Beam Background

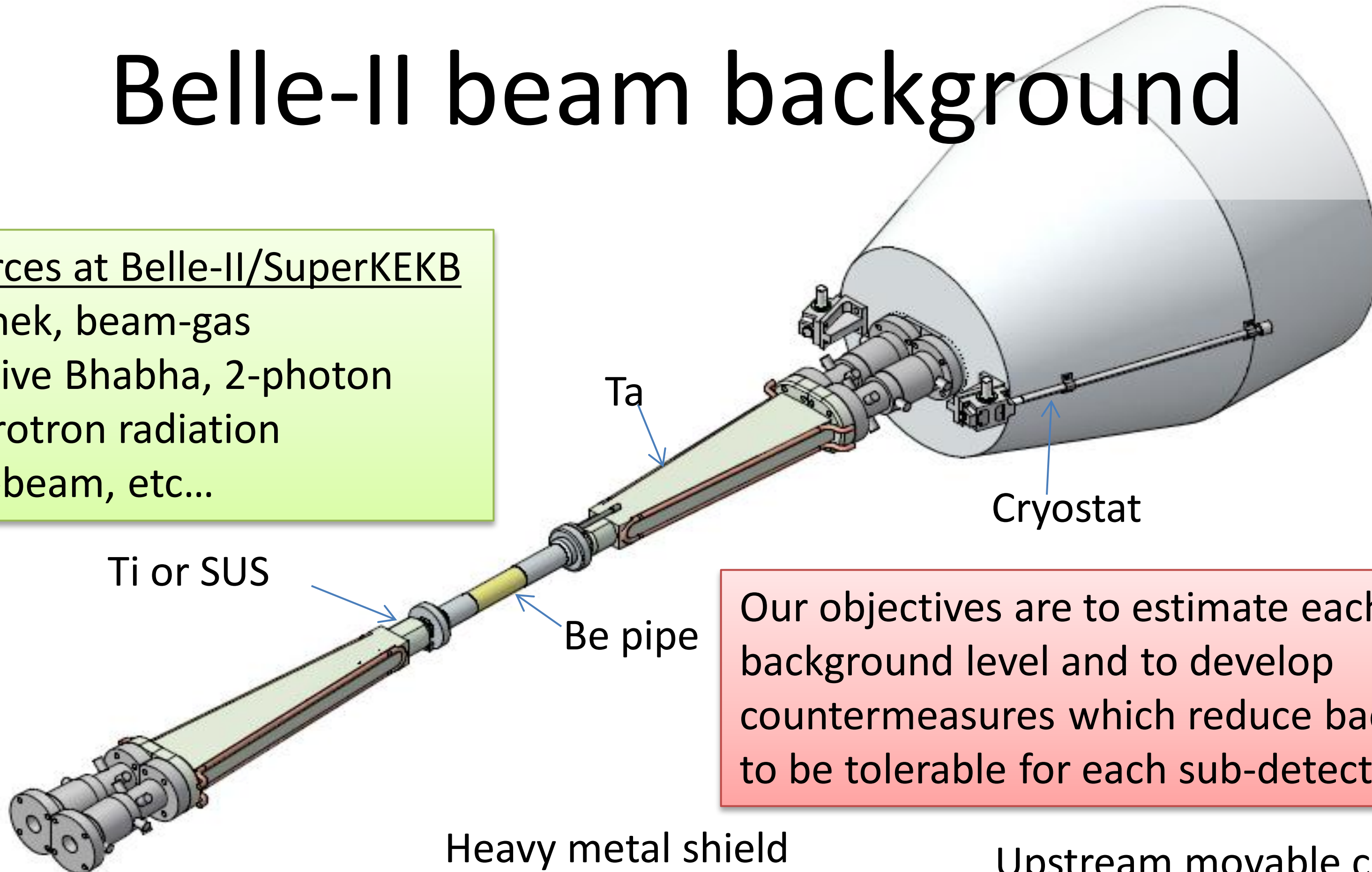
- Touschek/Beam-gas/Radiative Bhabha
- Full-detector GEANT4 simulation
  - Detector performance, radiation dose
- Synchrotron radiation BG
- Other background topics

Hiroyuki NAKAYAMA (KEK)

KEKB ARC(Mar. 4th, 2013)

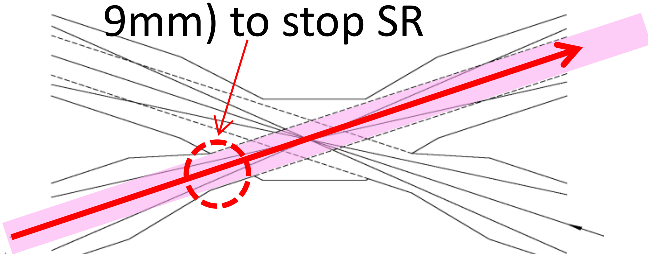
Belle-II beam background

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

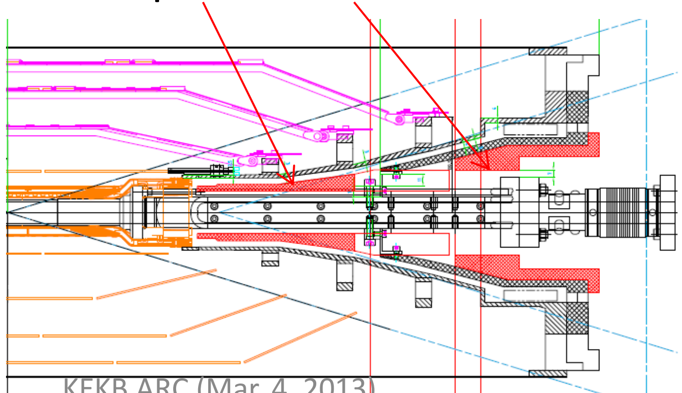


Our objectives are to estimate each background level and to develop countermeasures which reduce background to be tolerable for each sub-detectors.

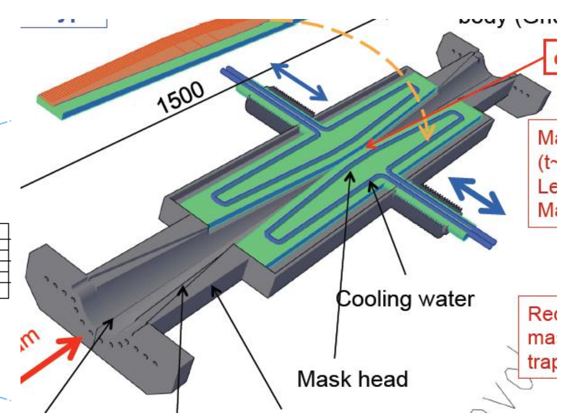
Collimation (20mm-> 9mm) to stop SR



Heavy metal shield to stop BG showers



Upstream movable collimators



What was reported last year

- Touschek loss in IR can be reduced by horizontal collimators
- Beam-gas Coulomb loss in IR can be reduced by very-narrow vertical collimator
- Spent e+/e- with large ΔE from RBB could be lost inside IR
- 2-photon BG is confirmed to be safe
- Full detector simulation shows RBB is dangerous
- SR full-simulation started

Today's topic

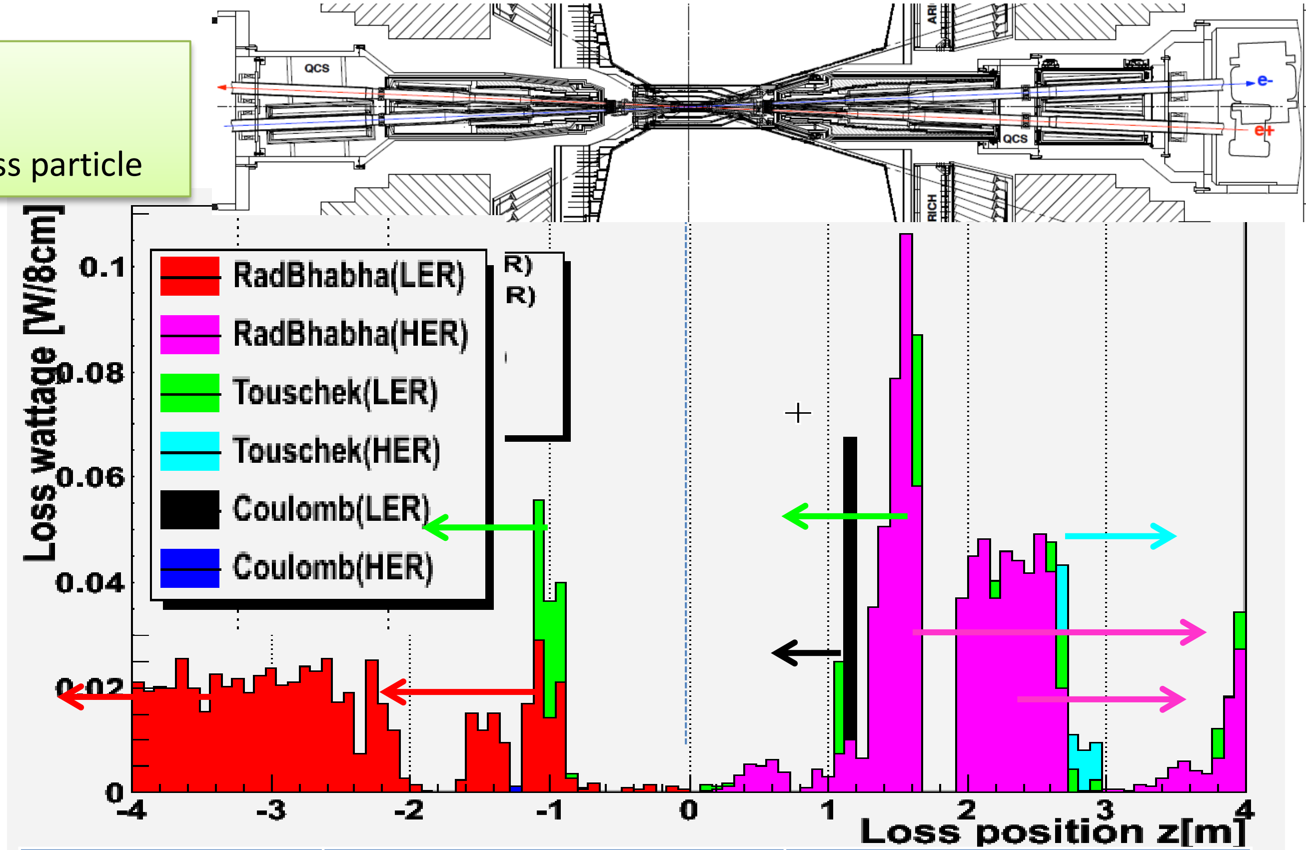
- Latest IR loss rate of each BG
- Thick tungsten enclosed inside cryostat for stopping BG shower
- Full detector simulation (Detector performance, radiation dose, neutron flux)
- Full detector simulation including loss from outside detector
- Other topics
  - Improved SR simulation study
  - IR loss rate at detuned optics
  - Injection BG

Ver. 2013.3.4
(5th campaign)

BG loss position

Loss wattage
= loss rate
 * energy of loss particle

HER
(e-)



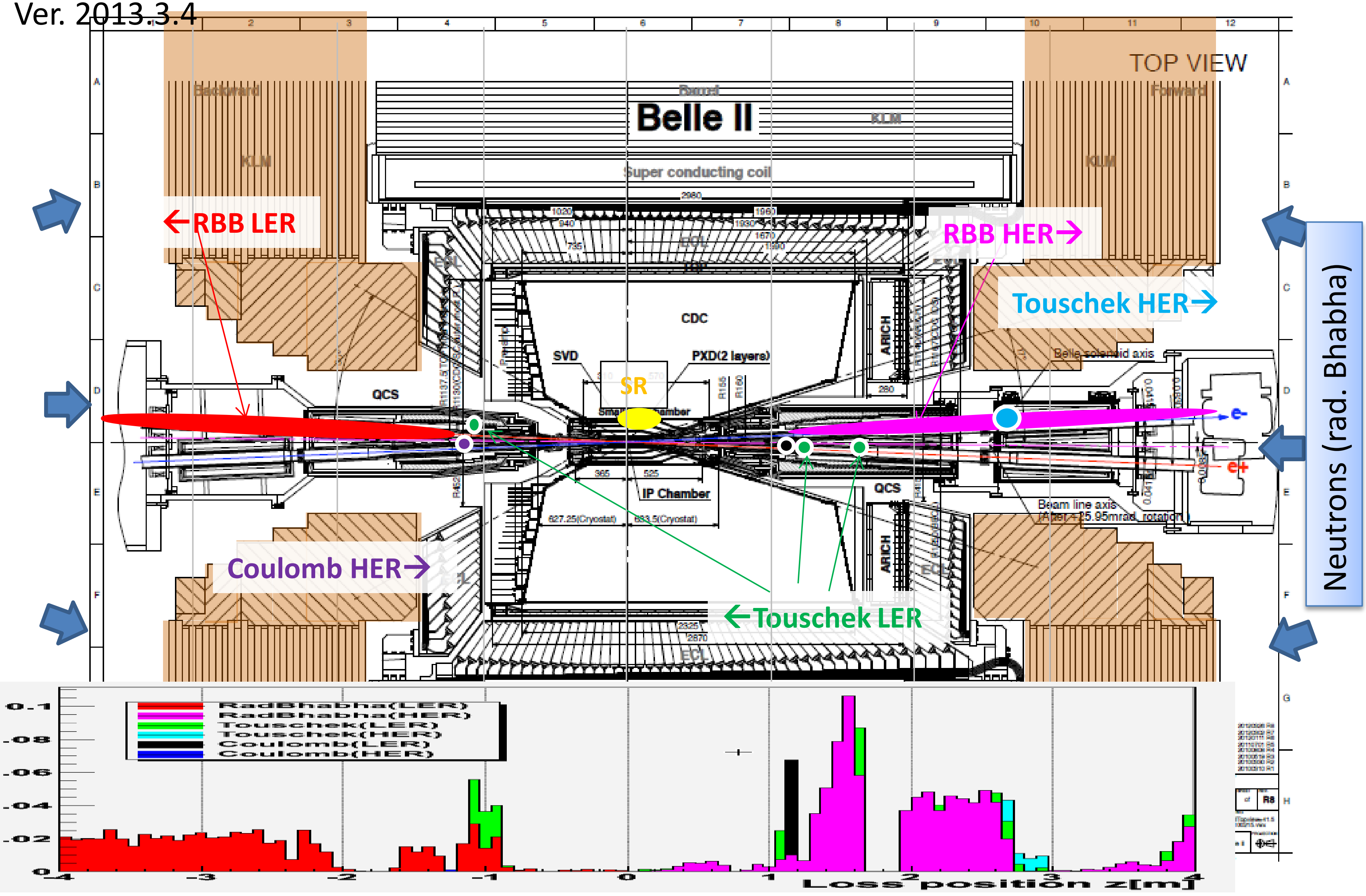
LER
(e+)

1GeV ,1GHz
 = 0.16W

	LER (4GeV e+)	HER (7GeV e-)
Rad. Bhabha	0.63 W (eff. 0.98GHz)	0.88W (eff. 0.78GHz)
Touschek	0.16 W (0.25GHz)	0.03 W (0.03 GHz)
Coulomb	0.06 W (0.09GHz)	0.001W (0.001GHz)

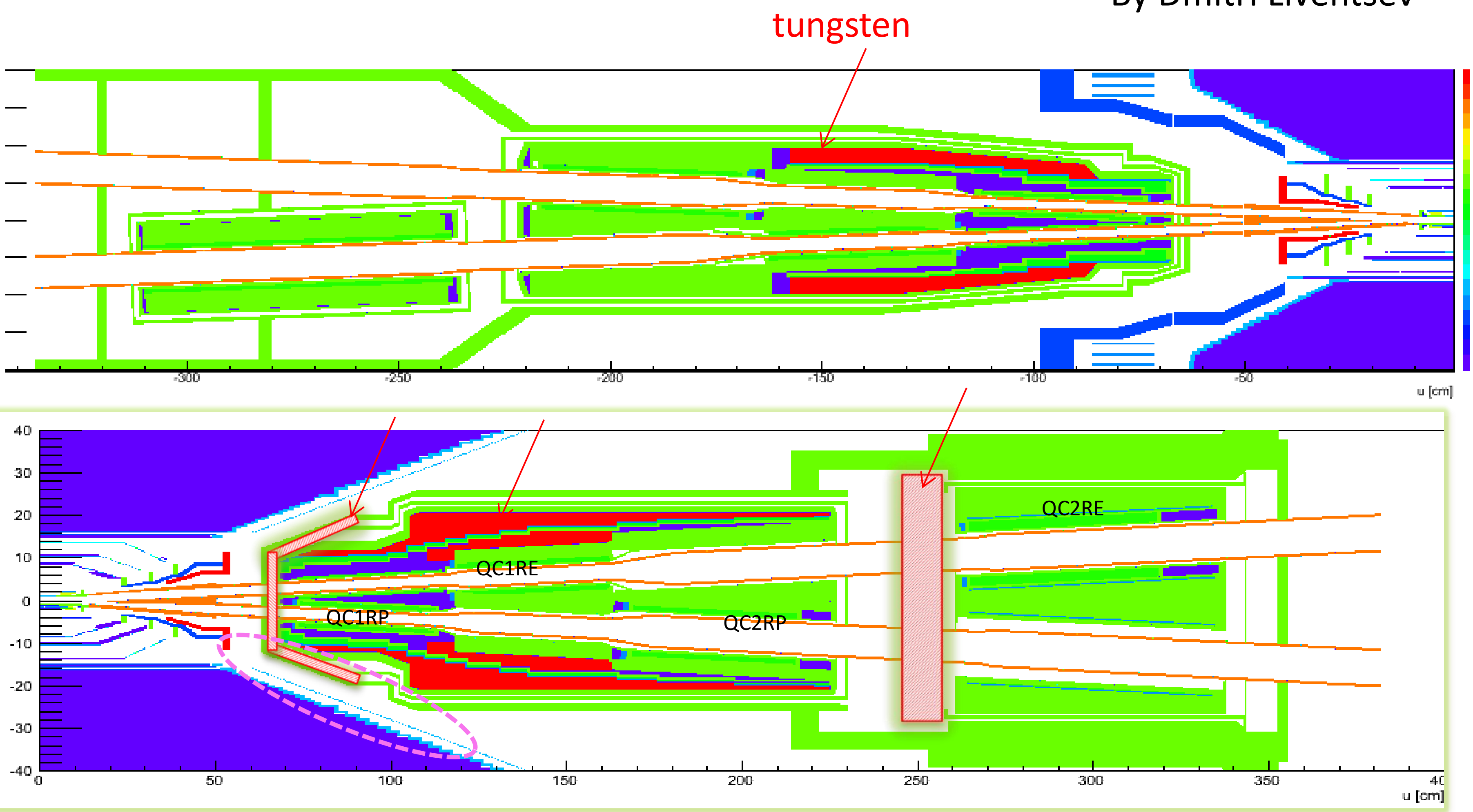
Background picture

Ver. 2013.3.4



QCS cryostat geometry

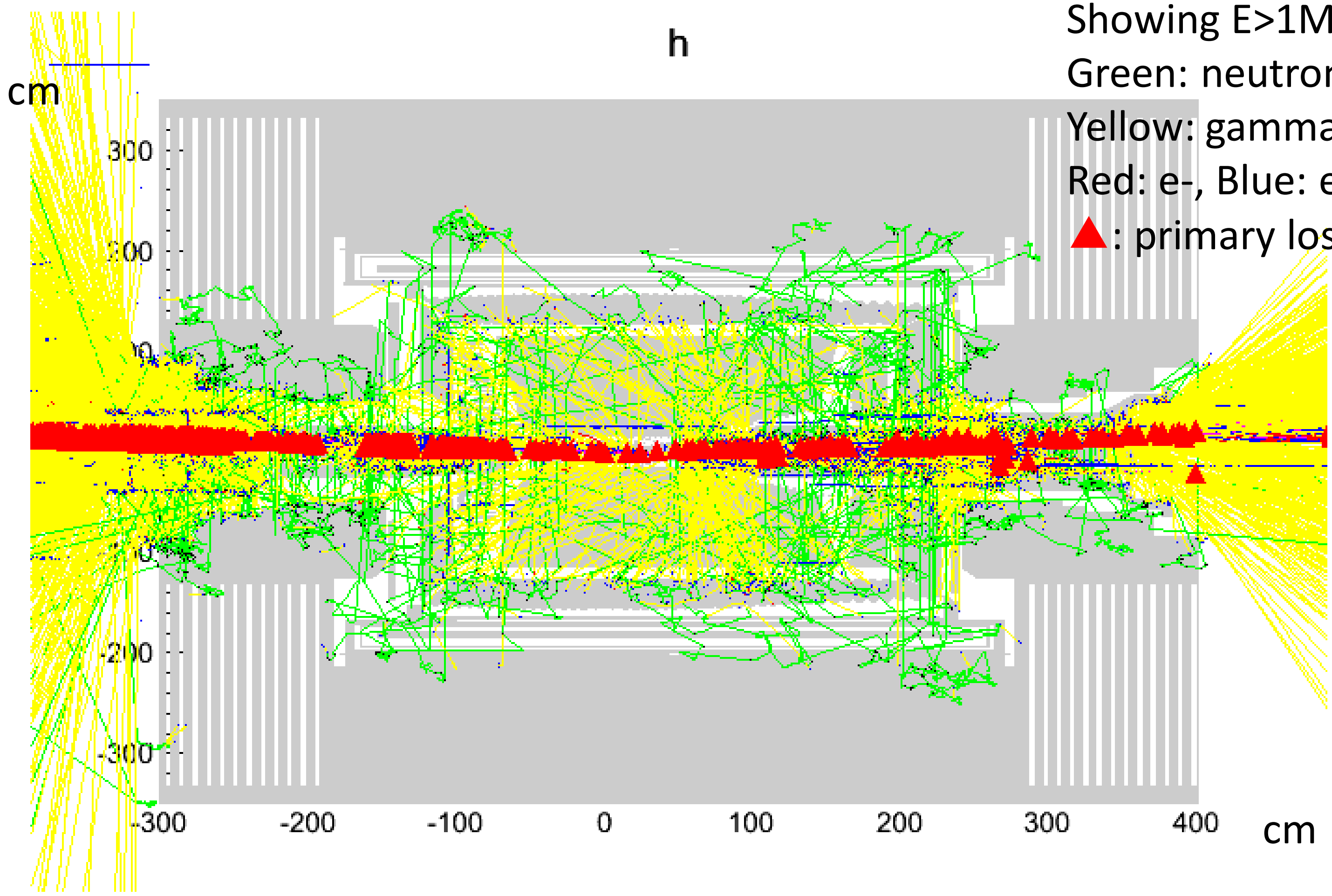
By Dmitri Liventsev



Less EM shower comes out from cryostat (neutrons slightly increased).
Very narrow gap for cabling btw detector and cryostat.

Full detector simulation

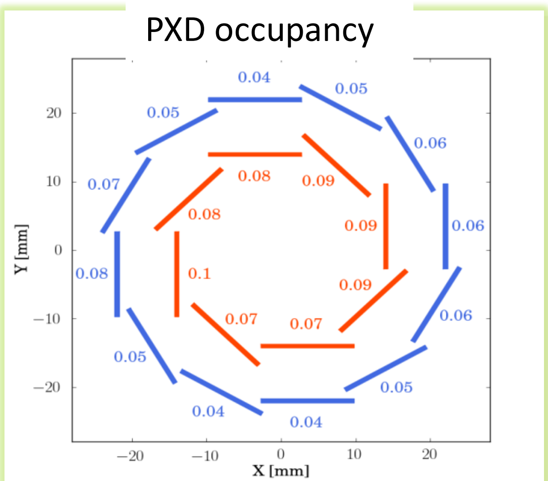
100ns
Showing E>1MeV
Green: neutron
Yellow: gamma
Red: e-, Blue: e+
▲: primary loss position

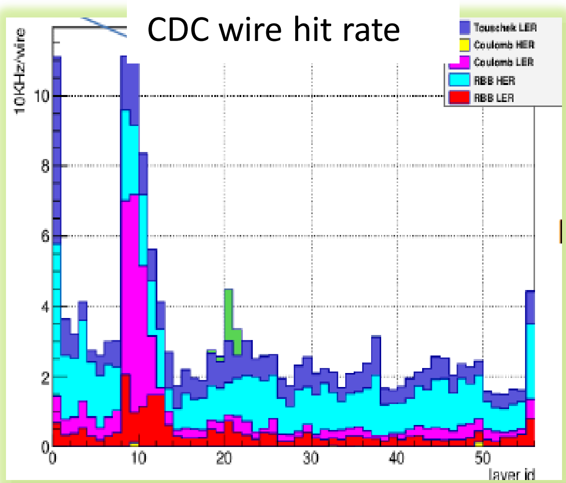


RBB+Touschek+Coulomb

Detector performance

- Too much beam background could lose data quality
  - PXD occupancy (limited by readout bandwidth)
  - SVD occupancy , ECL pile-up noise/fake cluster
  - CDC wire hit rate
  - Particle identification performance
  - etc..





Assuming design luminosity , estimated BG level is tolerable

Radiation dose

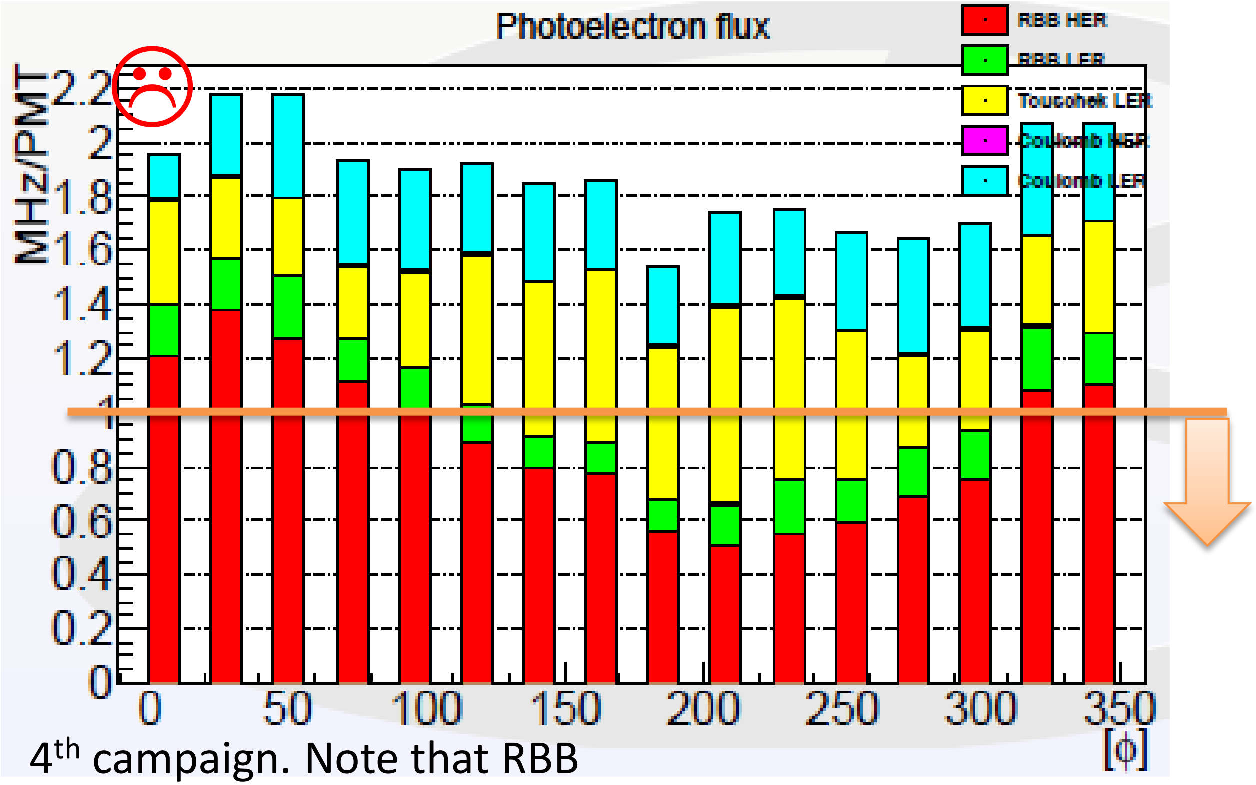
- Gy and 1MeV-equivalent neutron flux
- Could damage Si devices (FPGA, readout chips, HAPD, PIN diodes, etc..), calorimator crystals, etc..

Assuming design luminosity x 10 years, estimated BG level is more or less tolerable except for TOP PMT photocathode lifetime

Neutron flux are almost same levels with requirement.
Further mitigation with additional shields are possible but space issue for cable assembly should be accessed.

TOP PMT photocathode lifetime

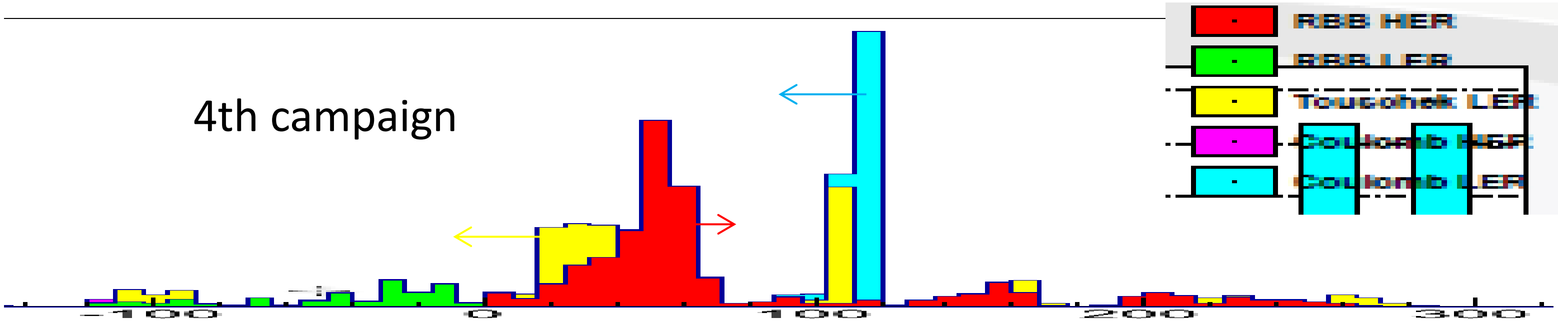
Gammas in BG shower reach TOP quartz bar and generate electrons by Compton scattering and etc.. Those electrons emit Cerenkov photons and those photons reach PMT photocathode.

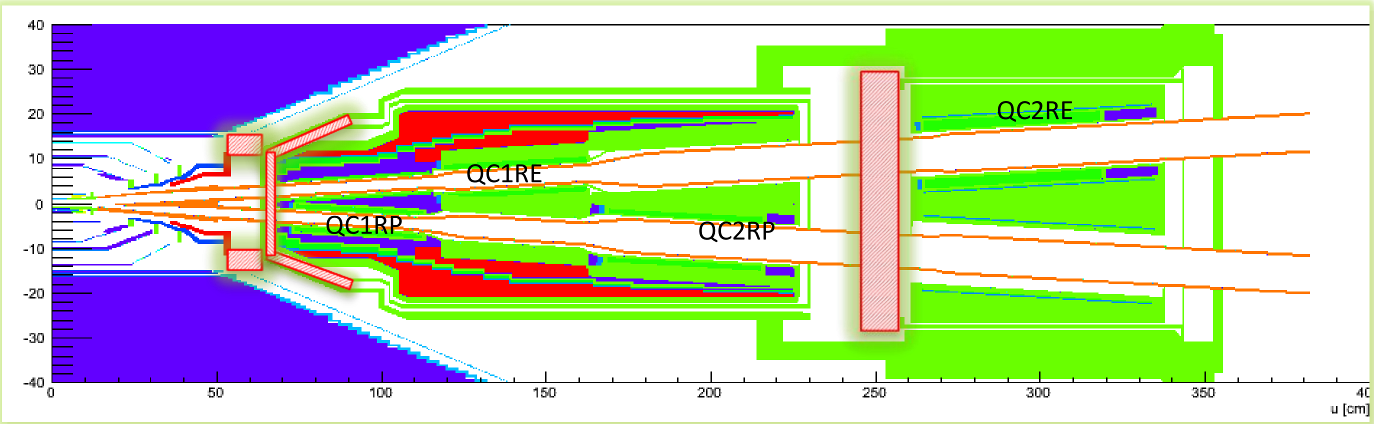


4th campaign. Note that RBB increases by x1.6 in 5th campaign

Factor x2~3 reduction is needed, or we need to replace PMTs every few years at design luminosity (replaceable TOP design being accessed)

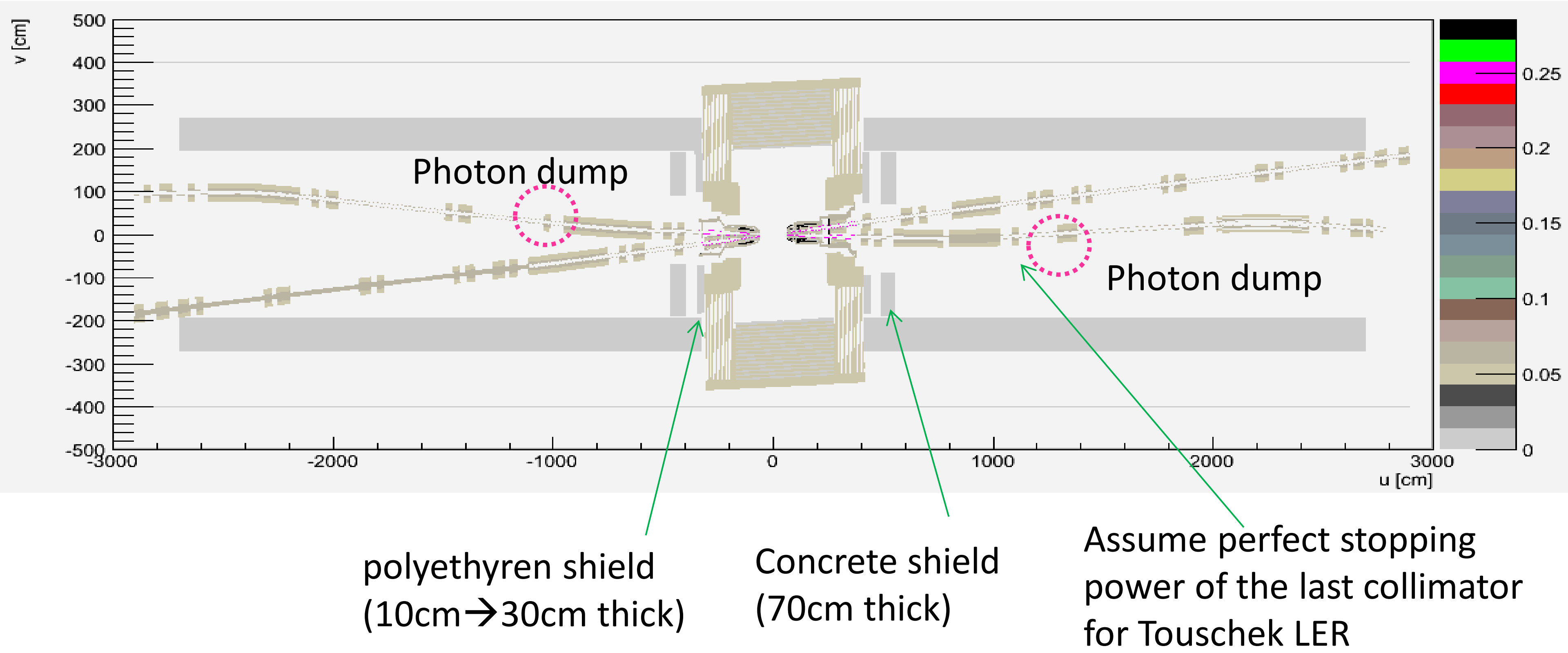
Beam loss position for TOP BG





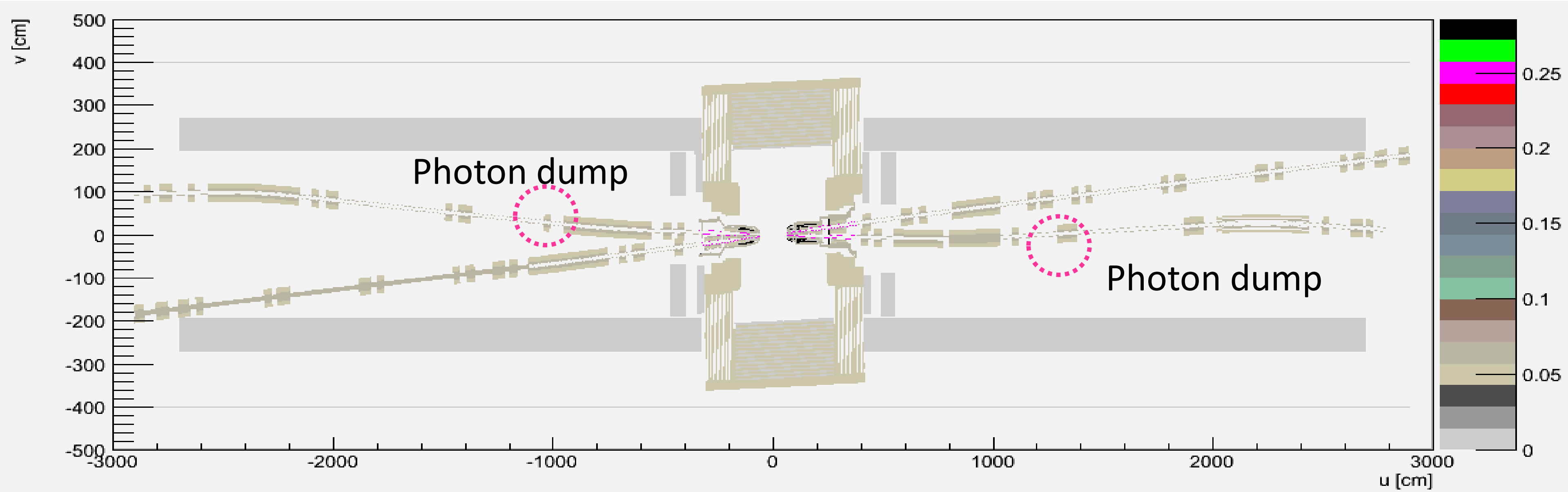
Beam loss at |z|<60cm (bet IP and cryostat) is dominant.
Beam pipe aperture is already widened as much as possible to reduce Touschek loss rate (SR might increase).
Very difficult to add shielding around there because of limited space.

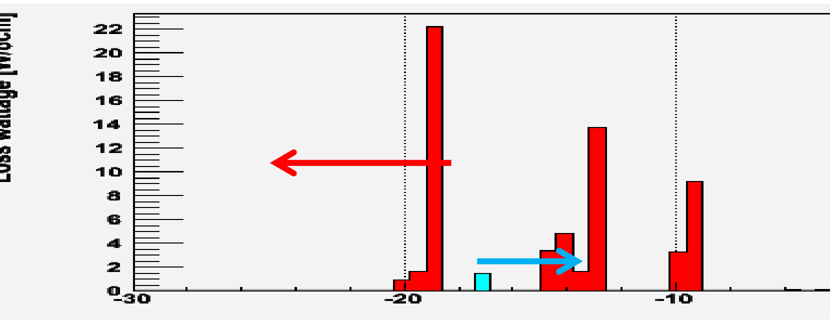
Tunnel geometry (|s|>4m)

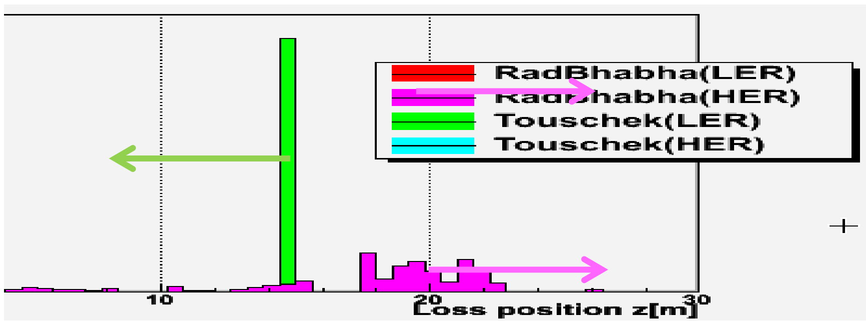


Additional neutrons shield under consideration surrounding "photon dump", main loss position of gammas emitted from radiative Bhabha event

BG loss positions



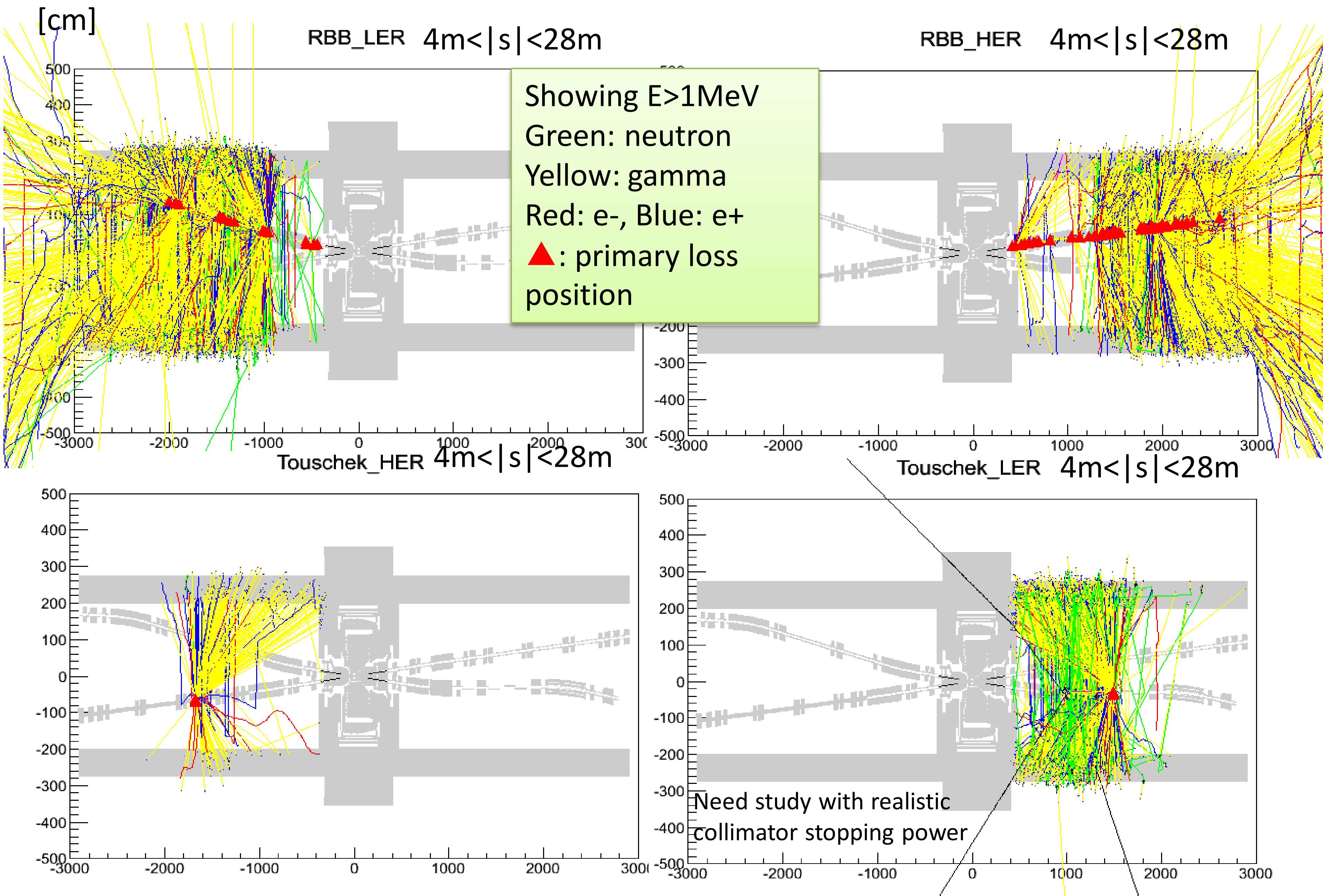




	LER (4GeV e+)	HER (7GeV e-)
Rad. Bhabha	61 W (eff. 96GHz)	23W (eff. 19GHz)
Touschek	20W (30GHz)	1.6W (1.4 GHz)

+ gammas emitted from Rad. Bhabha event

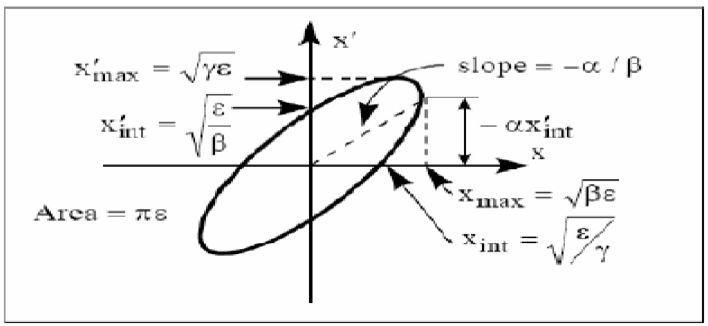
Event displays (1ns)



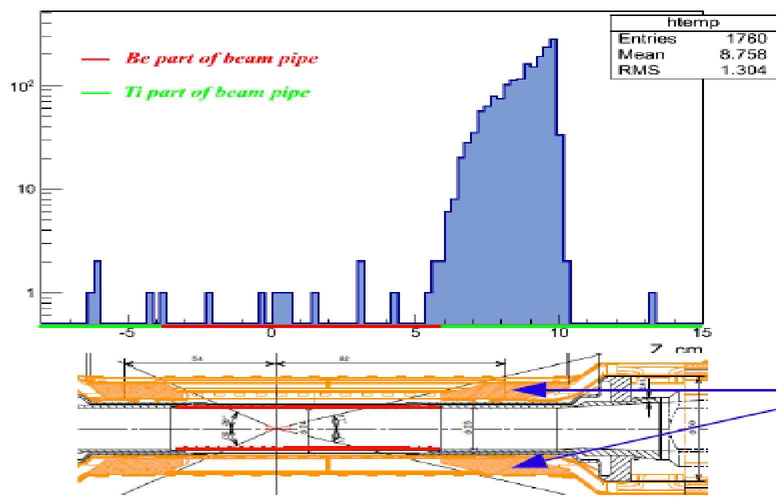
Other topics

SR simulation

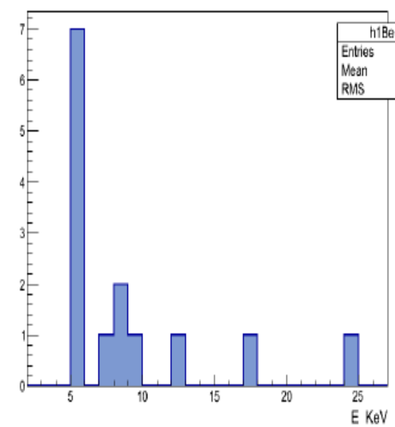
Yuri Soloviev



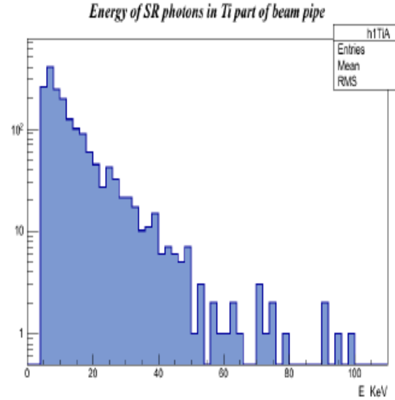
Z of Synchrotron Radiation photon hits in beam pipe



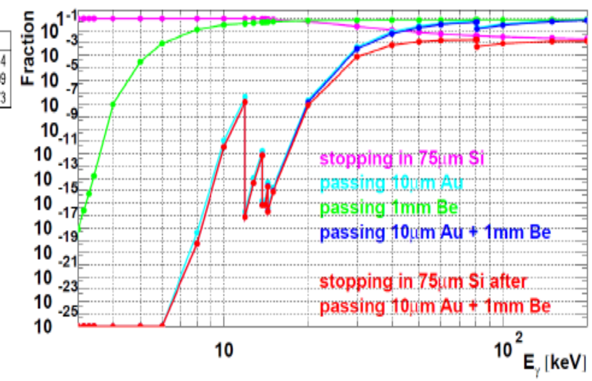
Energy of SR photons in Be part of beam pipe



Energy of SR photons in Ti part of beam pipe



Photon atten./absorpt., d_{Au} = 10μm, Θ = 0.1rad



With conservative assumption of incident angle of 0.1rad the stopping power for SR photons with energy 25 KeV is below 1e-6.
So the direct hit of photons on Be part with available statistics would give negligible occupancy.
PXD1 has 3,200 000 cells,
2% occupancy→ 64 000 hits/20μs.
Probability of stopping 70KeV photon in Si is lower than 1e-2.
Assuming the hit of scattered photon is not a statistical fluctuation it will give 3000 hits/20μs that is still less then 2 % limit. Needs more statistics.

- HER SR simulation assuming phase space distribution shows rate on PXD is small
- Apply same method on LER, especially to confirm inner shape of collimation
- Tip-scattering, back-scattered, miss-alignment/miss-steering etc.. should be studied

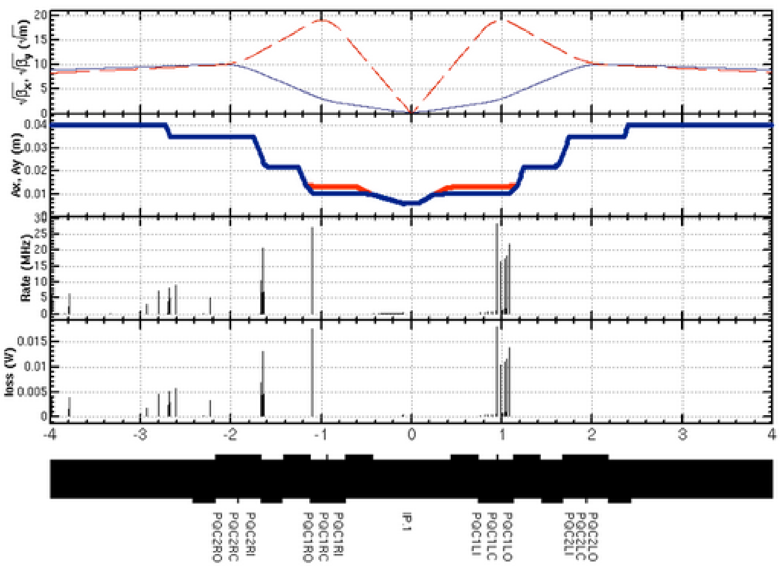
Background at detuned optics

Touschek_LER,

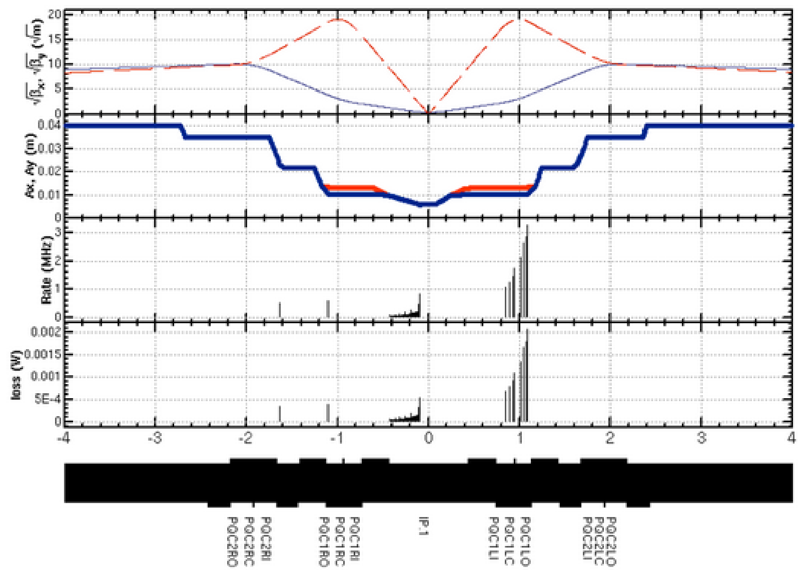
horizontal

vertical

nominal



detuned 4x8



248 MHz

22.4 MHz

-4 m < s < +4 m

~1/10

Y.Ohnishi, Sep. 2012

Important information for BEAST BG study

Injection Background

Dangerous background for PXD with long(20us) readout frame
Injection VETO scheme being developed

A. Phase-space distribution at e+/e- source
B. Phase-space distribution at injection point, after tracking through DR/LINAC/BT
C. Tracking in KEKB main ring, taking into account:

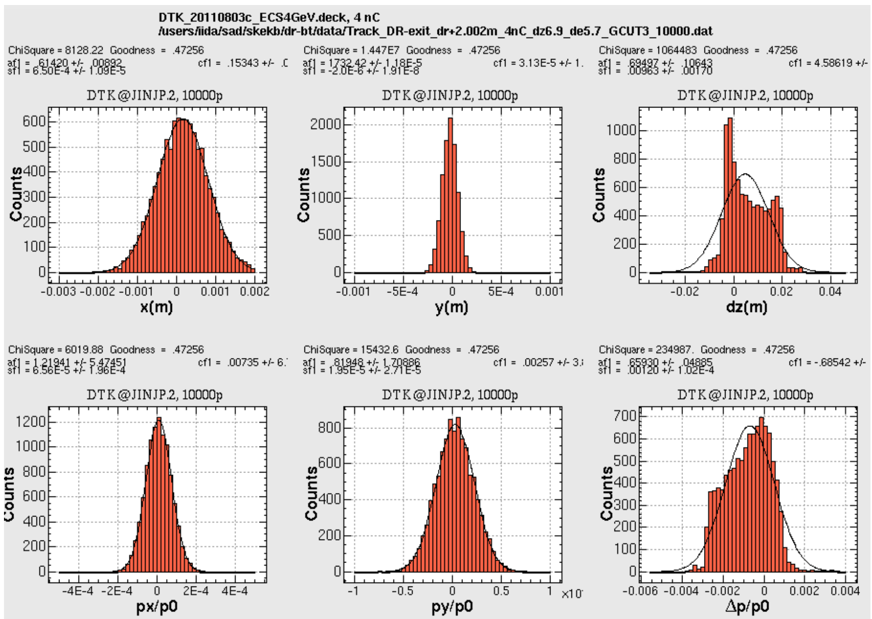
   - strong beam-beam effect by horizontal injection oscillation

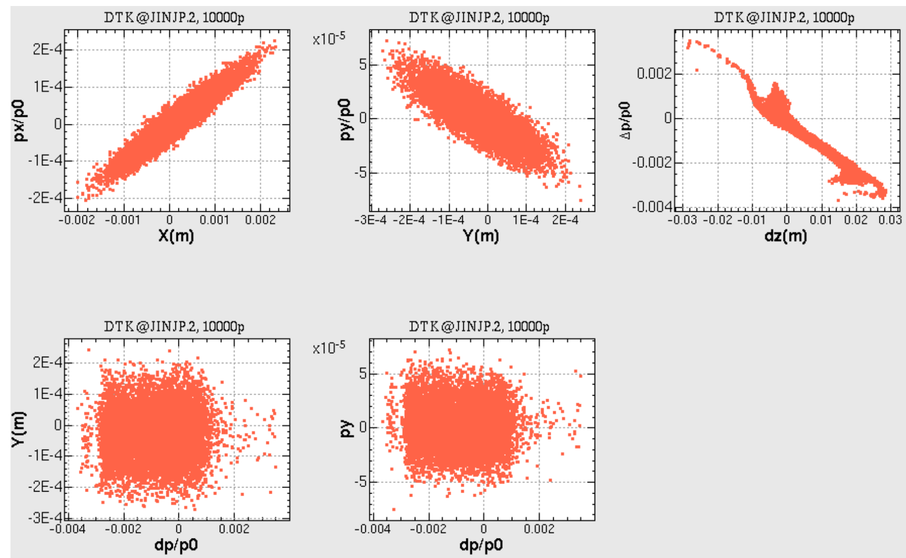
     (mitigated if synchrotron injection possible)

   - damping effect by feedback to suppress coherent oscillation

Phase space distribution at BT exit

4nC

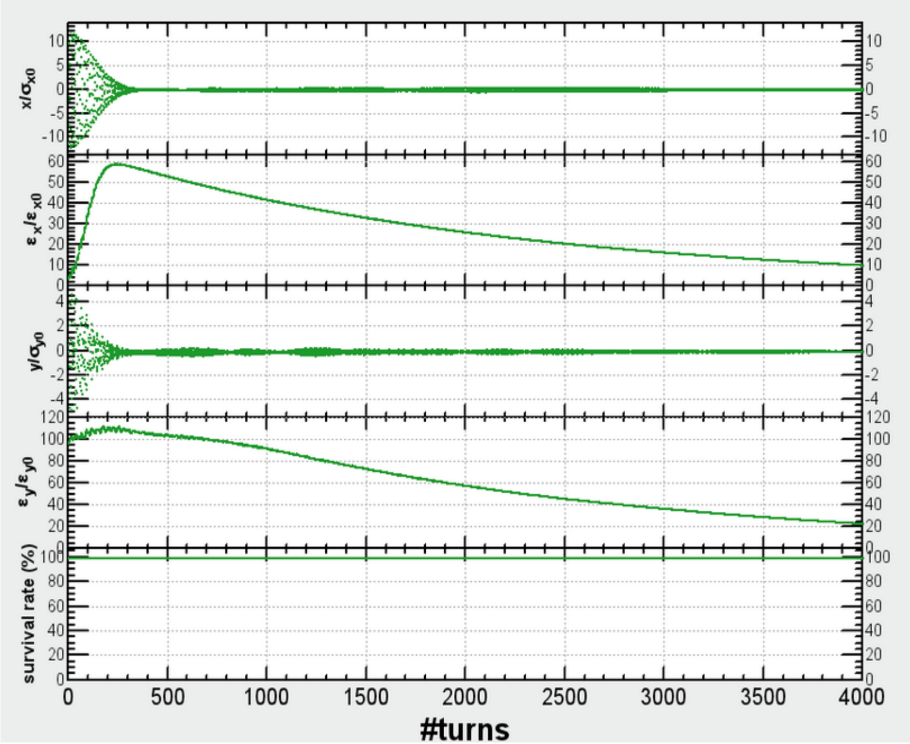




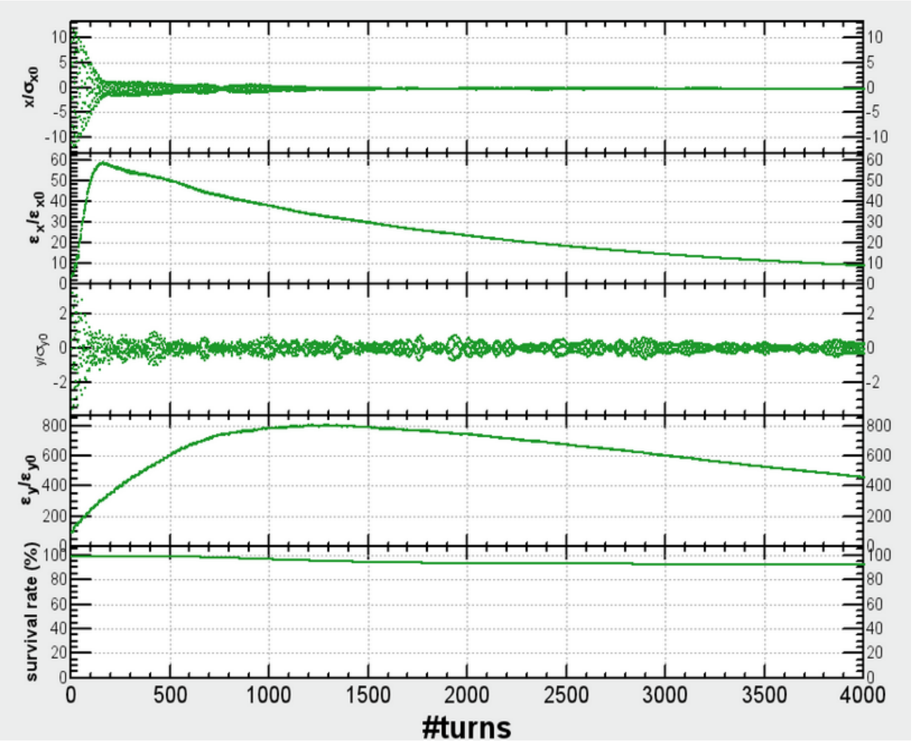
N. Iida, June 2012

Injection survival rate

without beam-beam effect



with beam-beam effect



Y.Ohnishi, Feb. 2012

Summary

- BG estimation now includes up to |s|<28m.
- SR full-simulation updated
- TOP photocathode lifetime is still the biggest concern

plans

- Additional neutron shielding vs. cabling spaces
- Tunnel shield design (to protect end-cap detectors)
- Radiation level in experimental hall (human-safety, FPGAs around detector)
- Collimator study (tip-scattering at the last collimator)
- SR simulation
  - Update with the latest optics, miss-alignment/miss-steering impact
  - Tip-scattering implementation using beam test data (optimize ridge structure)

backup

Neutron flux

1MeV equivalent rate

1 year = 10^7 sec

	Region	Simulation [$\times10^{11}$ eqn/cm^2/year]	Tolerance [$\times10^{11}$ eqn/cm^2/year]	Current tolerance
PXD	DHP,DCD, Swithers	0.8	<10	OK up to 100x10^{11} eqn/cm^2
SVD	Sensors, chips	-	-	Should be OK, irradiation test ongoing
CDC	Readout Boards	2.0	<2	OK up to 20x10^{11} eqn/cm2 (FPGA) but need to manage SEUs Optical receiver tested up to 10
TOP	Readout electronics	0.2	<1	Tested up to 10x10^{11} eqn/cm2 ASICs not tested yet
ARICH	HAPD	1.4	<1	Tested up to 10x10^{11} eqn/cm2
ECL	Crystals	1.4	<10	OK up to 100x10^{11} eqn/cm2
ECL	Diodes	1.4	<1	OK up to 10x10^{11} eqn/cm2 (dark=1uA, QE=97.6%)
BKLM	SiPMs	No hits found	-	

4th campaign

Note: In 5th campaign RBB increase by x1.6

1krad=10Gy
10krad=100Gy
100krad=1000Gy

Radiation dose

1 year = 10^7 sec

	Region	Simulation [Gy/year]	Tolerance [Gy/year]	Current tolerance
PXD	Sensor	20k (2MRad/y)	-	Tested up to 100kGy(=10Mrad) 200kGy would be also OK
SVD	APV	-	-	OK up to 100kGy (by Peter)
CDC	Readout boards	21	<100	Tested up to 1000Gy (FPGA and optical receiver w/ communication)
TOP	Readout electronics	2	<300	Tested up to 1000Gy ASICs not tested yet
ARICH	HAPDs	5	<100	APD tested up to 1000Gy
ECL	Crystals	8 (f-endcap)	<10	OK up to 100Gy (light yield -27% at 36Gy)
ECL	Diodes	12	<70	OK up to 700Gy (efficiency drop=1%)
BKLM	SiPMs	-	-	-

Note: In 5th campaign RBB increase by x1.6

4th campaign

Detector performance

	Simulation	Requirement
PXD occupancy	0.9%	< 2%
SVD occupancy	Safe	< ~10%
CDC hit rate	120kHz/wire	< 200kHz/wire
TOP K/pi separation	K/pi separation remains good (2nd campaign)	
TOP photo-cathode aging	Photoelectron flux: 2.2MHz/PMT	<1MHz/PMT
ECL	1.4 fake clusters 2.3 MeV pile up noise in f-endcap	Belle1: 6 fake clusters Belle1: 0.8 MeV pile up

Note: In 5th campaign RBB increase by x1.6

4th campaign

The Committee encourages the preparation of the simulation tools as planned, and to include beam-beam effects soon. Given the many difficult demands on the IR, as much as possible of the background reduction should be addressed in the ring. In addition, the Committee feels that there are a few questions to be addressed before the collimation system can be considered optimized:

Same ΔE process, smaller cross section than Touschek

- It is not clear why the beam-gas bremsstrahlung is not an issue as in many other colliders.
- To collimate beam-gas background, a vertical collimator (the only one vertical collimator in the design) is added at ~60 m from the IP. It was estimated/planned that this single collimator uses up the entire budget for the transverse mode coupling instability. This will need to be reviewed or re-optimized.
- The loss factor of collimator ridge geometry calculation gives unexpected results, leading to a particular choice of ridge design. This needs to be reconfirmed with other experts and/or other codes.

Yes, we do have such collimators at each arc positions

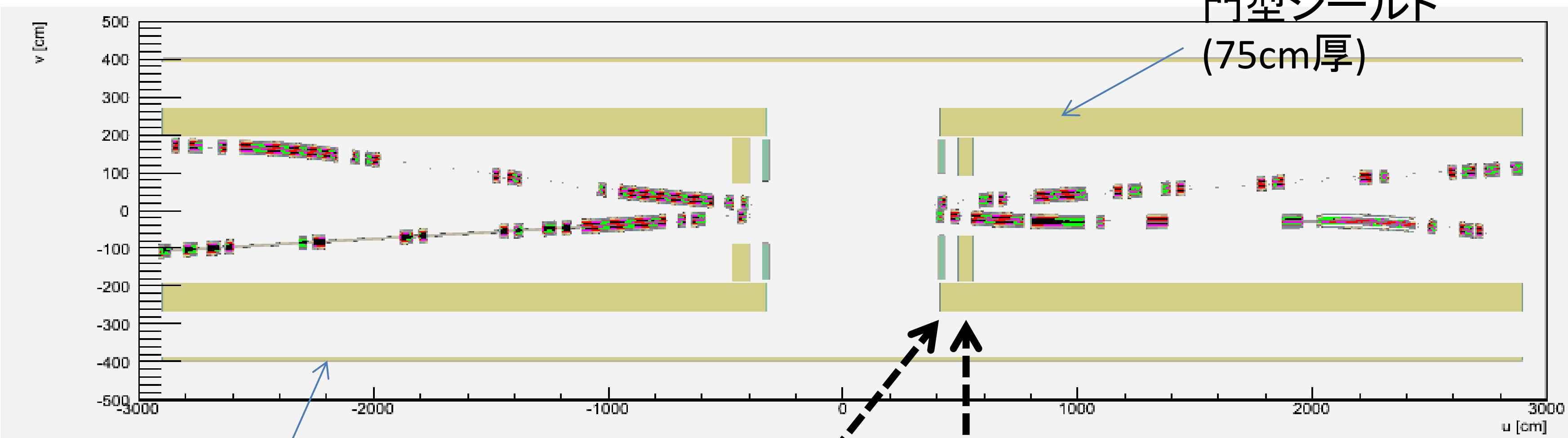
- In some cases, particle loss occurs in multiple turns. In those cases, it might be better to insert collimators away from the IP to minimize secondary background. In this study, multi-turn simulations will be needed.
- Another way to have an overall collimation design is not to differentiate according to the background sources, but according to beam dynamics, i.e. horizontal betatron, vertical betatron, and synchrotron collimations at dedicated, special-purpose locations.

It is planned that commissioning with Beast II will study background and collision tuning, with staged phases of increasing beam currents. The Committee feels this a good approach

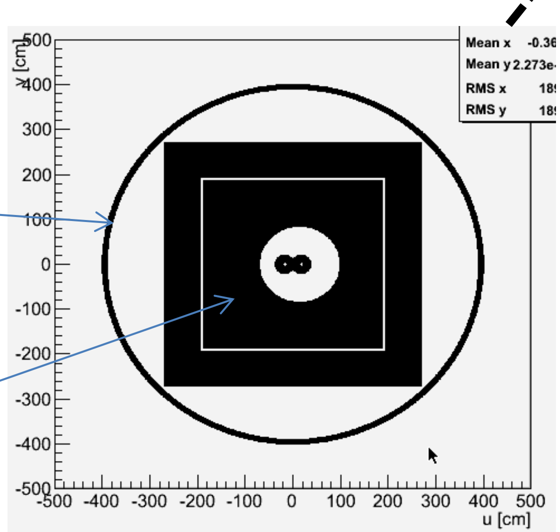
Implement Kanazawa-shields

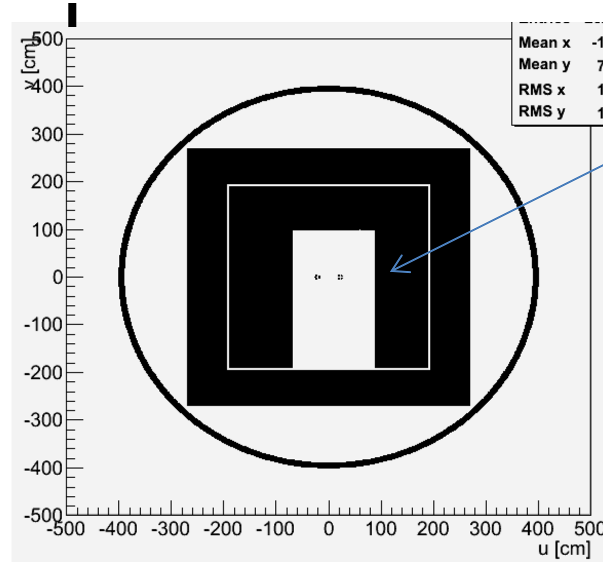
Pole tipと門型の隙間は約12cm

門型シールド
(75cm厚)



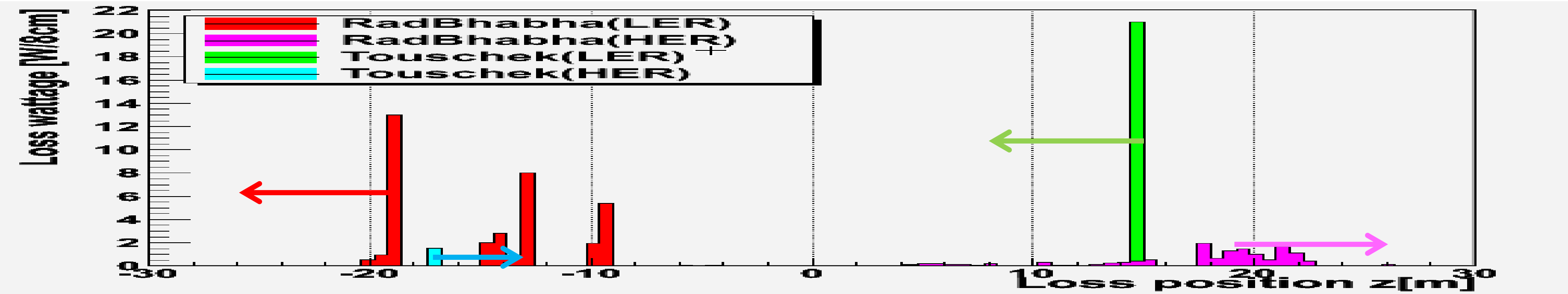
Radiation level
測定のための
仮想物質
（r=4m, dr=10cm,
コンクリート）

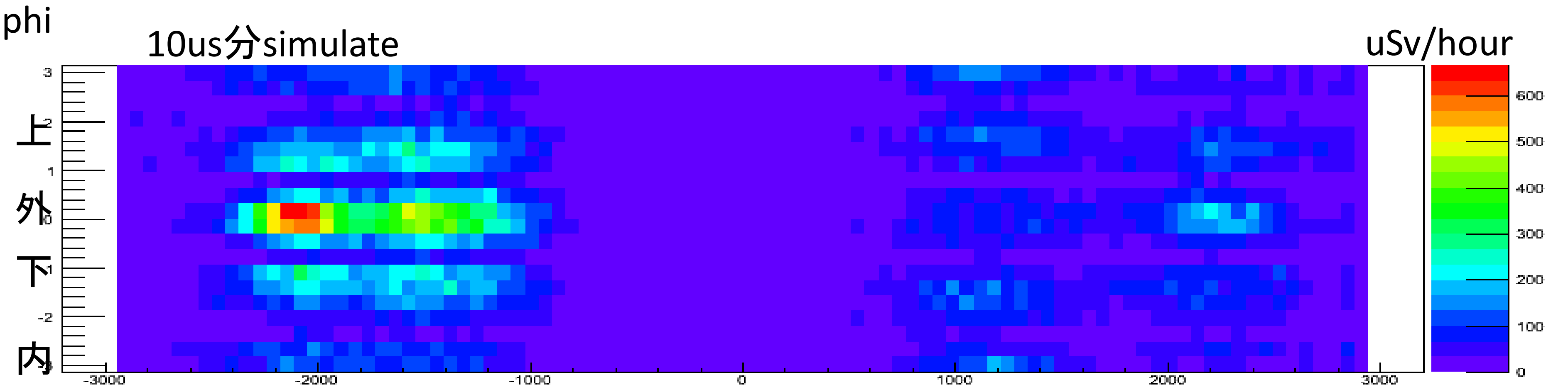


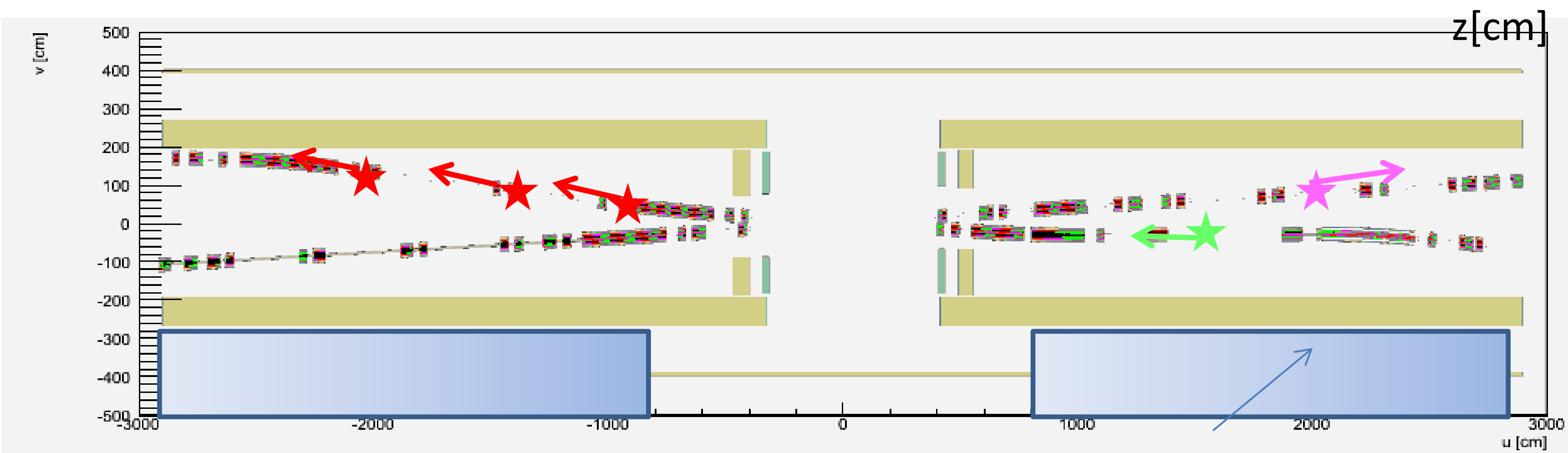


コンクリート
(70cm厚)

ポリエチレン
(30cm厚)

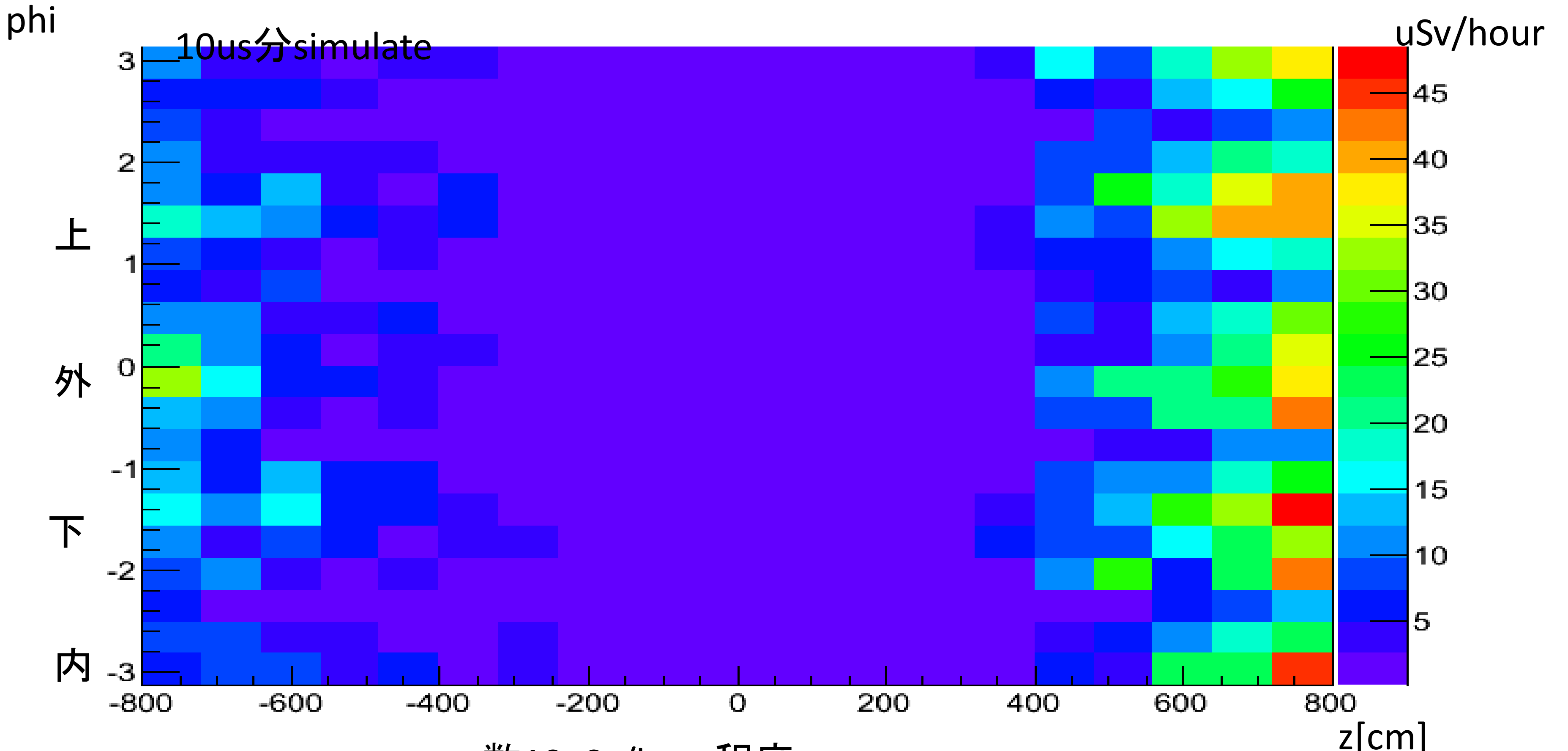






|z|>8mはさらに2m厚のコンクリシールドで囲われる。

|z|<8mを拡大



数10uSv/hour程度

Cf. 立入禁止管理区域: >200uSv/h, 立入制限管理区域:>20uSv/h,
一般管理区域: >1.5uSv/h, 周辺監視区域: 0.2uSv/h