Radiation safety design of Super KEKB factory

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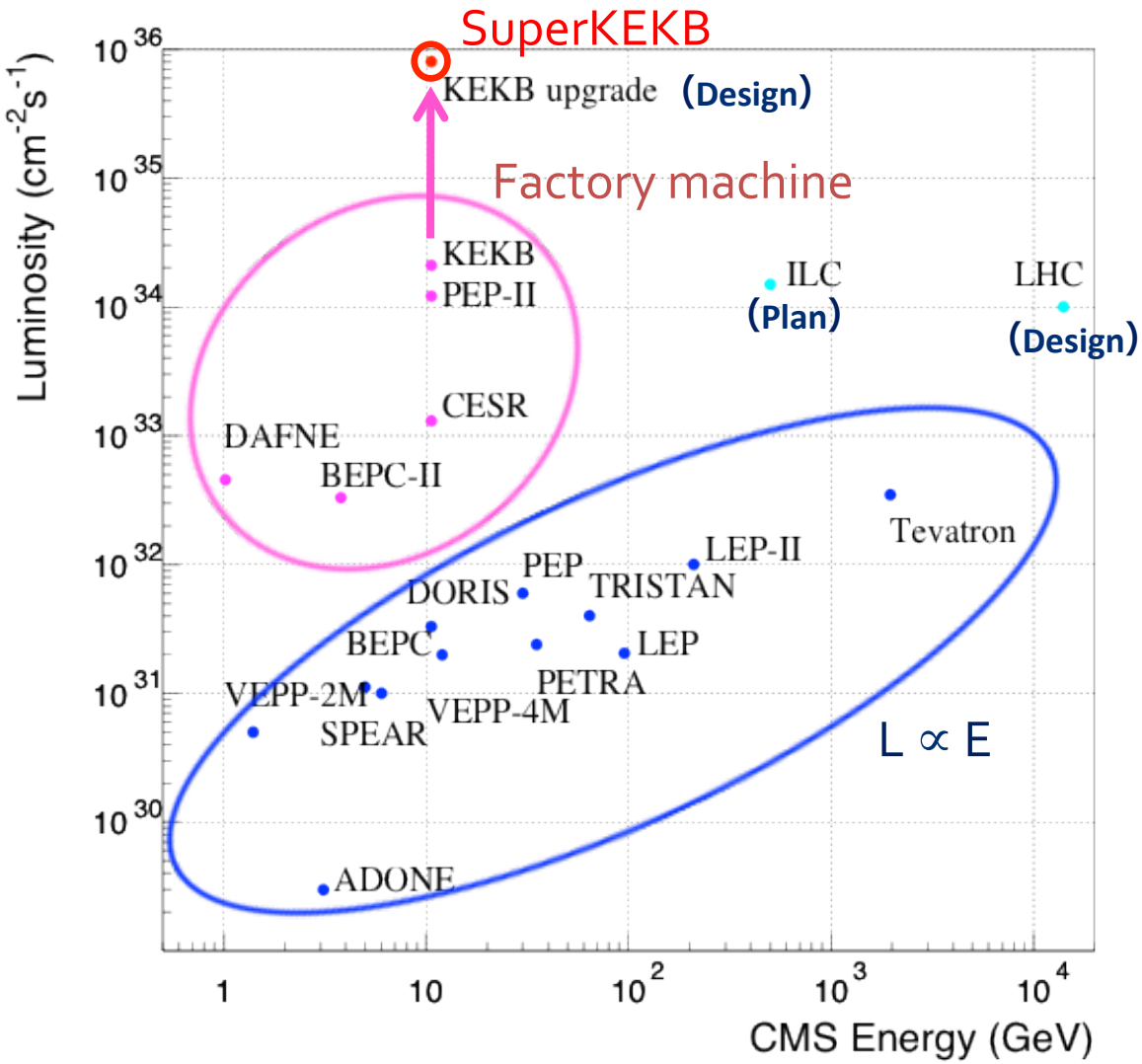
Outline

- Introduction of Super KEKB facility
  - Luminosity frontier
  - Accelerators and it's improvement
- Beam loss estimation
- Evaluation based on empirical equations
  - Activities in air
  - Leakage dose
- Detail studies using Monte-Carlo
- Conclusion

Super KEKB project

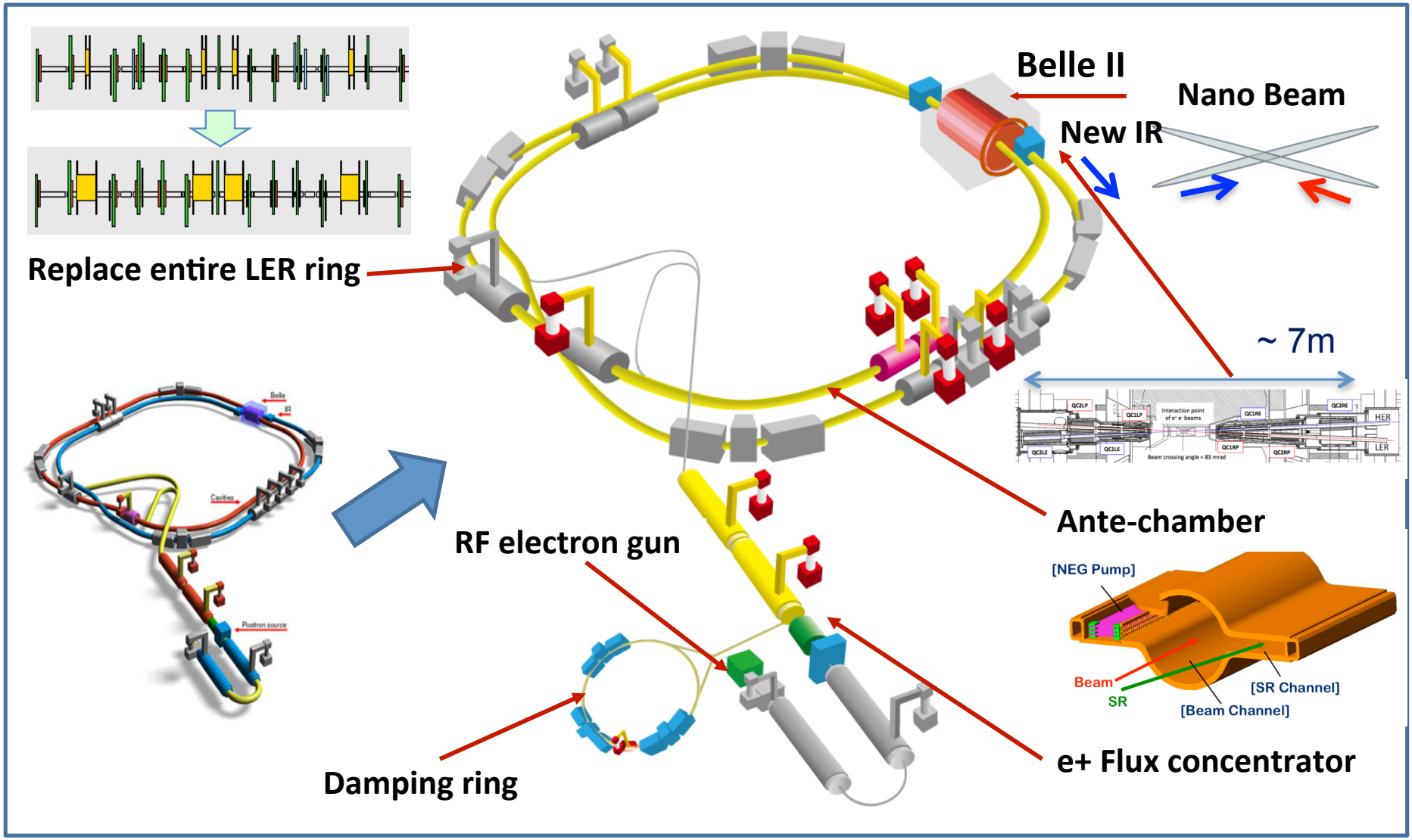
- KEKB factory, 8 GeV e- / 3.5 GeV e+ collider, achieved world highest record on luminosity.
- Super KEKB project : explore rare decay particles to find physics beyond standard model
- Increase luminosity 40 times more than previous



How to increase luminosity

	KEKB Achieved			SuperKEKB Nano-Beam	
	LER	HER		LER	HER
I_{beam} [A]	1.6	1.2	×2 →	3.6	2.6
β_y^* [mm]	5.9	5.9	×20 →	0.27	0.42
ξ_y	0.09	0.12		0.09	0.09
Luminosity [$cm^{-2}\ s^{-1}$]	2.1×10^{34}		×40 →	8.0×10^{35}	

Machine upgrade



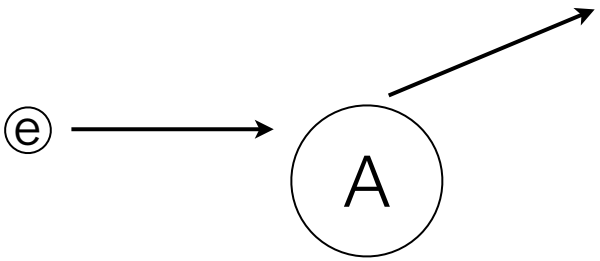
Design specifications

	KEKB KEK internal 2002-4	SKB phase1	SKB phase2	SKB phase3
Beam energy and current	LER 3.5GeV / 2.9A HER 8 GeV / 1.2A	LER 4GeV / 1A HER 7 GeV / 1A	LER 4GeV / 1.8A HER 7 GeV / 1.3A	LER 4GeV / 3.6A HER 7 GeV / 2.6A
Target luminosity	1×10^34	0	1×10^34	80×10^34
Duration	11 years from 1998	5 month from 2015	5 month after 9 month shutdown (Belle2 install)	after 3 month shutdown (VXD install)
Operation mode	Physics run	Beam injection, Vacuum scribing, without Belle2	Collision tuning with limited number of cavities, without VXD	Physics run

Step by step, to increase maximum power with confirmation of leakage dose and induced radio activity

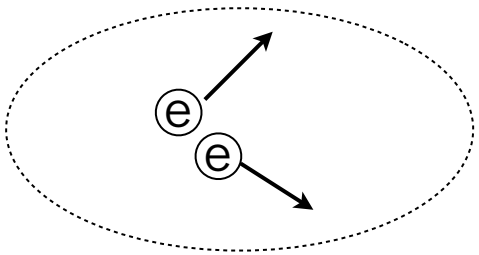
Beam loss processes

Beam-gas Coulomb



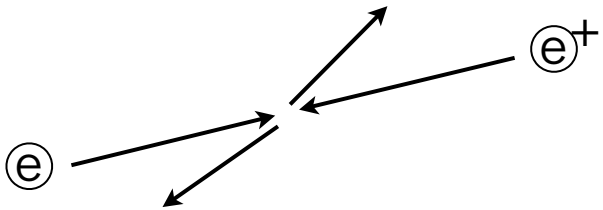
Vacuum and beam current

Touschek

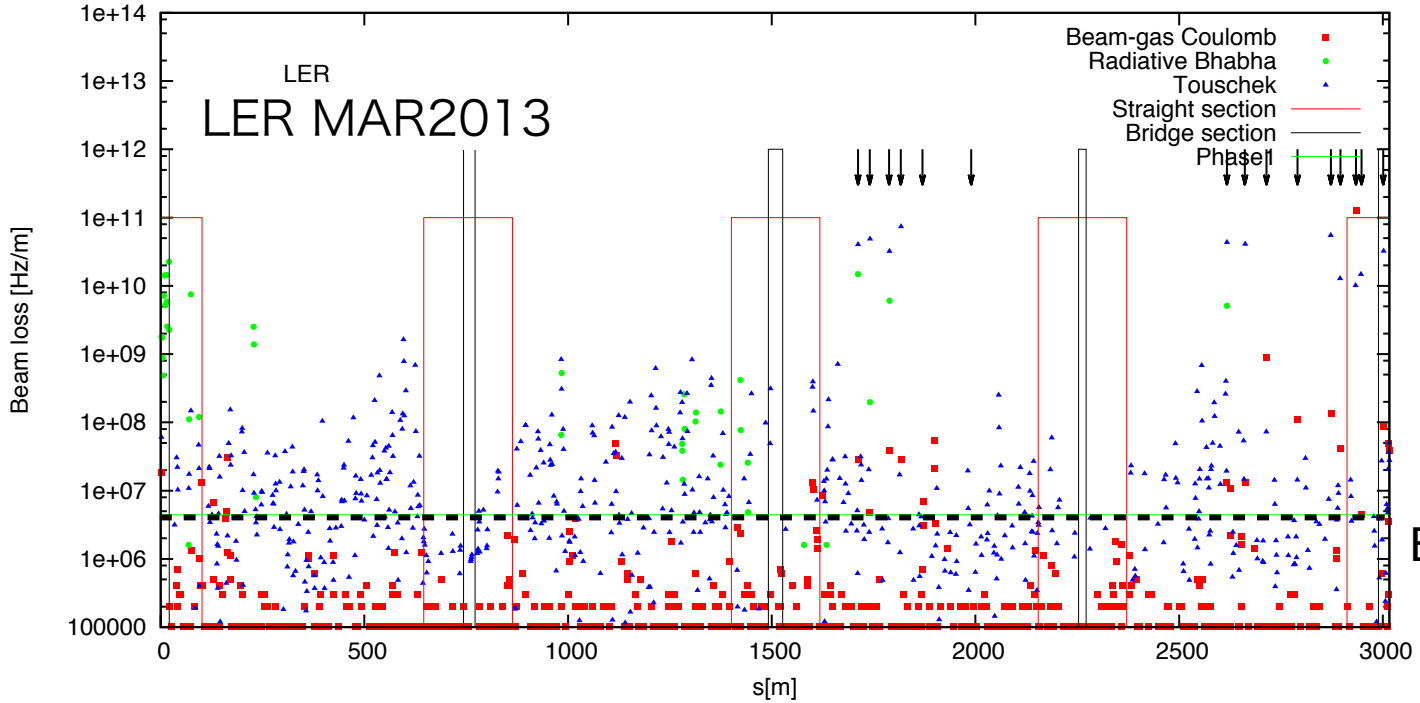


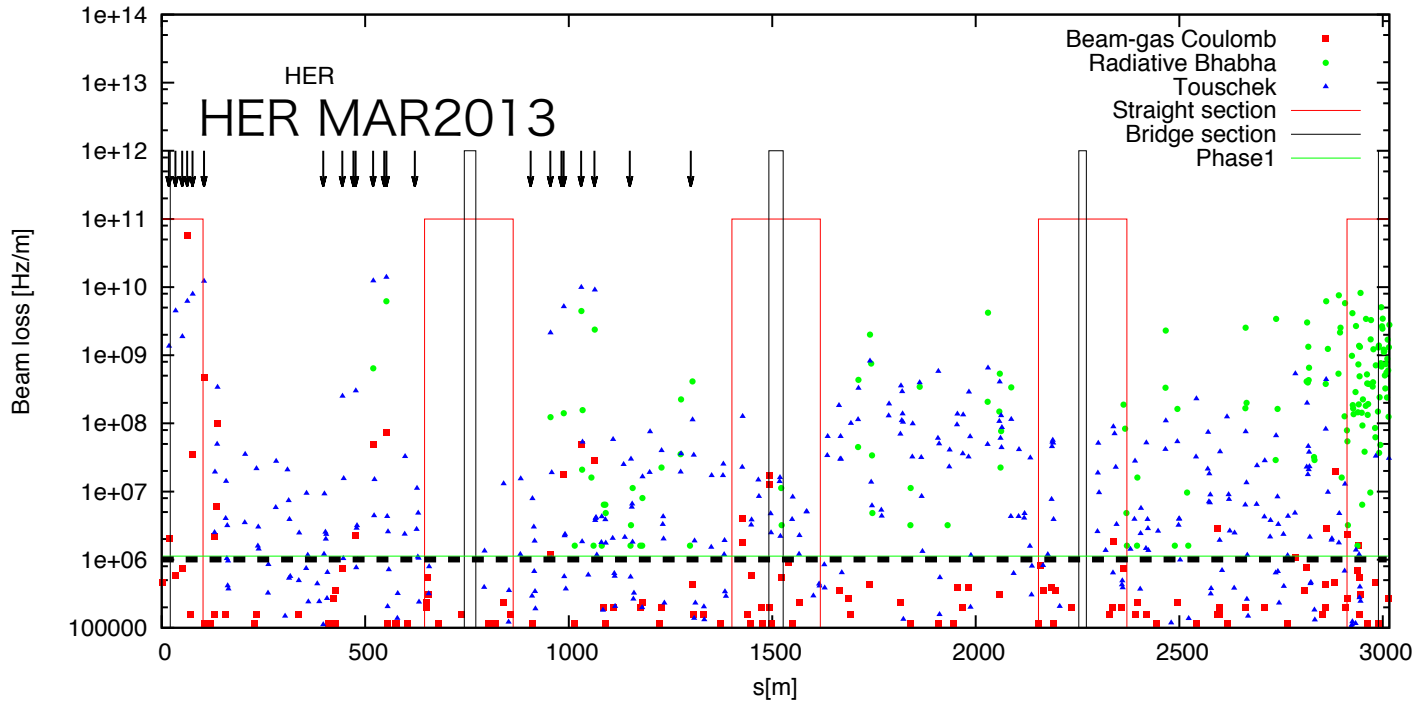
Beam size

Radiative Bhabha



Luminosity





Beam-gas Coulomb
Radiative Bhabha
Touschek
Straight section
Bridge section
Phase1

- Tracking with beam line device and aperture data

Beam loss estimation

unit 1e9 pps	Beam life					Injection and abort	Total
LER HER	Ring uniform (Beam gas)	Arc uniform (Touschek)	Mask local	Tsukuba R RBB	Tsukuba L RBB		
KEKB	0.53 0.01	0.98 0.65	5.44 0.71	0.0 1.44	1.43 0.0	15.2 6.12	24 9
SKB phase1	4.36 0.937	0 0	0 0	0 0	0 0	4.68 3.86	9 5
SKB phase2	16.95 0.67	31.25 31.30	233.5 80.0	0.0 0.83	1.13 0	69.1 24.9	351 138
SKB phase3	33.90 1.33	62.5 62.6	467.0 160.0	0.0 66.2	90.4 0	138 49.8	792 340

Increase beam loss with decreasing beam size.
Note:Phase2 loss is tentative

Methodology

- Bulk shield thickness :
  - Jenkins for neutron and gamma
- Duct streaming :
  - Mao and Tesch, MCNP
- Sky-shine:
  - Thomas
- Air and water activation:
  - Swanson

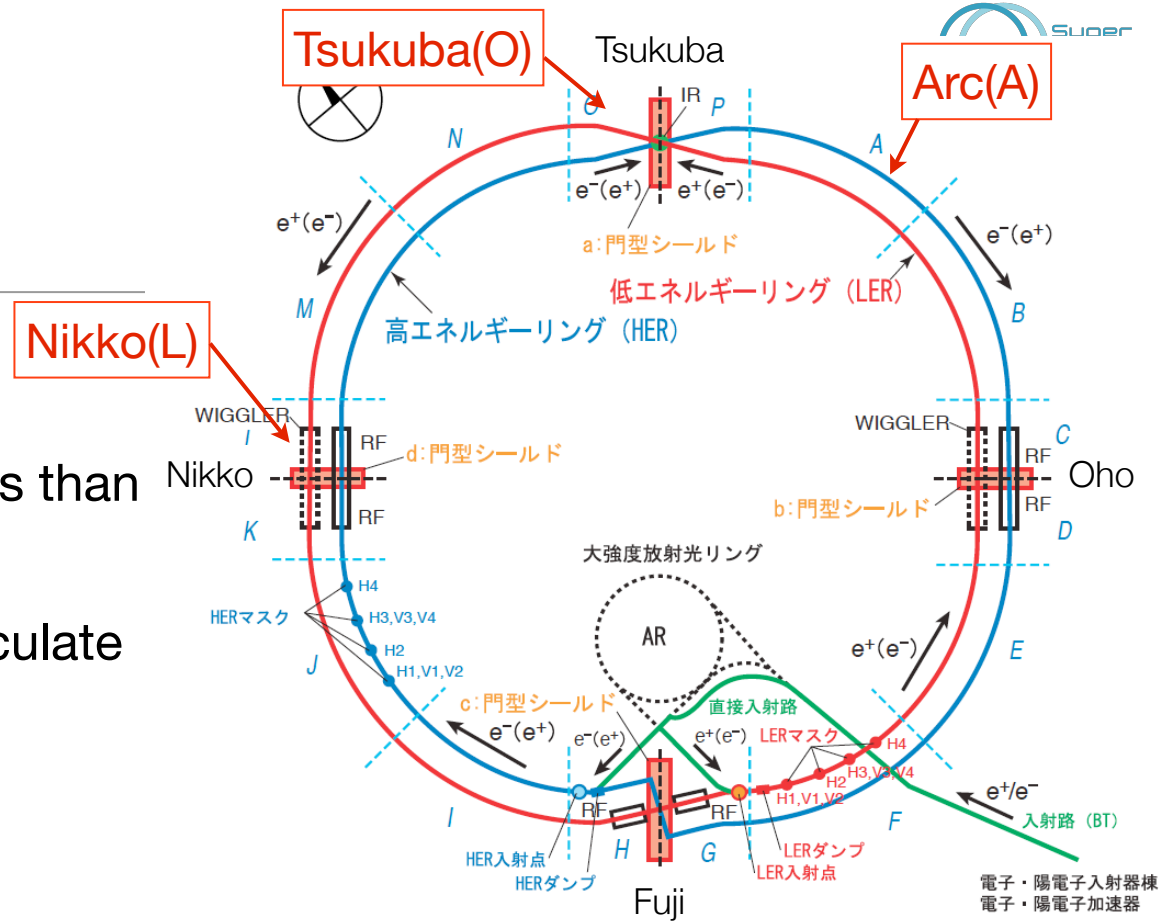
Design goal

- Law
  - Radiation controlled area: less than 1 mSv / week
  - General area:less than 1.3 mSv / 3 month
  - Site boundary: 250 μSv / 3 month

- KEK rule
  - Radiation controlled area: less than 20 μSv/h
  - Supervise area: less than 1.5 μSv/h
  - General area: less than 0.2 μSv/h
  - Site boundary: less than 50 μSv/year

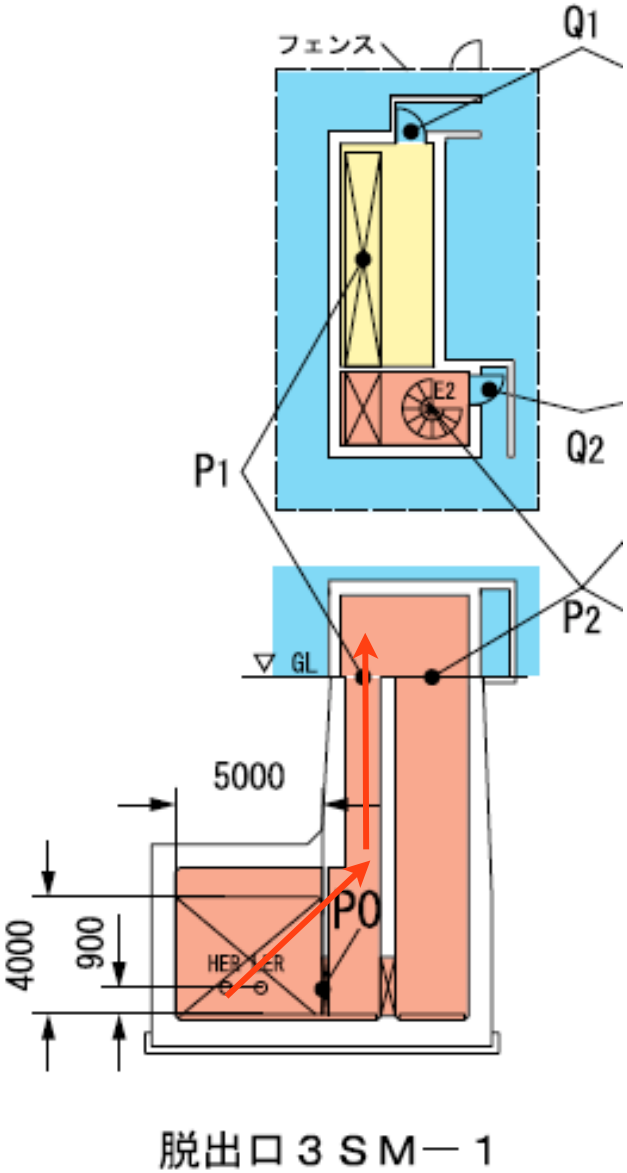
Activity in air

- 16 air condition units
- Ratio to DAQpa should be less than 1 for continuous release of air
- For arc section, air should circulate in closed loop
- Local shield is required for IR straight section

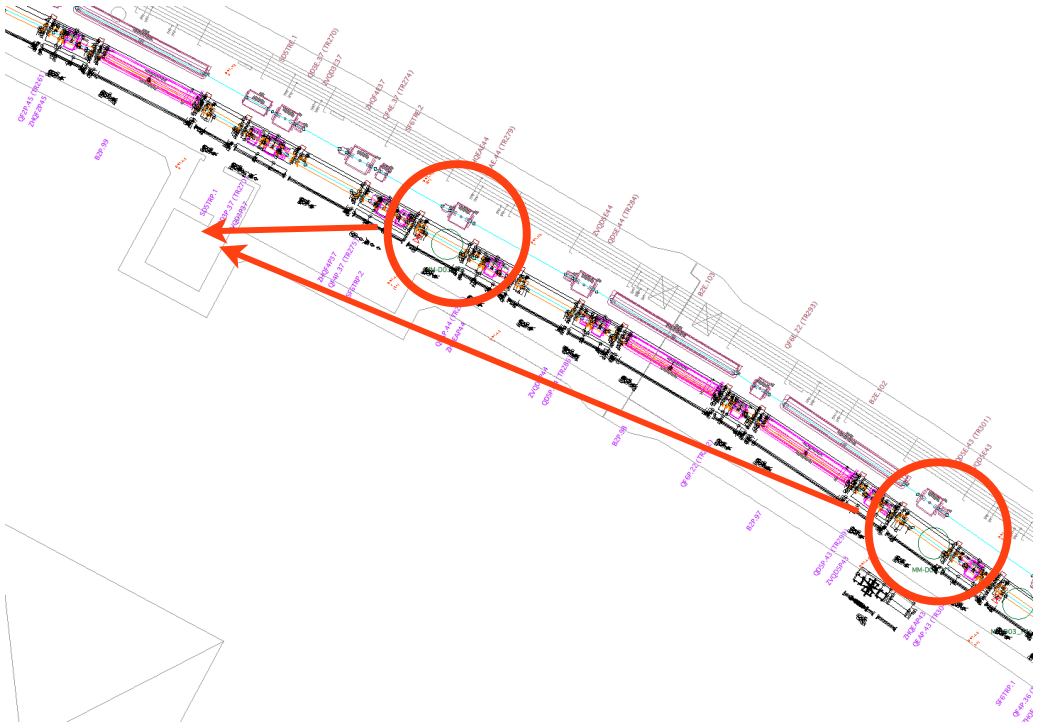


Unit	Ratio to DAQpa				
	KEKB	Phase1	Phase2	Phase3	Phase3 WO col.
Arc(A)	0.56	0.05	8.43	16.83	1.89
Nikko(L)	0.02	0.02	0.51	1.17	0.44
Tsukuba(O)	0.07	0.02	1.10	8.96	7.20

Leakage dose in control area (3SM1)

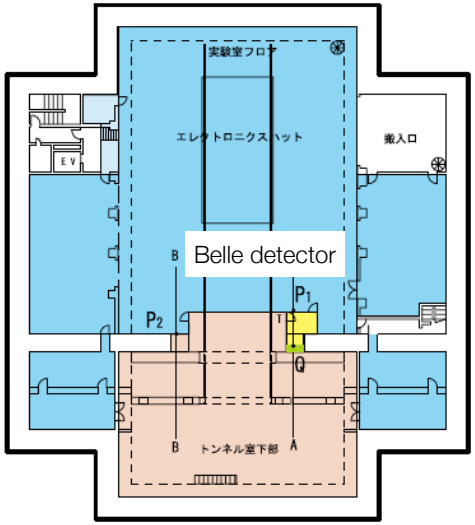


Unit	Dose (μSv/h) [KEK limit = 20 μSv/h]			
	Line	Mask	SR	Phase3
3SM1 P1	61.7	40.3	8.1	110.1

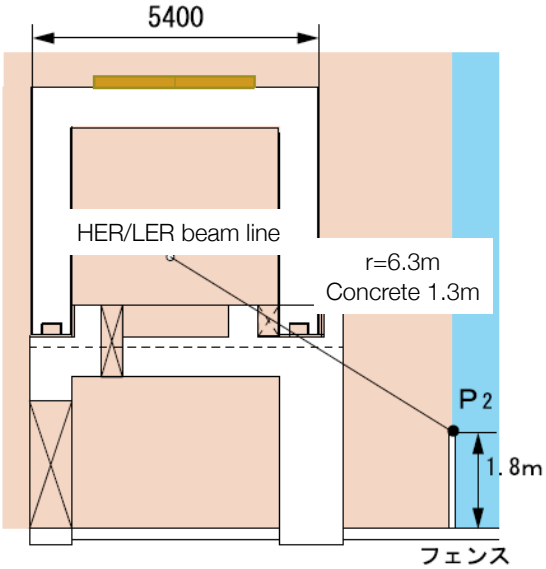


Leakage dose on experimental floor

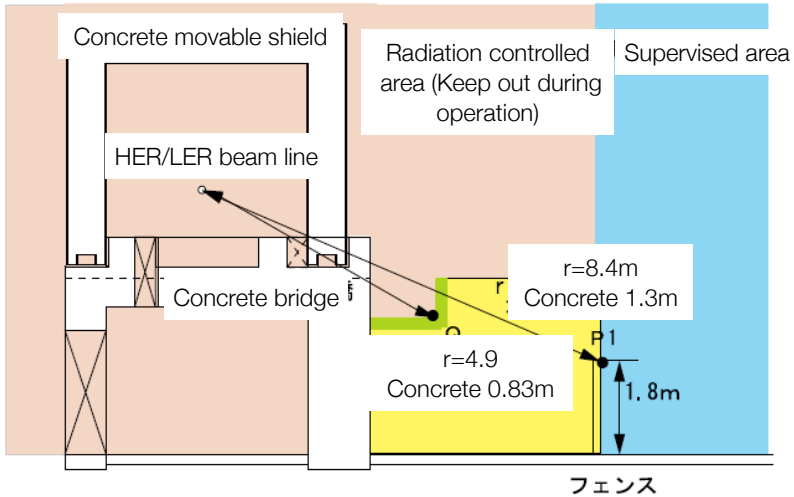
Unit	Dose (μSv/h) [KEK limit = 1.5 μSv/h]				
	KEKB	Phase1	Phase2	Phase3	Phase3 WO
Tsukuba P1	0.12	0.01	0.15	9.37	9.37
Tsukuba P2	0.17	0.05	0.64	40.3	40.3



Tsukuba B4



Tsukuba B-B cross section

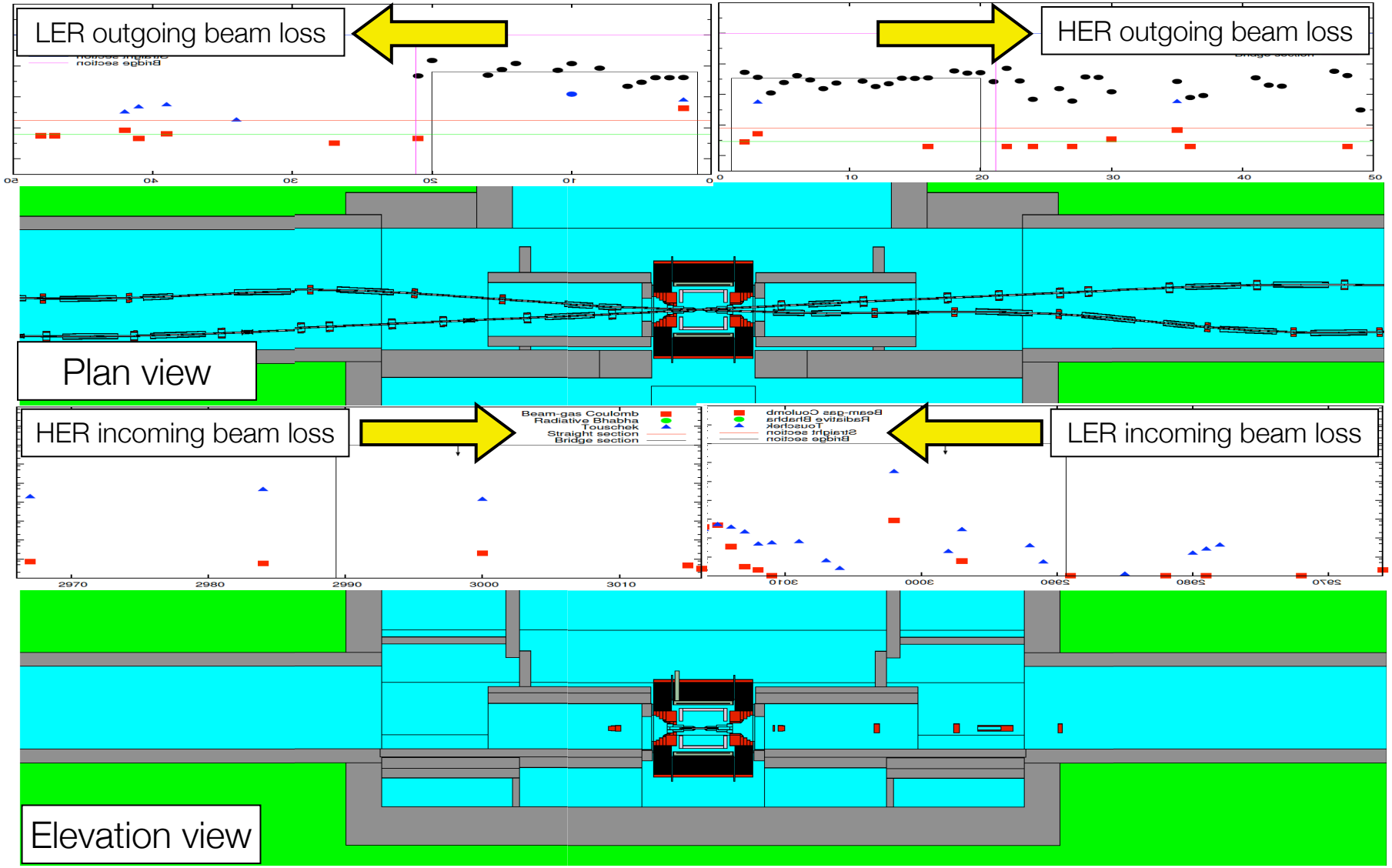


Tsukuba A-A cross section

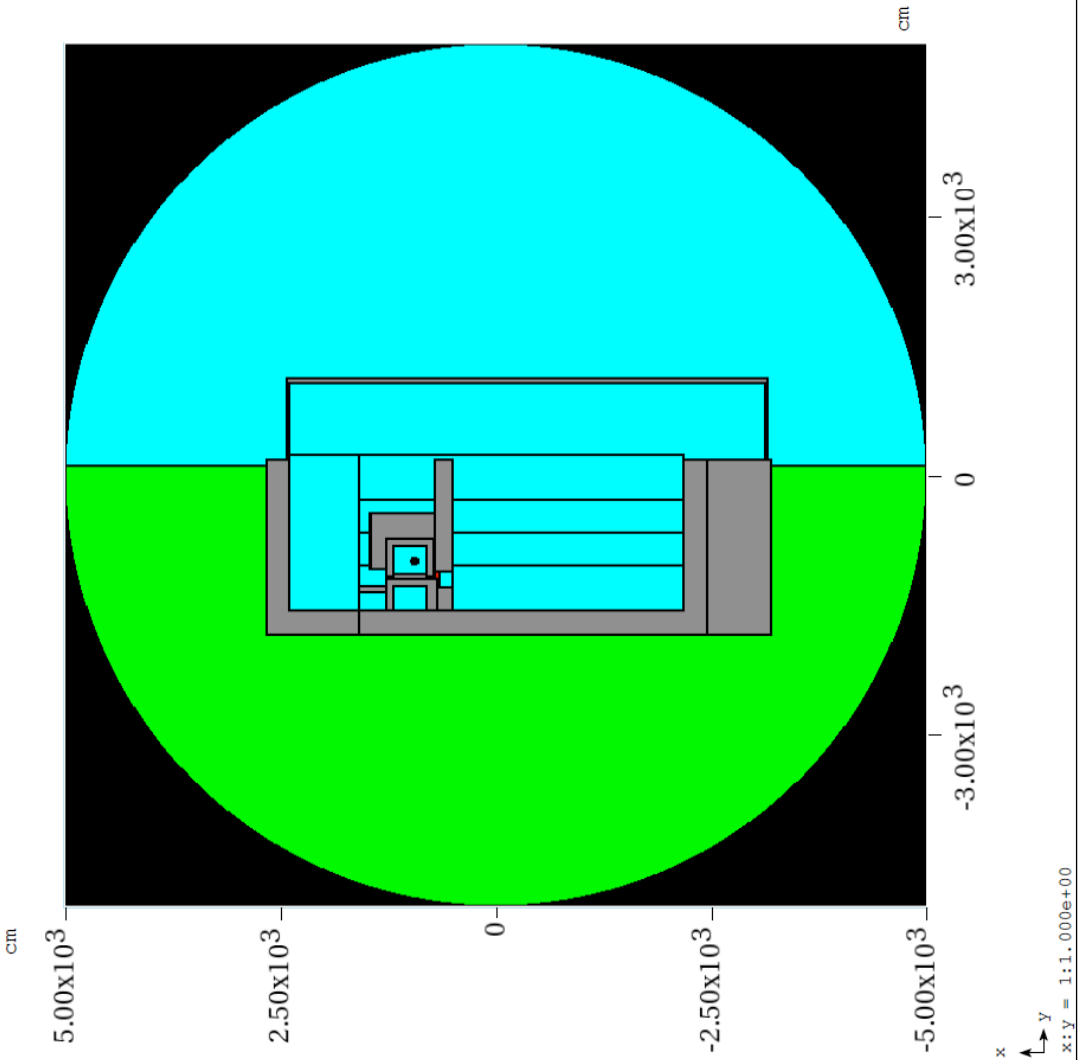
Radiation safety design should be updated

- Detail Monte-Carlo
  - MARS1512(29-Apr-2013) [http://www-ap.fnal.gov/MARS]
  - GEOM.INP, MCNP mode with default option
  - GeV electron interaction, low energy neutron transport with point wise cross section, with reasonable calculation time
  - Tsukuba(IR) experimental hall
    - Leakage radiation, air activation
  - Beam collimators
    - Air activation

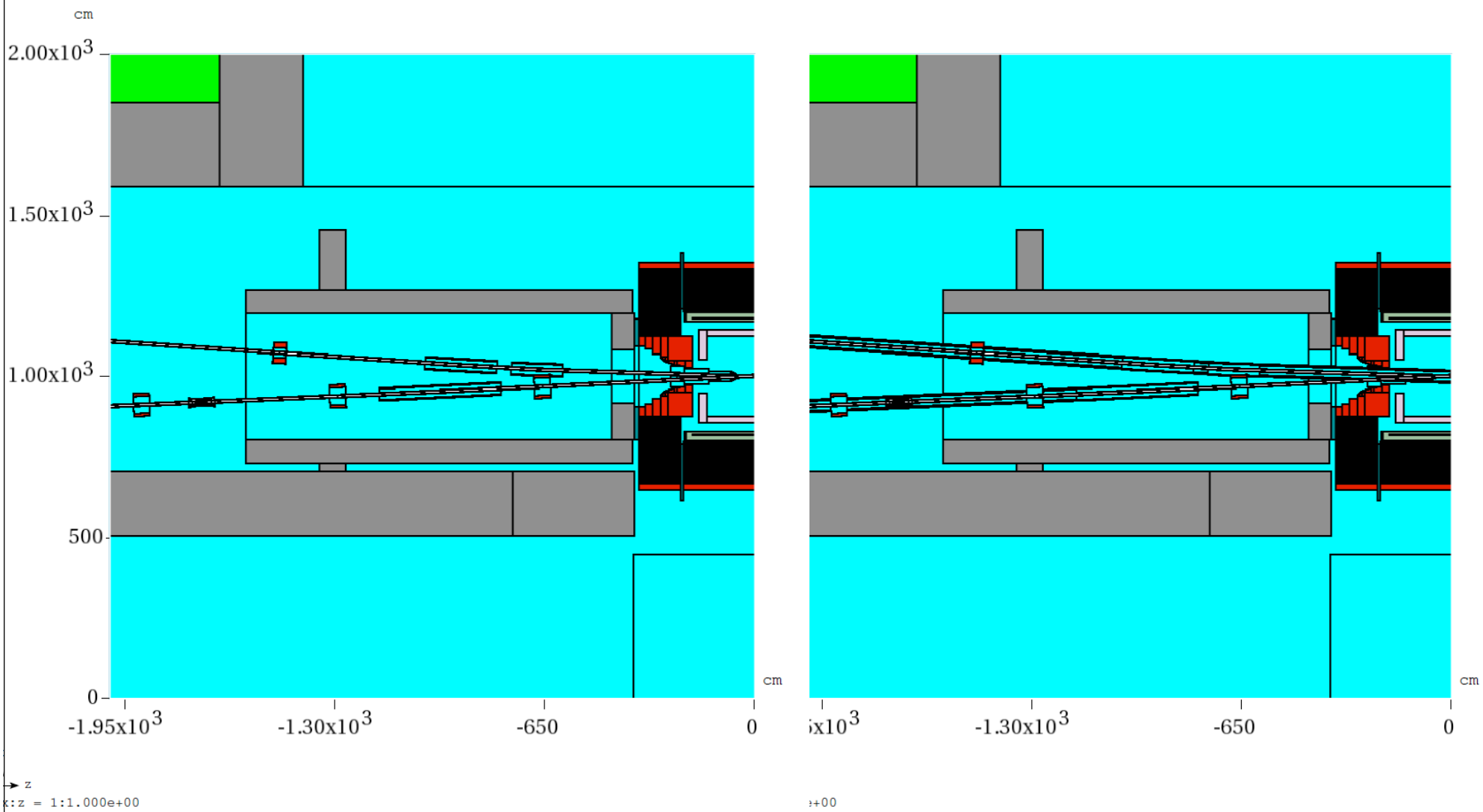
Detail geometry and beam loss modeling



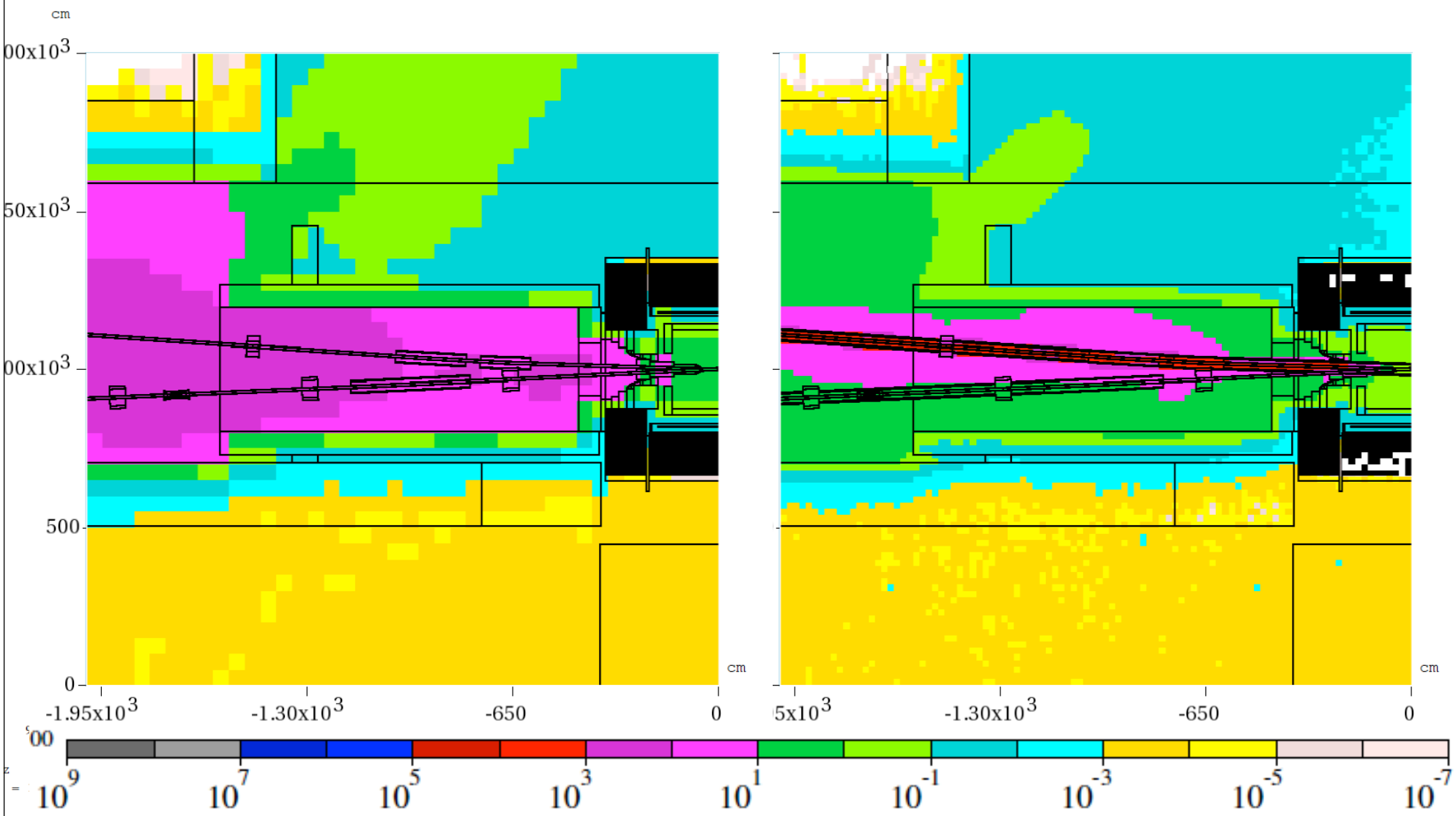
Phase1 -Leakage dose in Tsukuba exp. hall



To suppress air activation - lead shield for RBB

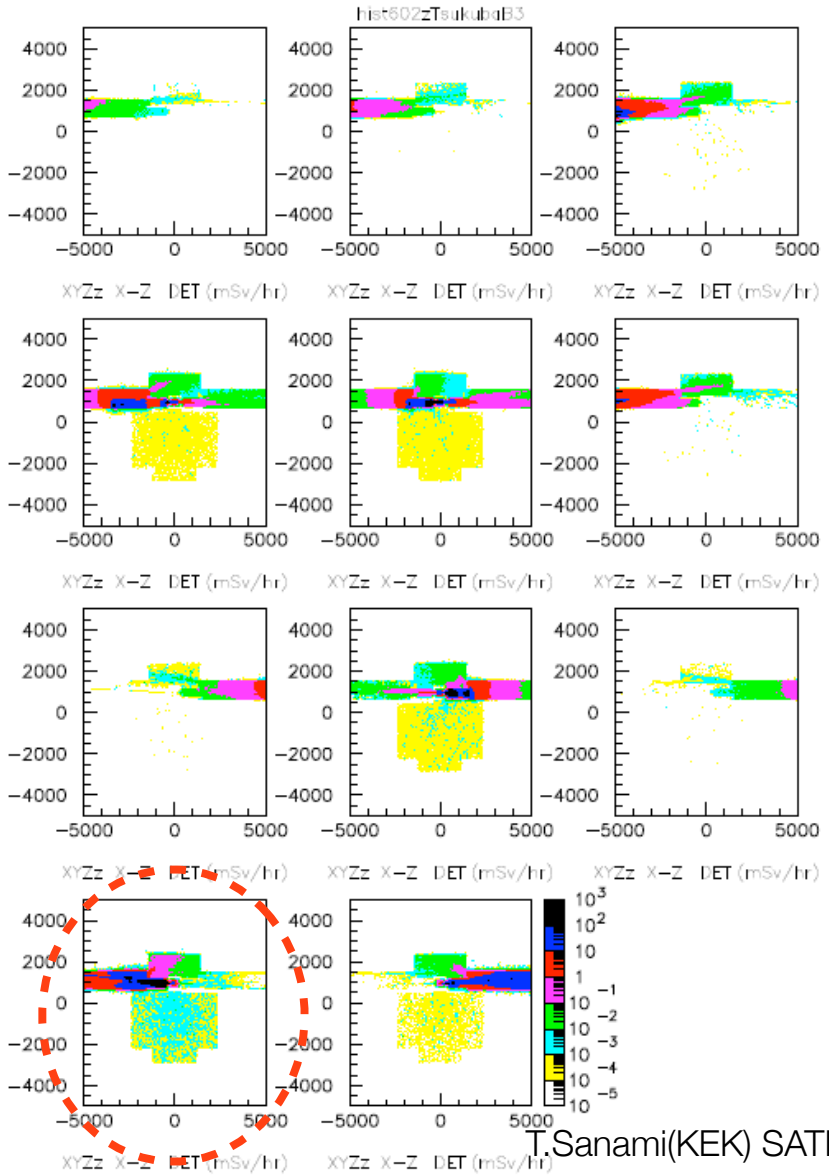


Progress at Tsukuba exp. hall (Beam loss)



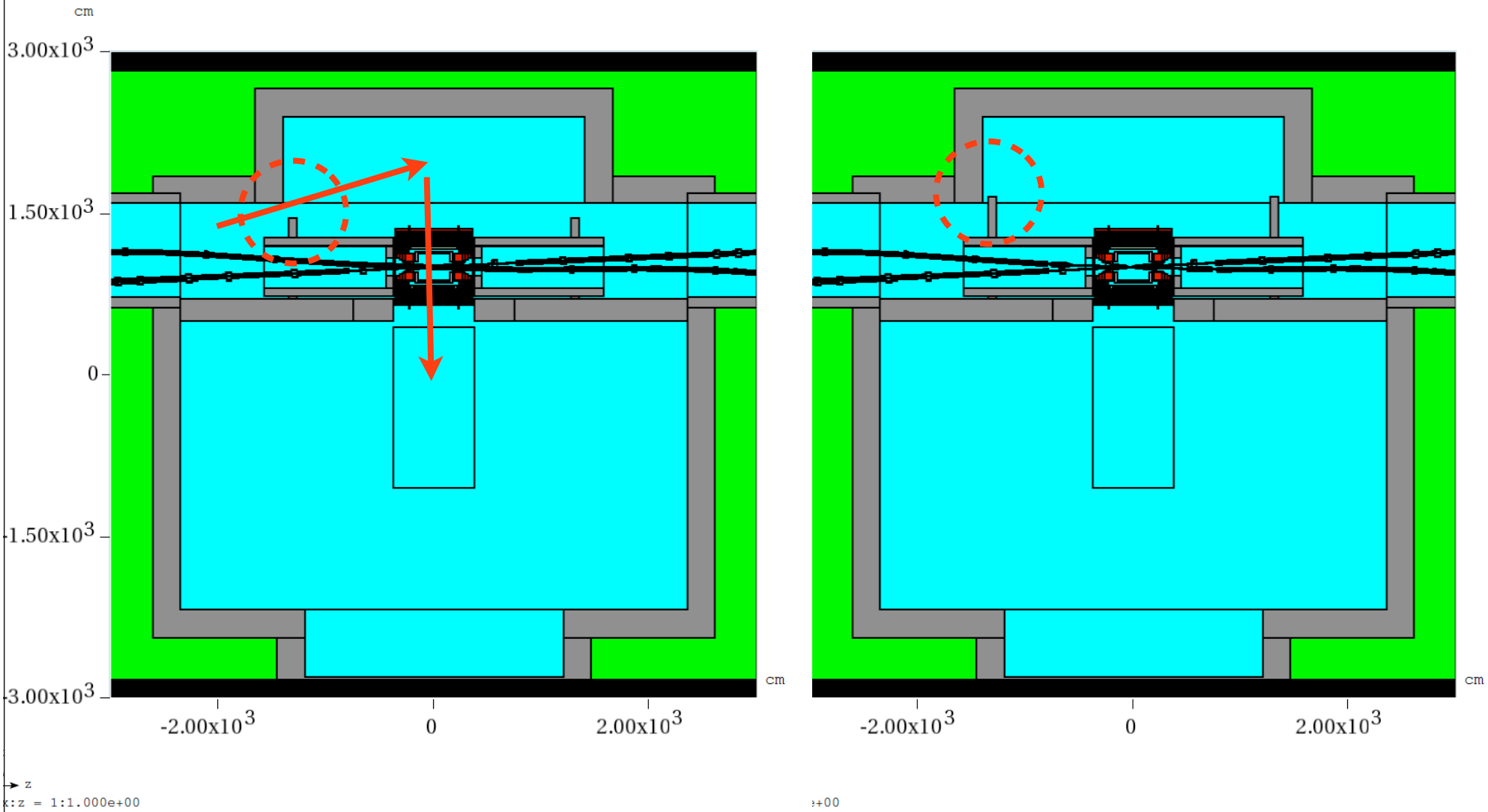
mSv/h

Phase2 - Leakage dose in Tsukuba exp. hall

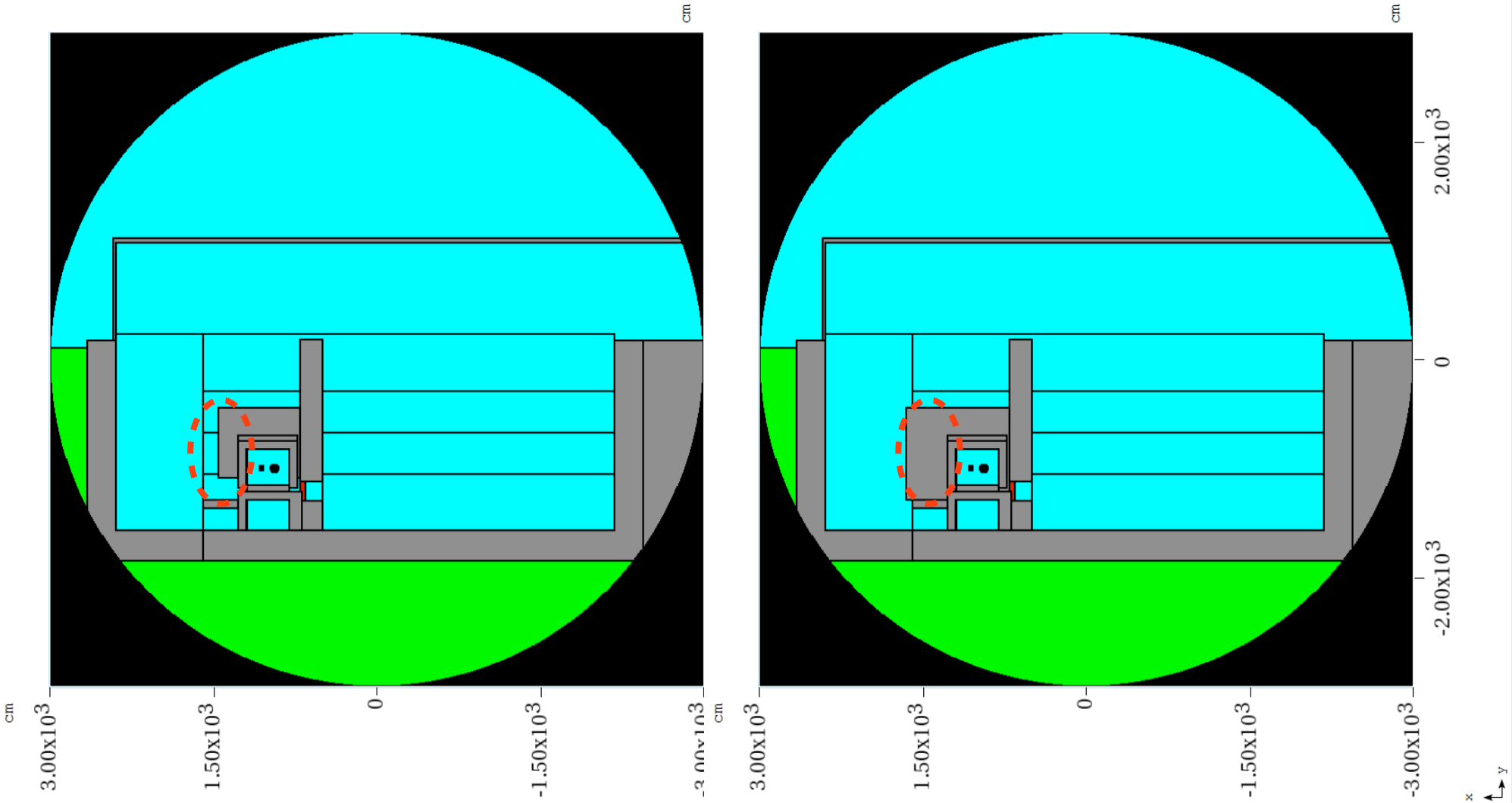


- Contribution survey for each beam losses
- Collimators:
  - HER: D01H1, D01H2, D01H3, D01H4, D01H5, D01V1,
  - LER: D02H3, D02H4, D02V1
- Radiative Bhabha for LER/HER

Phase2 - Leakage dose in Tsukuba exp. hall



Phase2 - Leakage dose in Tsukuba exp. hall



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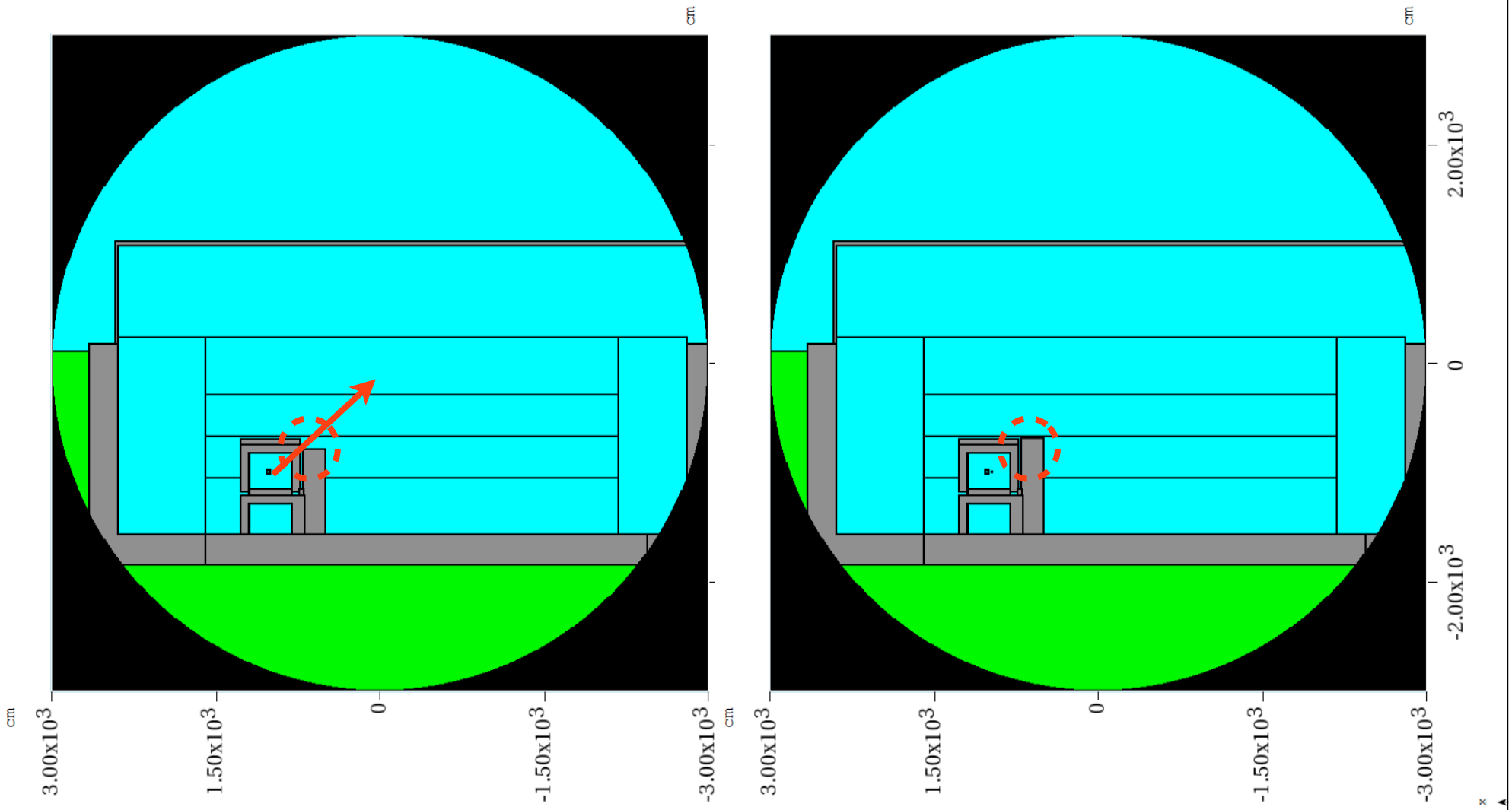

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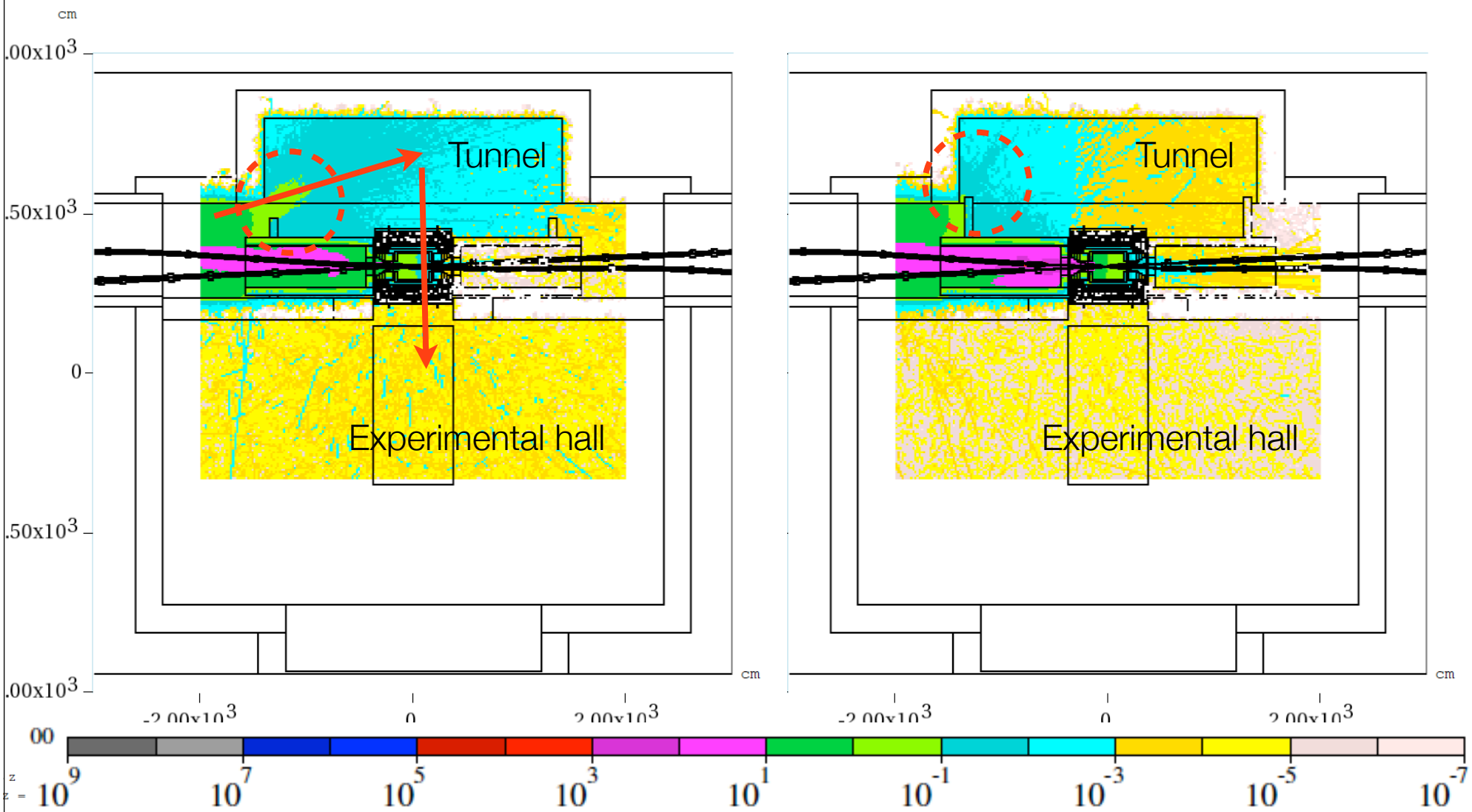
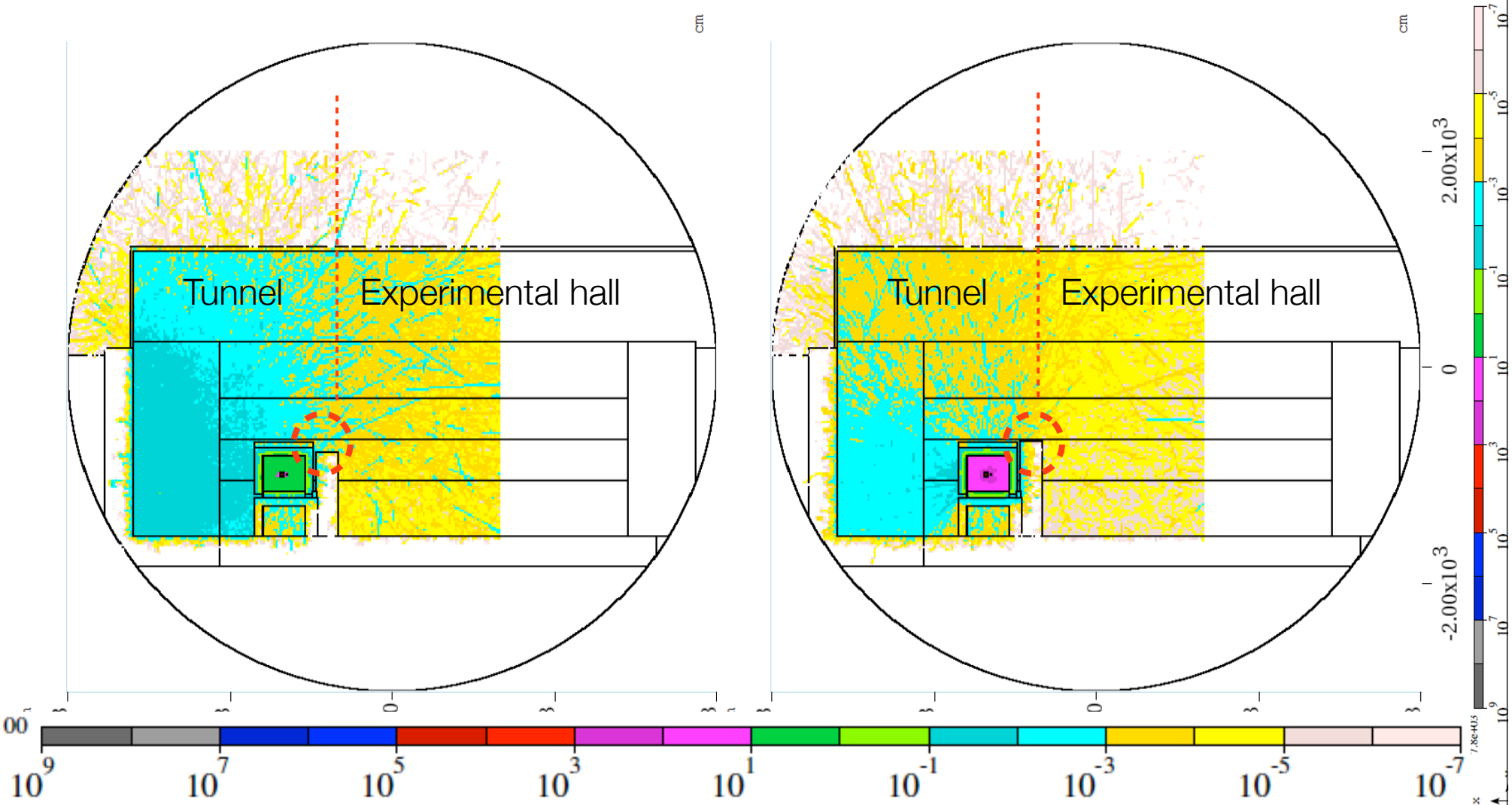


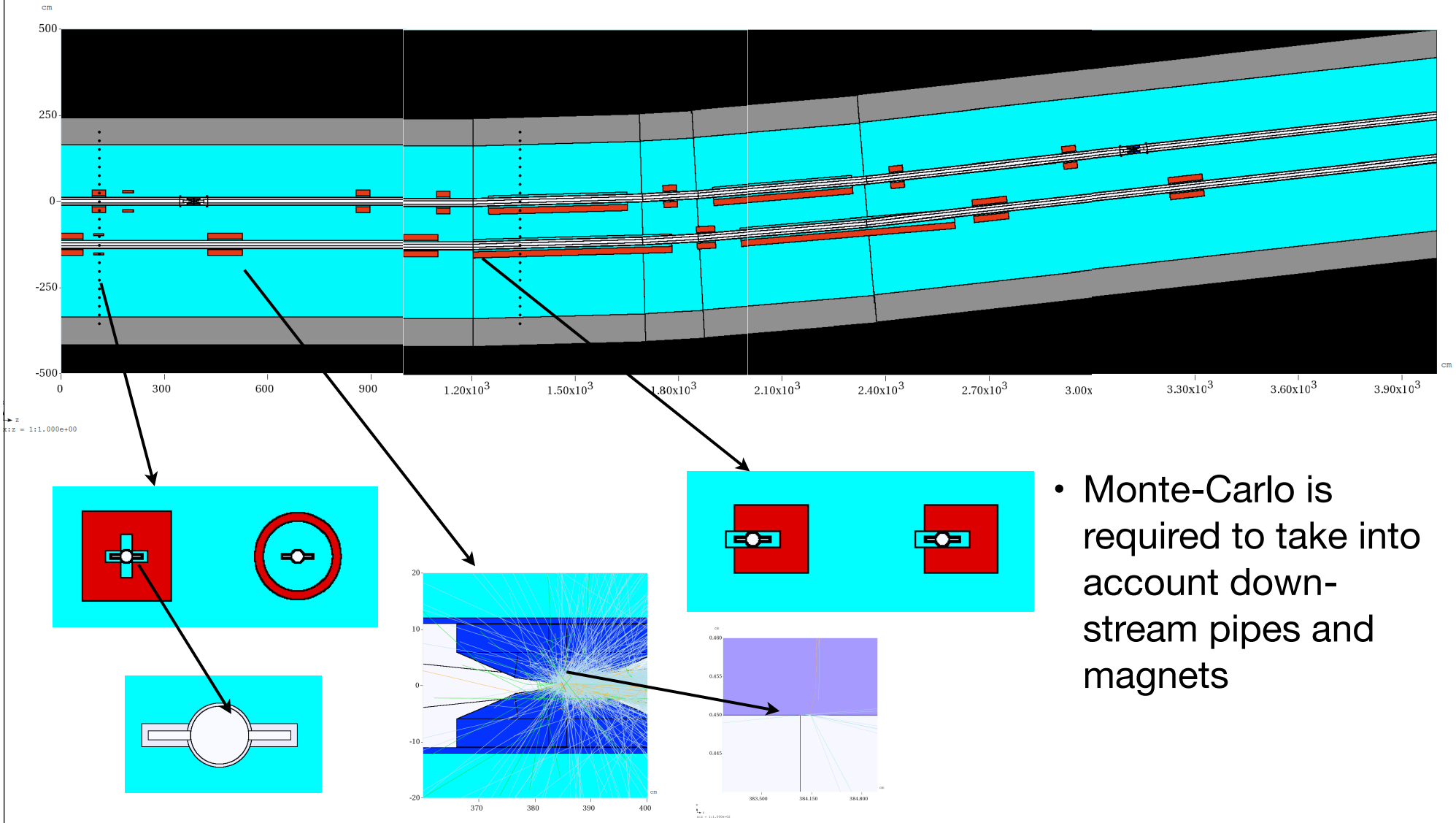
mSv/h

Phase2 - Leakage dose in Tsukuba exp. hall



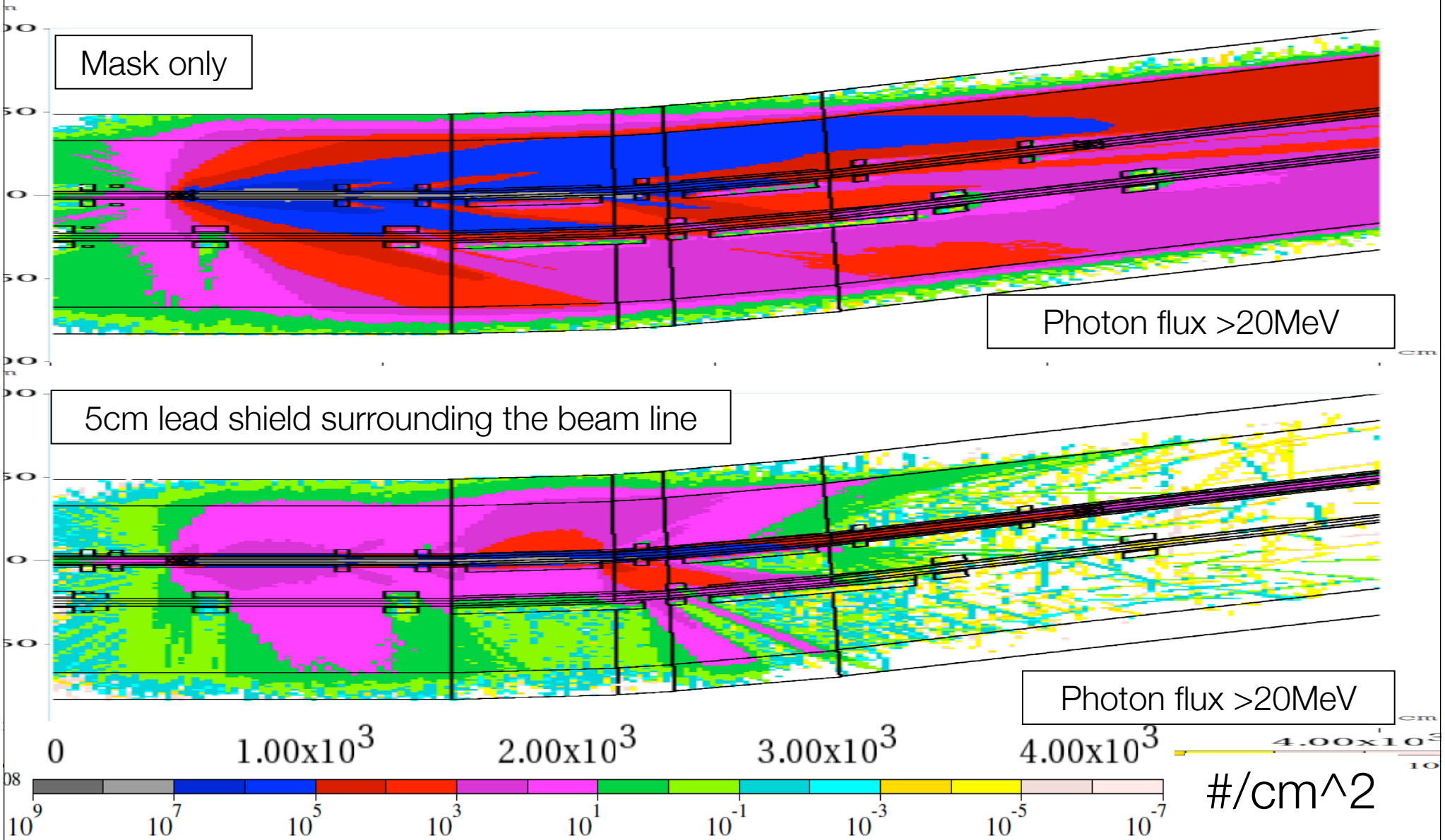
mSv/h

Collimator and beam line modeling



- Monte-Carlo is required to take into account down-stream pipes and magnets

Photon flux > 20 MeV



Summary

- Radiation safety design of Super KEKB is in progress
  - Bulk shielding wall and induced activities in air and water were evaluated using empirical equations
  - Supplemental shield should be designed at several locations
    - MARS15 code is used for this purpose
    - RBB loss at Tsukuba experimental hall to suppress ambient dose and activities in air
    - Losses at collimators to reduce activities in air

LER decommissioning

- More than 2500 chambers, magnets and related components were removed from tunnel on 2012
  - Three survey meters were used to categorize
    - NaI survey: Find highest point
    - GM counter: Record counts at the point
    - LaBr spectrometer: Record spectrum

  - 1500 : Non activated
  - 1000 : Activated, less than 0.6μSv/h on 10cm
  - 50 : Activated, more than 0.6μSv/h on 10cm

Courtesy H.Nakamura

Update injection scheme