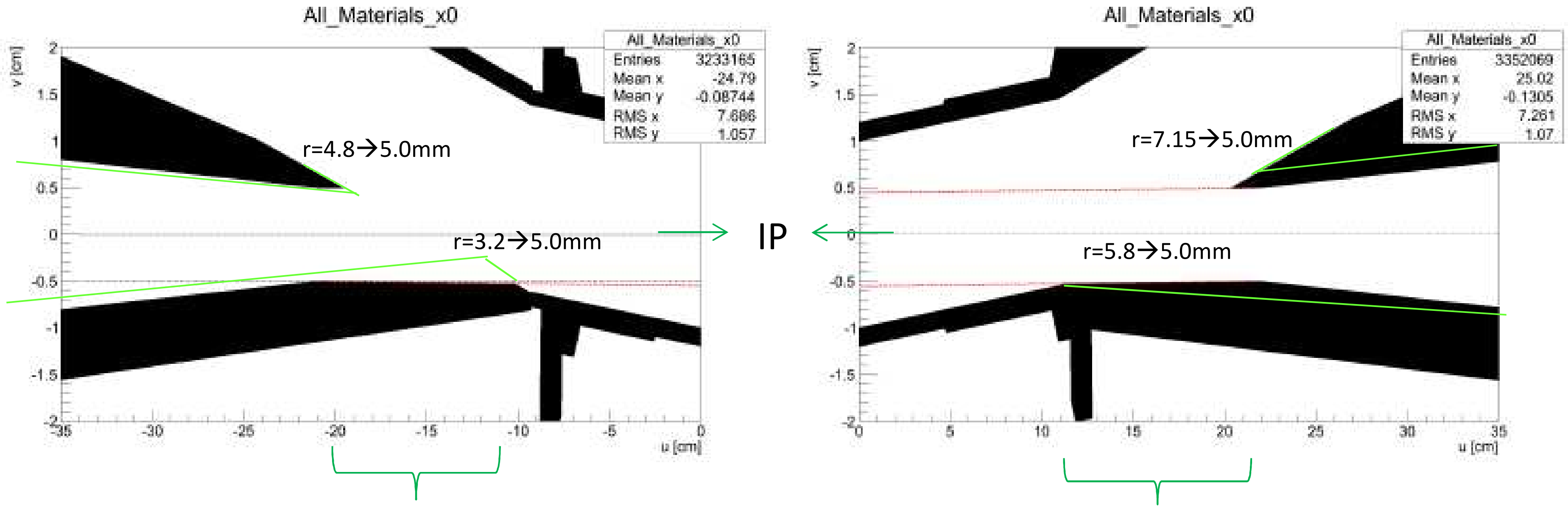
7^{th} campaign: 1.3 x 10^11 n/cm2/year

Tested up to about 1.0 x 10^11 n/cm2/year

Beam pipe aperture change for SR

HER: The aperture is 5mm radius that is larger than in previous geometry version (3.2mm).

LER: The aperture is smaller (5mm instead of 5.8mm) compare to the previous version of geometry.



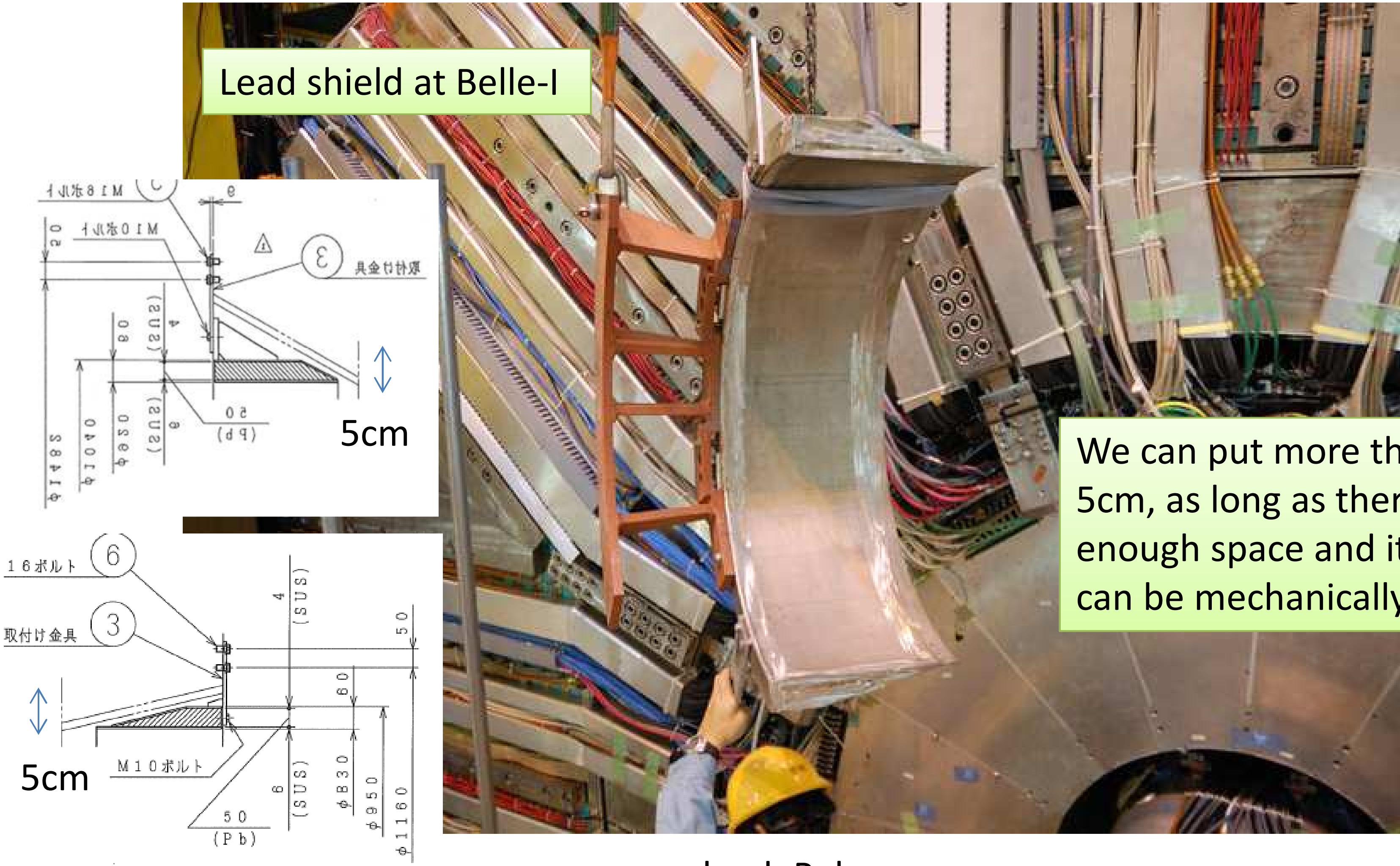
Now this cylinder part points at (z,x) =(0, -0.5)mm

Now this cylinder part points at (z,x) =(0, -0.5)mm

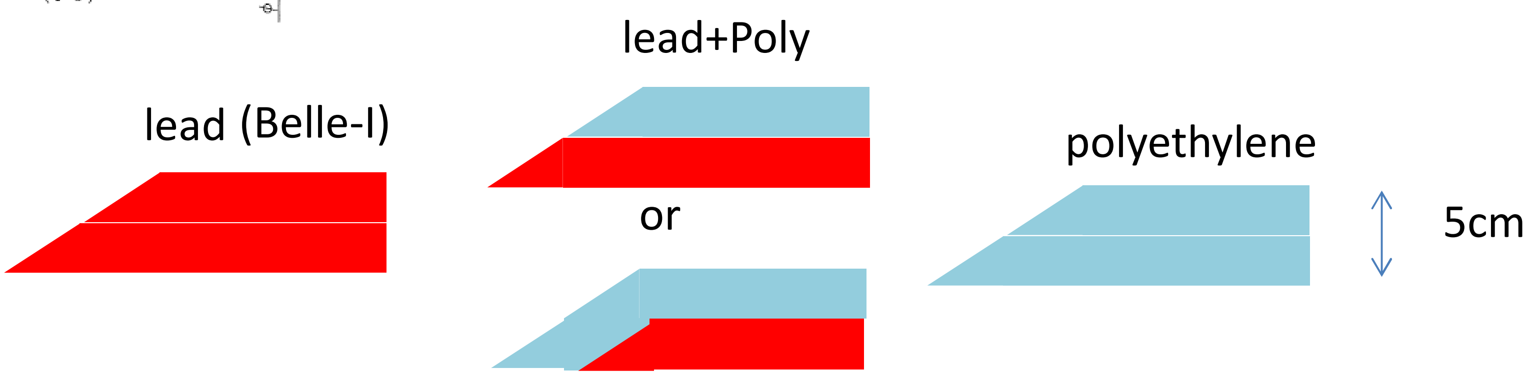
10um Au plating extended to Ti: (z=-3.7~5.9cm → -6.55~+10.5 cm)

Only used for stopping power calculation

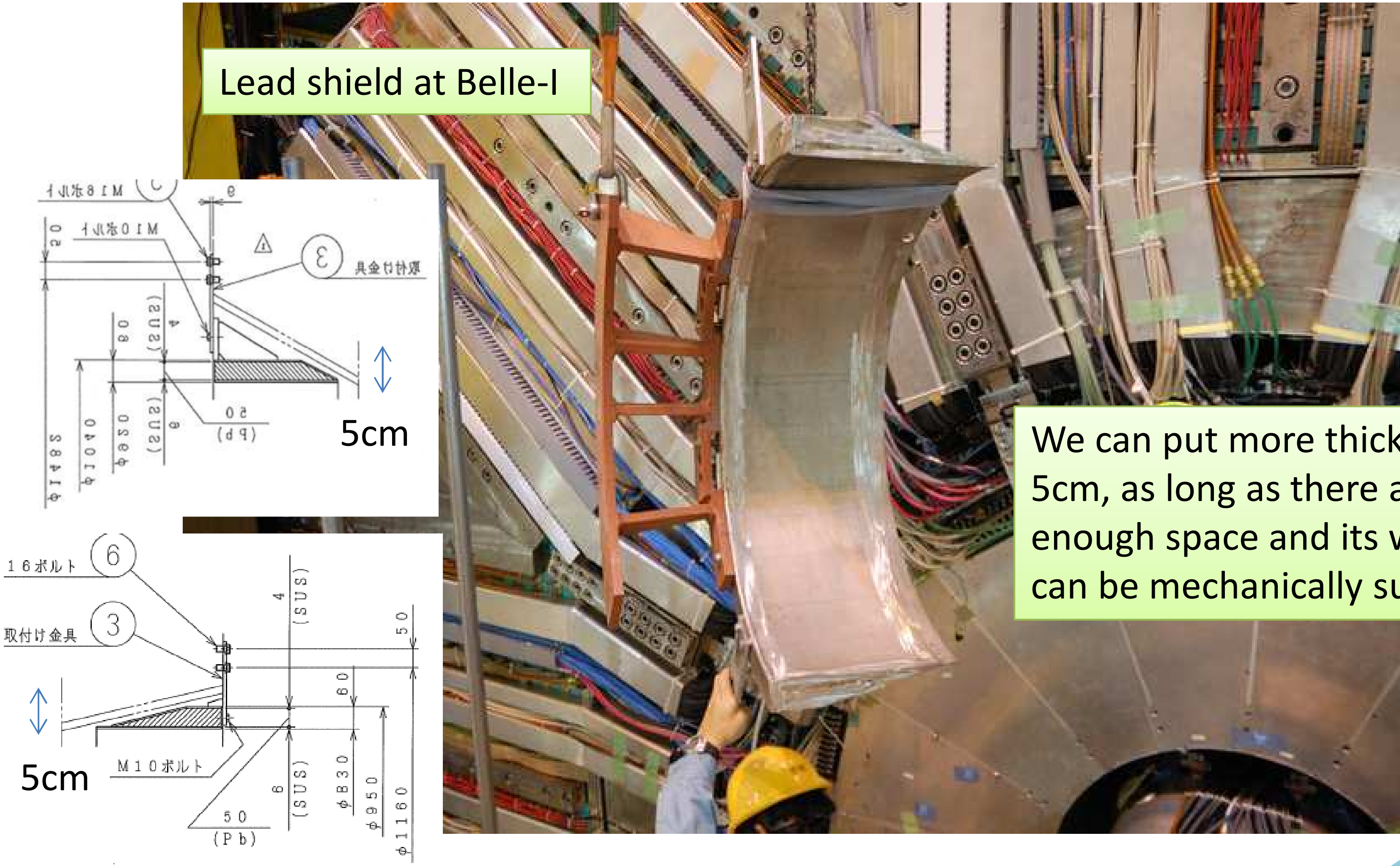
Lead shield at Belle-I



We can put more thickness than 5cm, as long as there are enough space and its weight can be mechanically supported.



Lead shield at Belle-I

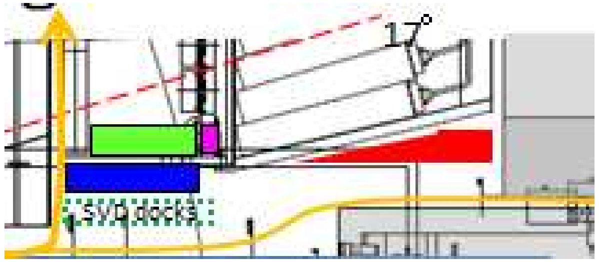


We can put more thickness than 5cm, as long as there are enough space and its weight can be mechanically supported.

lead+Poly preferred

- Unfortunately previous shield was already discarded
- But we are in contact with the same company who fabricated previous ones.

ARICH shield study



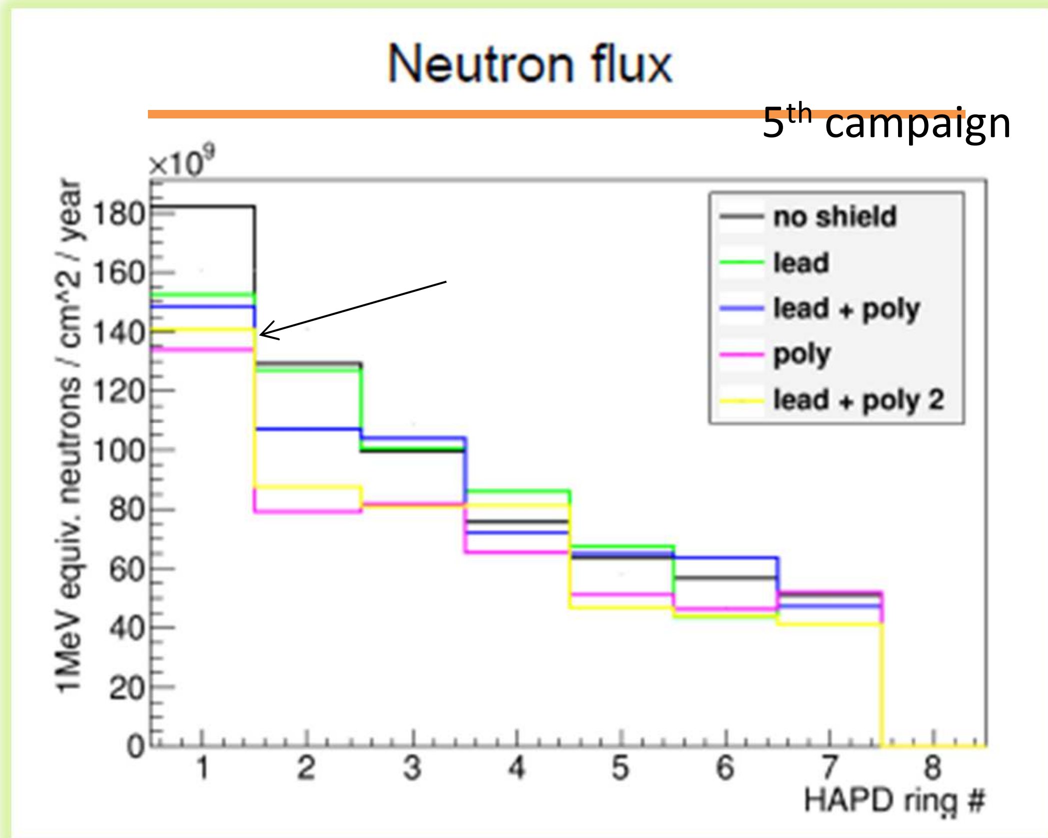
lead(Belle-I)

polyethylene

lead+Poly

Lead+poly2

Luka Santelj(6th campaign)



Even half (2.5cm) of polyethylene shield gives sizable reduction. Neutron shields <u>inside</u> ARICH structure (extended to +z) is also known to be effective.

ECL

Sam de Jong

		Type 1: no tungsten	Type 2: Tungsten	With Shielding	6th Campaign	Tolerance
Crystal Radiation Dose	Forward	11.25 ↓	11.75 ↓	4.0	13.3	
(Gy/yr)	Barrel	0.5	0.5	0.25	0.5	10
	Backward	2.0	2.0	1.5	2.1	
Crystal Neutron Flux	Forward	120 ↓	110 ↓	140	190	
(x$10^{9} yr^{-1} cm^{-2}$)	Barrel	10	10	5	20	1000
	Backward	15	30	5	30	
Diode Radiation Dose	Forward	13.5↓	29.5 ⇑	2.65	14.3	
(Gy/yr)	Barrel	<0.2	<0.2	<0.2	<0.2	70
	Backward	3	<0.2	0.3	1.7	
Diode Neutron Flux	Forward	120 ↓	110 ↓	140	190	
(x$10^{9} yr^{-1} cm^{-2}$)	Barrel	10	10	5	20	100
	Backward	15	30	5	30	
Reconstructed Cluster		1.66 ↑	1.90 ↑	1.36	1.34	6 for Belle
Pileup Noise Estimate	Forward	5.0 ↓	5.2 ↓	3.6	5.7	
(MeV)	Barrel	1.0	1.0	1.0	1.2	0.8 for Belle
	Backward	2.2	2.2	2.0	2.4	

Crystal radiation dose/ diode Neutron flux becomes OK, with “combined” shielding option.