IR introduction + Beam BG simulation1

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M. Iwasaki (Univ. of Tokyo)

Introduction

Super-KEKB → High luminosity experiment

Remarkable features of Super-KEKB

- **High beam current**
- **Strong dynamic-beam effect**

  … squeezes the beam at IP and increases the emittance

(To take care of the dynamic-beam effect, IR design has been changed)

- **Large beam size** at final Q → **High power SR** emission
- Place **final Q-magnets closer to IP**

→ **These features directly related to the detector beam BG**

To assure the stable detector operation,
IR design based on the beam BG study is important

Current status of the IR studies

- SR BG simulation studies (Tokyo / KEK)

Upstream SR

1. Design the IP beam-pipe to avoid SR from HER
2. Study of the energy deposit to the IP beam-pipe

Backscattered SR

→ C.Ng

Heat calculation by SR E deposit

→ T.Tsuboyama

- HOM heating studies (Tohoku / KEK) Just started!

→ K.Shibata

- To reduce SR BG, new optics is highly appreciated

→ H.Koiso

Upstream SR simulation studies

SR power is much higher than current KEKB,
then we start from SR BG estimation

1. Design the IP beam-pipe to avoid SR from HER
2. Study of the energy deposit to the IP beam-pipe

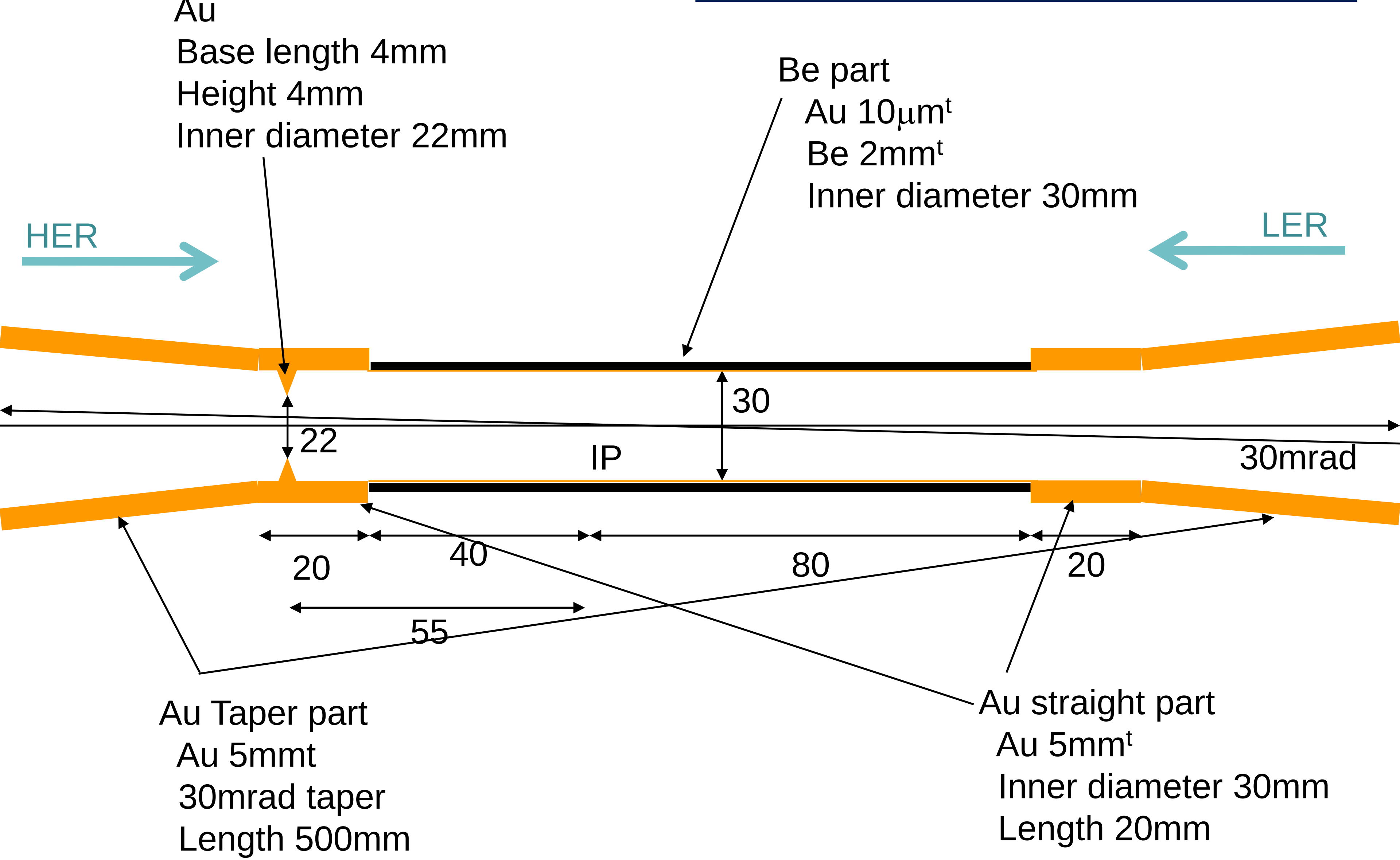
For the SR BG study,
we construct the beam line simulation based on GEANT4.

Simple beam pipe + 1st layer SVD + B-field of Q-magnets

Beam pipe v1

S.Uno

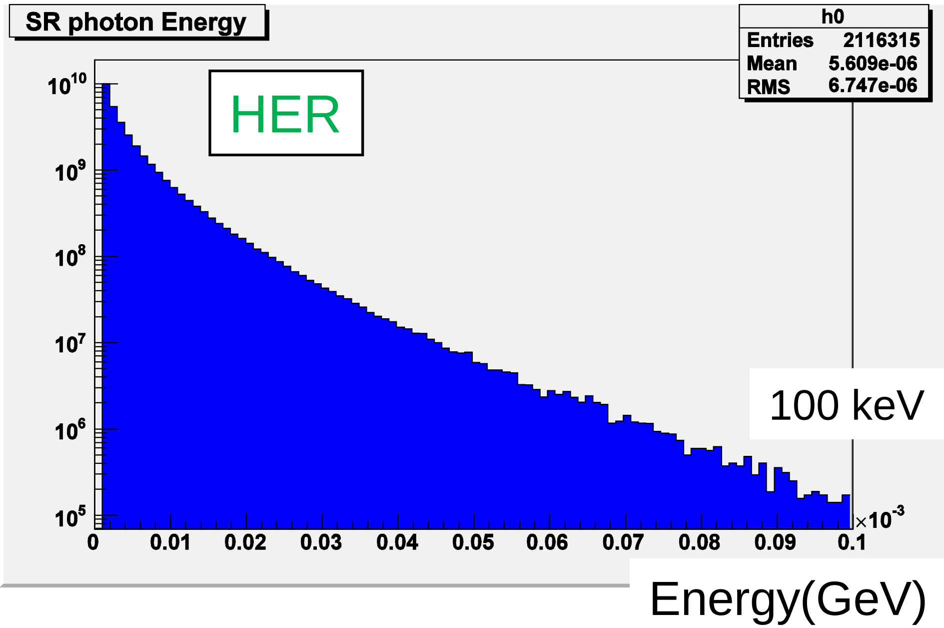
We put the beam pipe in our simulation

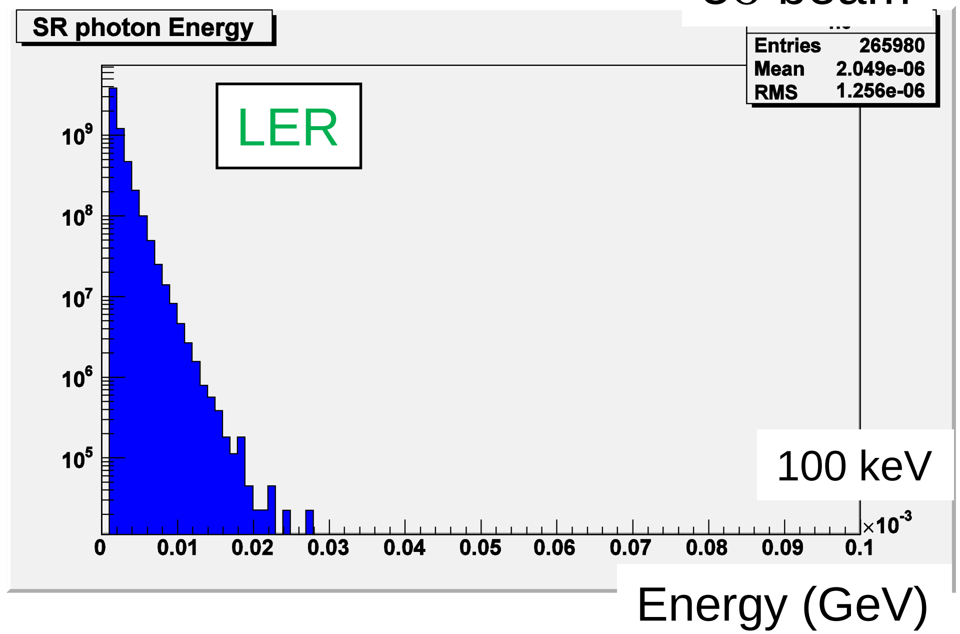


Upstream SR energy

SR energy (at IP)

5σ beam



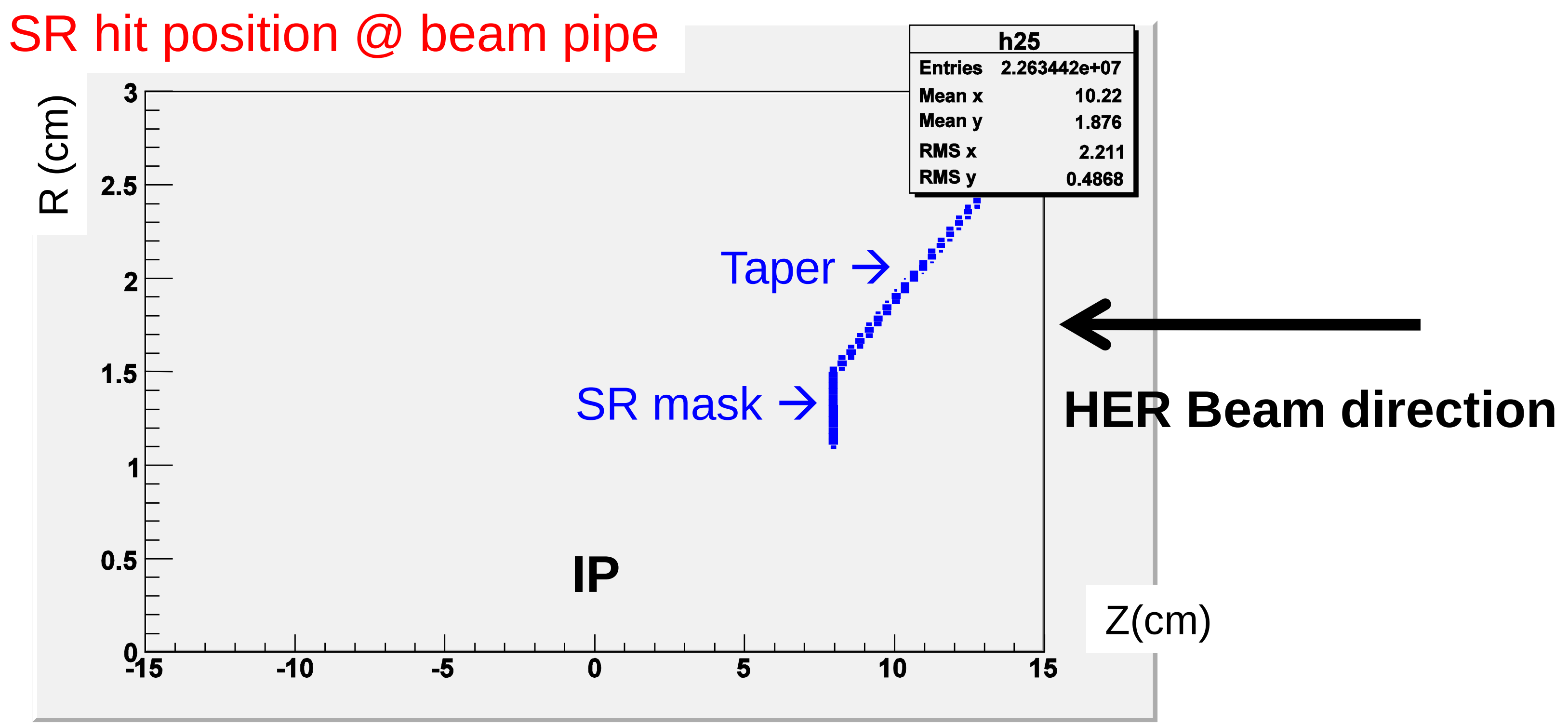


(Vertical scale: Scaled for 1-bunch beam)

The SR energy from HER is very high (< ~100keV)

→ We don't want the direct hits from HER SR at first

HER beam line simulation

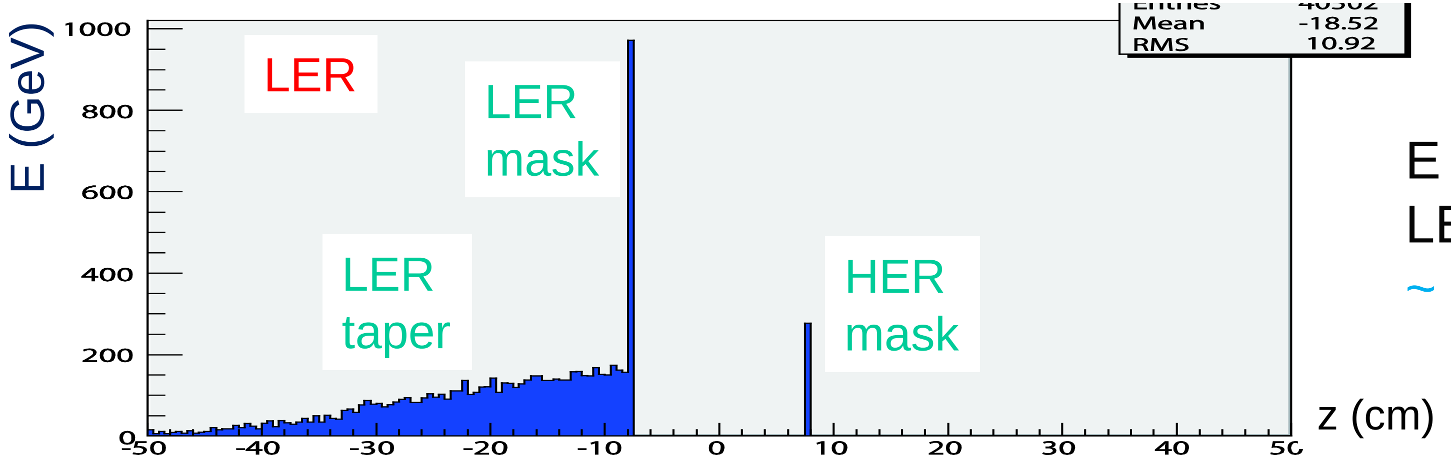


If we locate the beam pipe parallel to HER (22 mrad from solenoid) and put a 4mm SR mask, we can avoid direct SR hit from HER

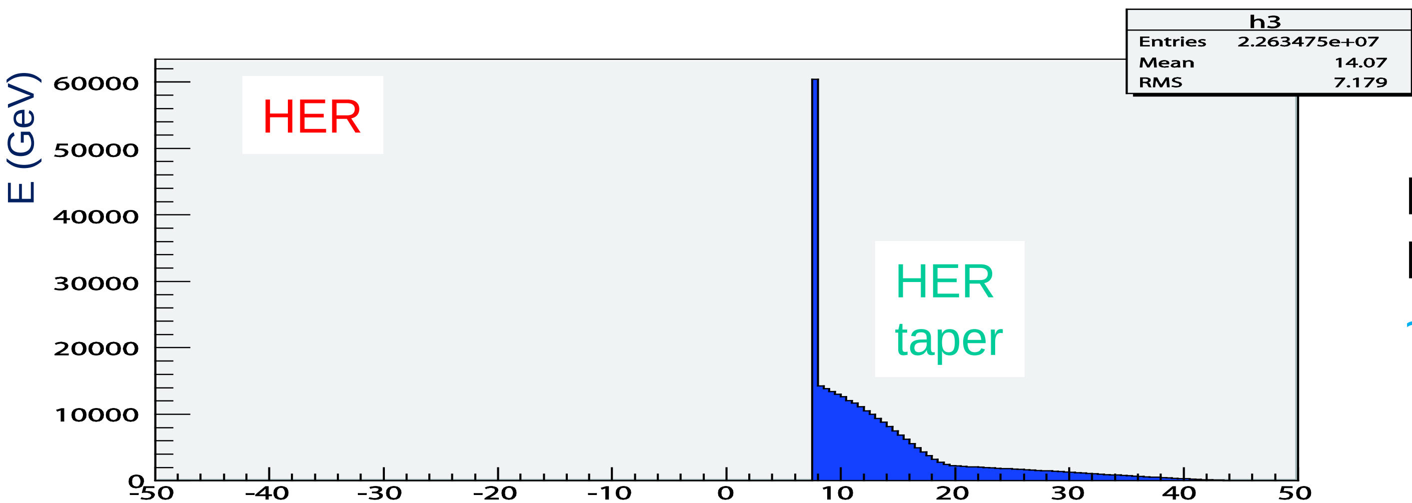
We cannot avoid the SR direct hit if:

- Without HER side SR mask,
- Put the beampipe parallel to Belle solenoid (0mrad) , nor
- Put the beampipe center of the LER and HER (7mrad)

Energy deposit from upstream SR



E deposit at LER mask
~ 1000GeV/bunch



E deposit at HER mask
~60000GeV/bunch

Results

E deposit at LER mask ~ 1000GeV/bunch → 80W

E deposit at HER mask ~60000GeV/bunch → 4.8kW

(HER mask may melt..)

Energy deposit from HER SR

- For 5σ beam

Mask total 4.8kW from QC1 2.7kW QC2 2.1kW
Taper total 20.4kW from QC1 7.8kW QC2 12.6kW

- For 2σ beam (corresponds to nominal Gaussian beam core)

Mask total 0.7kW from QC1 0.3kW QC2 0.4kW
Taper total 0.7kW from QC1 0.02kW QC2 0.7kW

→ We have ~1kW Energy deposit at 4mm height SR mask...
(Max. limit to cool : 10~100(?)W / mm^2)

Energy deposit from HER SR

Why do we have so high energy deposit?

1. Increase the beam current effect : x3

2. Change beam optics (QC2)
   - x3 Beam size at Q-magnet ↑
   - x7 B-field at the Q-magnet ↑
   - Same magnet length
   - No-bending component ↓

Critical Energy @ QC2L : 2keV for 10σ beam (KEKB)

56keV for 10σ beam (super-KEKB) effect : x28

→ We have 3x28 ~ 100 times higher E deposit at super-KEKB

Current super-KEKB beam optics produces huge power SR

Summary

- We design the IP beam-pipe to avoid SR from HER

To avoid the SR direct hit, we should

Locate the beam pipe parallel to HER direction, and

(22mrad from Belle solenoid)

Put a 4mm height SR mask

- Study of the energy deposit to the IP beam-pipe

There is huge energy deposit from HER SR

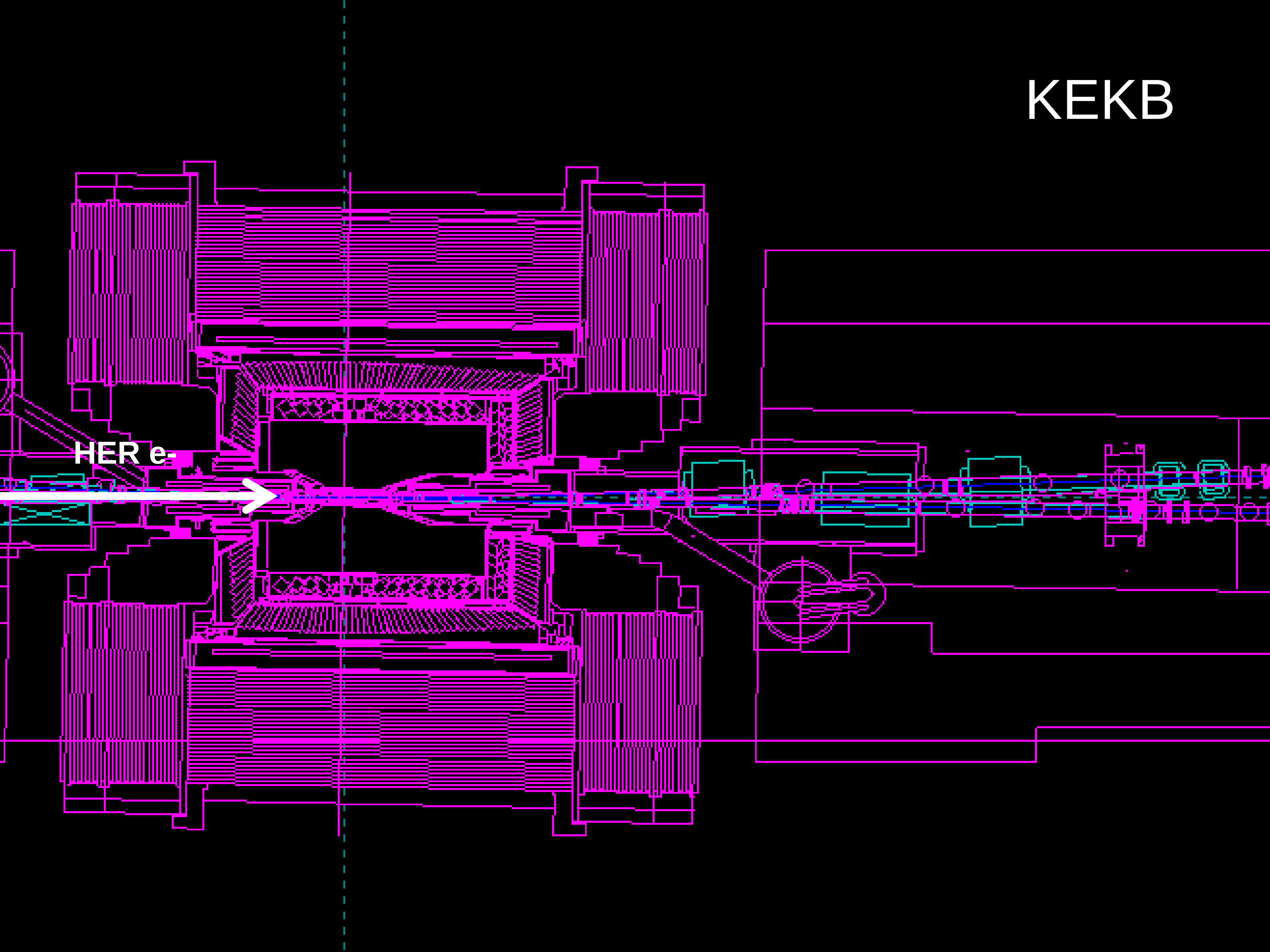
~5kW to SR mask ~20kW to beam-pipe

We try to minimize the BG effect in our beam-pipe design,
but SR power is so huge that beam-pipe easily melts…

New super-KEKB optics which provides lower SR power is highly appreciated

Back up

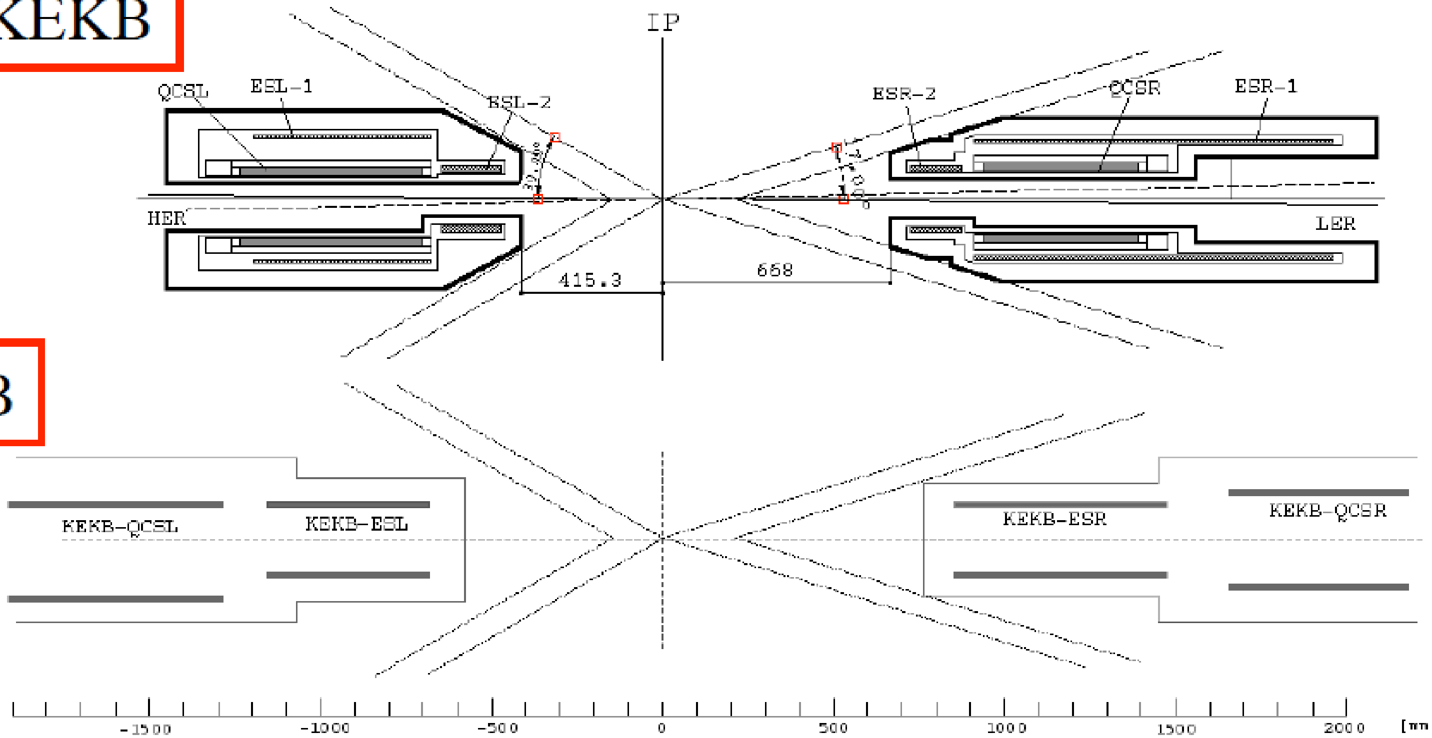
KEKB



Place QCS magnets closer to IP

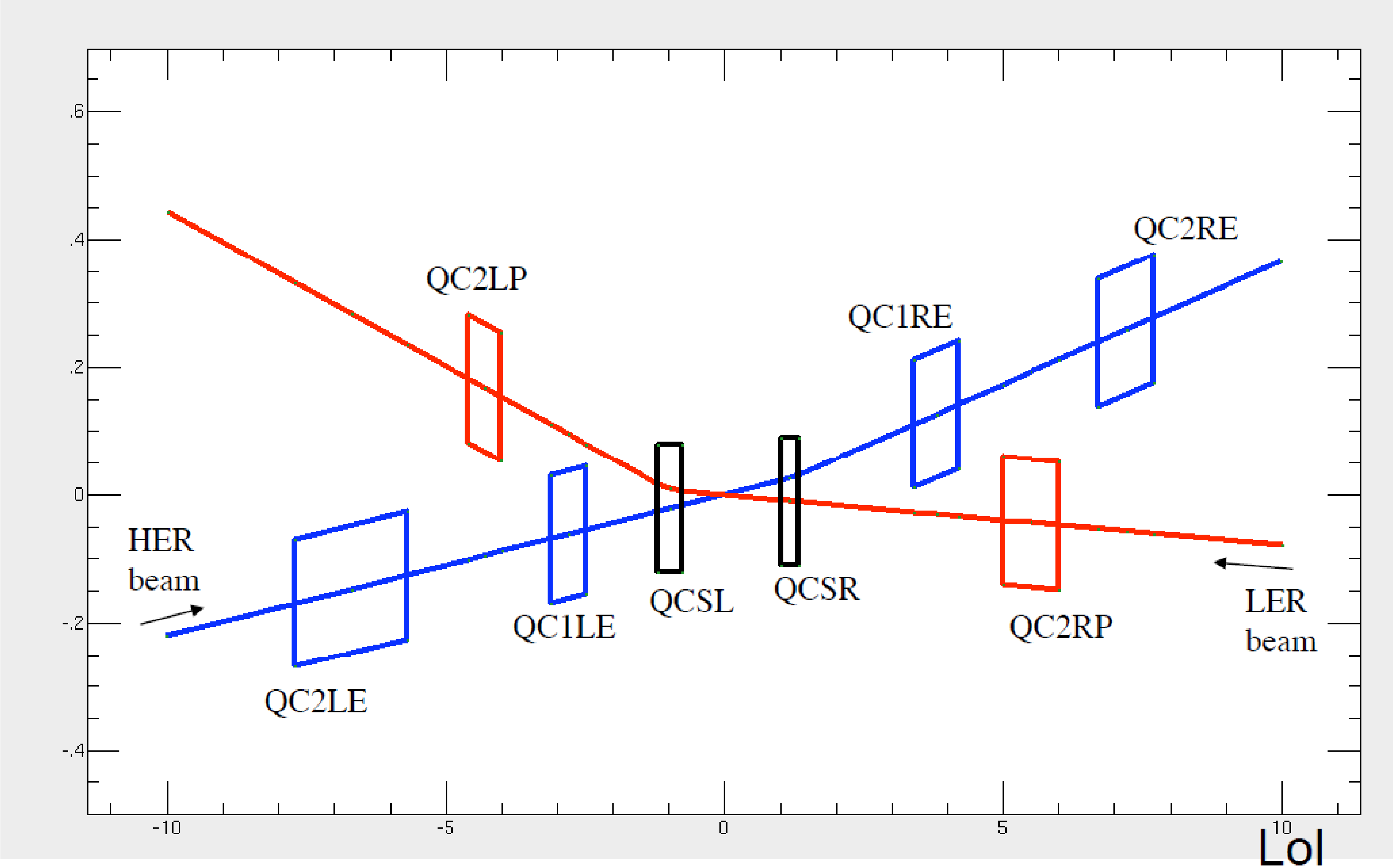
SuperKEKB

KEKB



The boundary between KEKB and Belle is the same.
ESL and ESR will be divided into two parts (to reduce E.M. force).
QCSL (QCSR) will be overlaid with (the one part of) ESL(ESR).

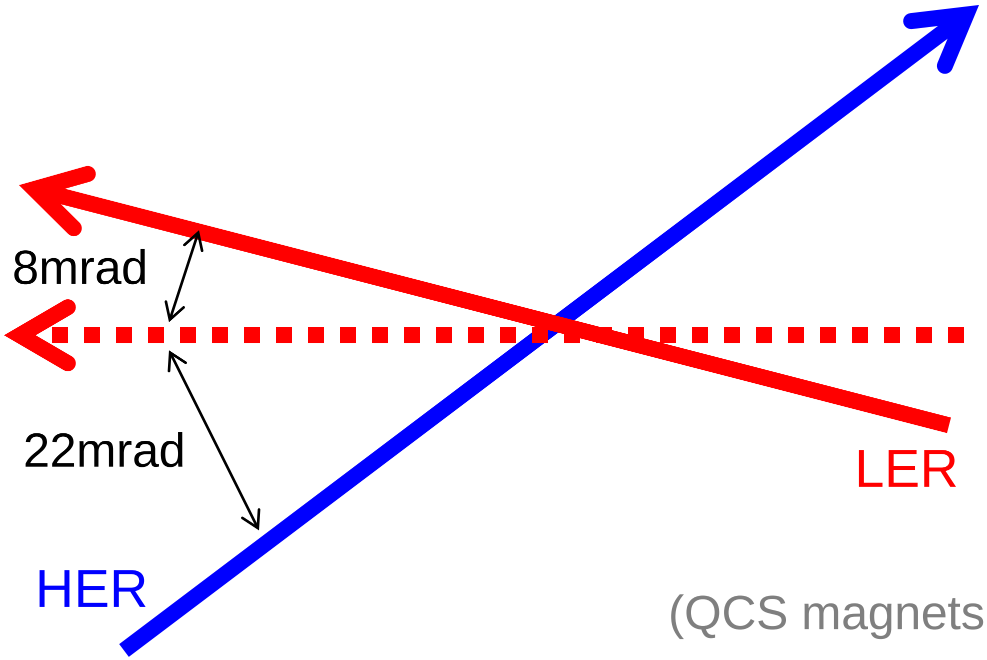
IR magnet layout



LoI

Relationship between s-Belle and Super-KEKB

In Super-KEKB, crossing angle will be increased : 22mrad → 30mrad



e^- KEKB / Super-KEKB
HER(e^-) axis will not change

e^+ KEKB, Belle solenoid
Belle solenoid will not change

e^+ Super KEKB
LER(e^+) axis will rotate by 8mrad

(QCS magnets will be set parallel to Belle solenoid)

Belle beam pipe (and SVD??) axis at Super-KEKB

- Belle solenoid
- Center of the LER and HER (7mrad from Belle solenoid)
- <u>HER axis (22mrad from Belle solenoid)</u>

Beam line simulation

Based on the following programs, we construct
the Super-KEKB beam-line simulation

- SAD

To get the geometry / element definition / Twiss parameters.
SAD file with dynamic beam-beam effect from Funakoshi-san
(Dynamic effect → 5 times higher ε, 10 times smaller β in x)

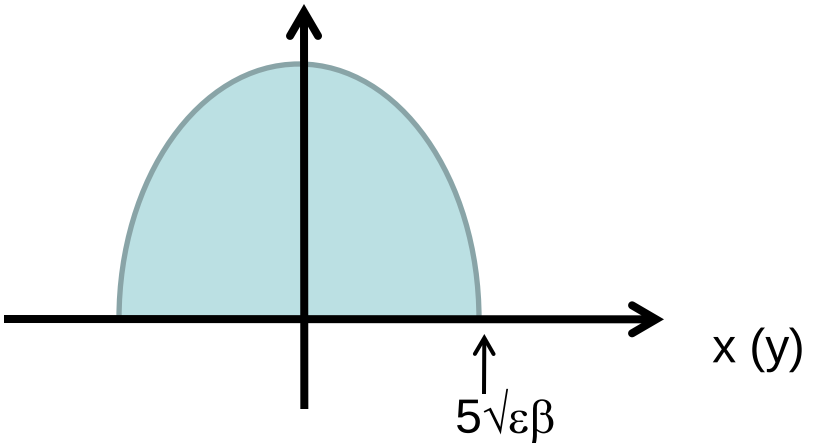
- LCBDS

Beam line simulation based on GEANT4
developed by K.Tanabe and T.Abe of U.Tokyo (for ILC/T2K)

At first, we just align the beam line components, beam pipe,
and 1^{st} layer SVD in the simulation

Beam line simulation setup

- Aperture of the Q-magnets ~ 5σ (= 5√εβ)
- Beam size 2.5σ (max = 5σ)
- Beam shape



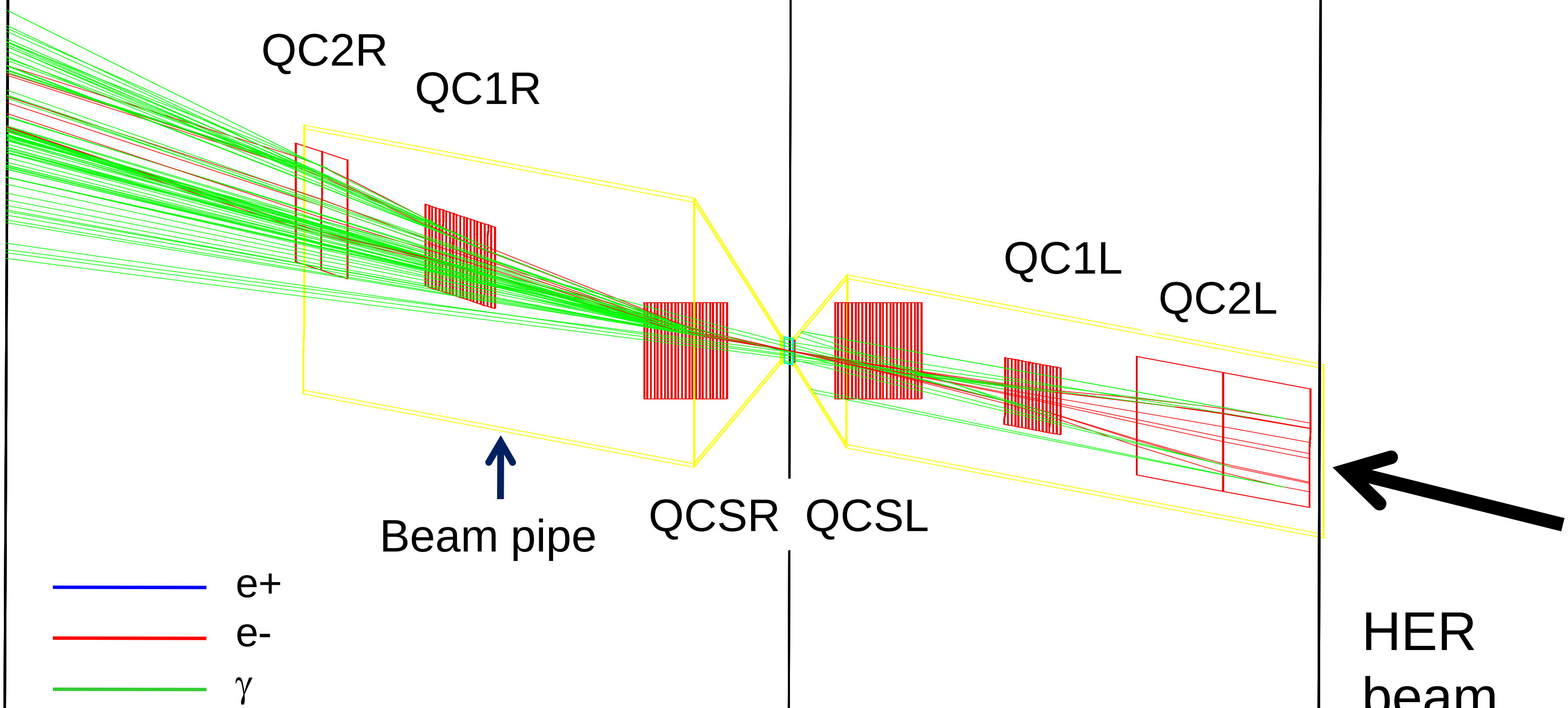
- The number of particles in a bunch

HER : 4.1A / (1.6*10^-19)/(100kHz)/5000 = 0.5 *10^{11}

LER : 9.4A / (1.6*10^-19)/(100kHz)/5000 = 1.2 *10^{11}

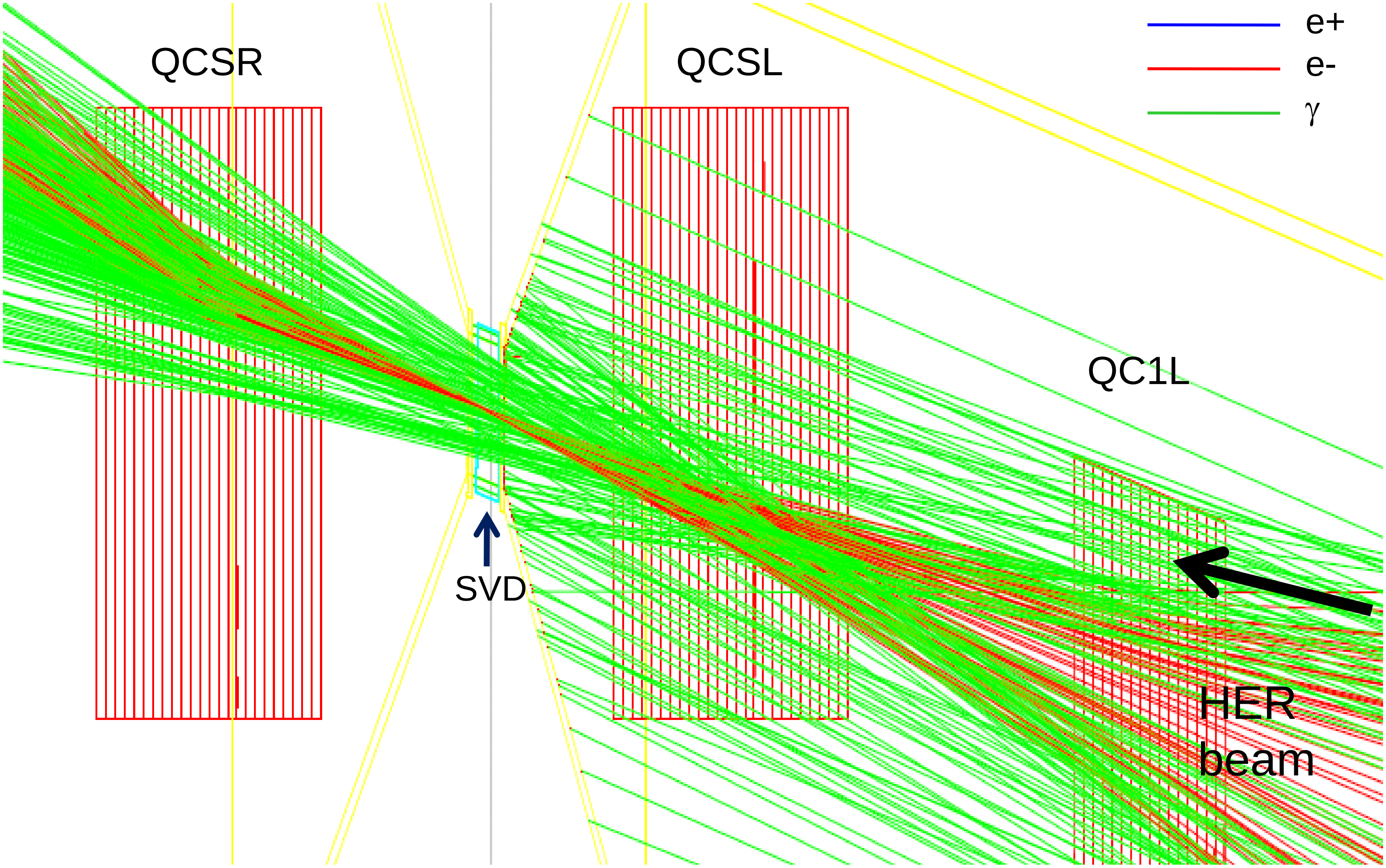
HER beam line simulation

HER simulation with LCBDS
5σ beam / physics process on



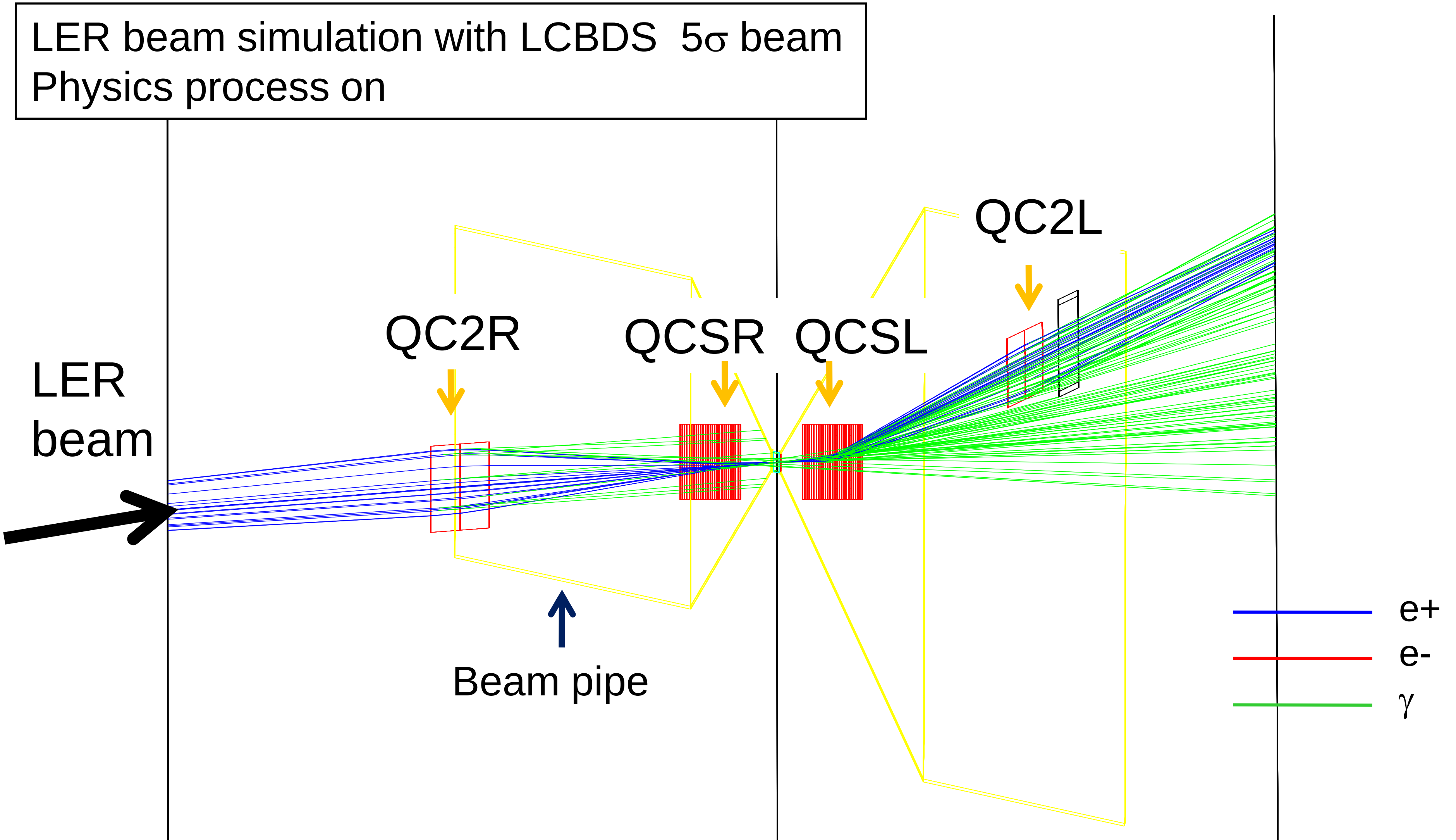
Beam pipe → parallel to HER

HER simulation



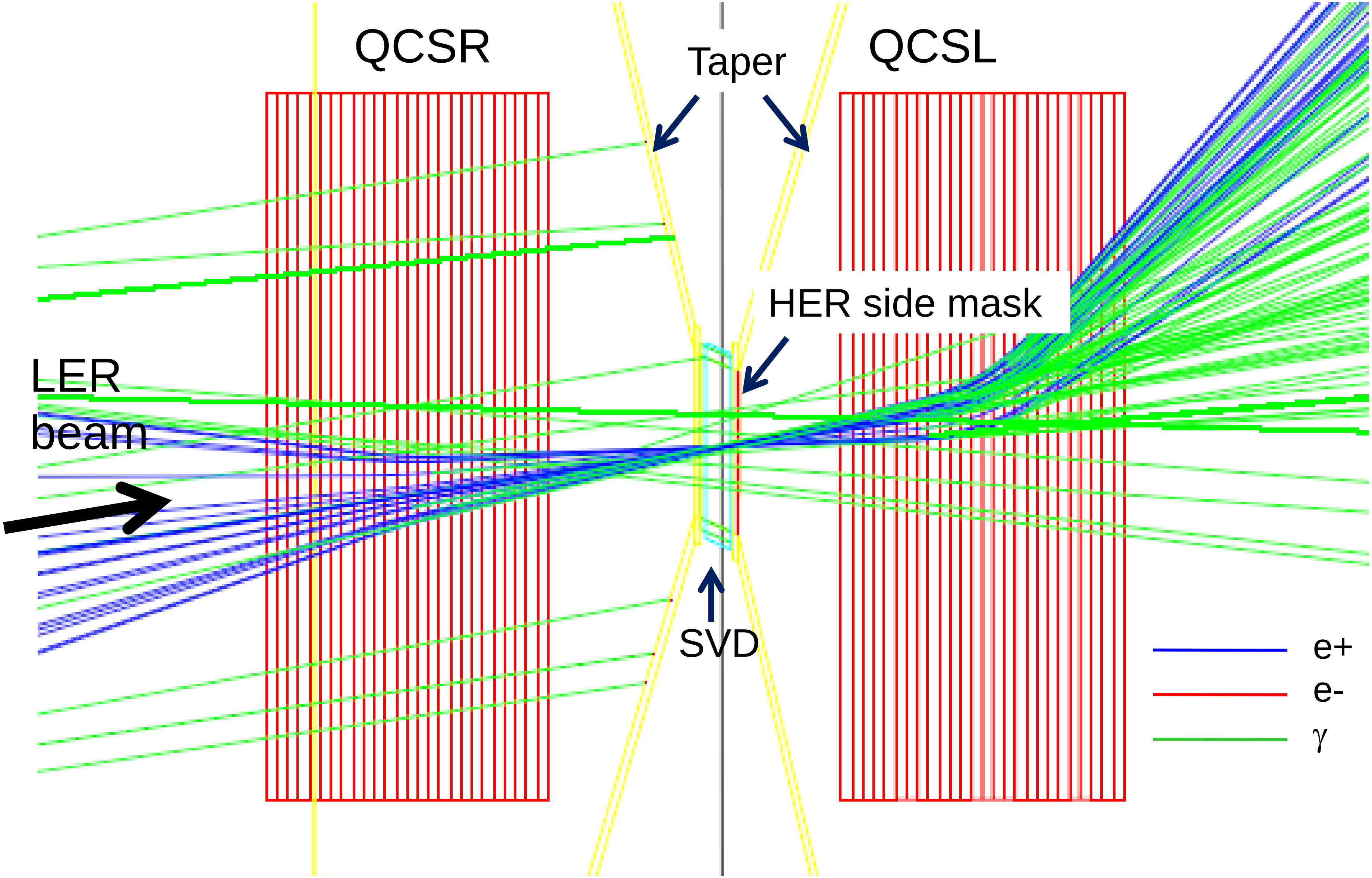
LER beam-line simulation

LER beam simulation with LCBDS 5σ beam
Physics process on



Beam pipe → parallel to HER (30 mrad from LER)

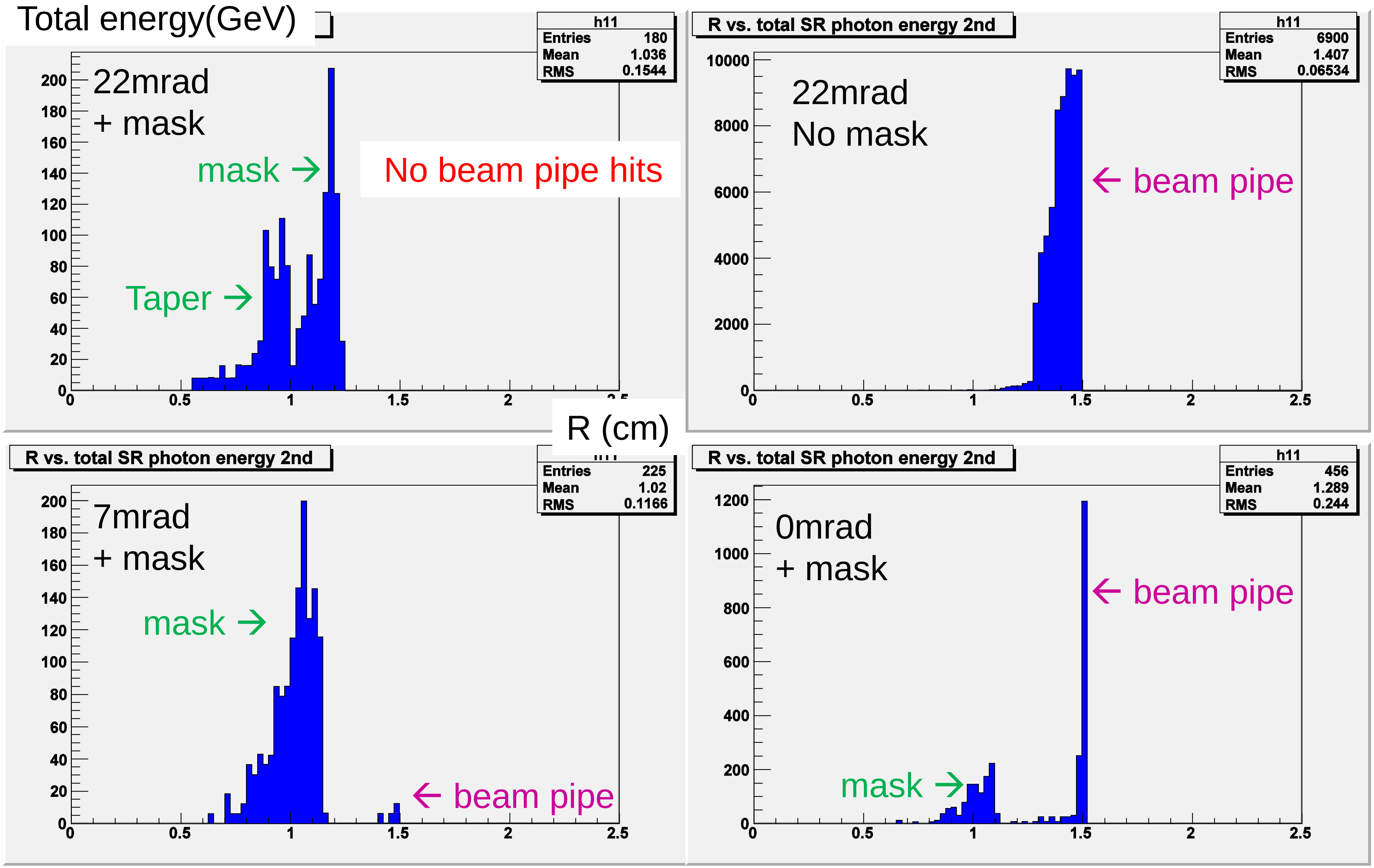
LER simulation



HER beam line simulation

2ndary particle production position @ IP

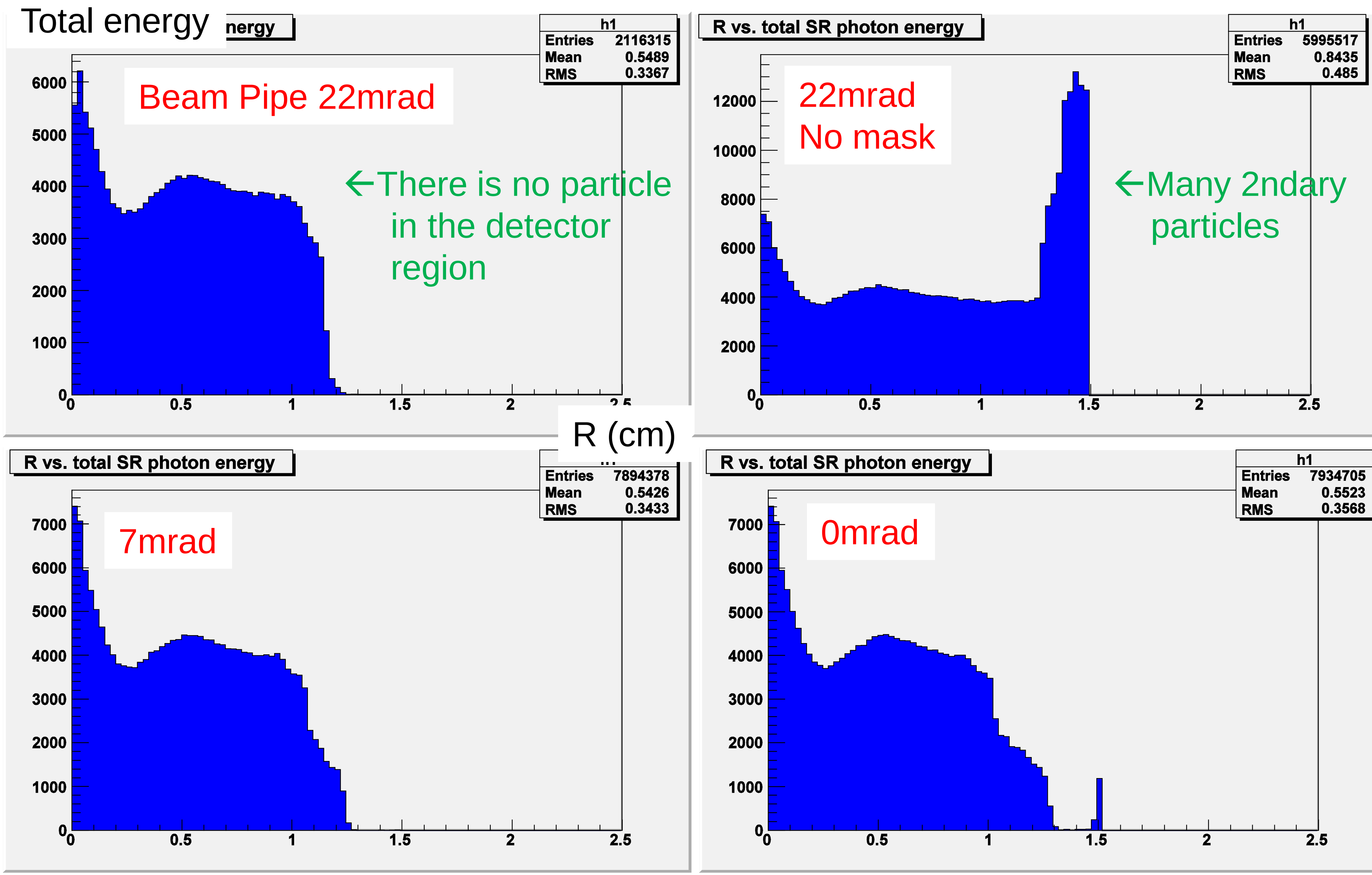
5σ beam



HER beamline simulation

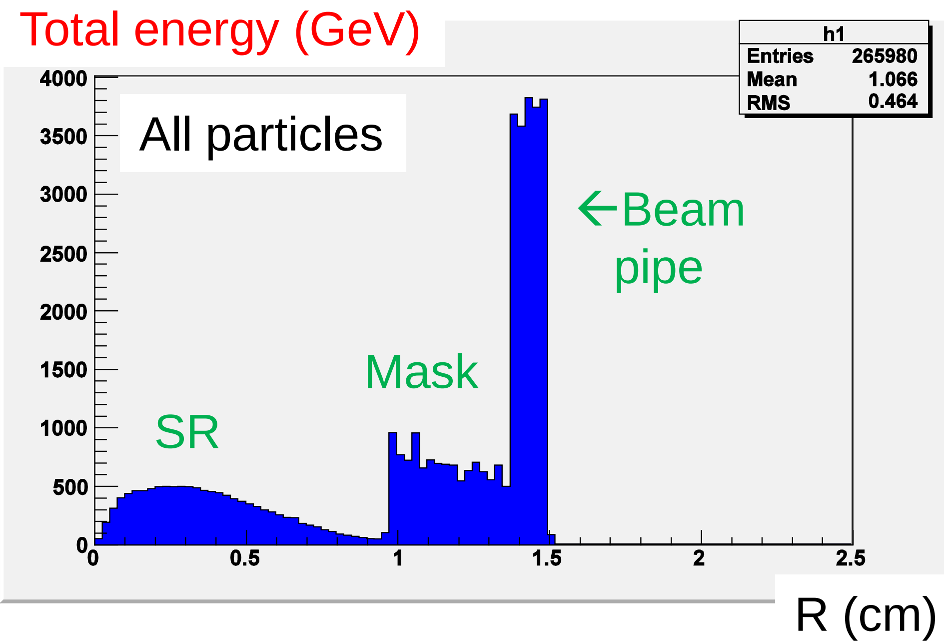
R vs total energy（E_{part} × #part）

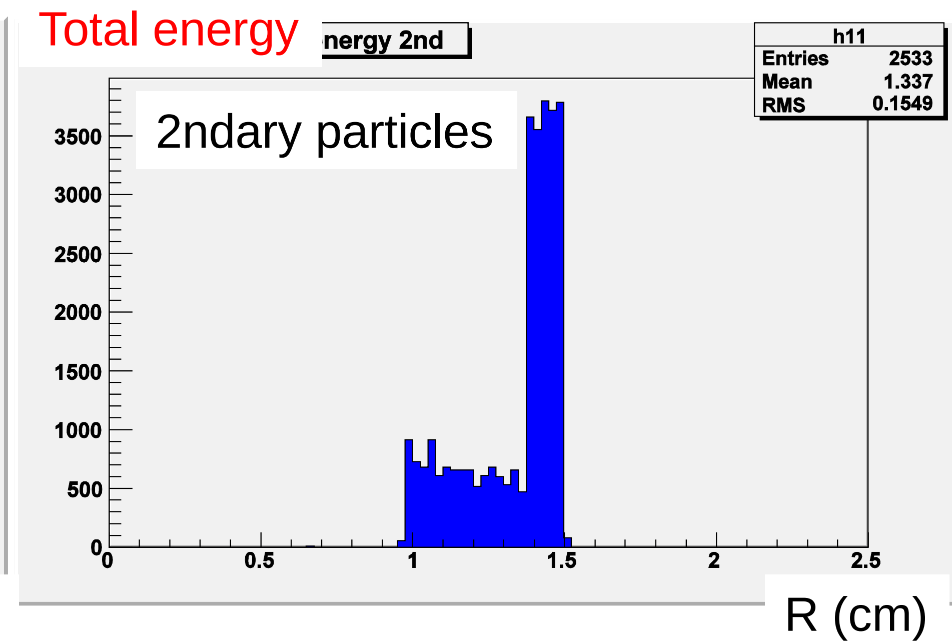
2.5σ beam



LER beamline simulation

Beam Pipe 22mrad ~5*10^6 event 2.5σ beam





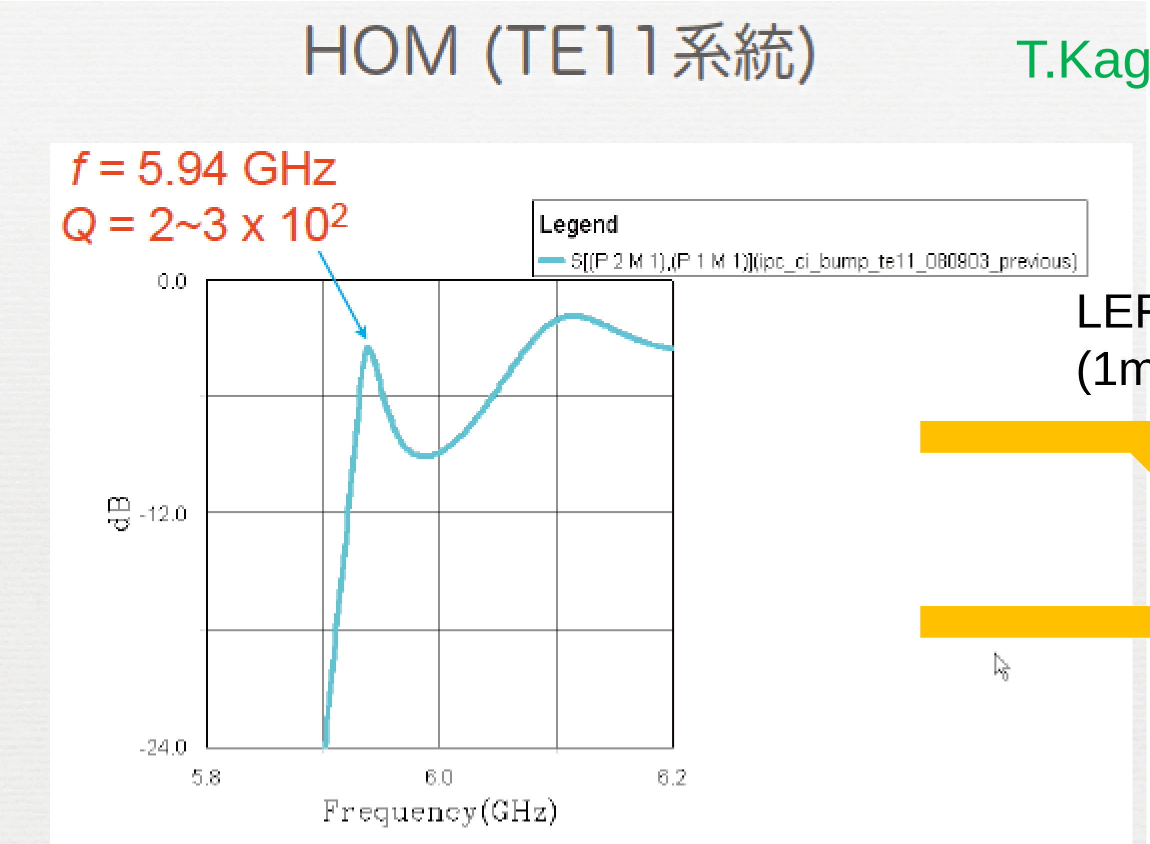
(Vertical Scale: Scaled for 1-bunch beam)

If we put the beam pipe parallel to HER,
there are many direct hits from SR from LER.

Even energy of LER SR is lower than HER SR,
we don't want to have direct hit, if possible.
→ Can we put a LER side mask???

Can we put a LER side mask? (1)

Higher Order Mode excitation of beam pipe

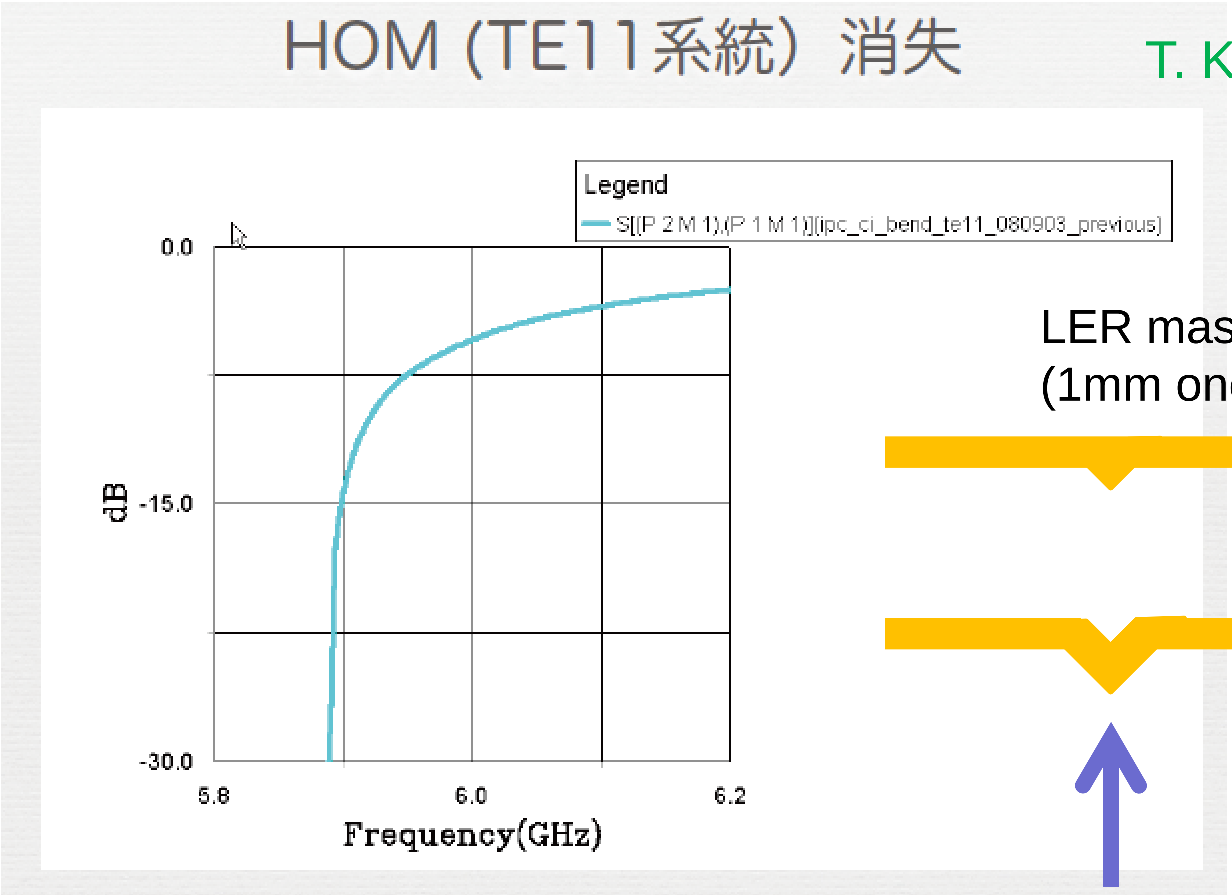


T.Kageyama

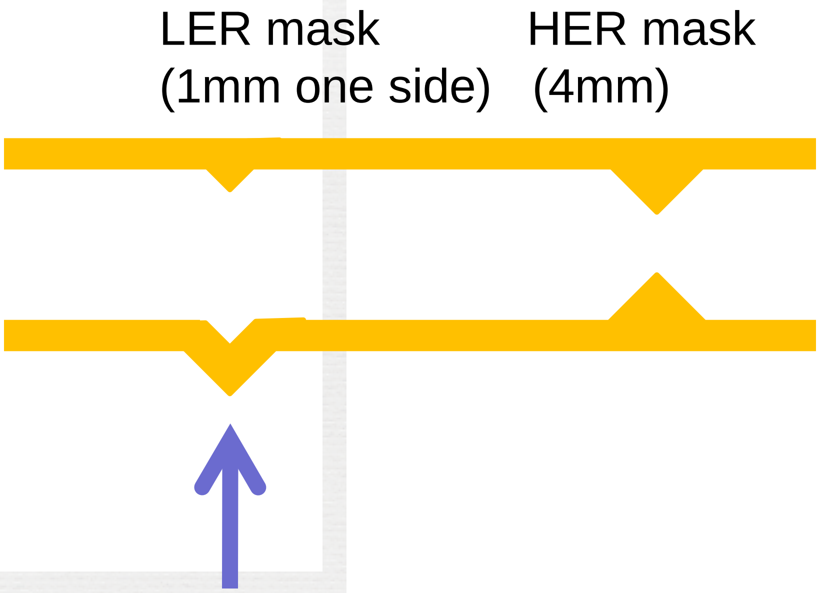
Even very tiny (and on-side) mask causes the HOM excitation

Can we put a LER side mask? (2)

Higher Order Mode excitation of beam pipe

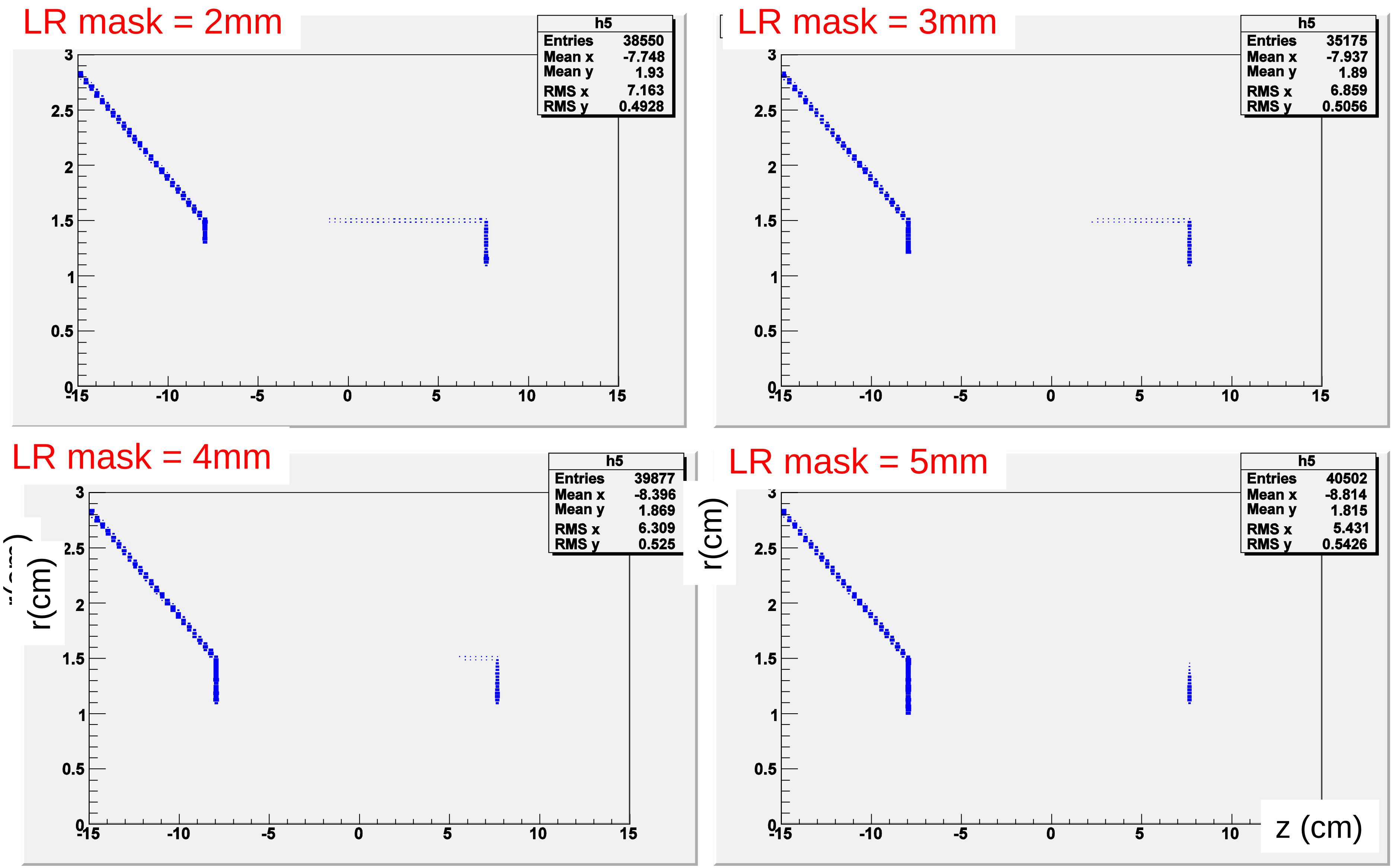


T. Kageyama



If we don’t change the diameter of beam pipe, we can put a mask

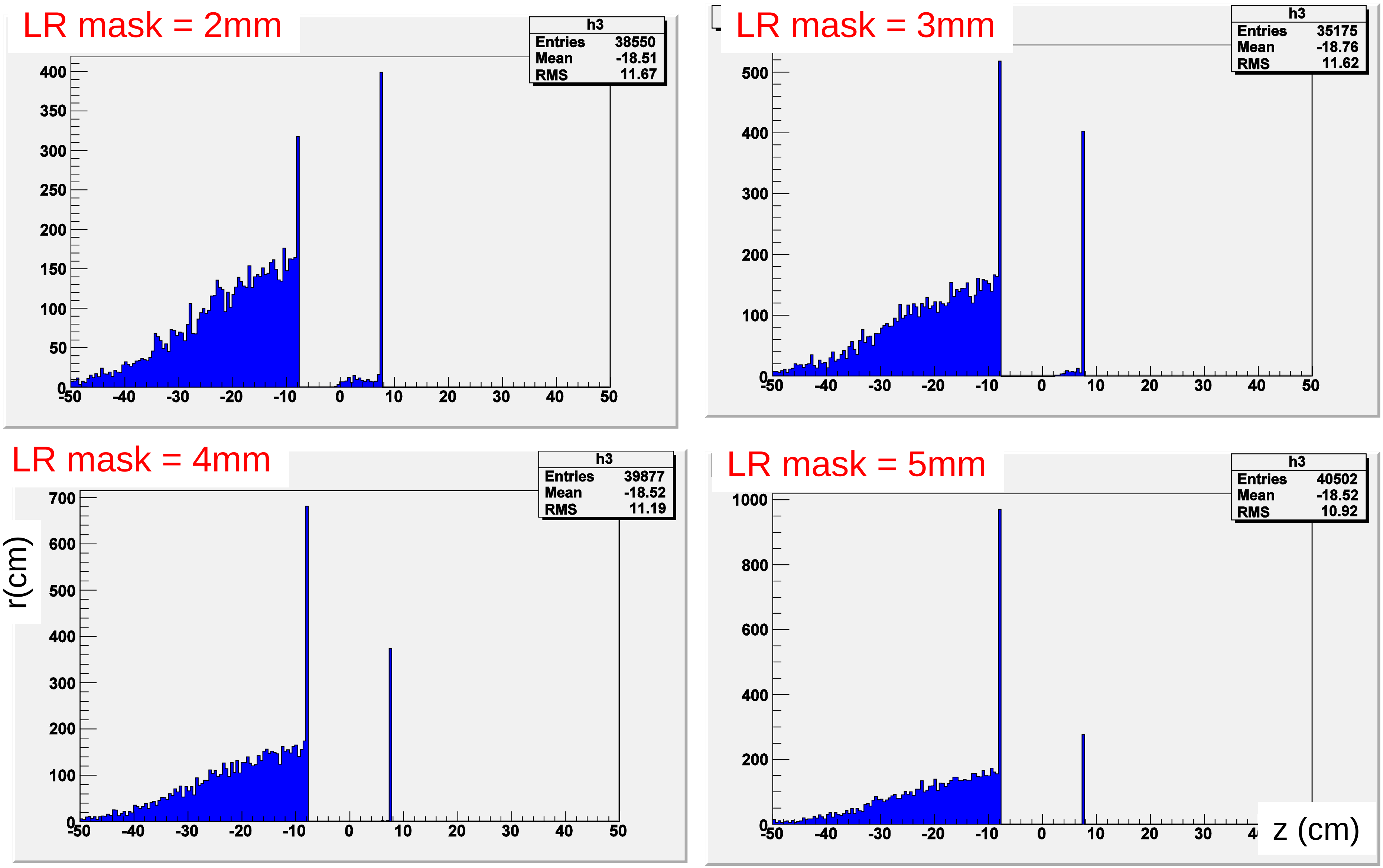
LER beamline simulation



We need 5mm LER-side mask to avoid the direct hit of LER SR

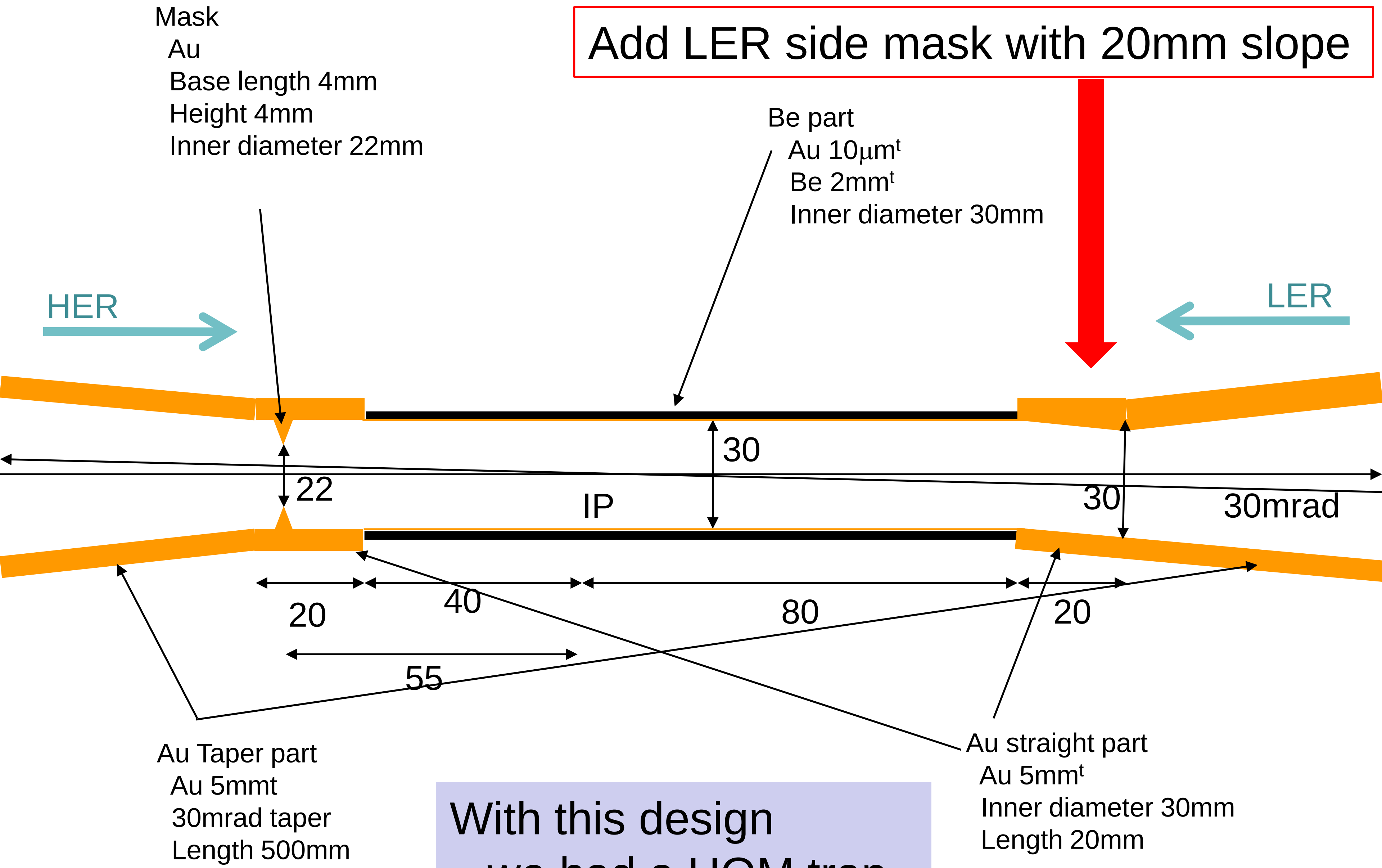
LER beamline simulation

E deposit vs z (all particles) (cm)



Beam pipe v2

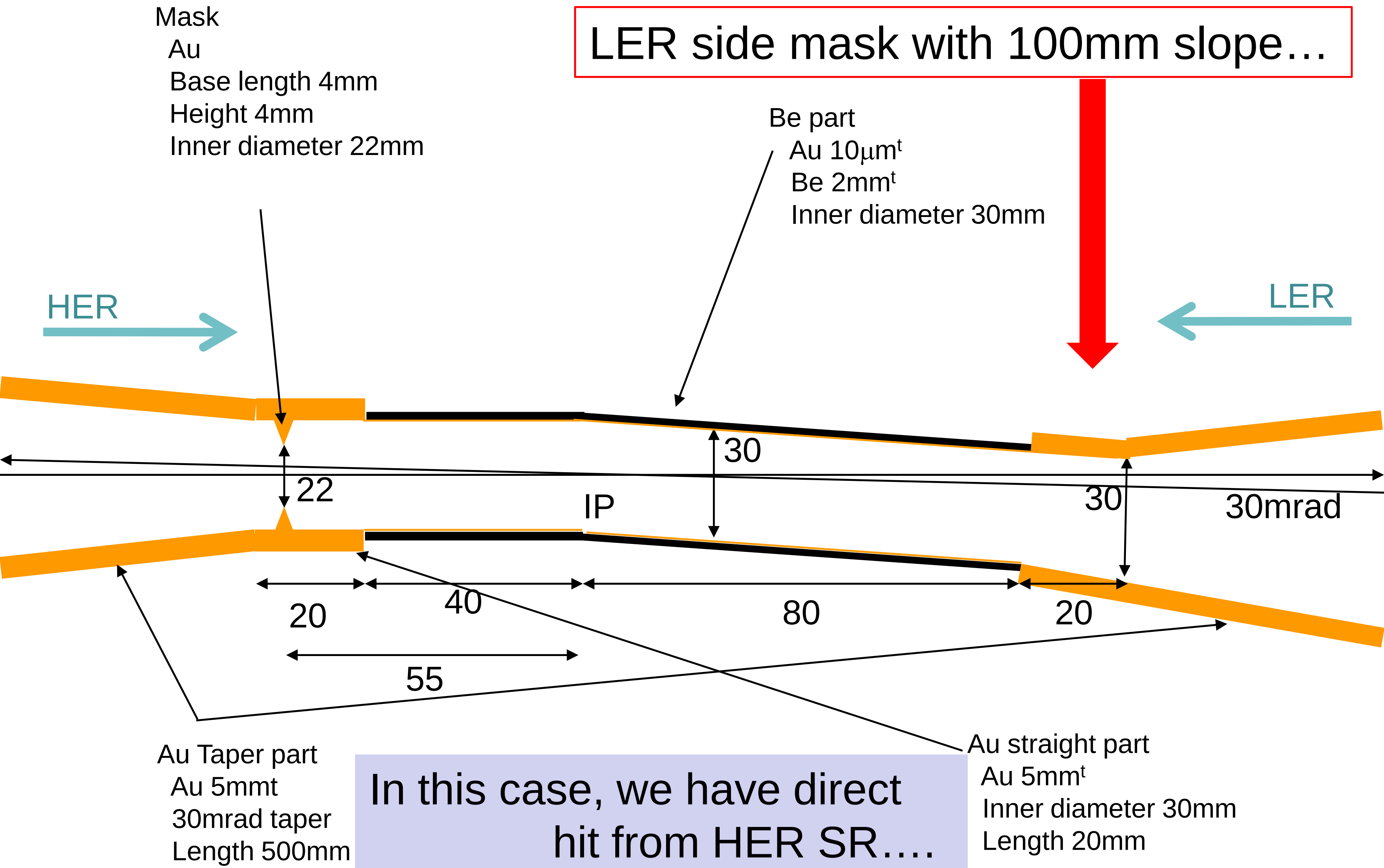
Add LER side mask with 20mm slope



With this design
we had a HOM trap..

Beam pipe v3??

LER side mask with 100mm slope…



In this case, we have direct hit from HER SR….

We must optimize the design

Dynamic beam-beam effect at Super-KEKB

The focusing force of the beam-beam interaction

- squeezes the beam at IR
- increases the emittance drastically

→ affects all around the ring … “dynamic beam-beam effect”

Dynamic effects at Super-KEKB is very strong

Beam optics is re-considered, and there is a big change in the IR magnet layout

We must re-estimate the beam BG with the new IR design

Dynamic beam-beam effect

Parameter search for smaller beam size

Y.Funakoshi

	no b-b	nominal			higher emittance			higher βx*			even higher βx*		
ν_{x0}		.503	.505	.510	.503	.505	.510	.503	.505	.510	.503	.505	.510
ε_{x0} [nm]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	12	12	12	12	12
β_{x0}^* [cm]	20	20	20	20	20	20	20	40	40	40	[illegible]	[illegible]	[illegible]
ξ_{x0}	0	.270	.270	.270	.135	.135	.135	.272	.272	.272	.273	.273	.273
ε_x [nm]		81.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	64.3	46.7	82.3	64.4	46.8
β_x^* [cm]		1.50	1.93	2.77	2.1	2.7	3.8	2.99	3.87	[illegible]	[illegible]	[illegible]	[illegible]
σ_x@QC2RE [mm]	4.0	39.5	30.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Emittance ε (wo dynamic effect)

β (wo dynamic effect)

ε (with dynamic effect)

β (with dynamic effect)

5 times higher ε, 10 times smaller β in x

Dynamic effect at Super-KEKB is very strong

Beam size @ IR Q-magnets

ν_x =.505
(): 5 σ_x

	QC1LE	QC2LE	QC1RE	QC2RE	QC2LP	QC2RP
β_x^*=20cm QC2RE:元	8.2 (41)	26.9 (134.5)	11.6 (58)	28.8 (144)	14.7 (73.5)	18.6 (93)
β_x^*=20cm QC2RE->IP	8.4 (42)	19.0 (95)	12.0 (60)	20.7 (103.5)		
β_x^*=40cm QC2RE-	5.9	13.4	8.5	14.6	9.8	12.3

		QC1LE	QC2LE	QC1RE	QC2RE	QC2LP	QC2RP
Field gradient	T/m	15.5	3.4	12.0	8.8	6.7	3.4
Pole length	m	0.64	2.0	0.75	0.8	0.6	1.0
b bore radius	mm	25	50	48	90	80	40
Current	AT	3920	3400	11050	28400	17100	1980
coil turns	/pole	3	8	3	16	15	3
Current density of Septum conductor	A/mm^2	30	10	70	24	31	15
Field in the area for couter-circulating beam	Gauss	0∼-0.65	0∼-0.4	0∼-1.1	0∼-0.35	0∼-0.85	0∼-0.35

Table 3.3: Parameters of special quadrupole magnets

We set the aperture of QC1, QC2 and QCS to be 15cm