Beam Background at Super-KEKB/Belle

Osamu Tajima (KEK, IPNS)
for Belle collaboration
Feb 22, 2005
KEKB review

Outline

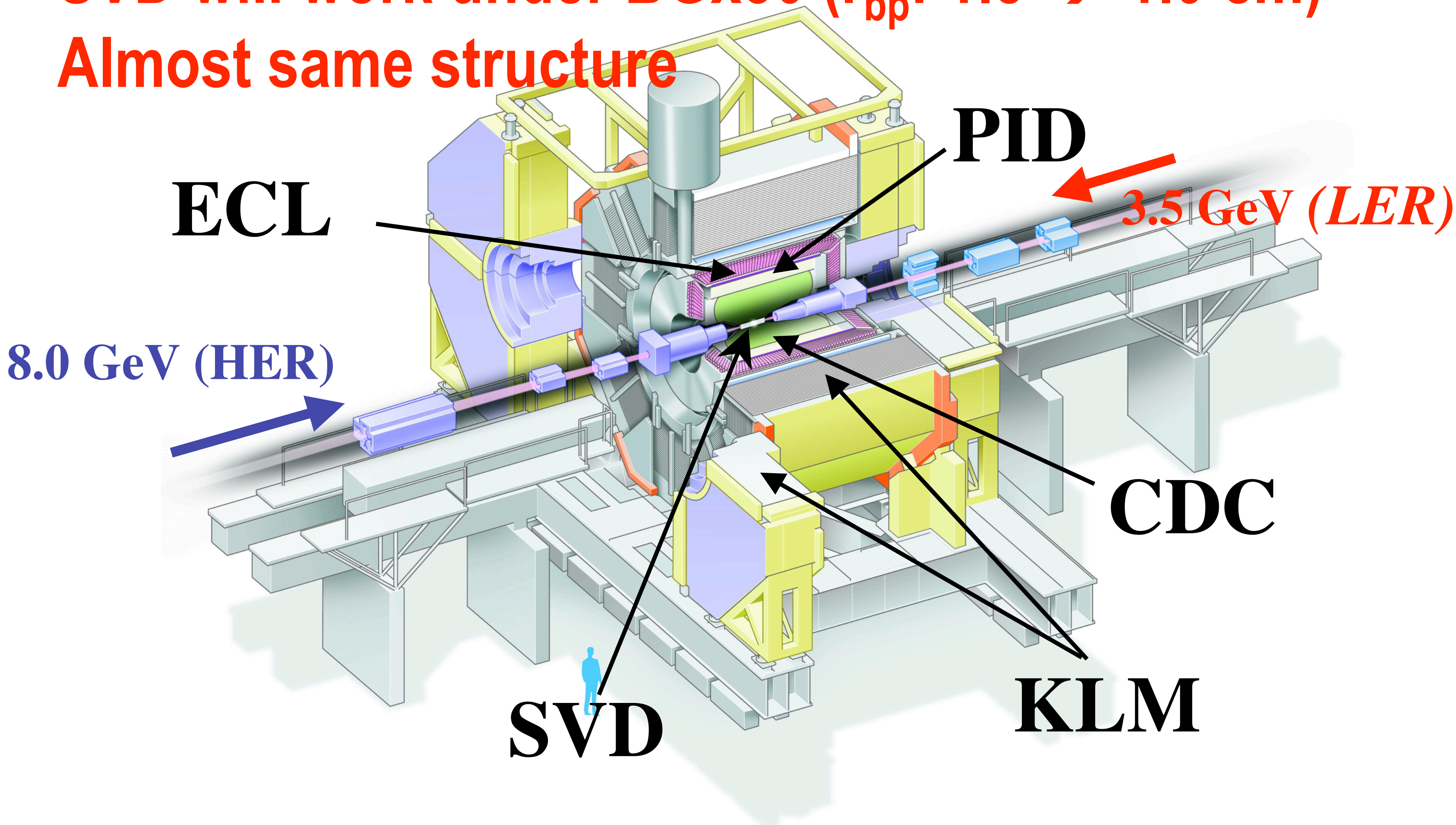
- Current Status
- Expectation & Reduction
- Summary

Belle Detector

Detector will be upgrade to work under BGx20

SVD will work under BGx30 (r_{bp}: 1.5 → 1.0 cm)

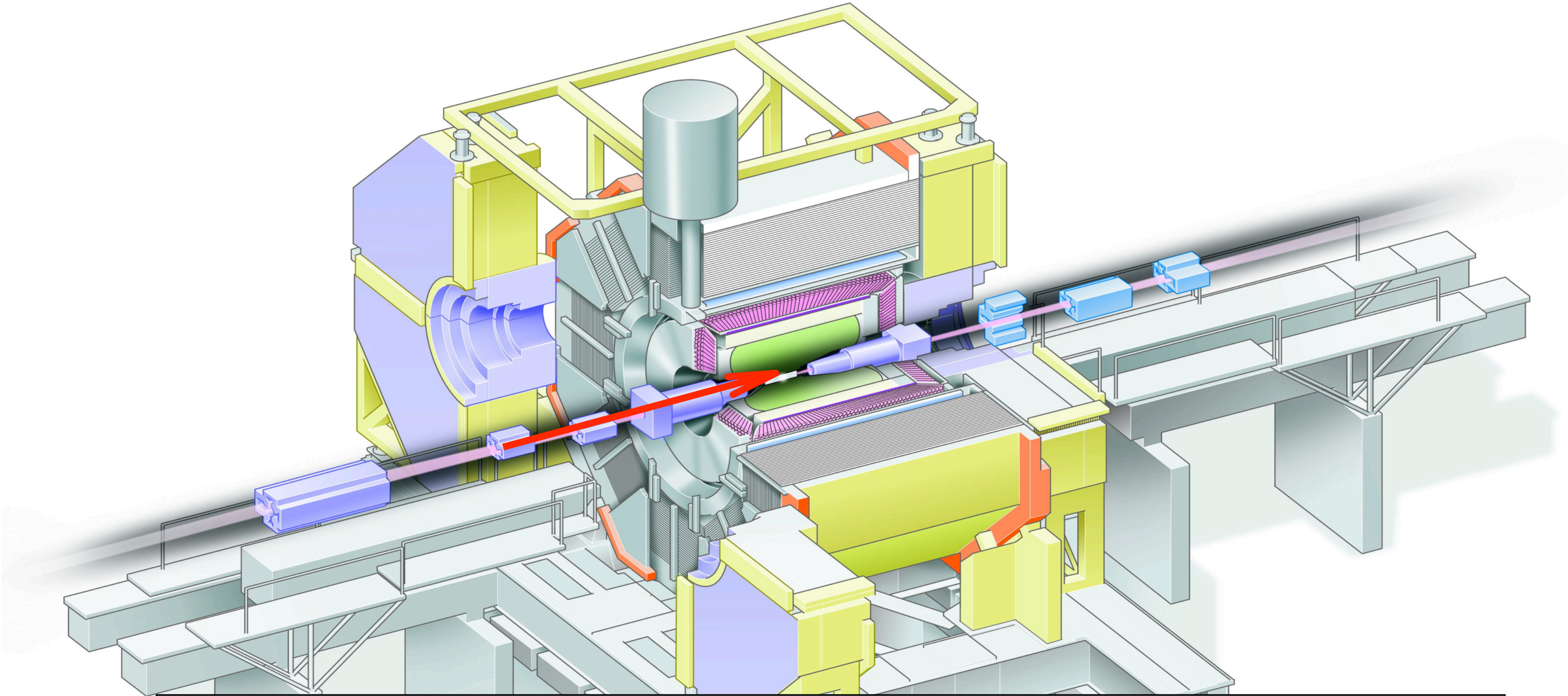
Almost same structure



Beam backgrounds should be concern

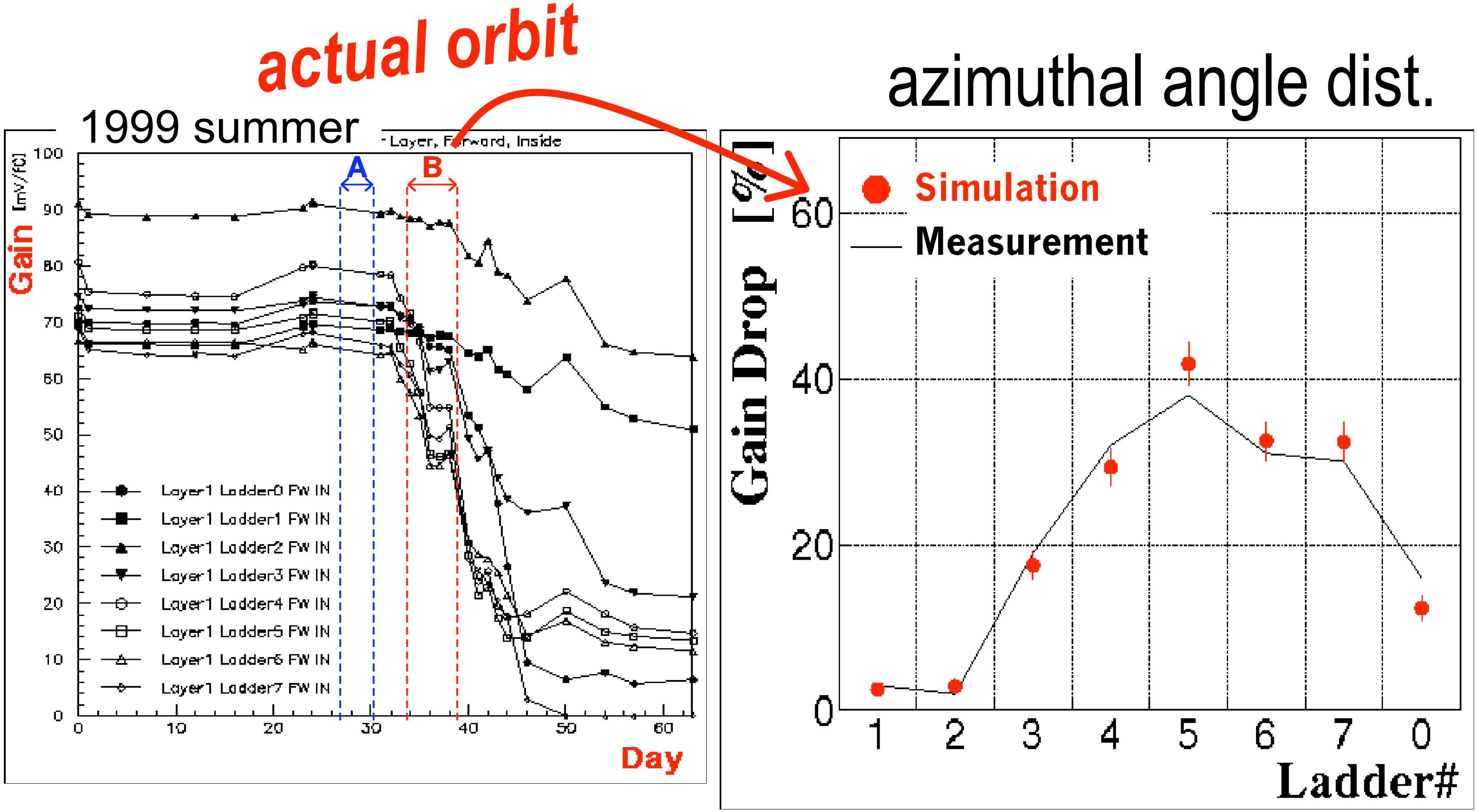
- **Synchrotron Radiation (SR) photons**
  - generated in upstream magnets
  - generated in downstream (QCS) magnet
- **Shower caused by spent particles**
  - beam-gas scattering
  - Touschek scattering
- **Radiative Bhabha origin**
  - Neutrons from downstream beamline
  - Showers caused by over bend beams

SR from upstream magnets



SVD1.0 killer source (1999)

Past troub'

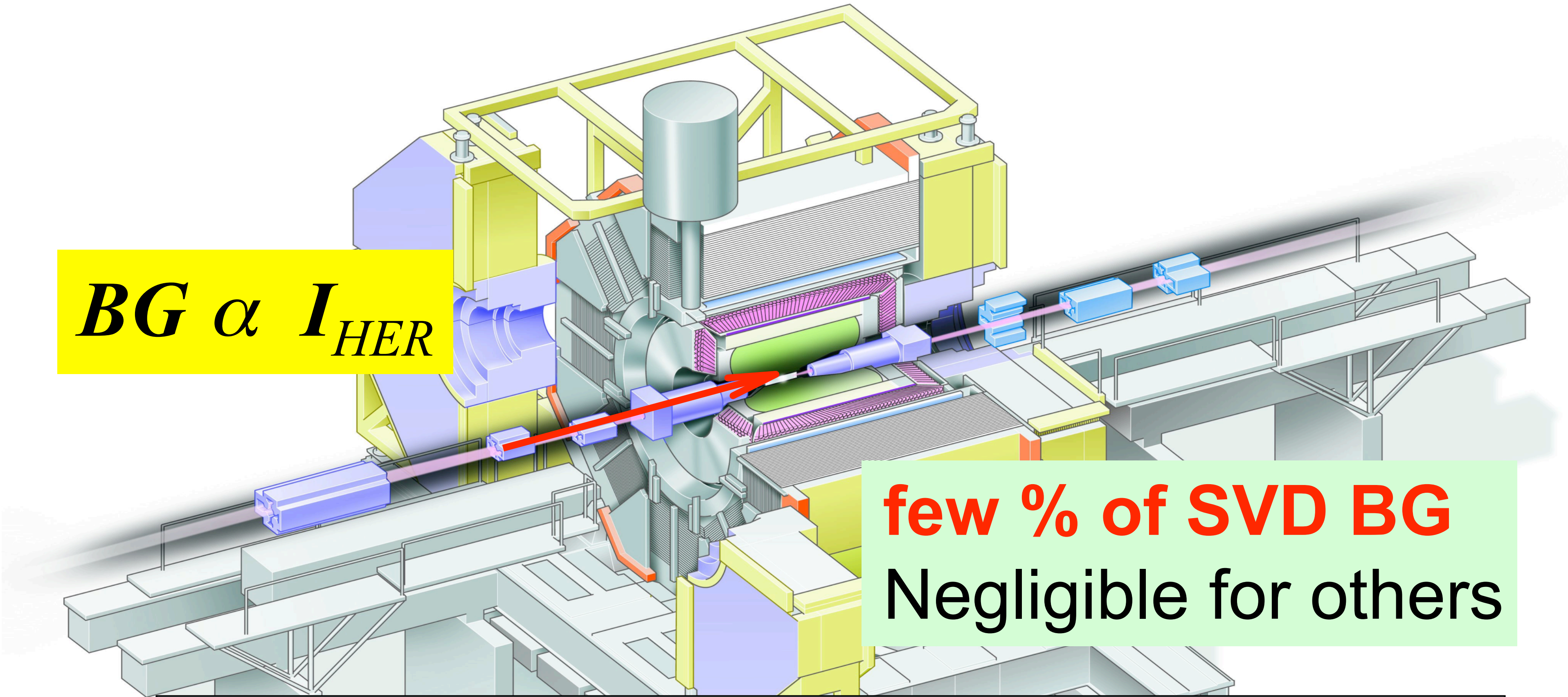


T.Abe (KEK)

Steering angle was critical

No more trouble w/ limitation of steering magnet

SR from upstream magnets



$BG\ \alpha\ I_{HER}$

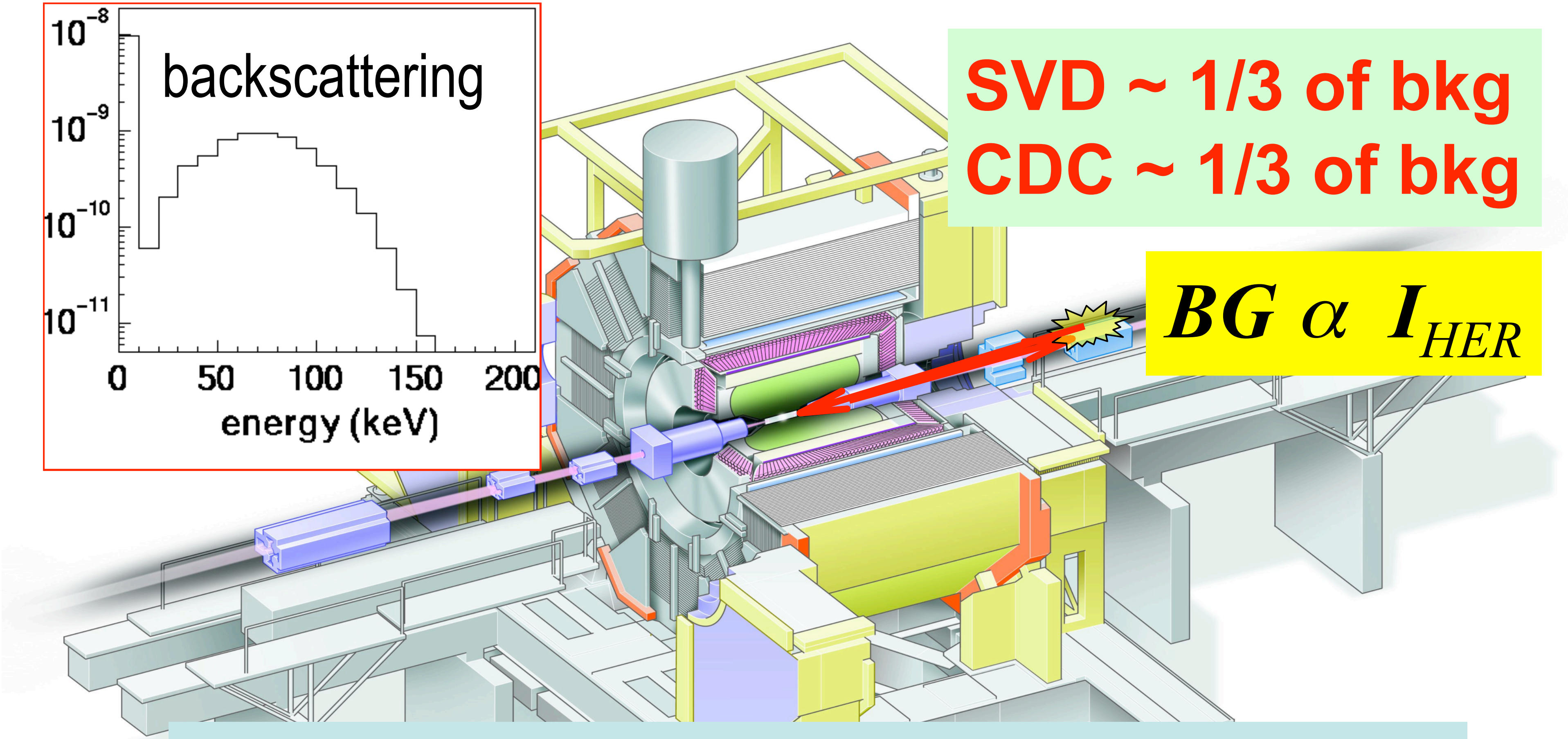
few % of SVD BG

Negligible for others

SVD1.0 killer source (1999)

→ Not serious after limitation of steering

SR, downstream magnet (QCS) origin



SVD ~ 1/3 of bkg
CDC ~ 1/3 of bkg

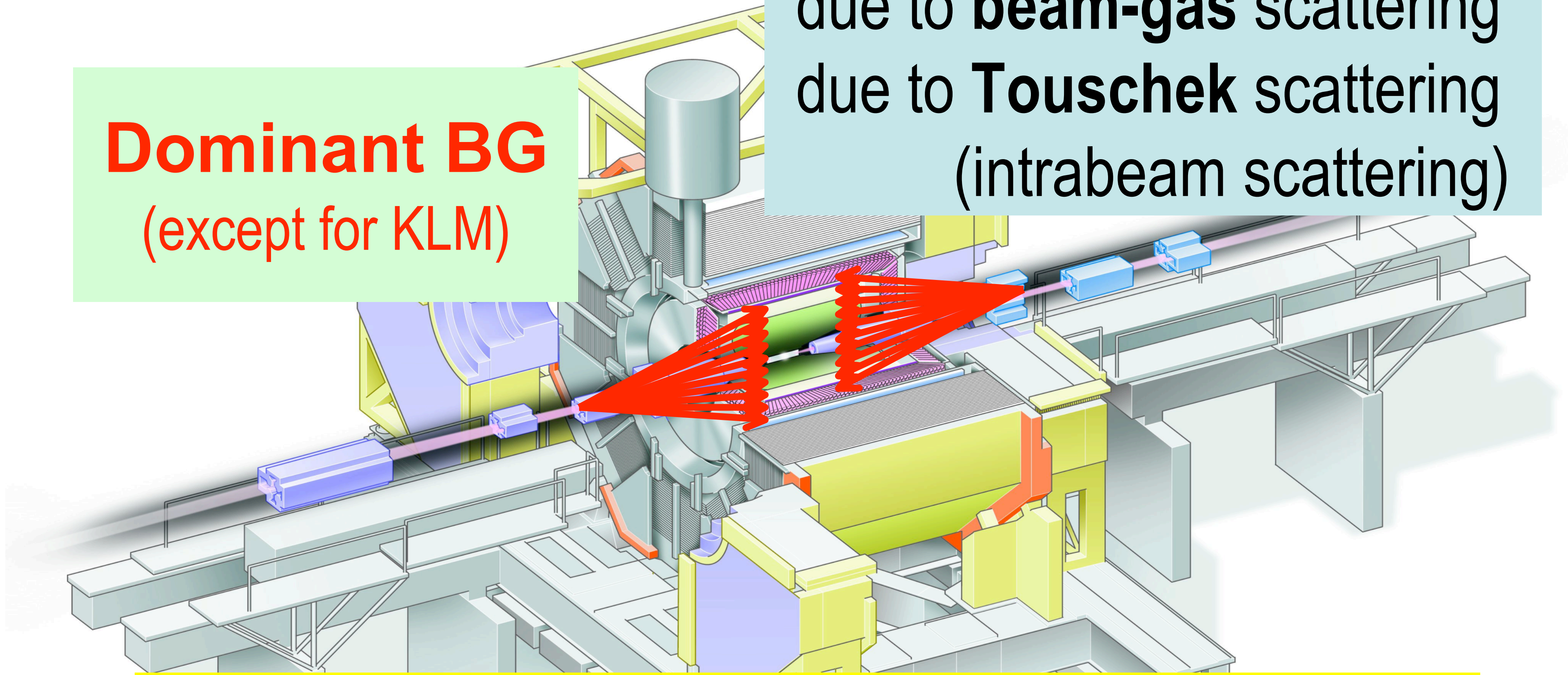
$BG \propto I_{HER}$

1. Downstream final focus magnet (QCS) generate high energy SR (E_{crit} ~ 40 keV)
2. SR photons are scattered at downstream chamber (~9m)
3. Backscattering photons enter to the detector (E_{eff} ~ 100 keV)

Shower caused by Spent Particles

due to **beam-gas** scattering
due to **Touschek** scattering
(intrabeam scattering)

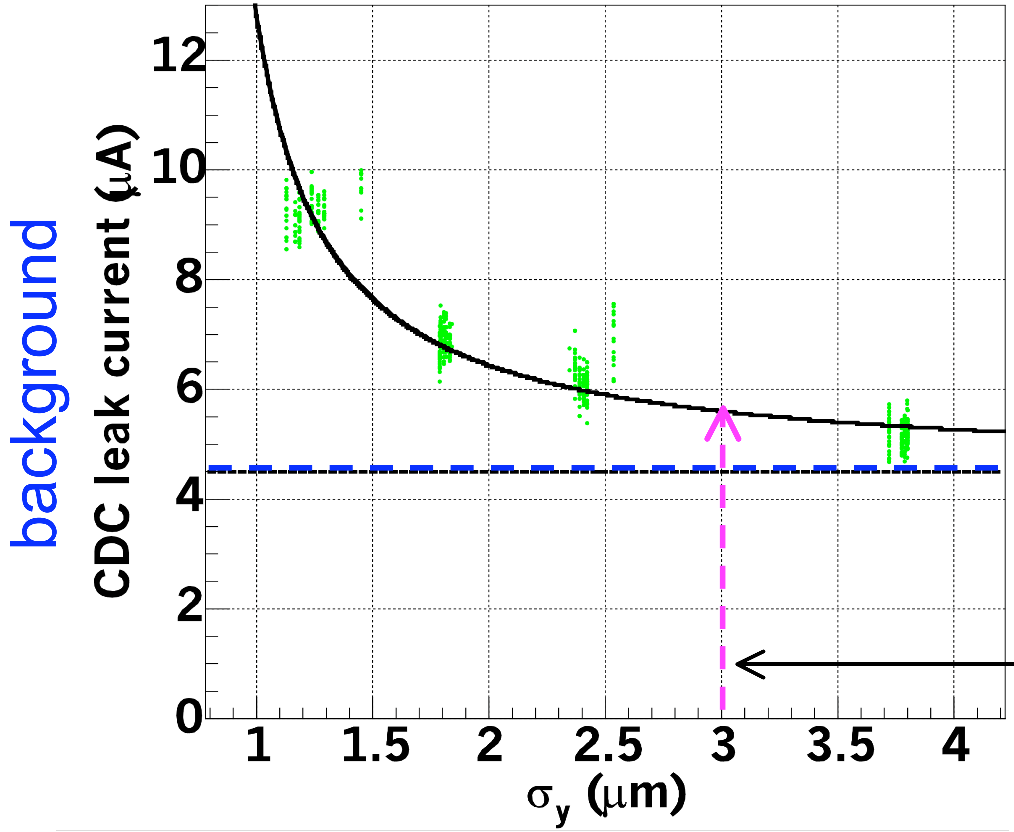
Dominant BG
(except for KLM)



$$BG_{beam\text{-}gas} = a\,P_{HER} \times I_{HER} + b\,P_{LER} \times I_{LER}$$

$$BG_{Touchek} \propto I_{LER} \times I_{LER} \qquad (\sigma_{Toucheck} \propto E^{-3})$$

Study for Contribution of Touschek



Smaller beam-size (larger density)

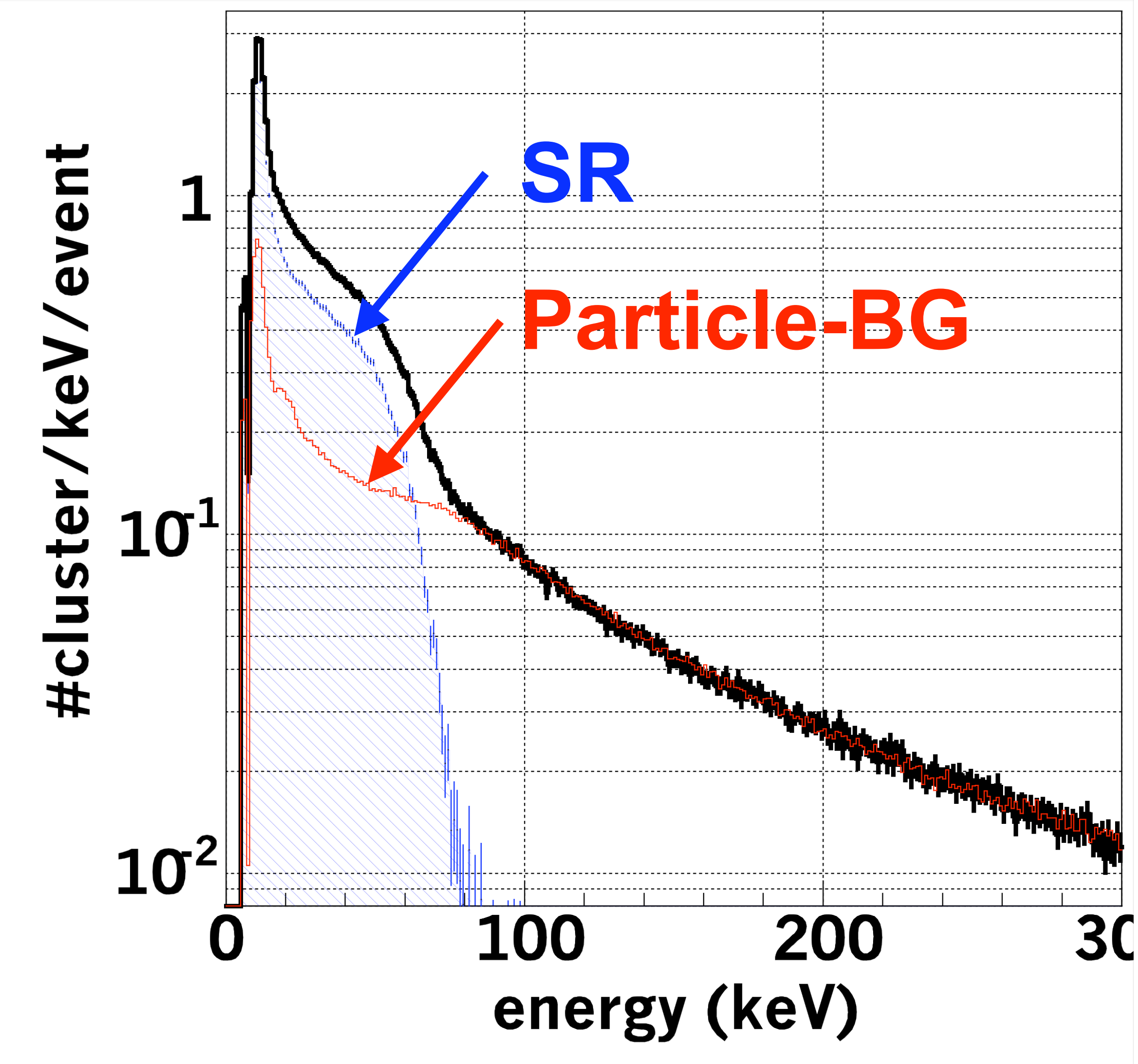
→ larger background

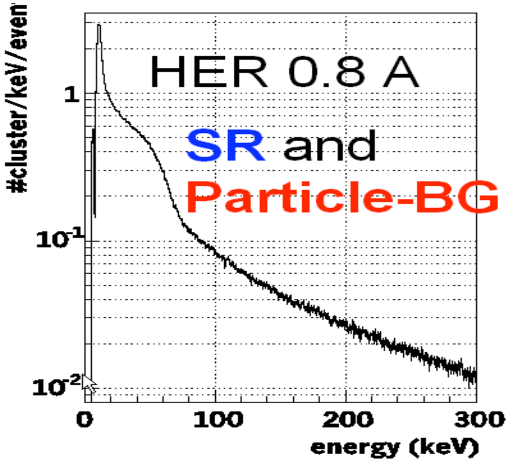
If no Touschek

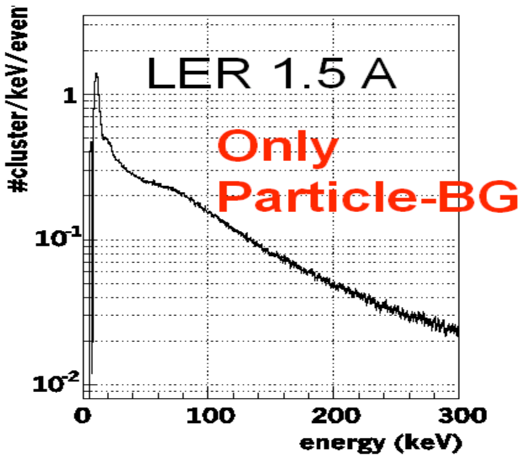
KEKB Collision

Contribution ~ 20 % of
LER BG from particle showers

SVD BG Extraction





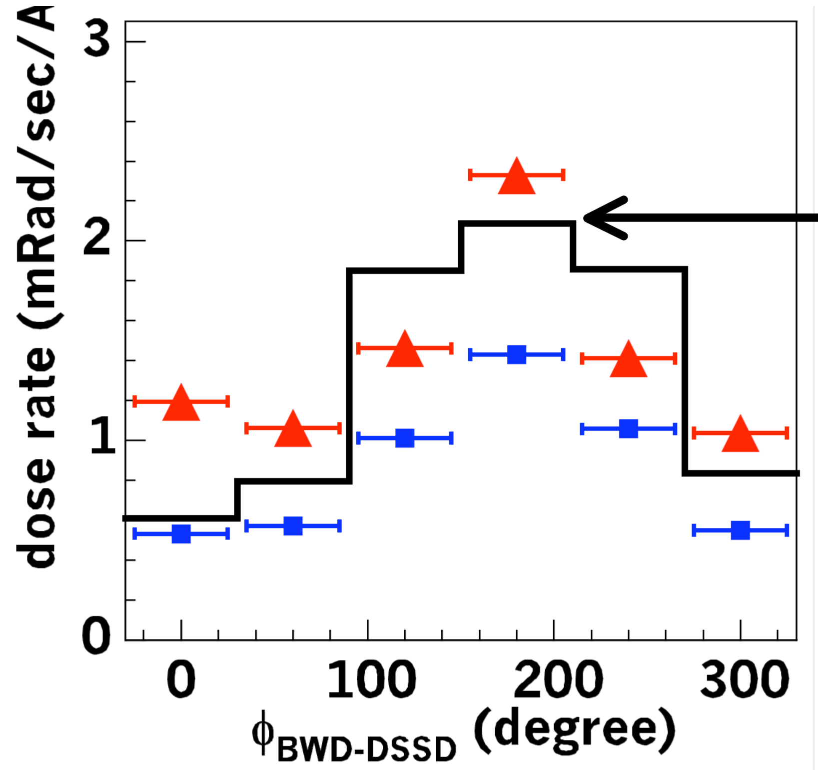


Azimuthal angle dist. of SR at 1st layer of SVD

▲ Single-Bunch 15 mA (trigger-timing is adjusted)

■ Total 0.8 A w/ 1284 bunch (random timing)

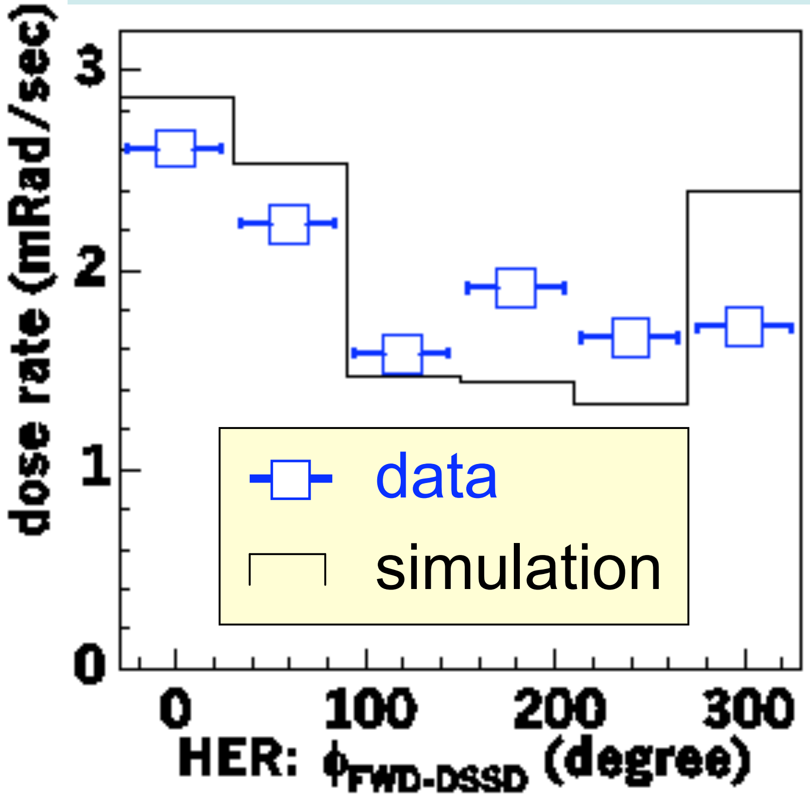
⊓ Simulation for **SR-backscattering**



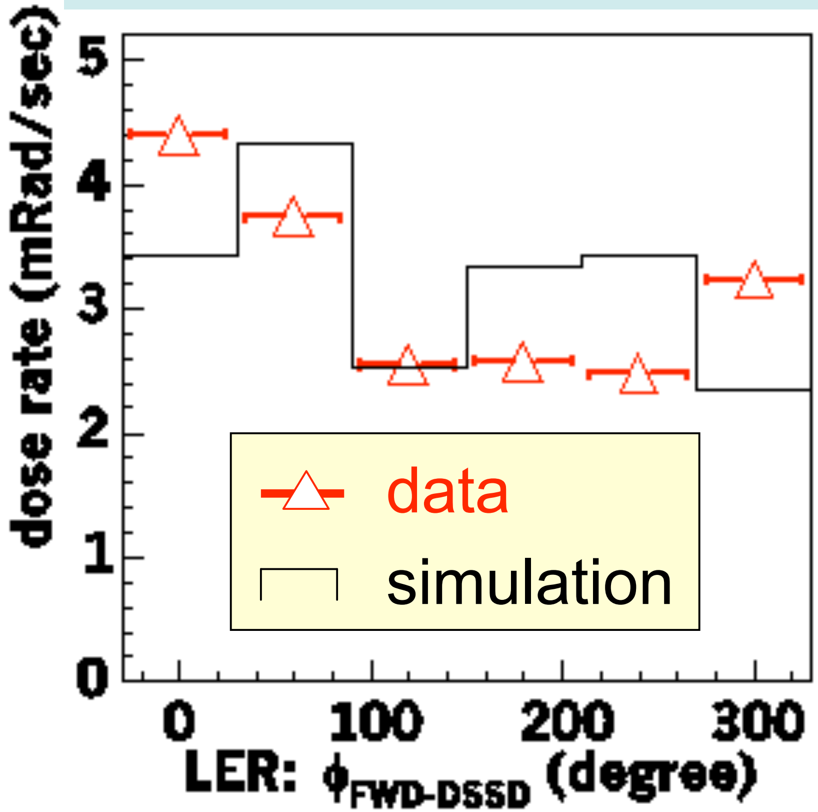
simulation
63 kRad/yr
HER 1.2A

Azimu. angle dist. of Shower particles at 1st layer of SVD

HER single beam 0.8 A

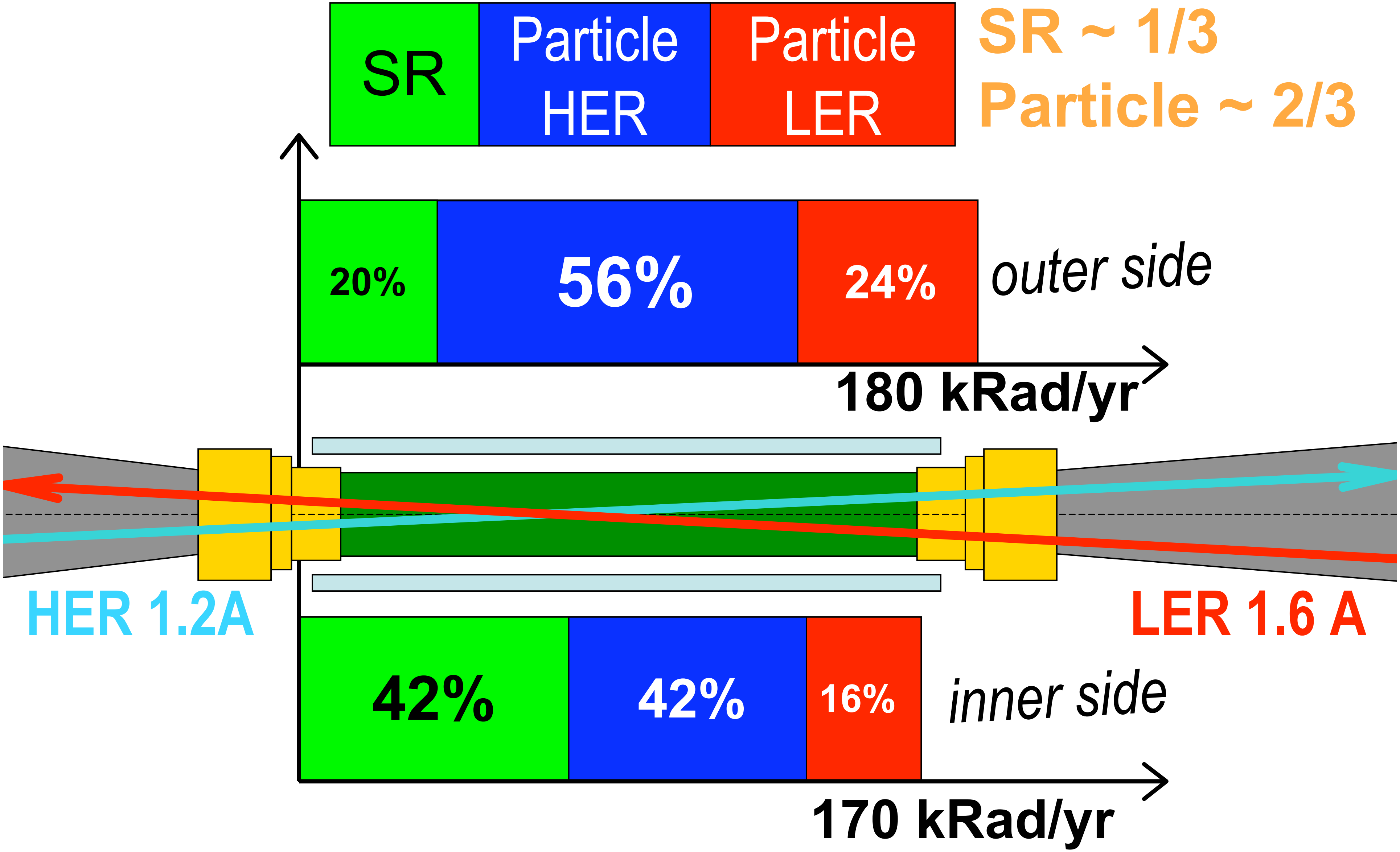


LER single beam 1.5 A



Almost consistent with simulation ~40% accuracy

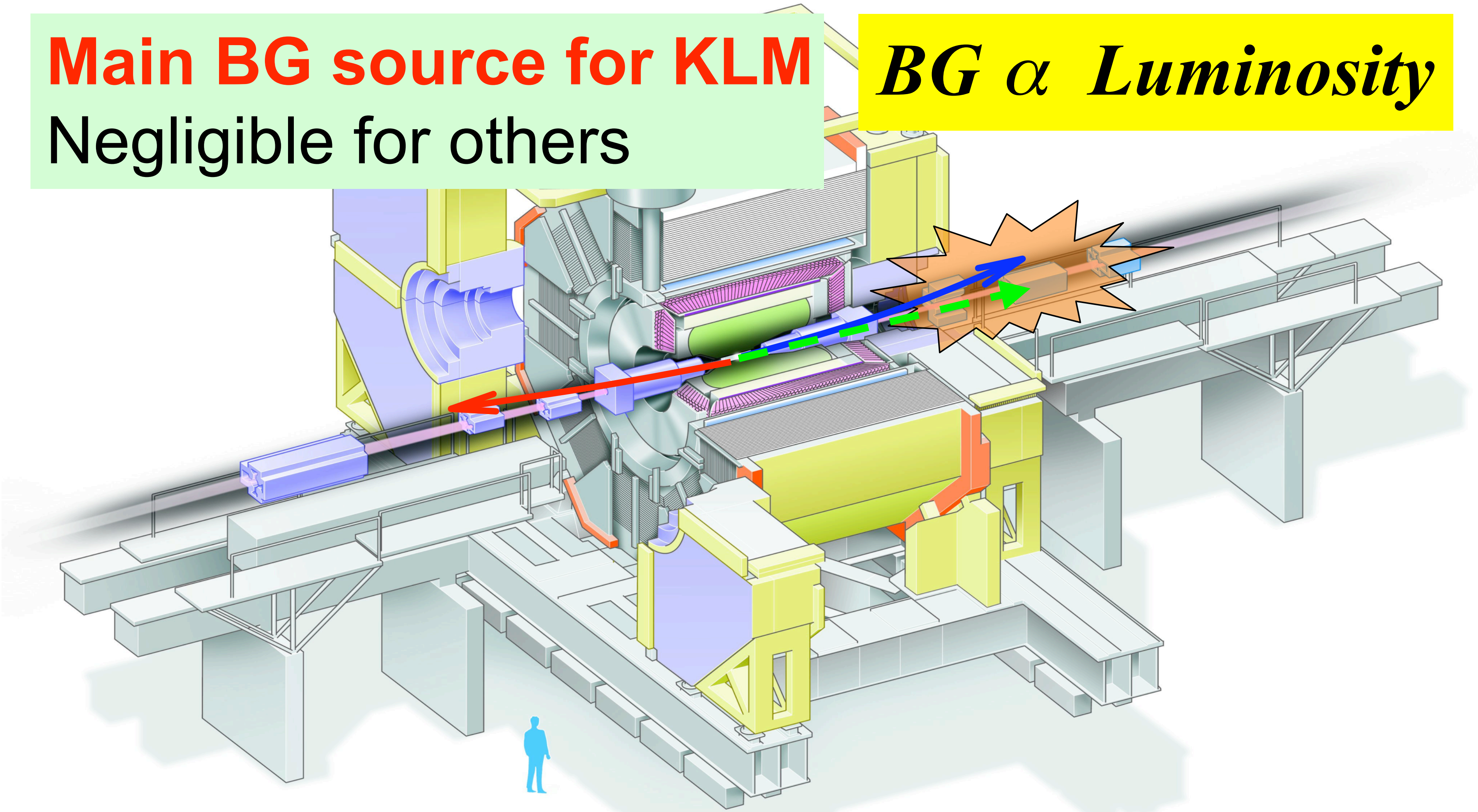
BG of SVD at 1st layer



Radiative Bhabha origin

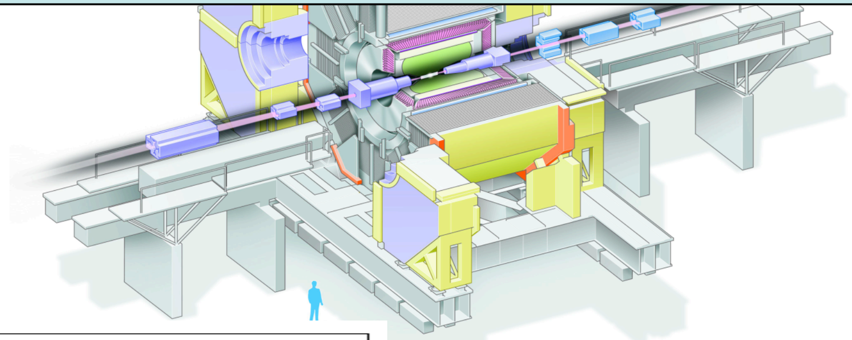
Main BG source for KLM
Negligible for others

BG α Luminosity

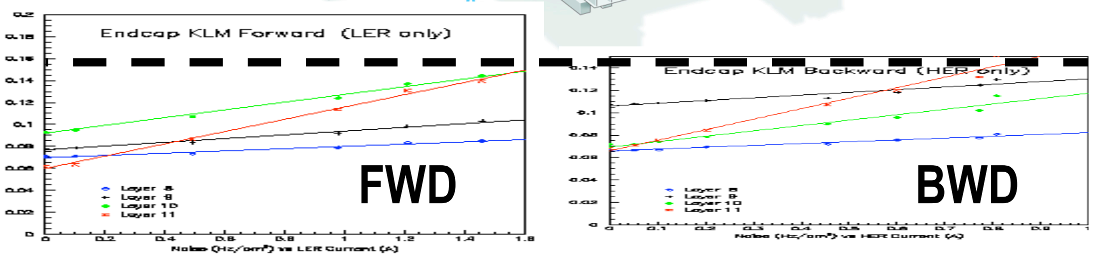


KLM : EndCap

Main bkg source is luminosity origin
Luminosity component ~ 75 %
Beam current component ~ 25 %



rate (Hz/cm^2)



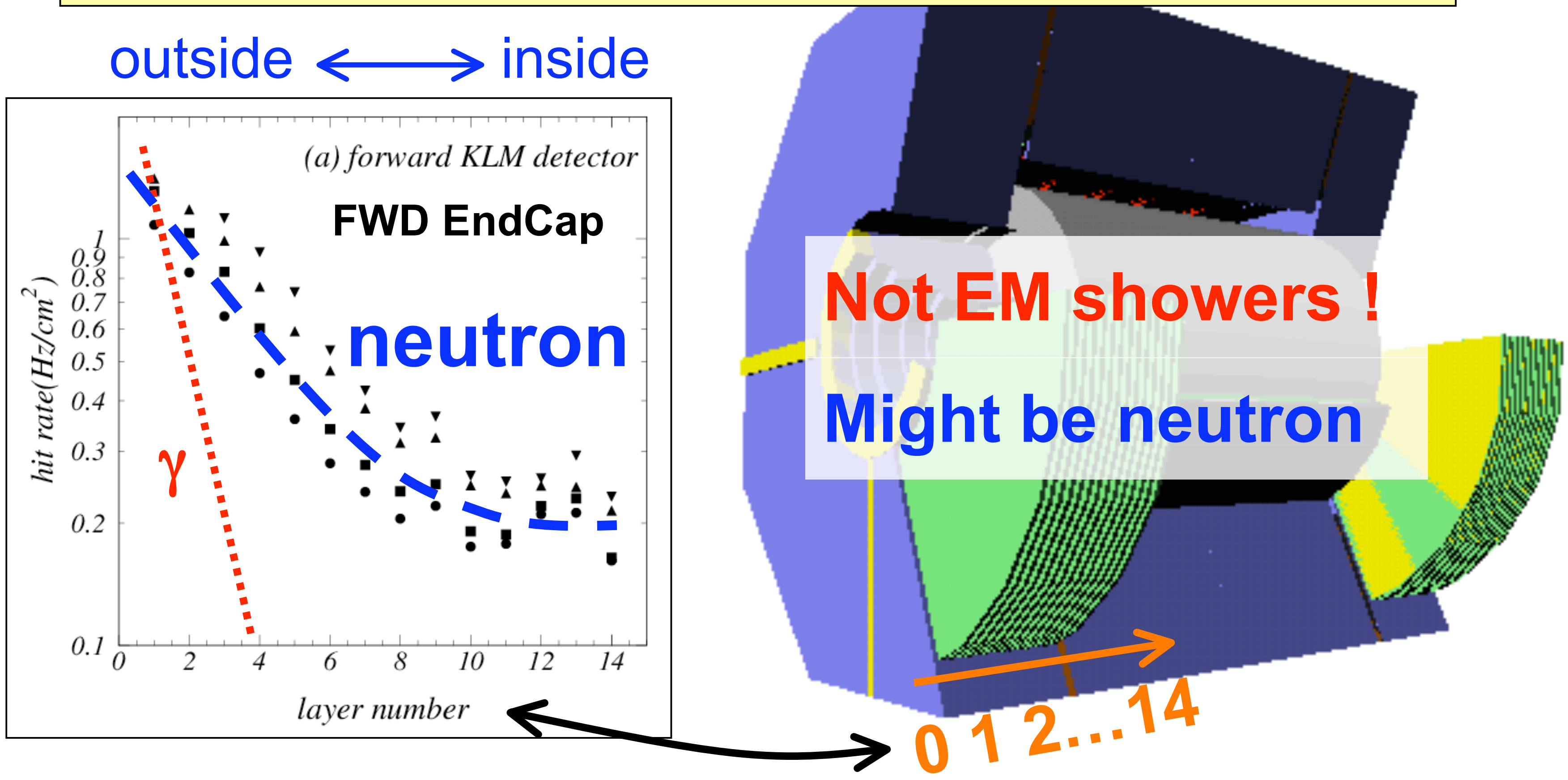
LER current (A) HER current (A)

layer8 layer9 layer10 layer11

inner → outer

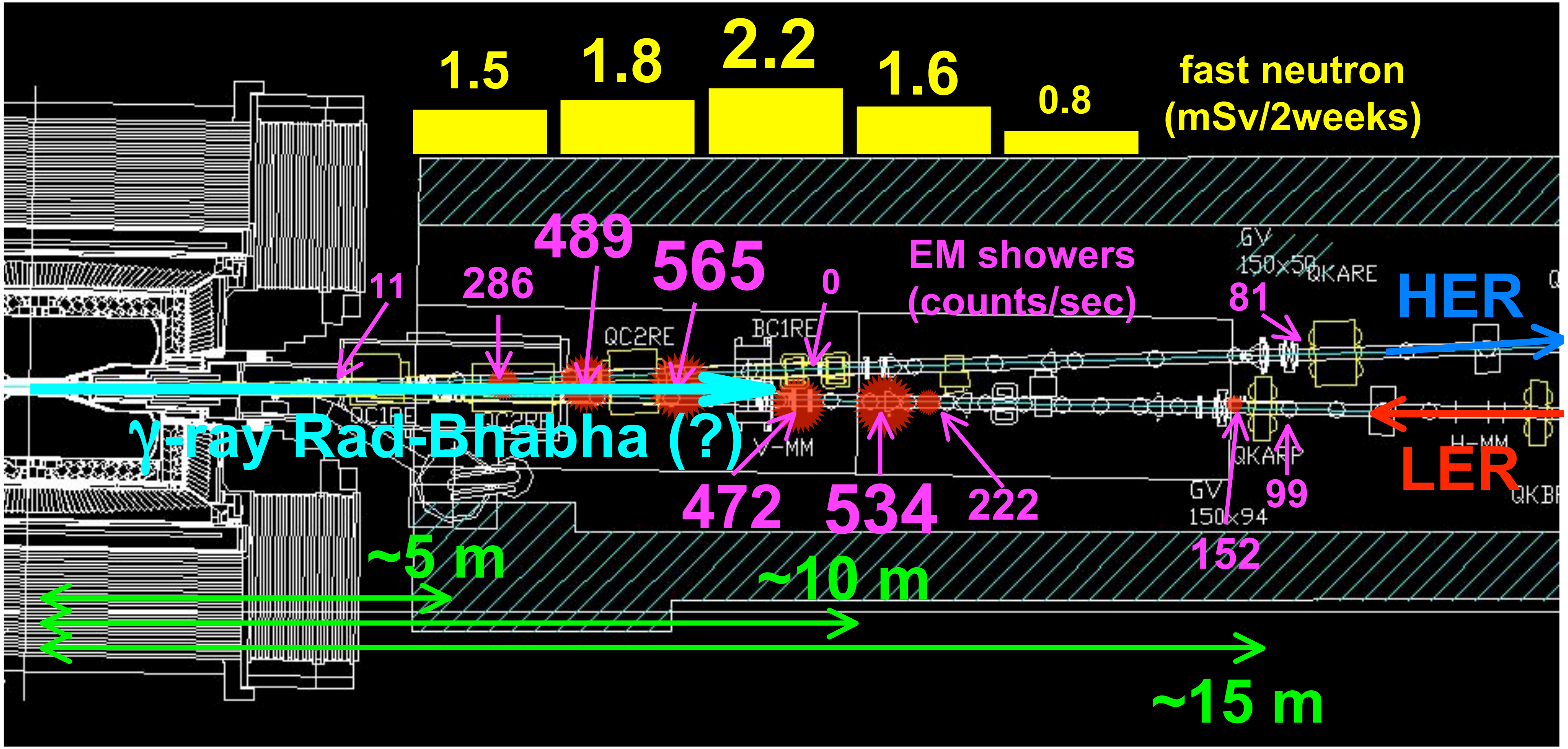
What is KLM bkg ?

- Strong correlation with Luminosity



Where is neutron source?

Radiative-Bhabha might be origin

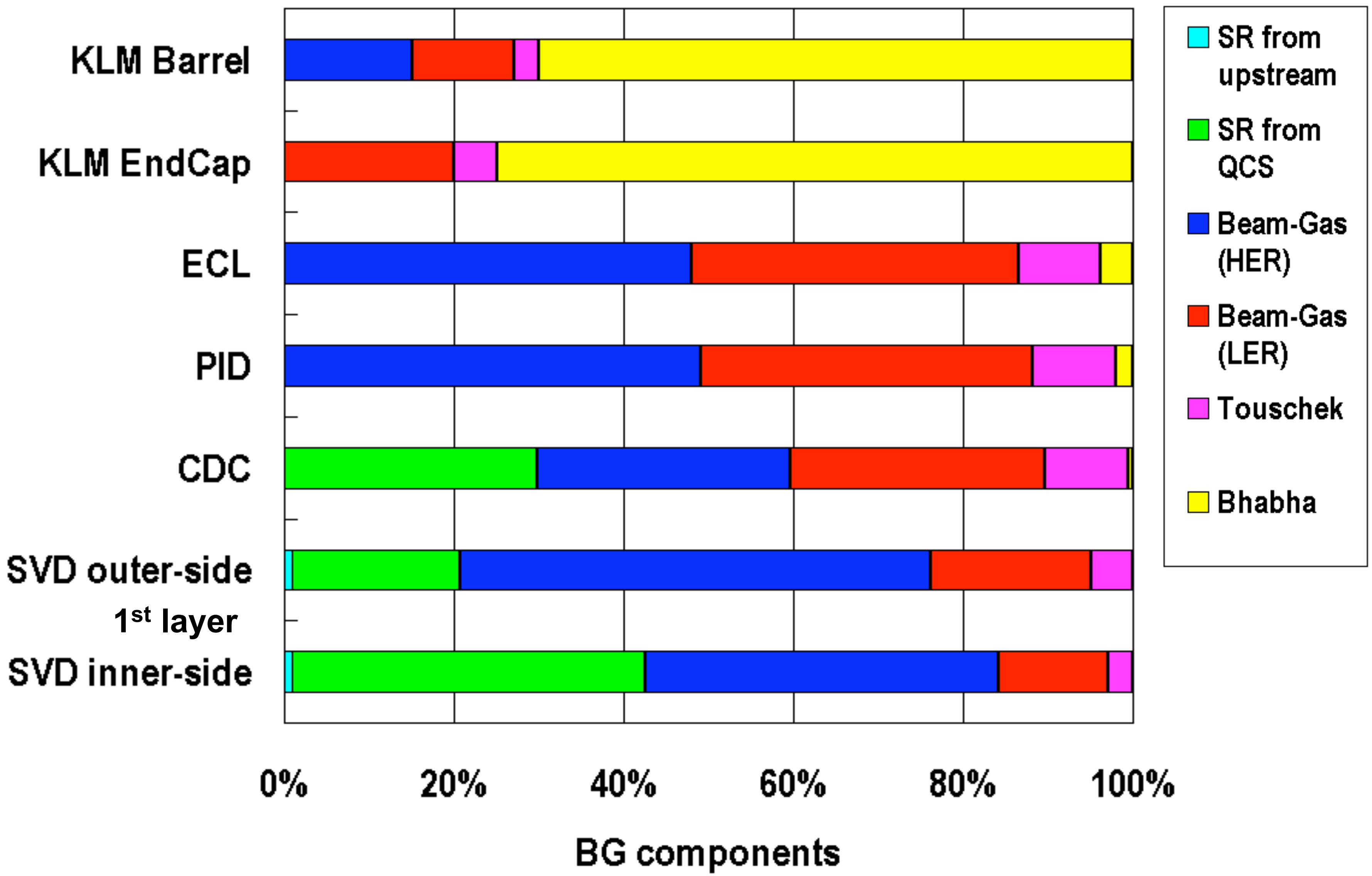


Apr, 2003 (by Tawara, Nakamura)

Oct 27,2004 (by K.Abe & T.Sarangi)

LER / HER = 1630 / 1160 mA

BG components



BG Estimation & Reduction for Super-KEKB/Belle

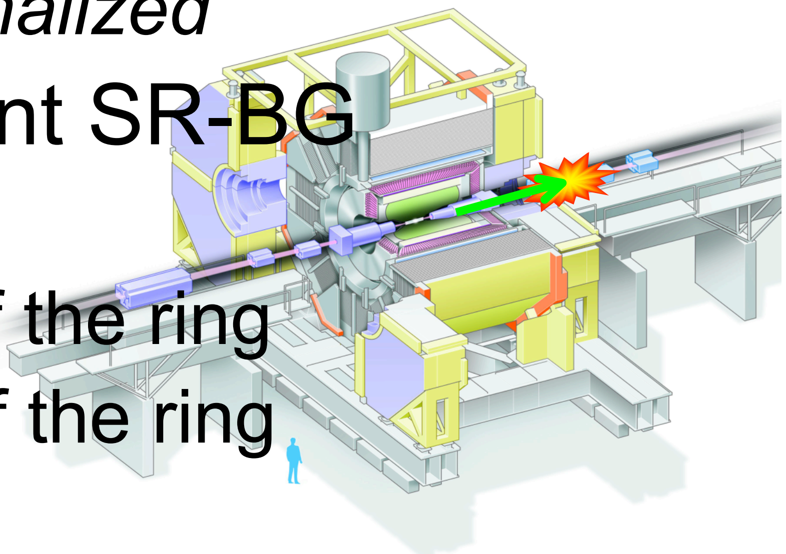
Machine parameters for BG estimation

	KEKB		SuperKEKB	
	LER	HER	LER	HER
I [A]	1.6	1.2	9.4	4.1
β_x^*[cm]	33	33	20	20
β_y^*[mm]	10	10	3	3
L [/cm^2/sec]	1.3×10^{34}		2.5×10^{35}	
σ_y [um]	3	3	1.5	1.5
σ_l [mm]	5	5	3	3
Ave. Vacuum (10^{-7} Pa)	1.25	1.25	5 (2.5)	5 (2.5)
ϕ [mrad]	11		15	
SR power : QCSR (kW)	29		179	
Run time (days/year)	200		200	

Backscattering of QCS-SR

- Larger current and critical energy gives larger QCS-SR wattage → x6 (179 kW)
- Assume that scattered position will be same as current KEKB (~9m)
  - *IR chamber design is not finalized*
- **6 times higher** than current SR-BG

  Dose at 1st layer of SVD
  - 400 kRad/yr at inner side of the ring
  - 130 kRad/yr at outer side of the ring

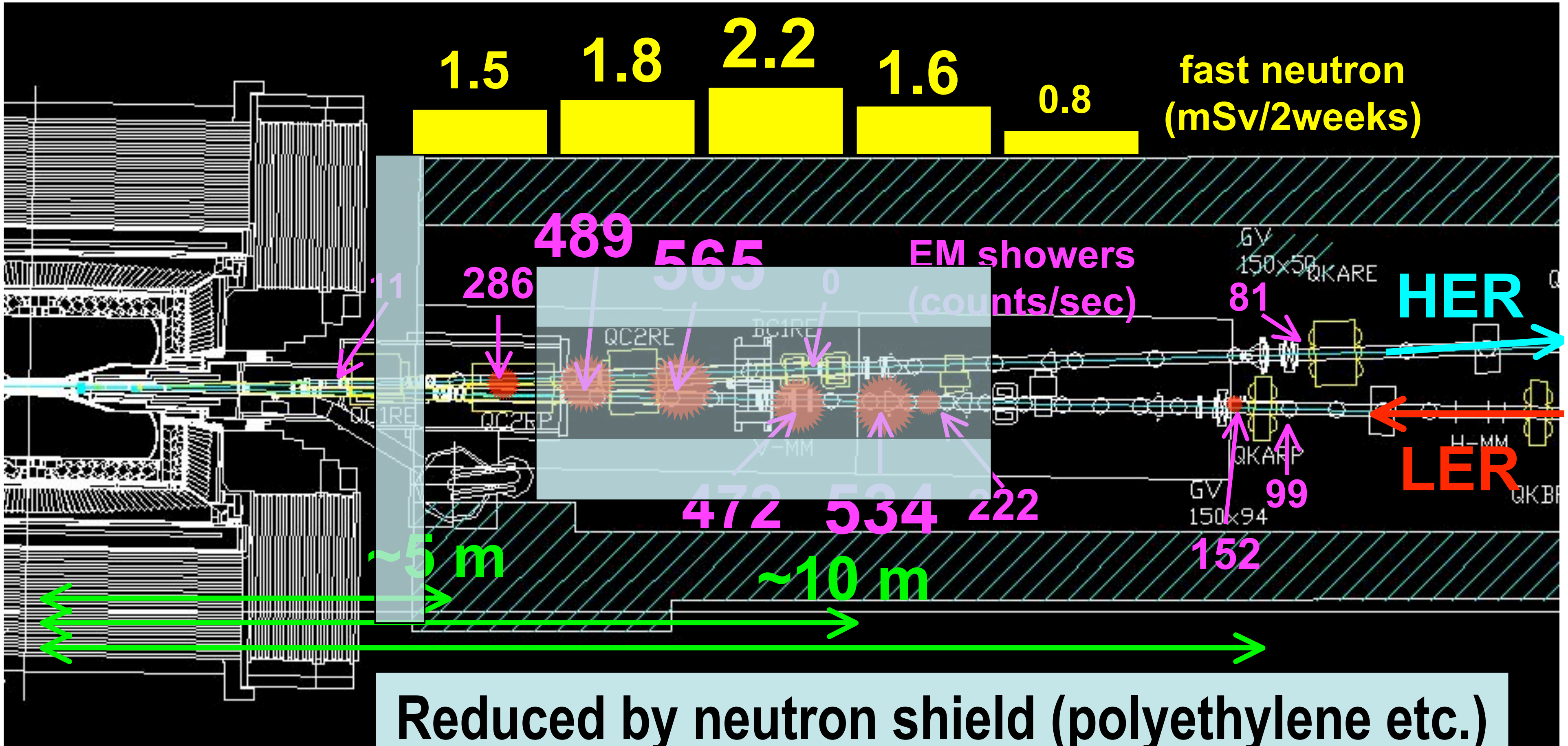


Shower of Spent Particles

- **Beam-Gas scattering origin**
  - HER / LER currents: 1.2/1.6 A → 4.1/9.4 A
  - x4 Worse Vacuum : 1~1.5x10^{-7} Pa → 5x10^{-7} Pa
  - **x13.6 (HER), x23.6 (LER) higher contribution**
- **Touschek origin**
  - smaller beam size ~ 1.5um/3um
  - shorter bunch length ~ 3mm/5mm
  - higher bunch current ~ 1.5 times
  - many #bunch ~ 3.9 times
  - currently just 10% of total BG
  - **x97 times higher contribution**

Rad. Bhabha : KLM

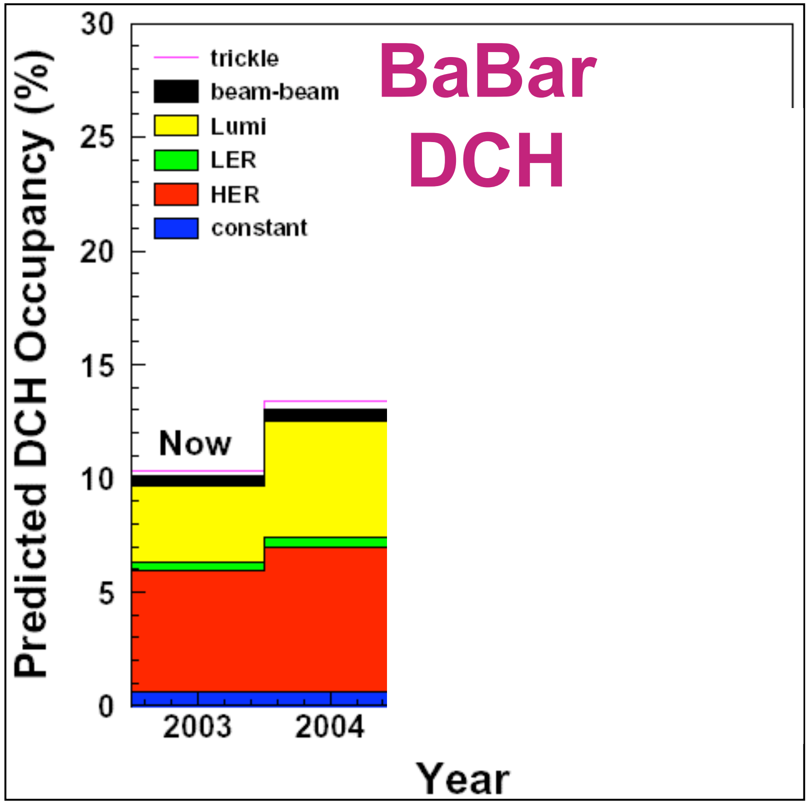
$L_{super\text{-}KEKB} / L_{KEKB}$ = 25 / 1.3 ~ 19 times higher



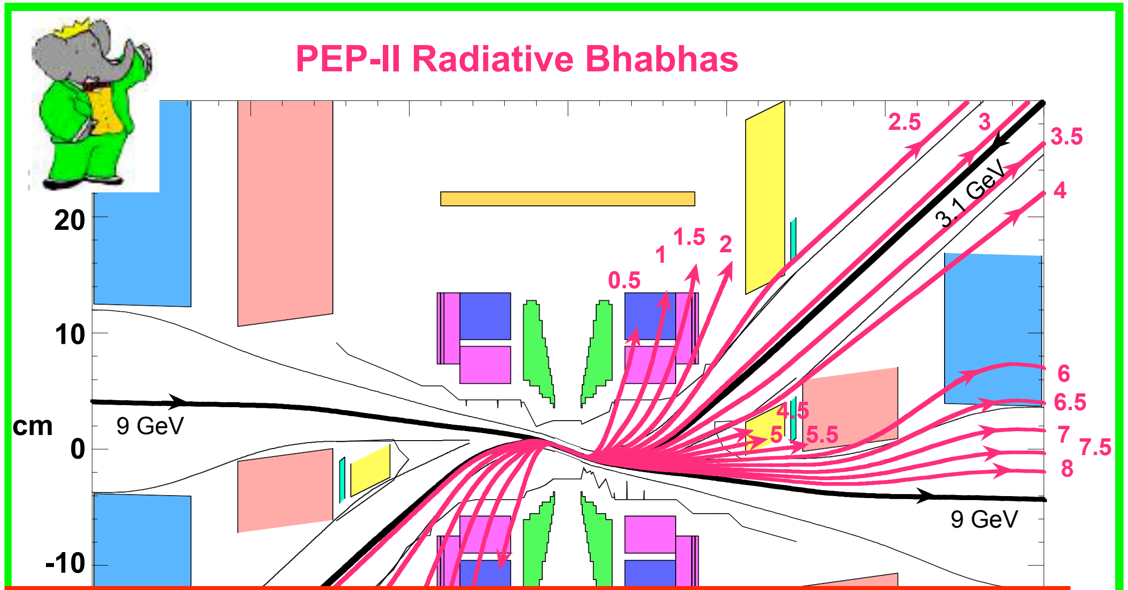
Reduced by neutron shield (polyethylene etc.)
→ ~0.1/(25cm thickness)

Radiative Bhabha : inner detectors

- Actually, BaBar has large BG for inner detectors while it is negligible at Belle

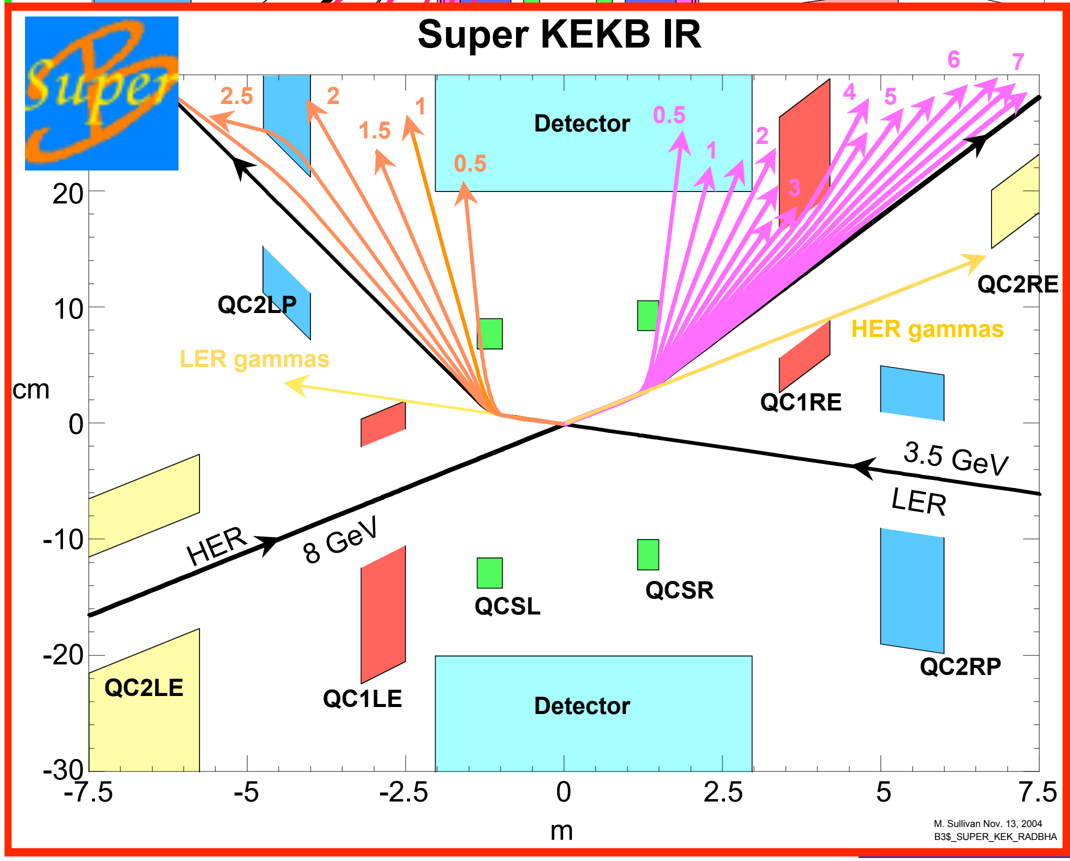


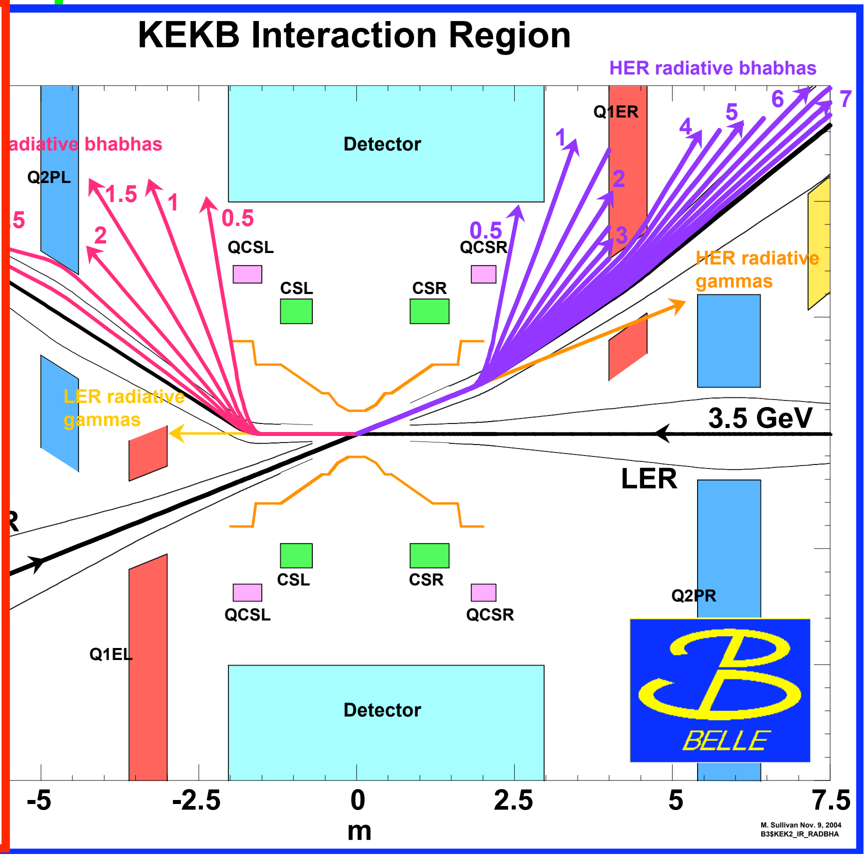
We should consider because higher lum gives higher BG



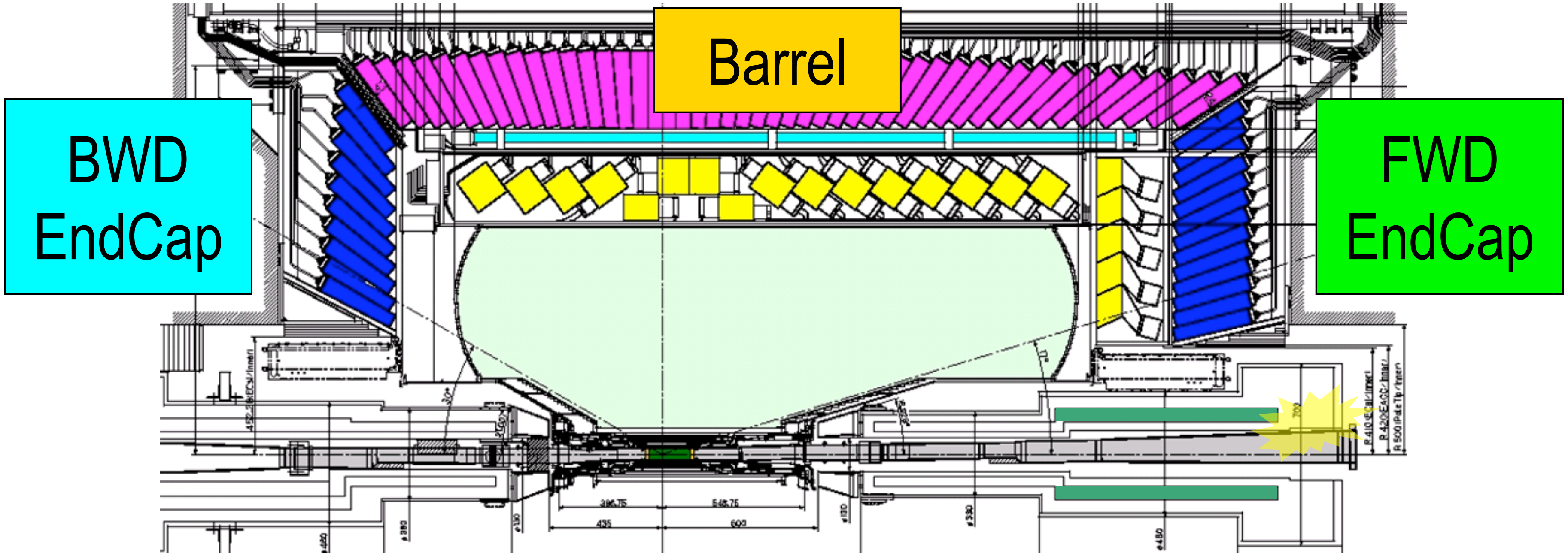
Difference of QCS position is the reason Shower caused by over bend particle

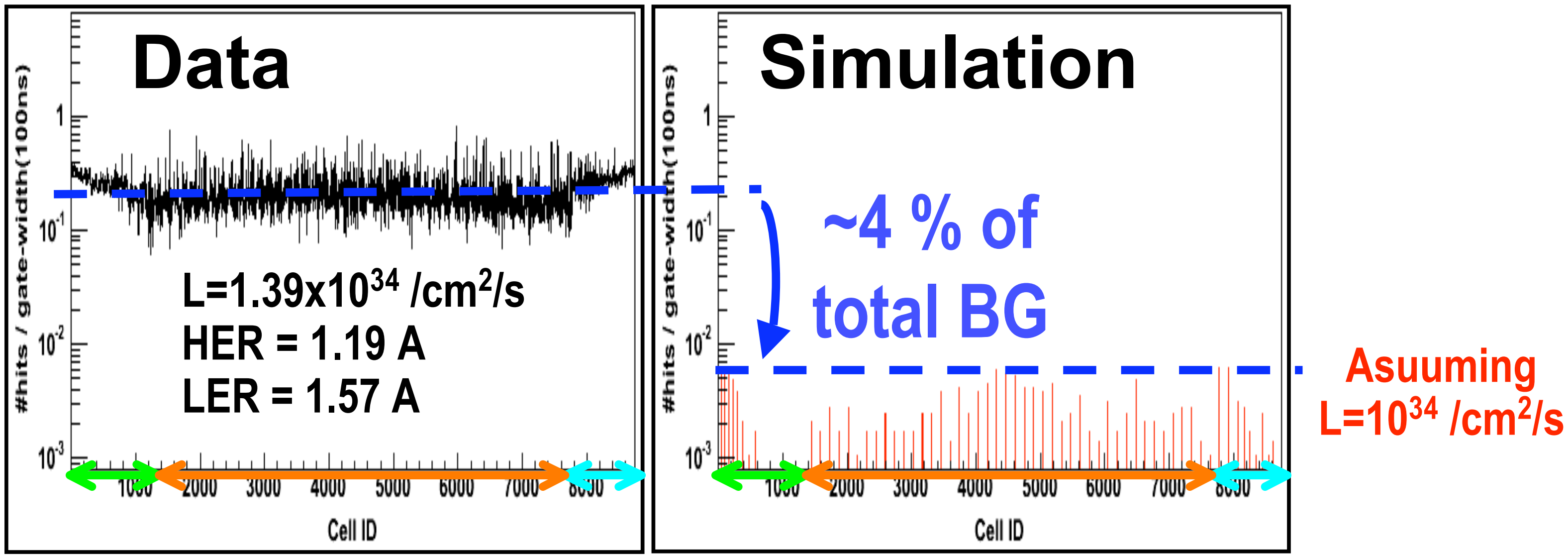
Pointed out by M.Sallivan in 6th HLWS (Nov,2004)



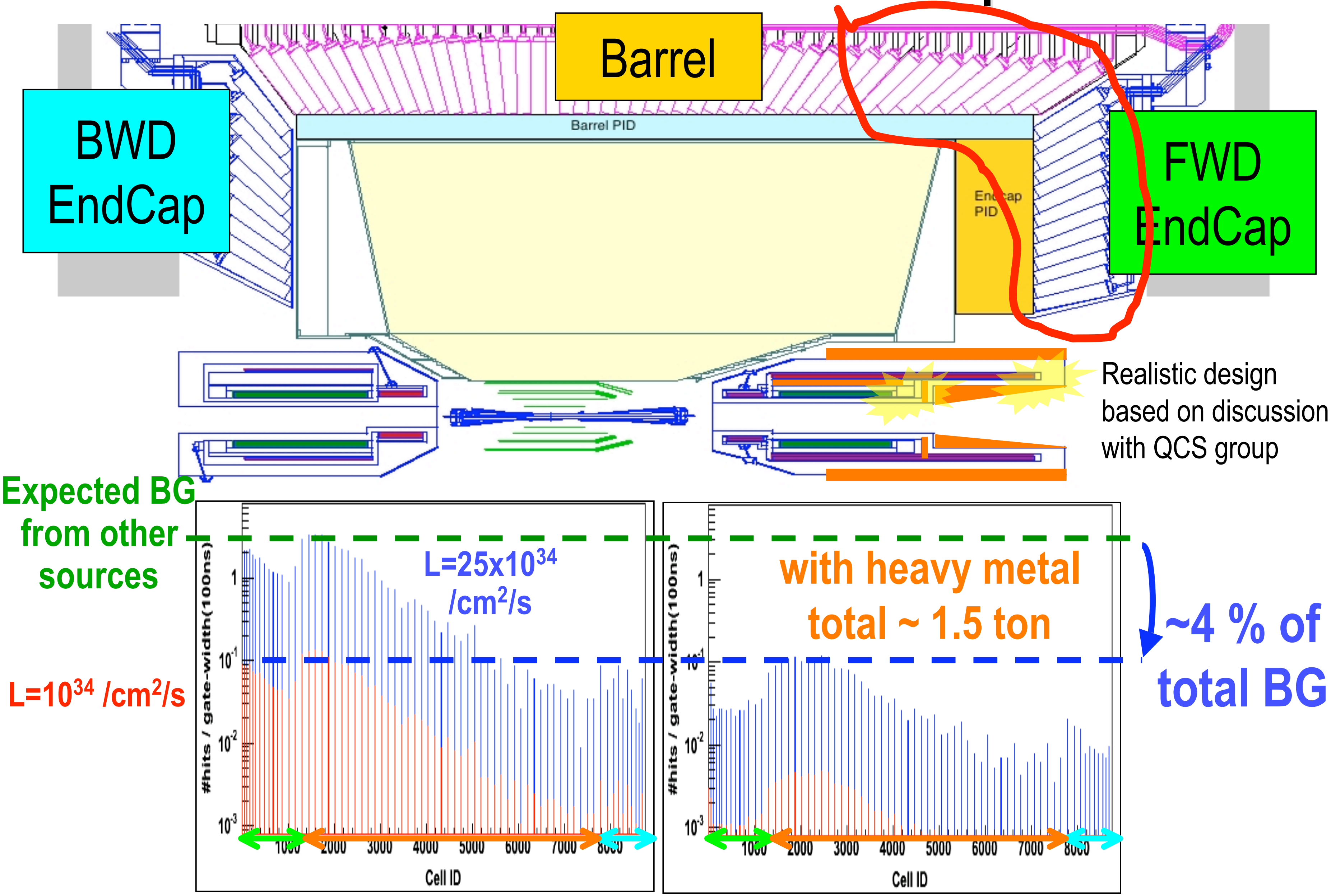


Rad. Bhabha BG at ECL, NOW



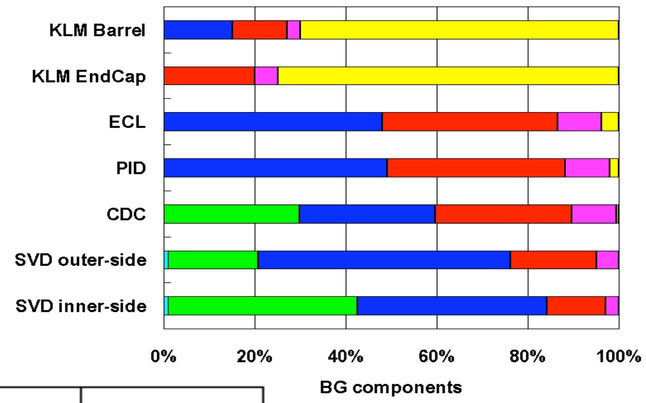


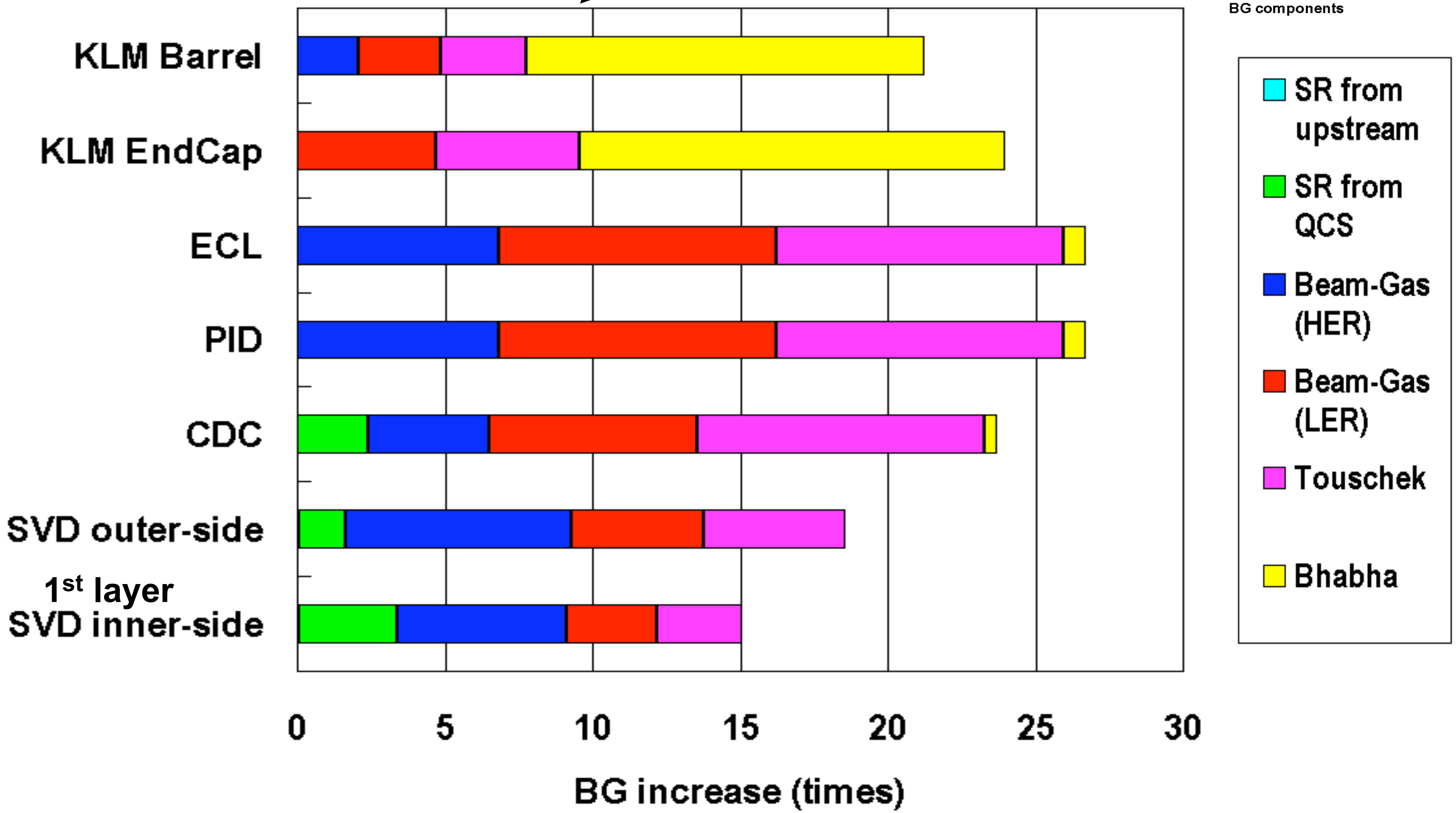
Rad. Bhabha BG sim. for Super-KEKB



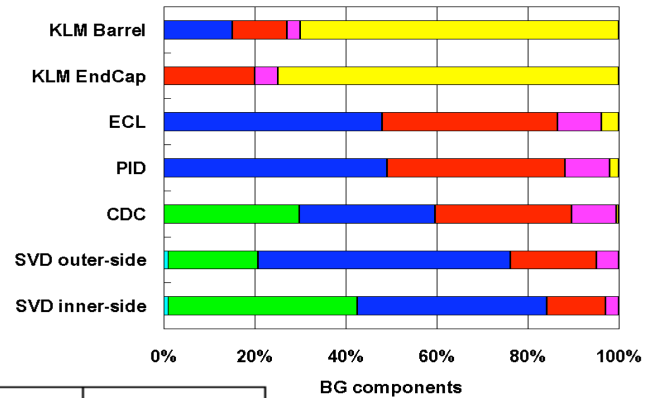
Super-KEKB (current) design

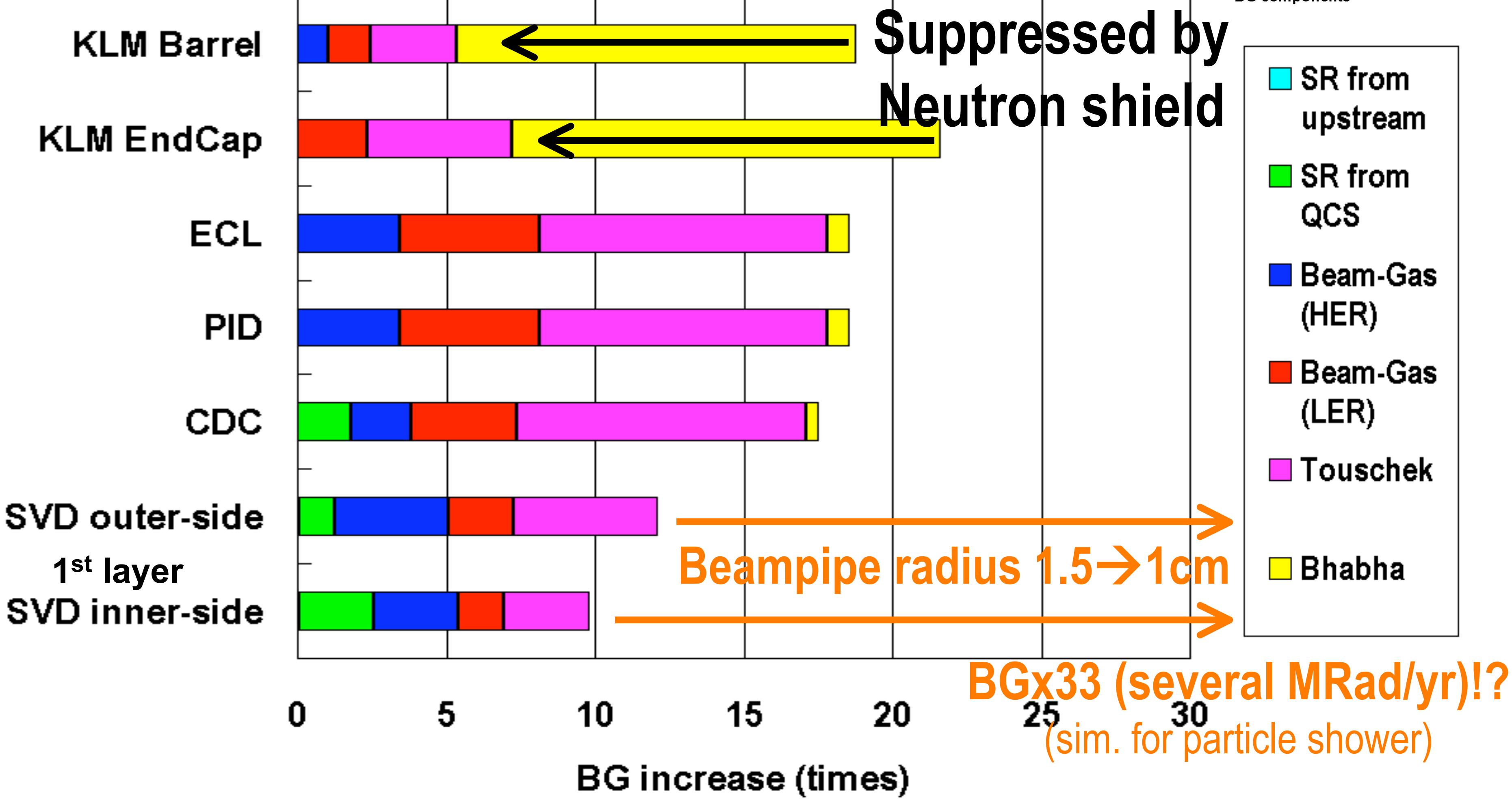
Average Vacuum
5×10^{-7} Pa





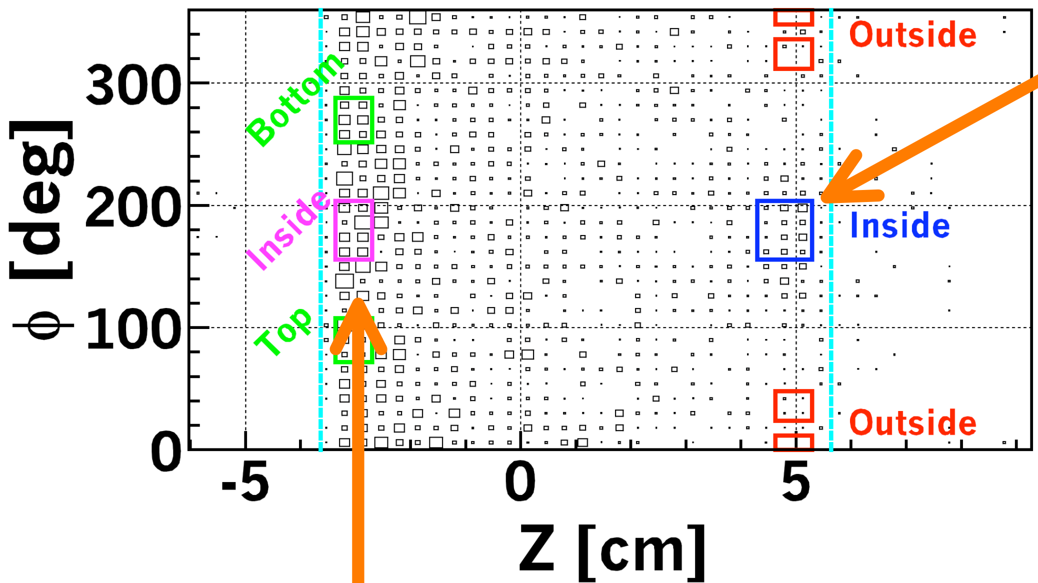
Average Vacuum
2.5×10^{-7} Pa





SR from upstream magnets
simulation for SVD 1st layer

QC1L(-3m) during injection

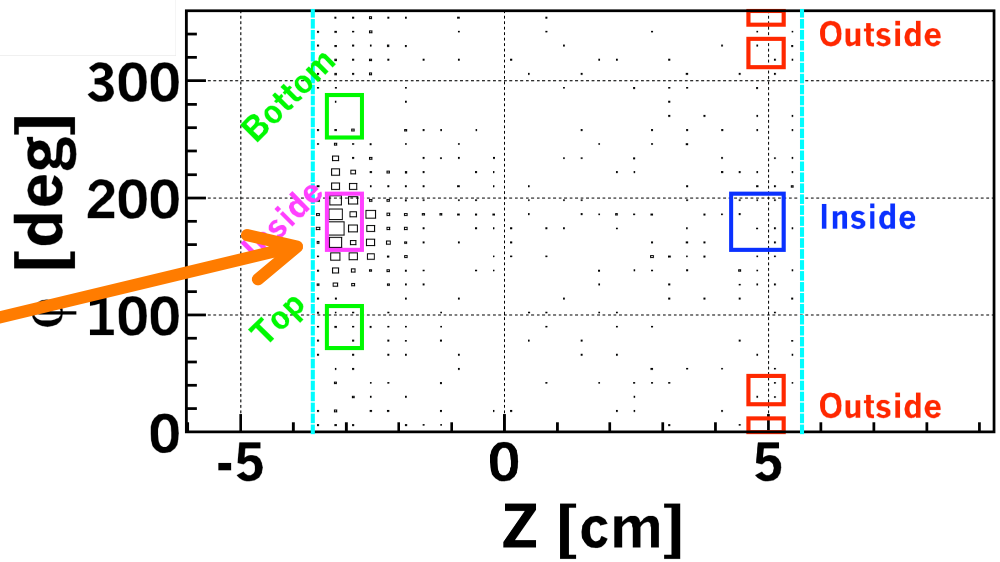


~20 kRad/yr

~40 kRad/yr

Deposit dose is localized on 1st layer of SVD
But, still lower than others

QC2L(-7m) at stored



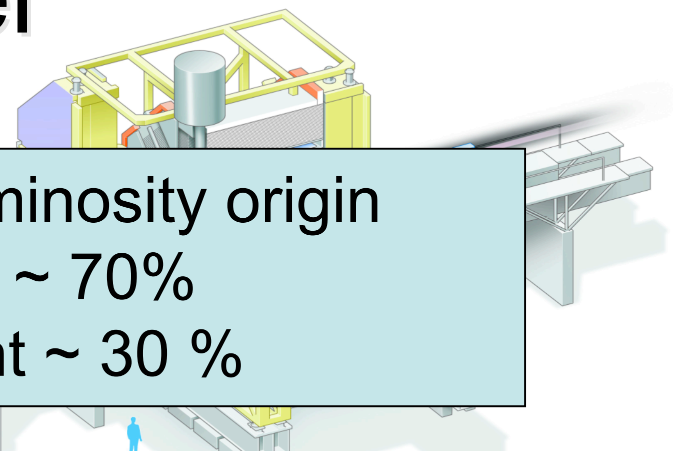
~100 kRad/yr

Summary

- **Backscattering of QCS-SR** is not serious, but **strongly depends on IR chamber configuration**
- **Vacuum level is very important**
  - Original design ($5x10^{-7}$ Pa) is serious → **BGx25**
  - w/ further effort ($2.5x10^{-7}$ Pa) → **BGx18** ← **-30%**
- Increasing of Touschek origin BG
  - Smaller bunch size & higher bunch currents are reason
  - Might be reduced by further study
- **Radiative Bhabha origin BG can be suppressed**
- **Beampipe radius 1.5cm → 1cm**
  - Further simulation study of shower particles into SVD is important

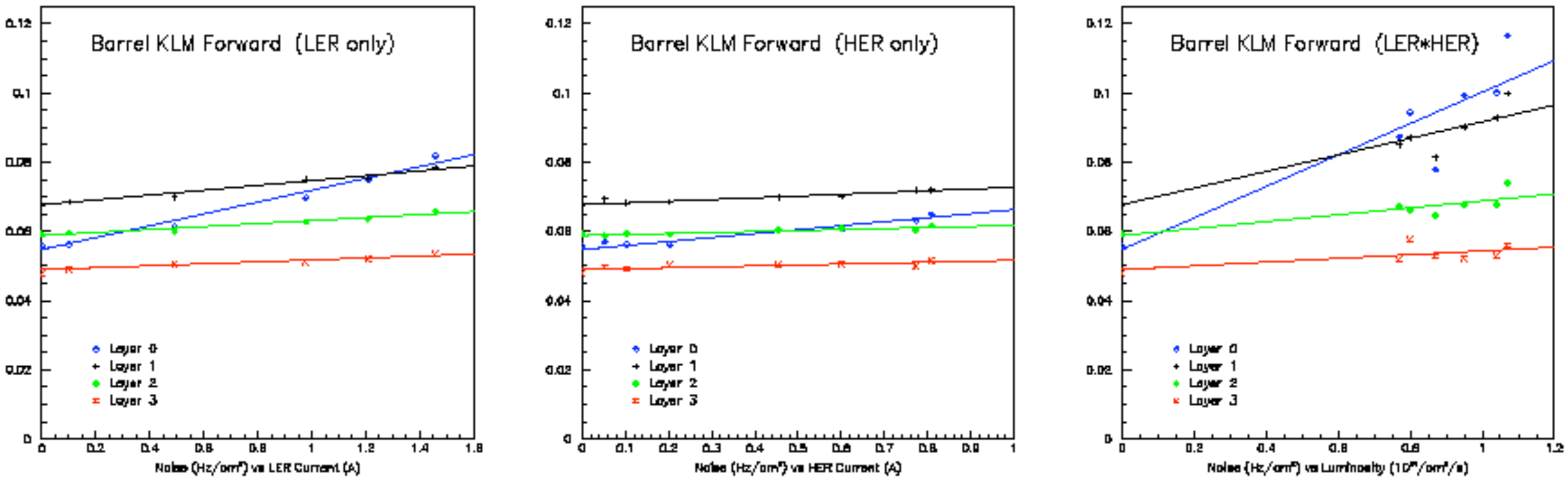
backup

KLM : Barrel



Main bkg source might be luminosity origin
Luminosity component ~ 70%
Beam current component ~ 30 %

rate (Hz/cm^2)



LER current (A) HER current (A) Luminosity (10^{34}/cm^2/s)

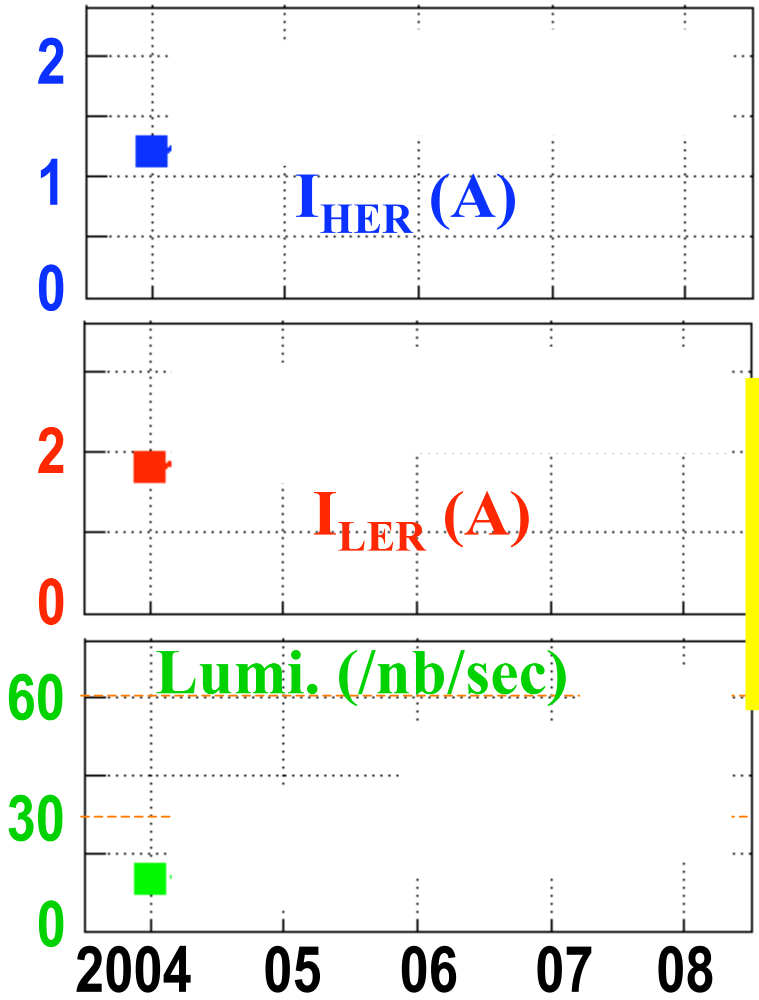
layer0 layer1 layer2 layer3

inner ⟶ outer

Now

- HER / LER = 1.2 / 1.8 A
- Luminosity ~ 13 /nb/sec (1.3×10^{34} $/cm^2/sec$)
- Which is dominant background?
  - SVD : SR ~ 1/3, Spent particles ~ 2/3
  - CDC : SR ~ 1/4, Spent particles ~ 3/4
    (HER ~ 1/4, LER ~ 2/4)
  - KLM EndCap : L ~ 75 %, Spent particles ~ 25 %
    Barrel : L ~ 70 %, Spent particles ~ 30 %
  - Others : Spent particles might be dominat

Near Future Prospects of KEKB



Now (2004)

L = 13 /nb/sec
HER / LER = 1.2 / 1.8 A
RF limits beam-current

RF repair & minor upgrade (2005)

within 3~4 years …

Beam current : x 1.7 higher

Luminosity : x 4.6 higher

Crab cavity (2006) HER&LER

→ twice luminosity !?

Minor upgrades (2007-2008)

→ L = 60/nb/sec
HER / LER = 2 / 3 A

Near Future

SR ($\propto I_{HER}$)

Spent particles ($\propto I^2$)

Luminosity origin ($\propto L$)

SVD outer x 2.6

inner x 2.3

CDC x 2.5

KLM EndCap x 4.2

Barrel x 4.1

Others x 2.8

If we can keep good vacuum
(optimistic case)

most of detectors x 1.7

KLM x 3.9

lower limit !?

3 times bkg is good target value for near future

Summary

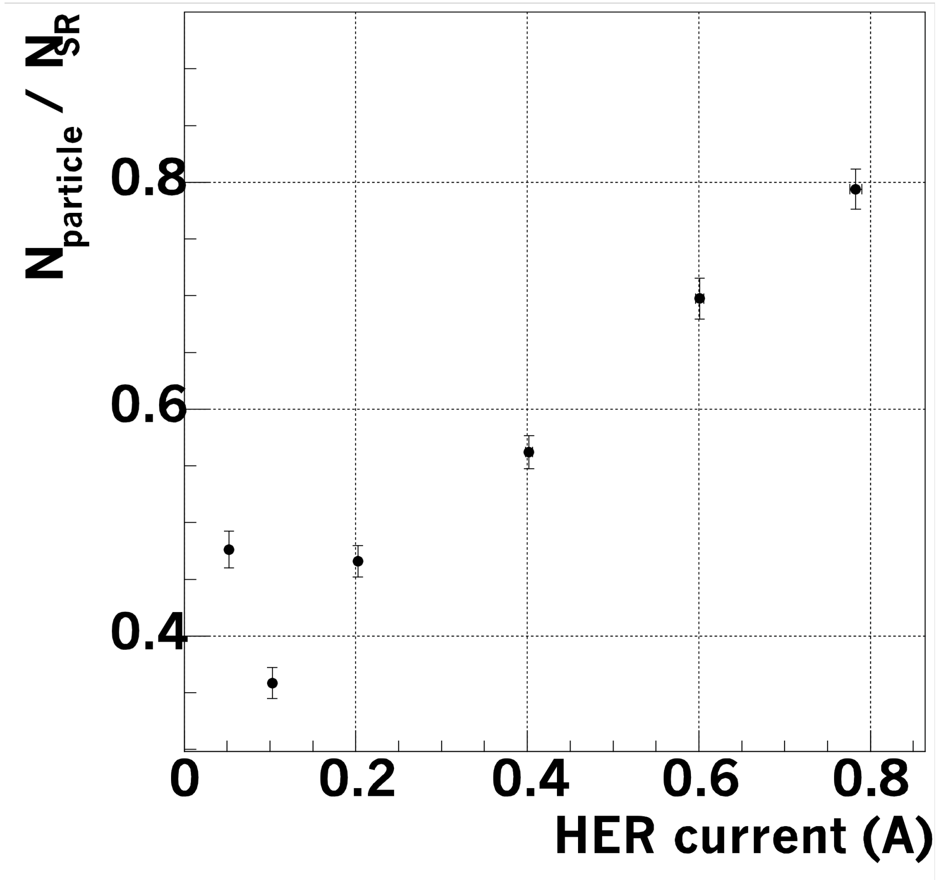
	2004	→	2008
Lumi.	13 /nb/s	→	60 /nb/s
HER	1.2 A	→	2 A
LER	1.8 A	→	3 A
SVD	*Bkg*	→	x 1.7 ~ 2.6
CDC	*Bkg*	→	x 1.7 ~ 2.5
KLM	*Bkg*	→	x 3.9 ~ 4.2
Others	*Bkg*	→	x 1.7 ~ 2.8

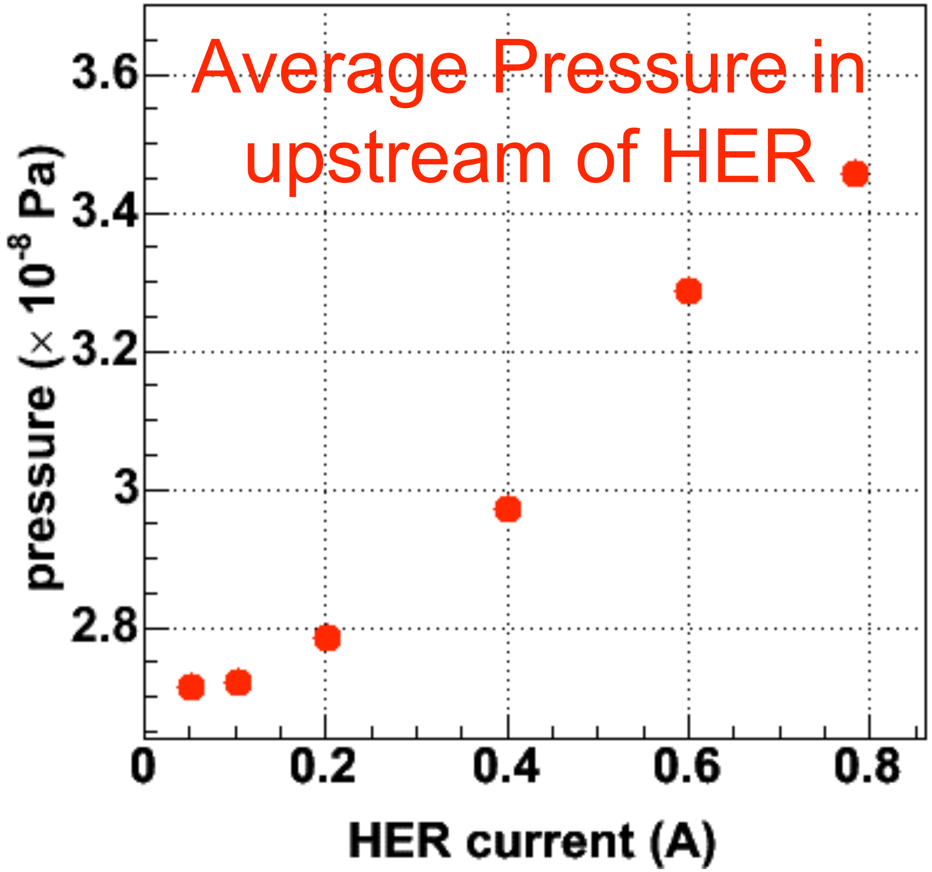
Higher bkg study must be needed for ~3 year later

KLM bkg reduction must be start as soon as possible

Beam Current dep. of Vacuum

$N_{particle}/N_{SR}$ α P(Pa) ← N_{SR} α I(A)
$N_{particle}$ α I(A) x P(Pa)

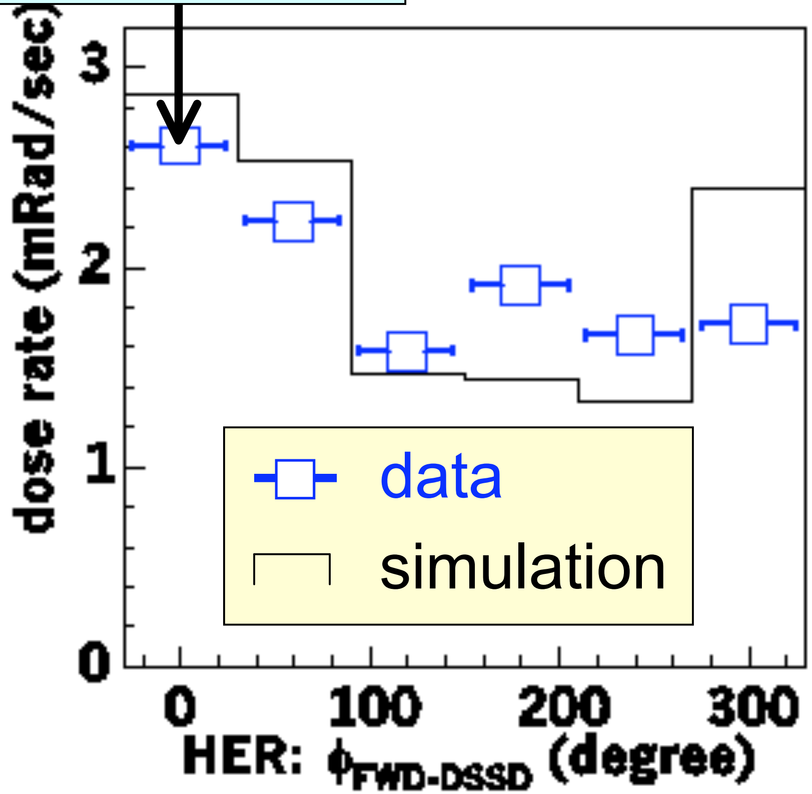




Azimu. angle dist. of Shower particles

88 kRad/yr
at HER 1.1A

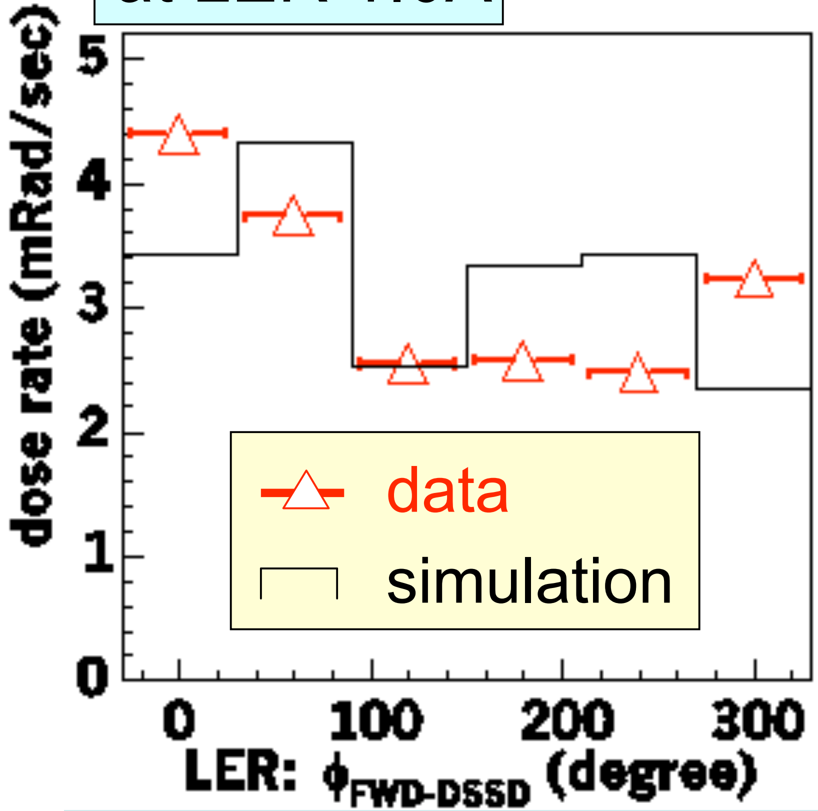
simulation
106 kRad/yr



HER single beam 0.8 A

86 kRad/yr
at LER 1.6A

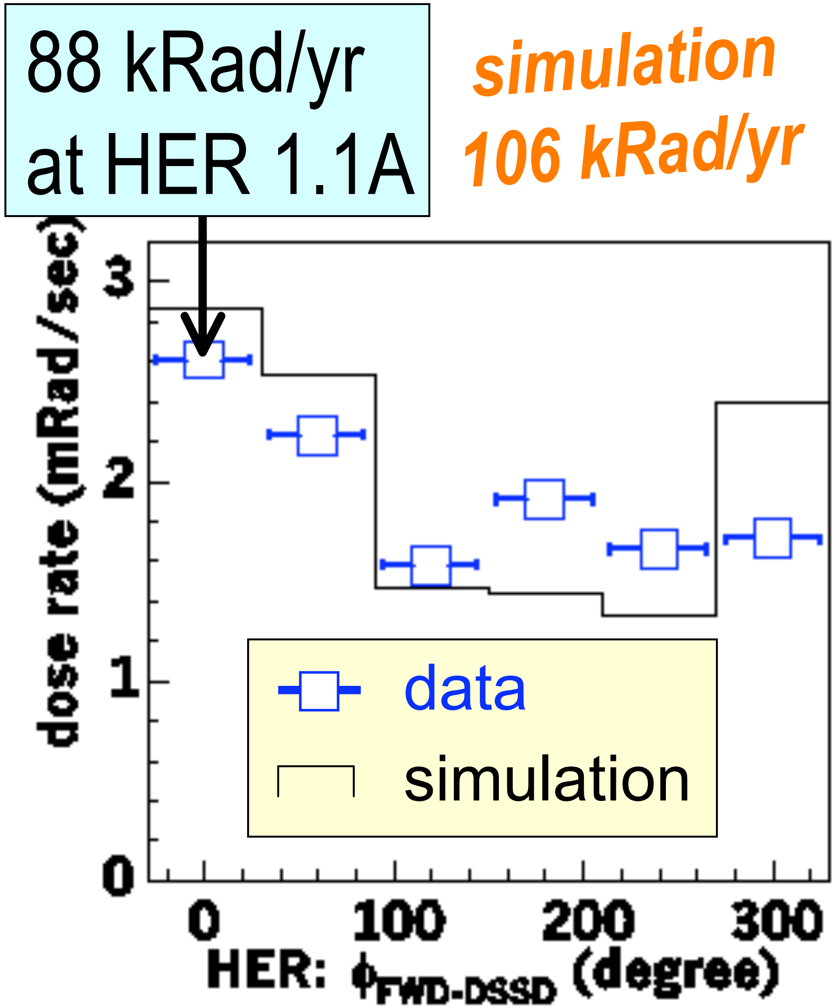
simulation
42 kRad/yr



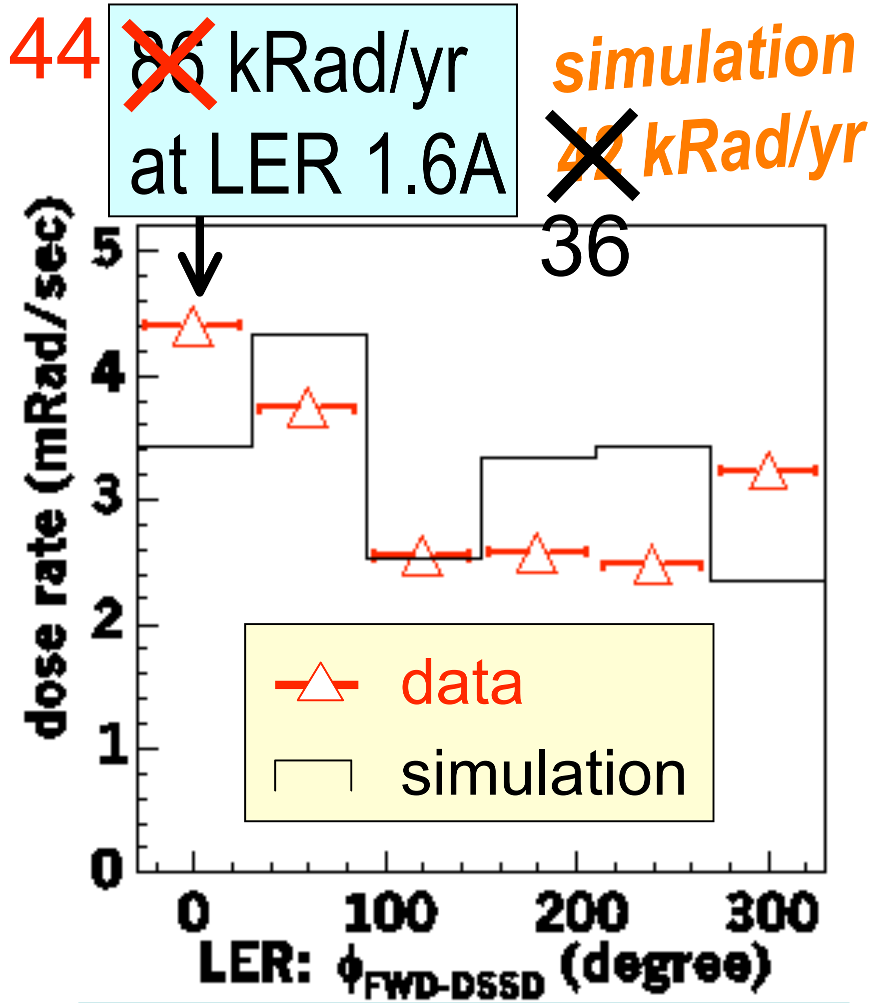
LER single beam 1.5 A

Azimu. angle dist. of Shower particles

w/ correction of Touschek



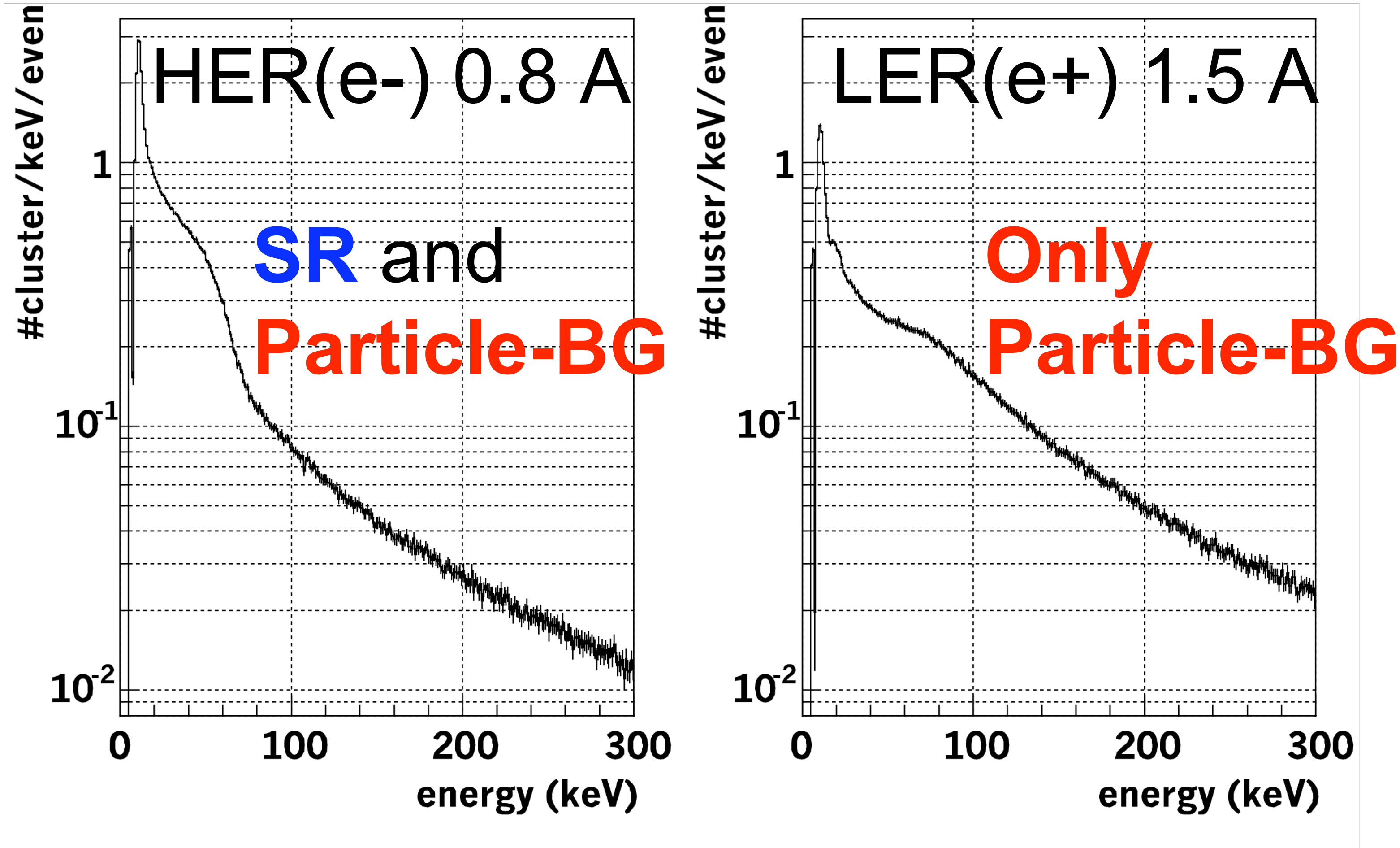
HER single beam 0.8 A



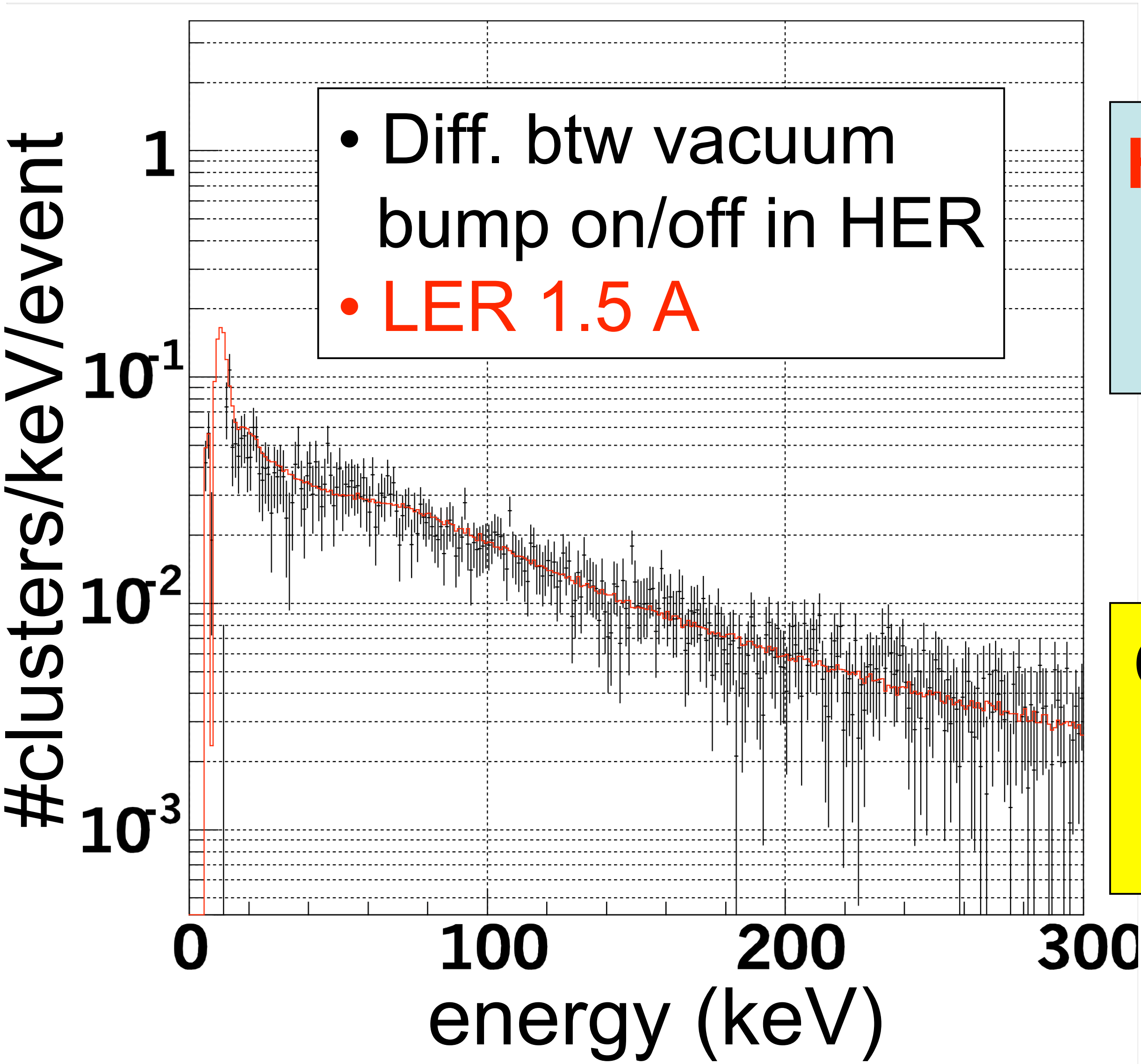
LER single beam 1.5 A

SVD Cluster Energy Spectra in Single Beam Run (1st layer)

Energy deposition → Radiation dose



E-spectrum of HER Particle-BG



HER E-spectrum of particle BG is same as LER !!

Can measure SR and particle-BG separately

Variation of Pressures at Pump

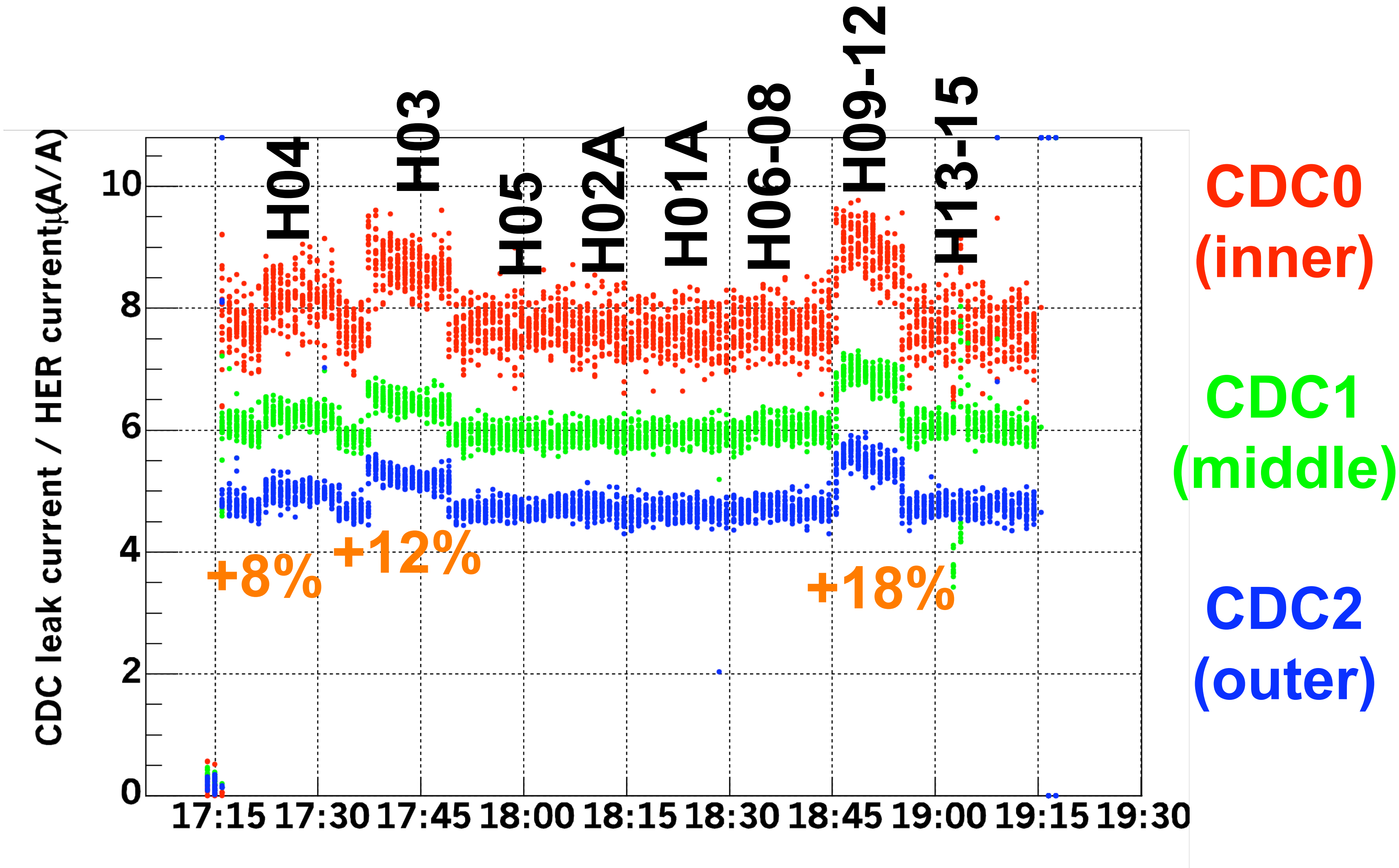
pressure (x10-8 Pa)

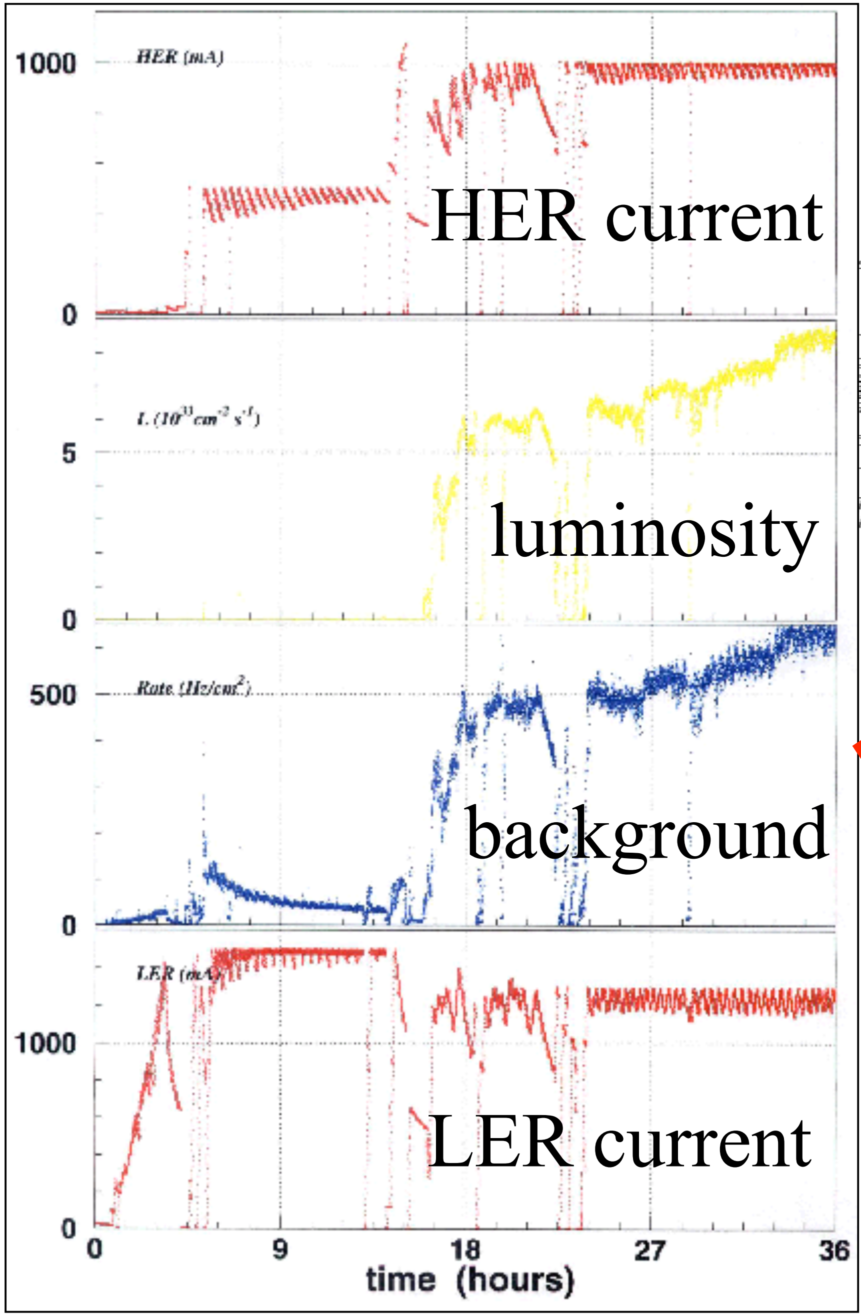
H01A (3.5m)	1.9 → 3.3 (x1.7)
H02A (7m)	6.7 → 14 (x2.1)
H03 (15m)	15 → 35 (x2.4)
H04 (25m)	4.8 → 13 (x2.7)
H05 (35m)	1* → 6.8 (x6.8)
H06-08 (~80m)	1* → 13 (x13)
H09-12 (~120m, ARC)	10 → 259 (x2.6)
H13-15 (~160m)	4.5 → 107 (x24)

monitor limit *

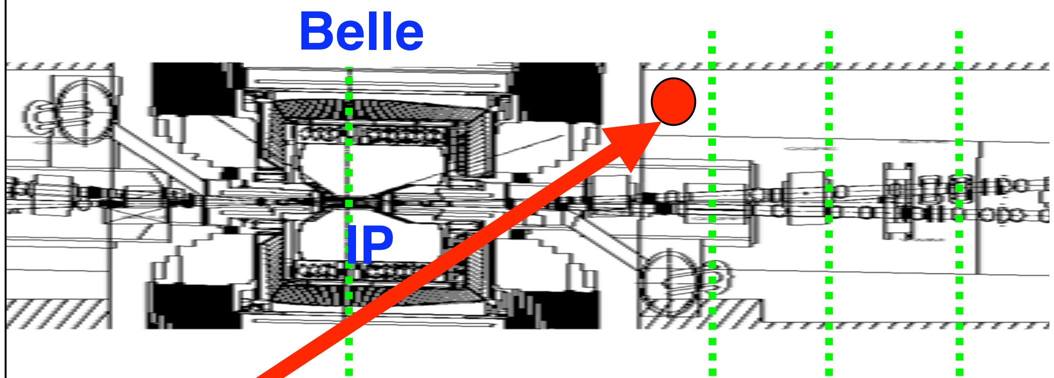
Maximum value (H06-08, H09-12, H13-15)

CDC Leak Currents





鉛ブロック(5cm厚)で囲まれたプラスチックシンチレーター検出器



ビーム電流だけでなく、ルミノシティーに比例したバックグランド(中性子と思われる)が大量に存在する

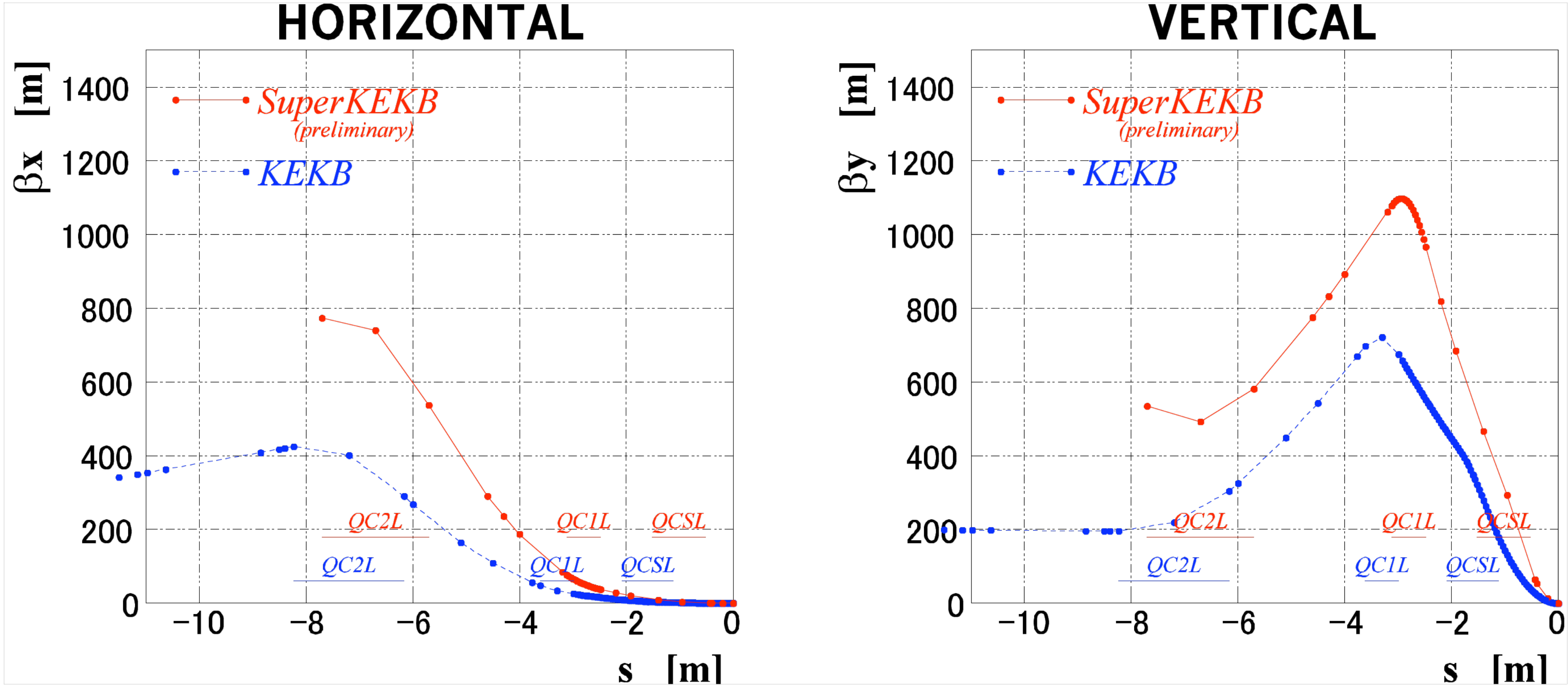
SuperKEKBではルミノシティーは50倍になる!!

Super-KEKB Machine Parameters

	KEKB	SuperKEKB
Horizontal emittance	24 nm	33 nm
x-y coupling	~ 3 %	6.4 %
β_x* / β_y* (cm)	63 / 0.7	30 / 0.3
Beam current	1.1 A	4.1 A
Crossing angle	22 mrad	30 mrad
HER-beampipe tilt	11 mrad	15 mrad

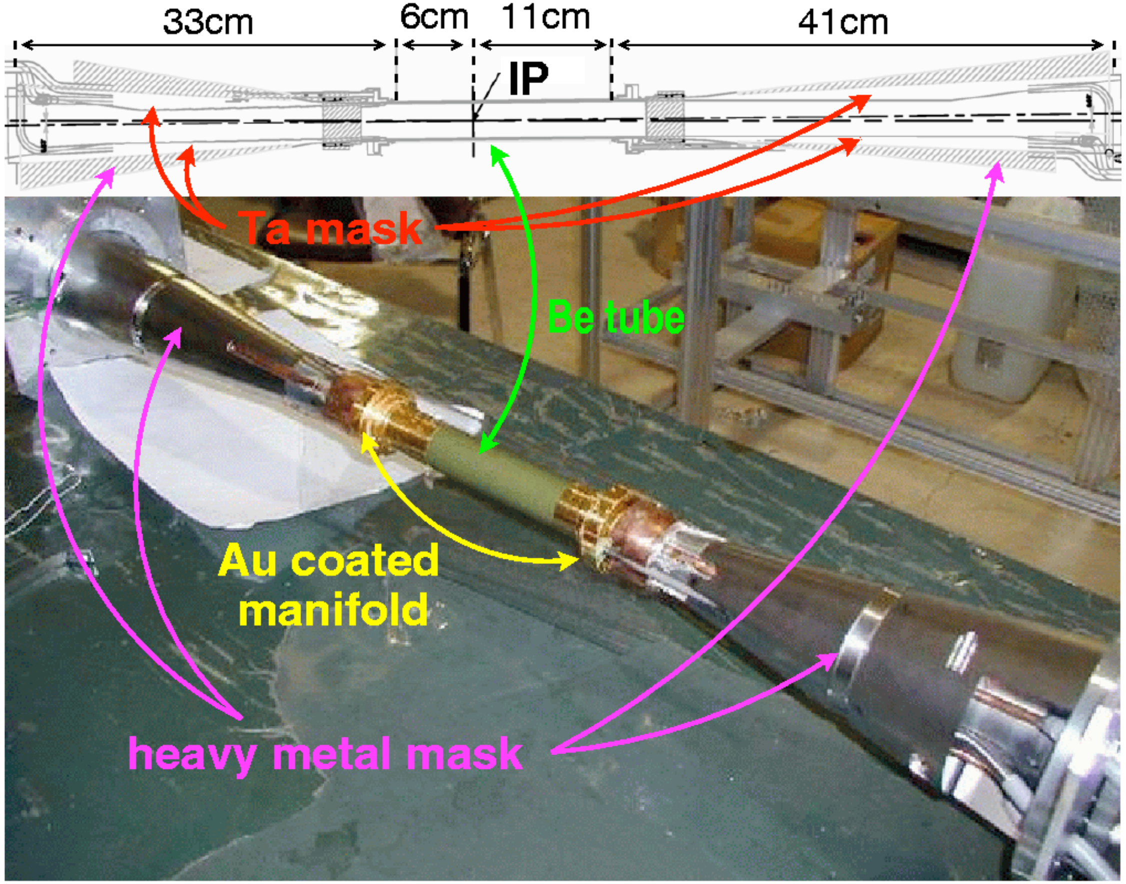
HER β Functions

Based on IR_HER6.sad



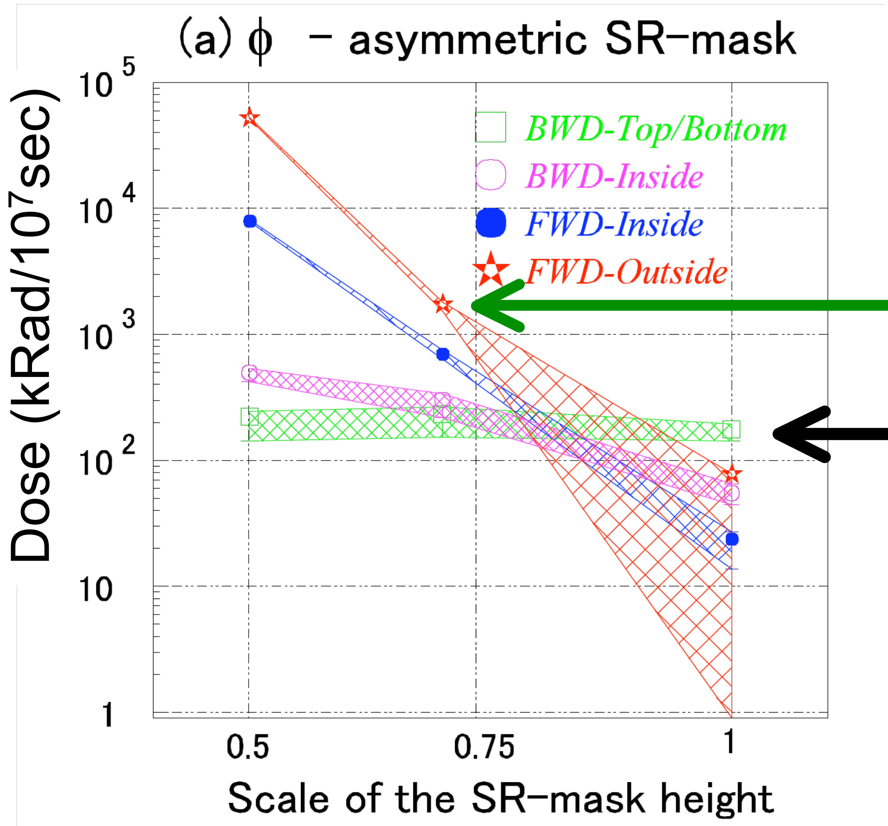
Beampipe in Super-Belle

- Scaled to 2/3 (r_{bp} 1.5 → 1.0 cm)



→ Can we also scale SR-mask height ?

Discussion for SR-mask (r_{bp}=1cm)



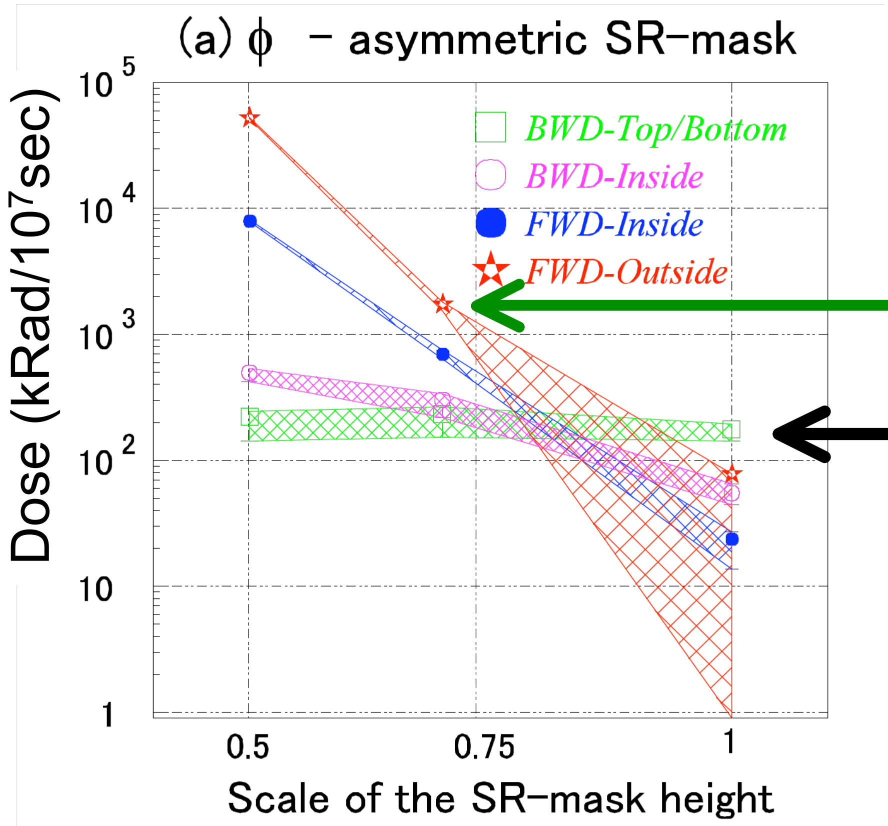
2/3 scale
3.5 MRad/yr !!

350 kRad/yr

Discussion for SR-mask (r_{bp}=1cm)

Mask height should be same as r_{bp}=1.5 cm case (~2.5 mm height)

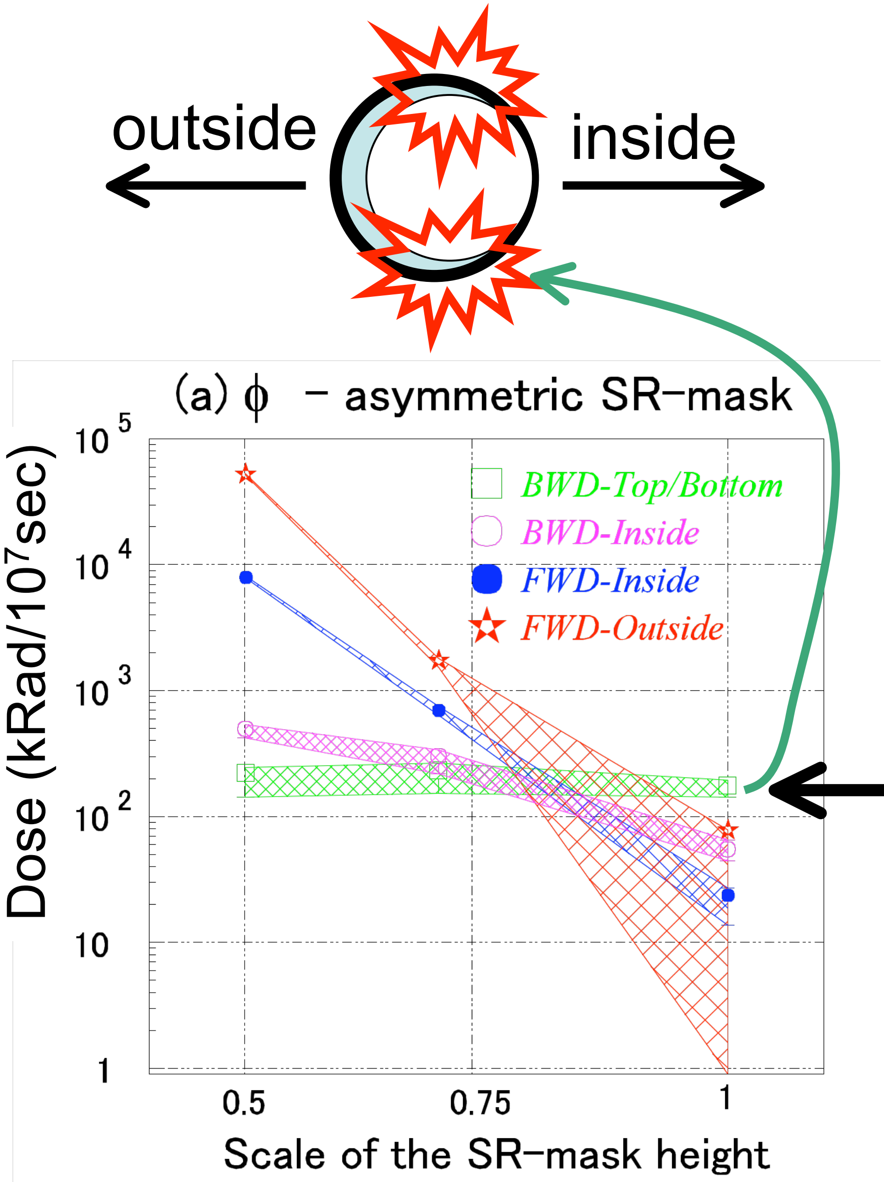
Acceptable height



2/3 scale
3.5 MRad/yr !!

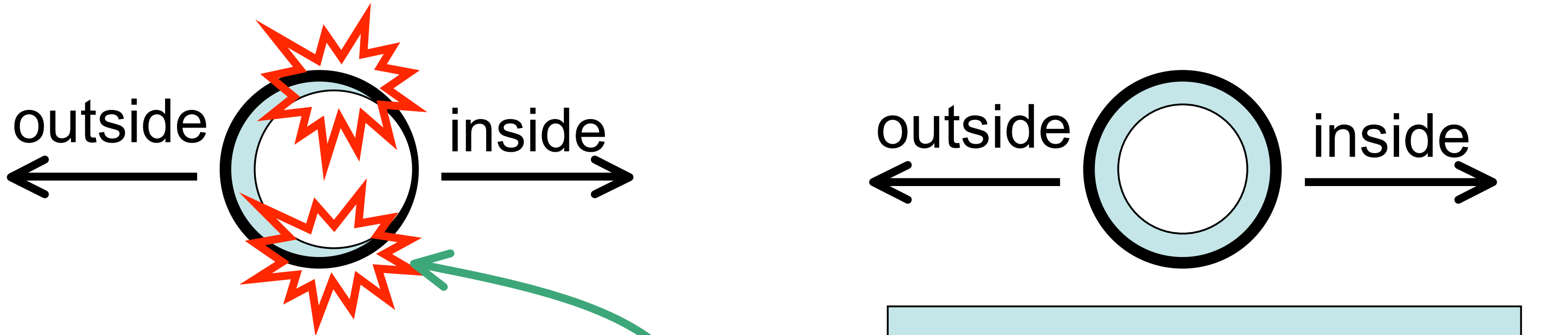
350 kRad/yr

Discussion for SR-mask (r_{bp}=1cm)

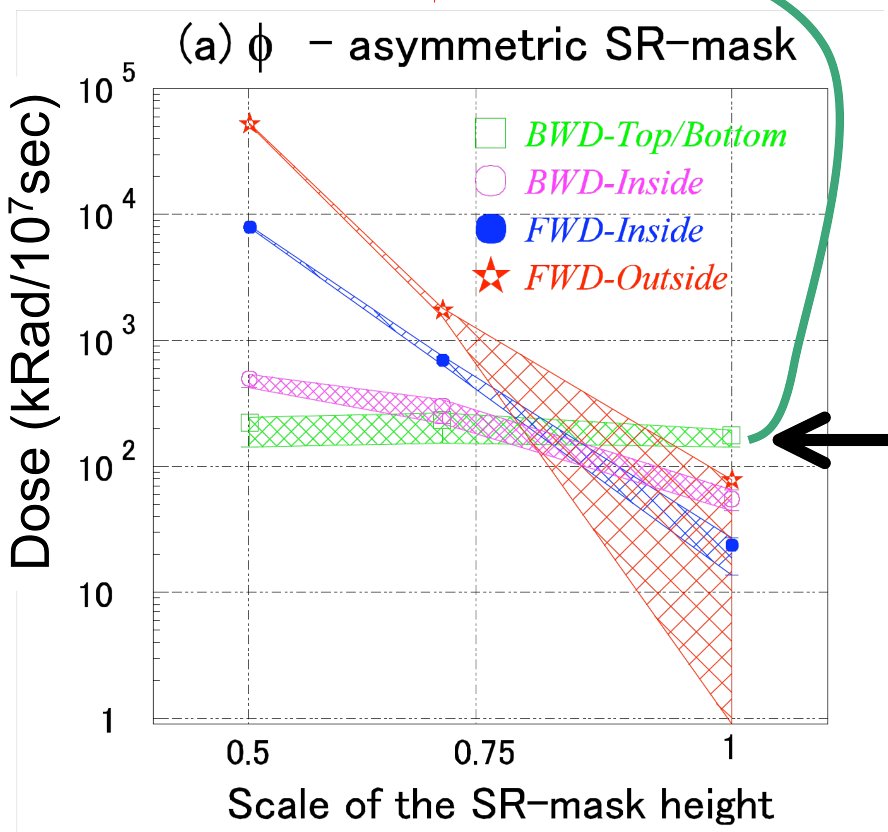


350 kRad/yr

Discussion for SR-mask (r_{bp}=1cm)



If vertical direction is higher ?



350 kRad/yr

Discussion for SR-mask (r_{bp}=1cm)