『JLC加速器R＆D報告会』

Beam Delivery System

2000年4月26日
JLC-FFIR グループ，田内利明
http://acfahep.kek.jp/member/subg/ir.html for the members

0. FFIR issues to be studied (JLC-DS,1997).

1. Collimation System

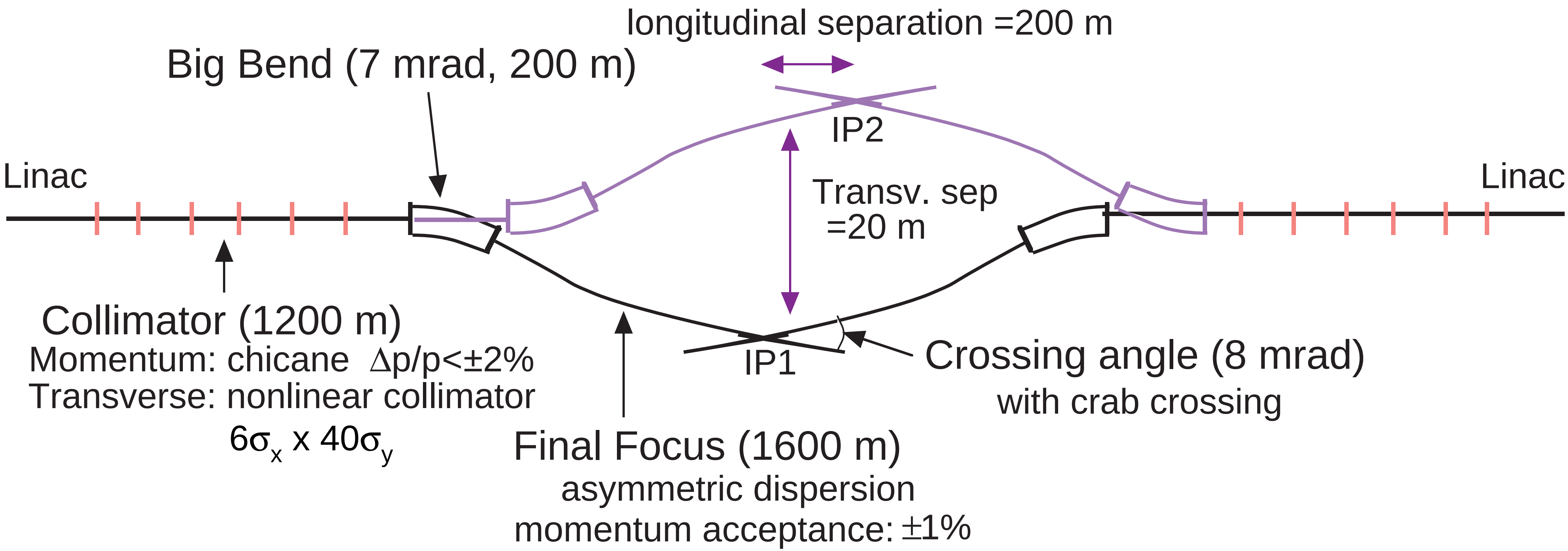
2. Final Focus System

3. Interaction Region
QC1, Background, Instruments etc.

4. Dump Line

5. Future Plan

Contents



JLC: Beam Delivery System

Probability of tail; gas scattering

$$\sigma_{el}(\theta > \theta_o) = 4\frac{\pi Z^2 r_e^2}{\gamma^2}\frac{1}{\theta_o^2}$$

tail (= beam halo) outside of $6\sigma_x \times 40\sigma_y$

$$\theta_o = n\sqrt{\frac{\varepsilon}{\beta}}$$

$$P_{tail} = N_{gas}\frac{4\pi Z^2 r_e^2}{\gamma^2 n^2}\frac{1}{\varepsilon}\int \beta ds$$

$N_{gas} = 3.6\times 10^{22} P(\text{torr}),\ Z(\text{CO}) = 14,\ r_e = 2.8\times 10^{-15}\text{m}$

$\gamma\varepsilon_y = 3\times 10^{-8}\text{mrad},\ \gamma = 0.25\times 10^6\ (E_{beam} = 250\text{GeV})$

$$P_{tail}^y = 0.01\times P_{tail}^x = 0.08P\frac{1}{n_{y(x)}^2}\int \beta_{y(x)} ds$$

Assuming $P = 10^{-8}$ torr and $n_x = 6, n_y = 40$,

(1) Pre-linac Collimation

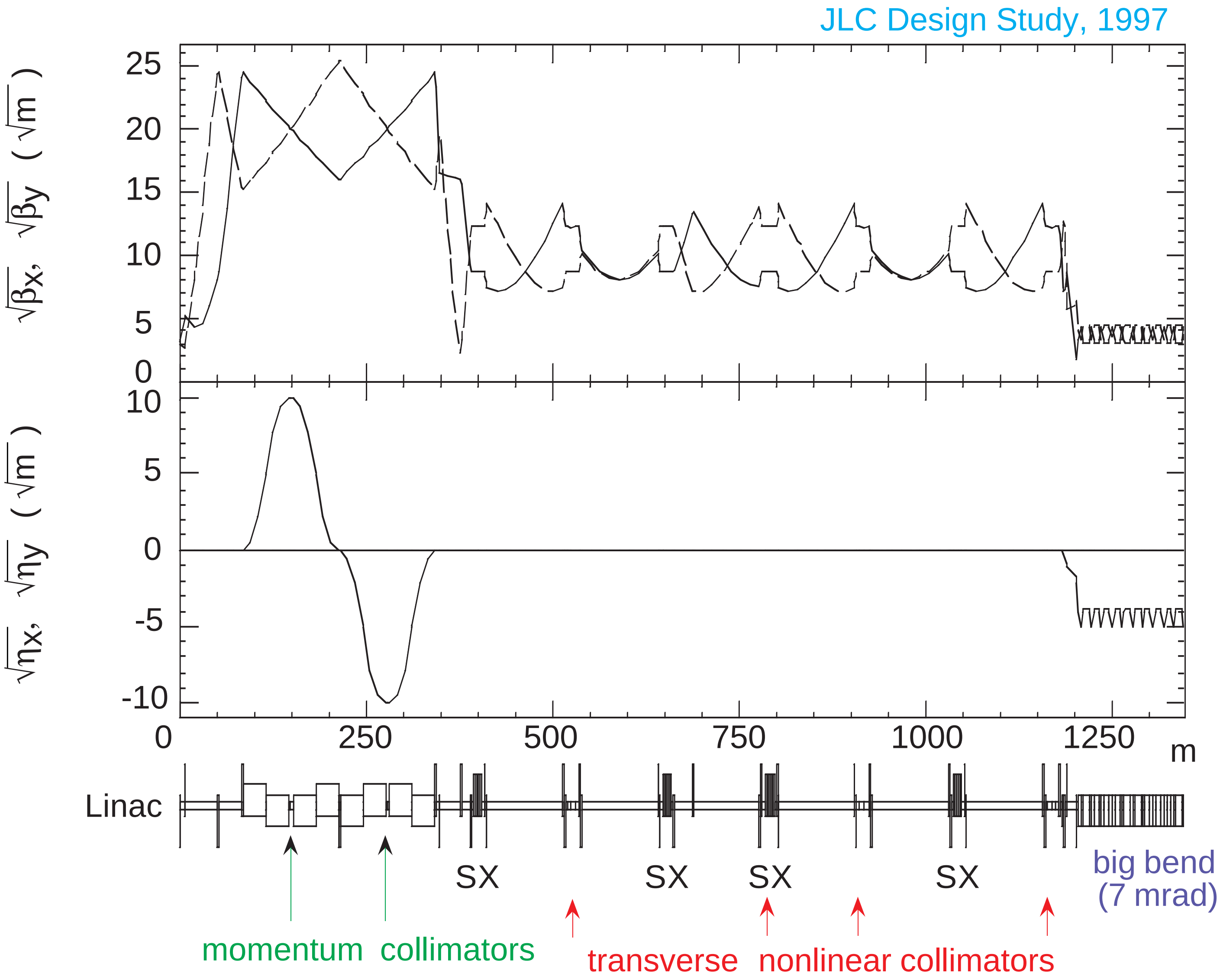
$s = 11500\text{m},\ \ \beta_x = \beta_y = 100\text{m}$

$P_{tail}^y = 5\times 10^{-7}, P_{tail}^x = 2\times 10^{-7}$

(2) Post-linac Collimation

$\int \beta_{y(x)} ds = 2.6\times 10^7 (1.6\times 10^6)\text{m},\ s_{FF} = 588.4\text{m}$

$P_{tail}^y = 1.3\times 10^{-5}, P_{tail}^x = 3.6\times 10^{-7}$



Location of bending magets and collimators

element	s from IP (m)	function
bend1	90	-3.28 mrad
bend2	1600	7 mrad
COLLI1.8	1840.3	x', y' second colli.
COLLI1.7	1966.7	x', y' first colli.
COLLI1.6	2093.1	x, y second colli.
COLLI1.5	2219.5	x, y' first colli.
COLLI1.4	2357.4	momentum second colli.
COLLI1.3	2483.9	momentum first colli.
COLLI1.2	2725.4	(in the linac)
COLLI1	2855.6	(in the linac)

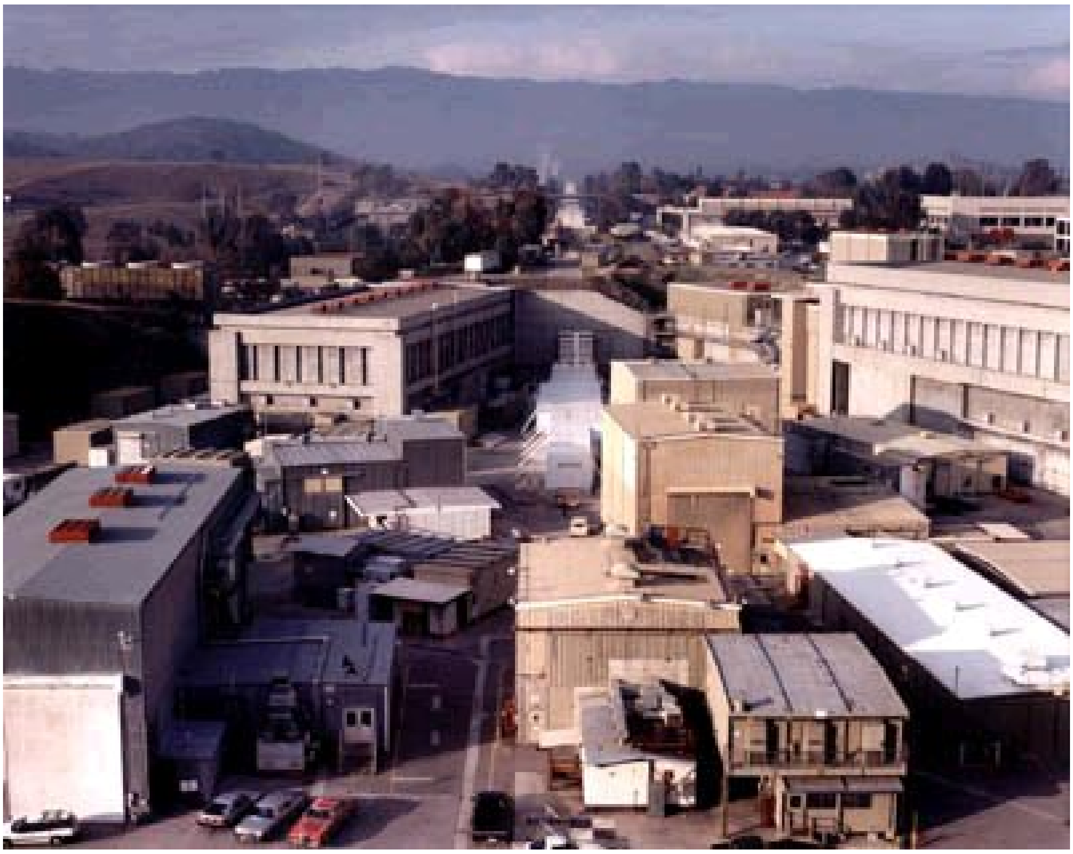
NLC

FFTB

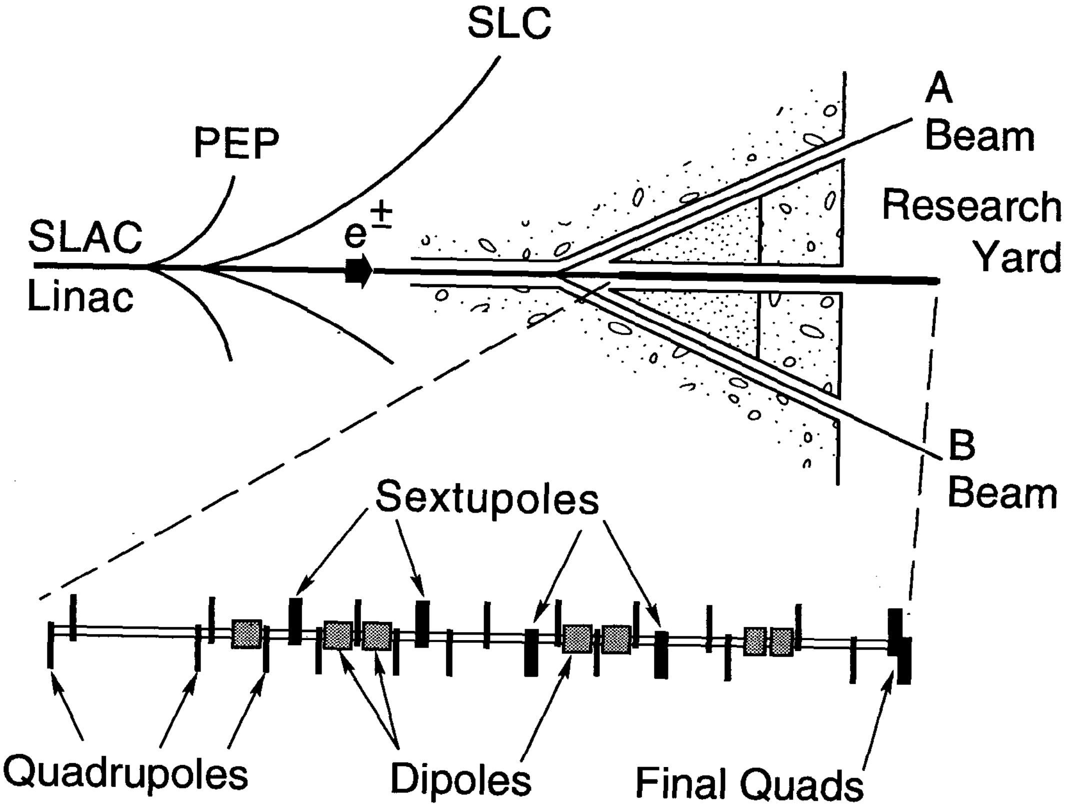
Collaboration
Components
Concepts
Detectors
Test Facilities
NLC Technical
NLC Home
Virtual Tours
Other HEP Labs
US DOE HEP

Construction of the Final Focus Test Beam (FFTB) facility was finished in 1993 and includes magnets and other beam elements constructed in Russia, Japan, France, and Germany, as well as the United States.

The purpose of this test facility is to investigate the factors that limit the size and stability of the beam at the collision point of a linear collider. Since the rate of collisions depends on beam density, the ability to focus the beam to a tiny size at the collision point (also called the interaction point or IR) is one of the critical parameters that will determine the research capability of a facility, such as the NLC.

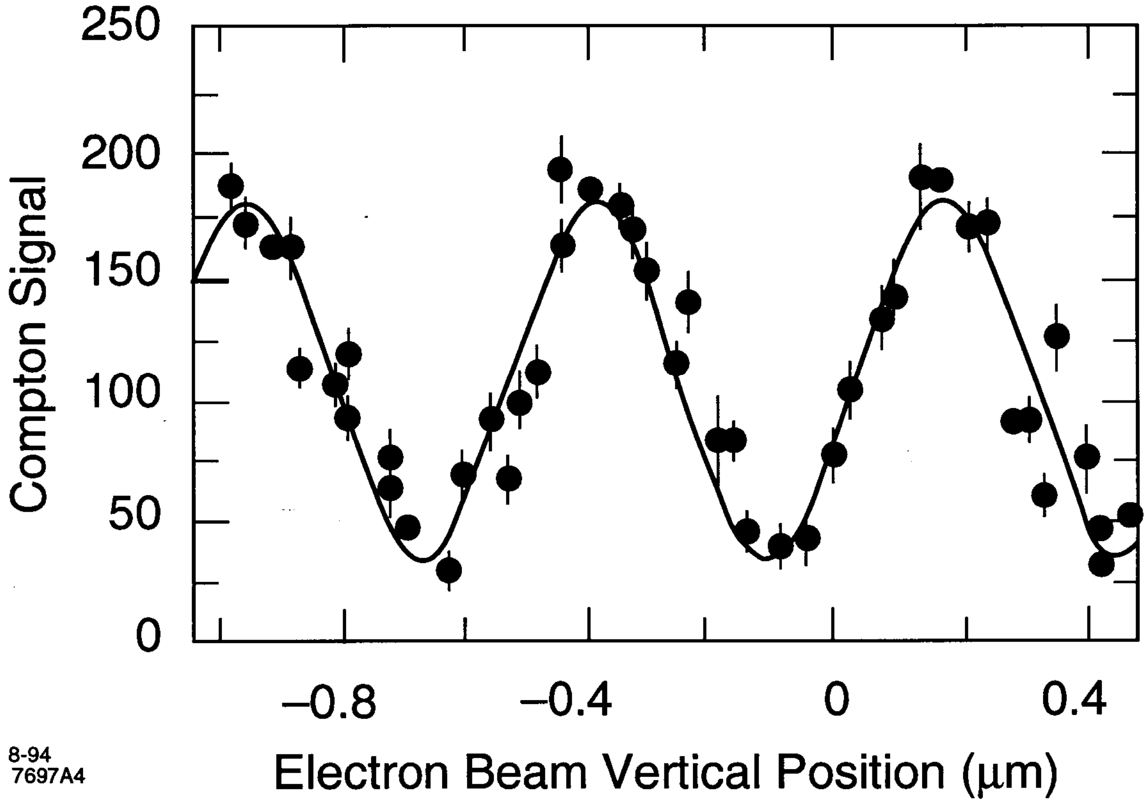


The FFTB facility is a straight-ahead extension of the



8-90 Final Focus Test Beam 6700A2

Fig. 1



250
200
150
100
50
0
Compton Signal
−0.8
−0.4
0
0.4
Electron Beam Vertical Position (μm)
8-94
7697A4

Fig. 2

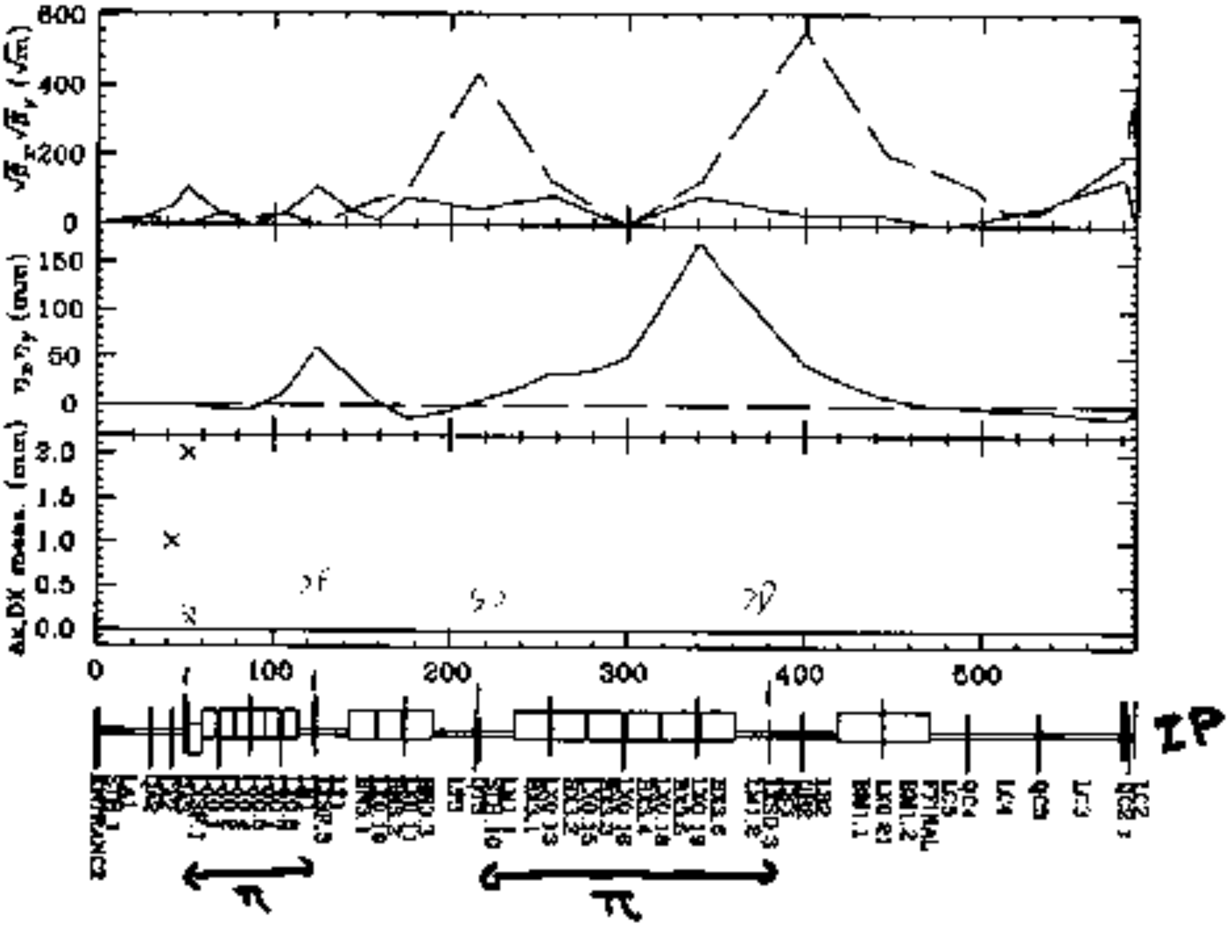


図 1: JP27 optics for T-JLC by K. Oide

k_2 2.54 SF

-0.88 SD

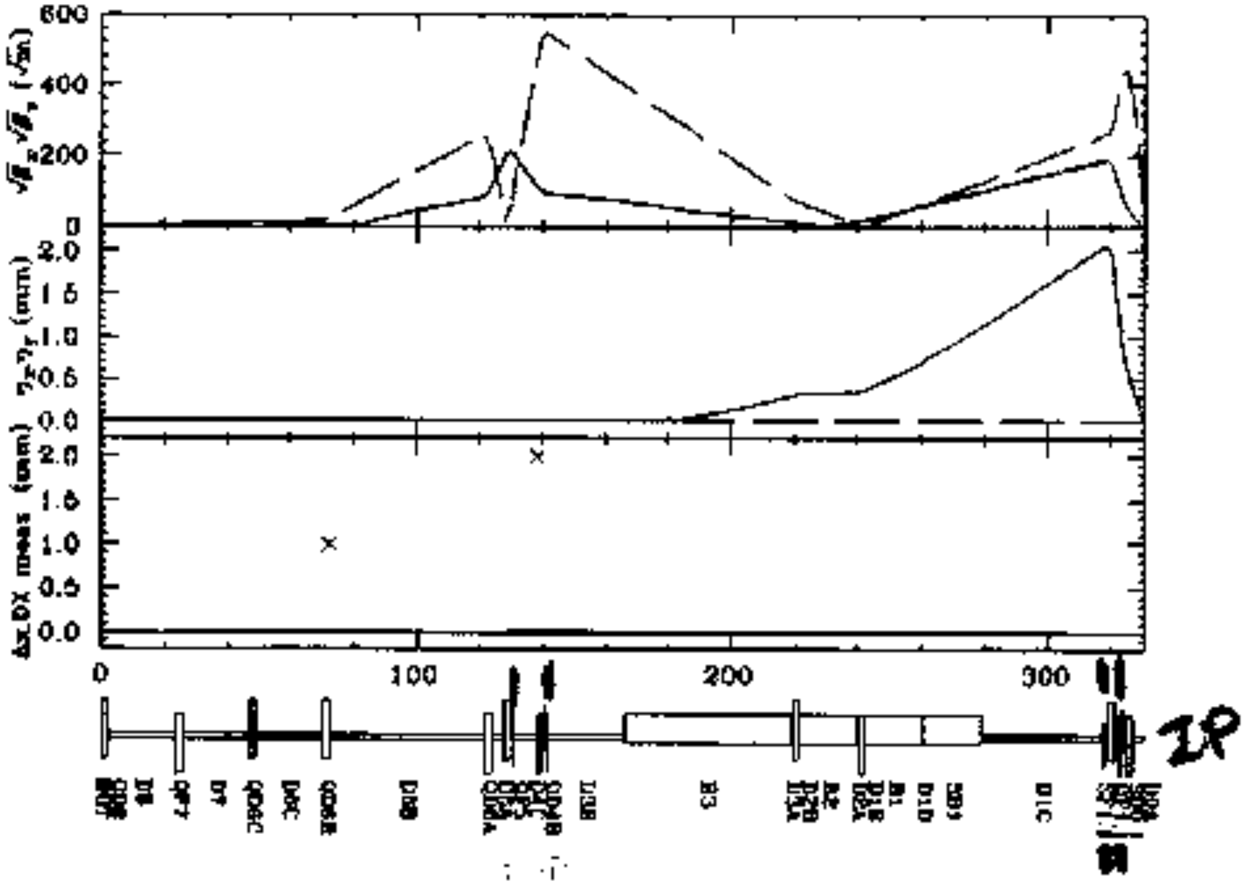
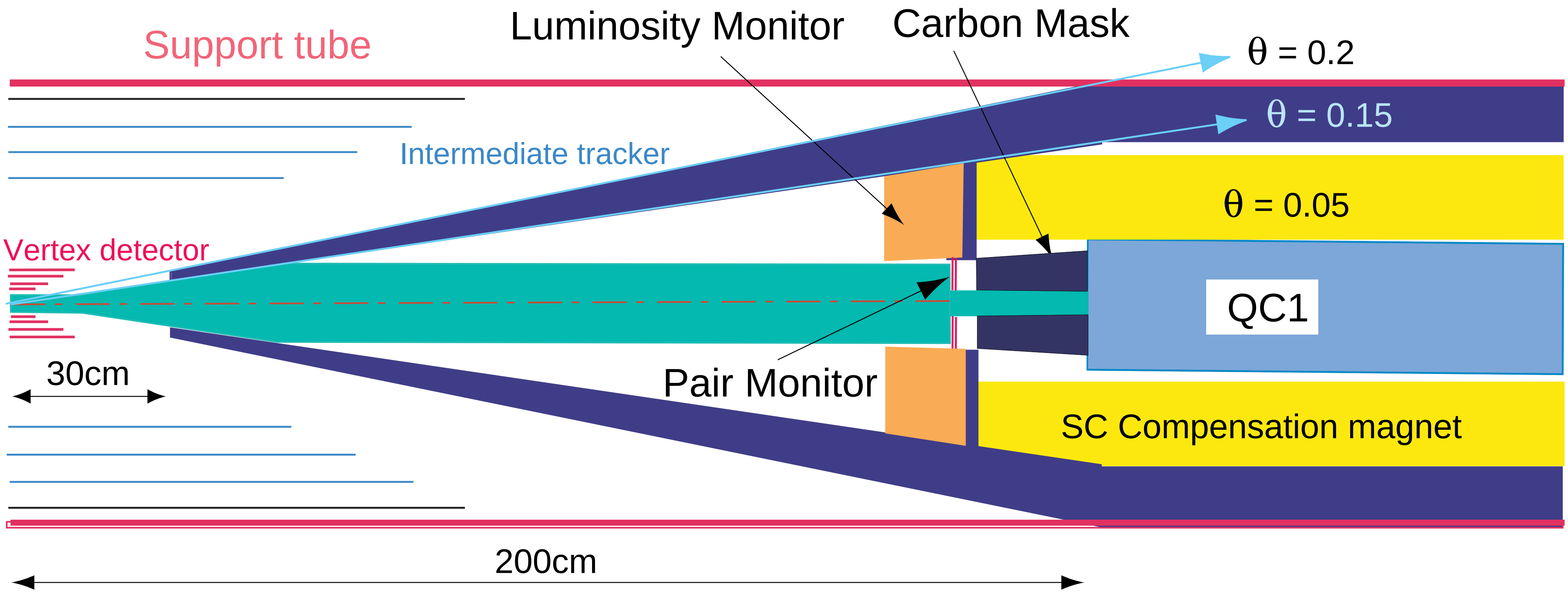


図 2: Ir[redacted]m optics by Pantaleo

2m
TL
TC

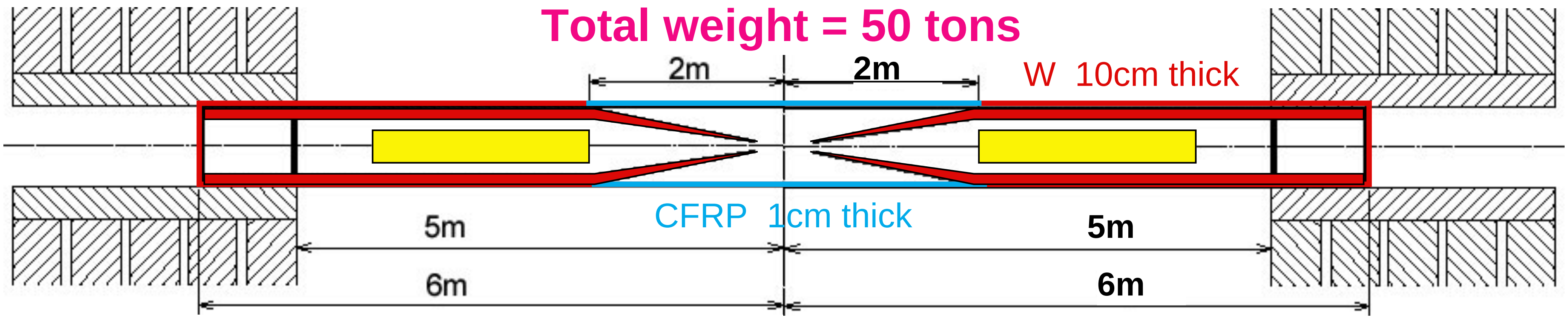
K2 @ SDO ~330



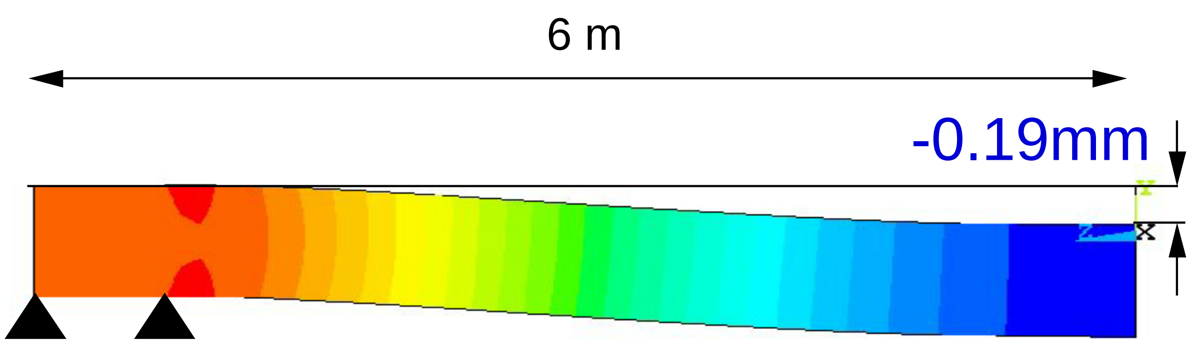
Support tube
Luminosity Monitor
Carbon Mask
θ = 0.2
θ = 0.15
Intermediate tracker
θ = 0.05
Vertex detector
QC1
30cm
Pair Monitor
SC Compensation magnet
200cm

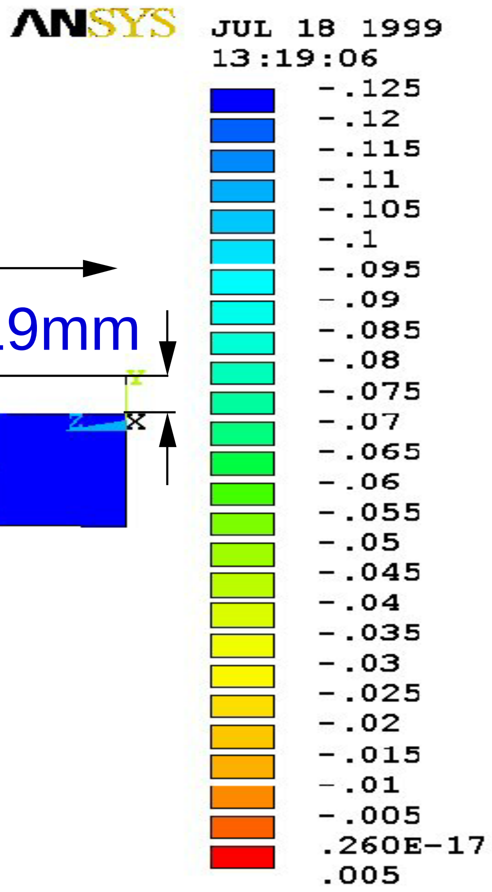
H.Yamaoka, 2nd ACFA-LC, Seoul, Nov.,1999

Support Tube **(80cmϕ x 12m)** Analysis by ANSYS



Result; Gravitational Sag





Backgrounds

(1) Muons

10^7 muons/trains at the collimators
Assuming 0.1% flat beam-tail, 10^{-3}(tail) x 10^{10}(beam)x10^2(bunch)=10^9electrons/train would hit the collimators.
Tolerance: One muon in 16x16x16m^3 at IP

(2) Synchrotron radiations in FF-system.
collimation is important: 6 σ_x x 40 σ_y

(3) e^+e^- pairs created in collisions

number of pairs	25,000 / bunch
average energy	4 GeV ($E_e > 3$MeV)
total energy	100 TeV / bunch

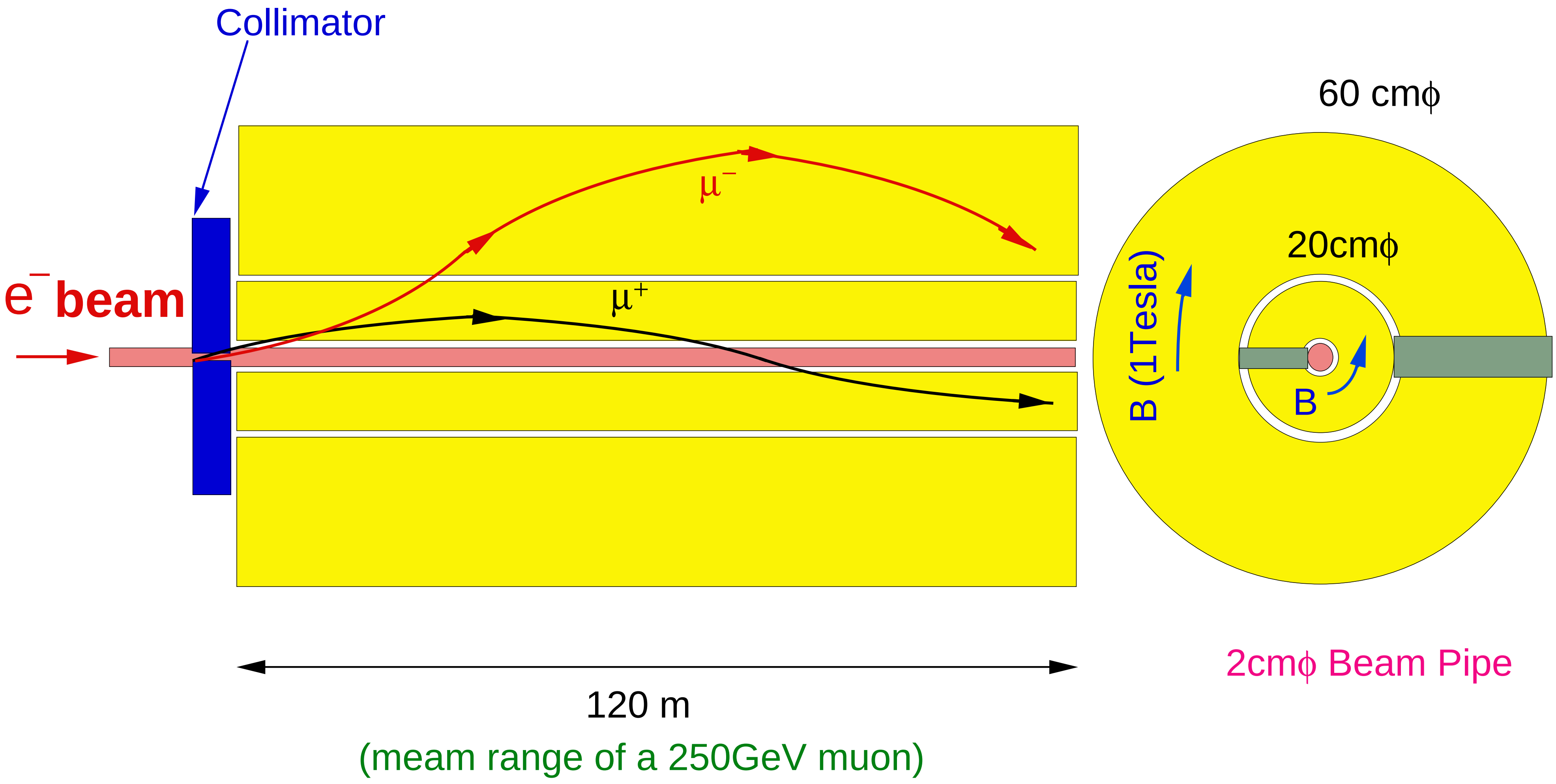
signals for pair monitor for E_e = 300 ~ 500MeV

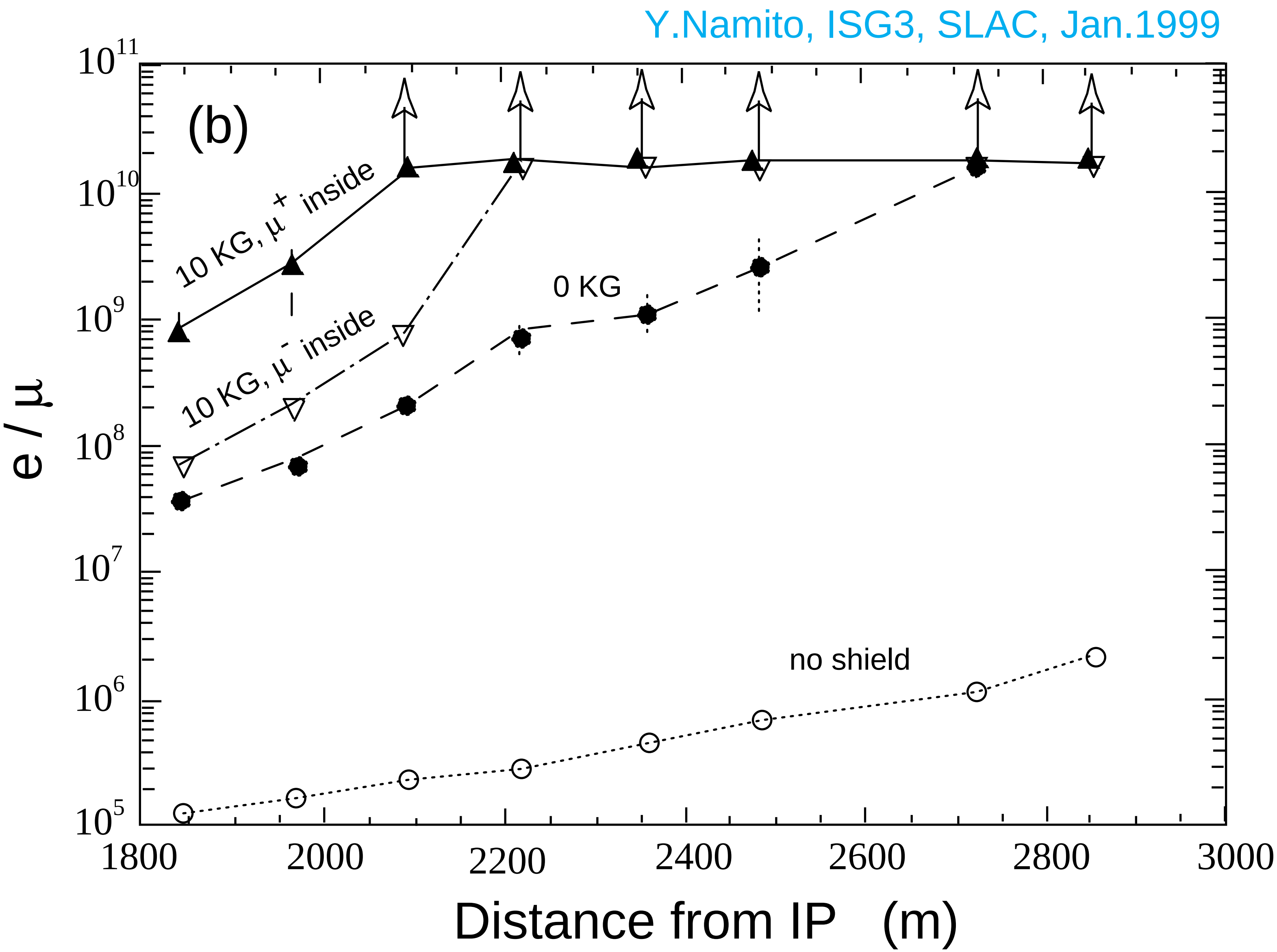
(4)neutrons (1 neutron/100MeV)

pairs at QC1 and masks	~30 TeV / bunch
	$3\text{x}10^5$neutrons / bunch
beamstrahlung photons	340 kW (4%x2)
	$2\text{x}10^{16}$ neutrons / sec

disrupted beam in dump line

Muon Attenuator





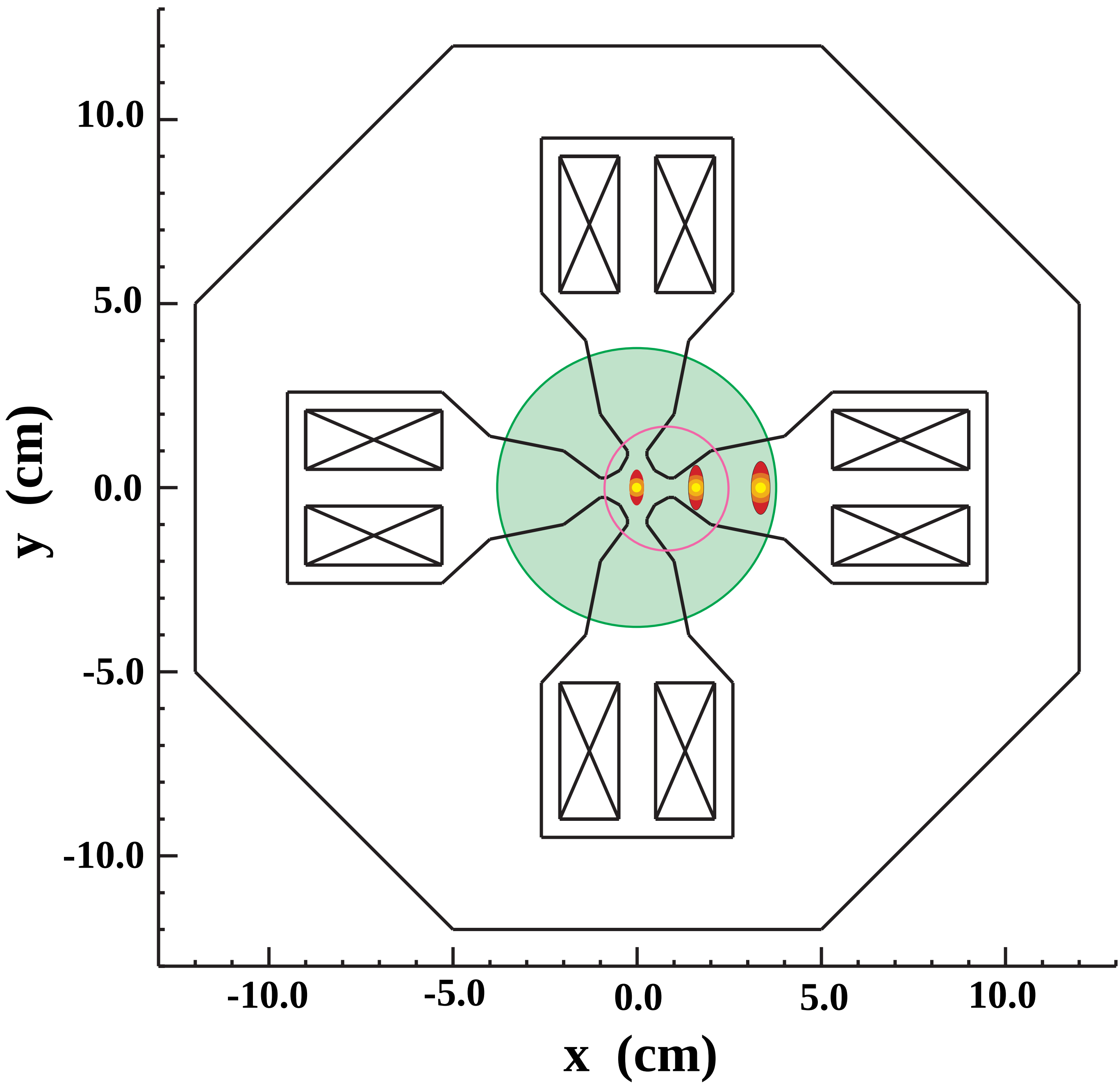
Y.Namito, ISG3, SLAC, Jan.1999
(b)
10 KG, μ+ inside
10 KG, μ- inside
0 KG
no shield
e / μ
Distance from IP (m)
10^11
10^10
10^9
10^8
10^7
10^6
10^5
1800
2000
2200
2400
2600
2800
3000

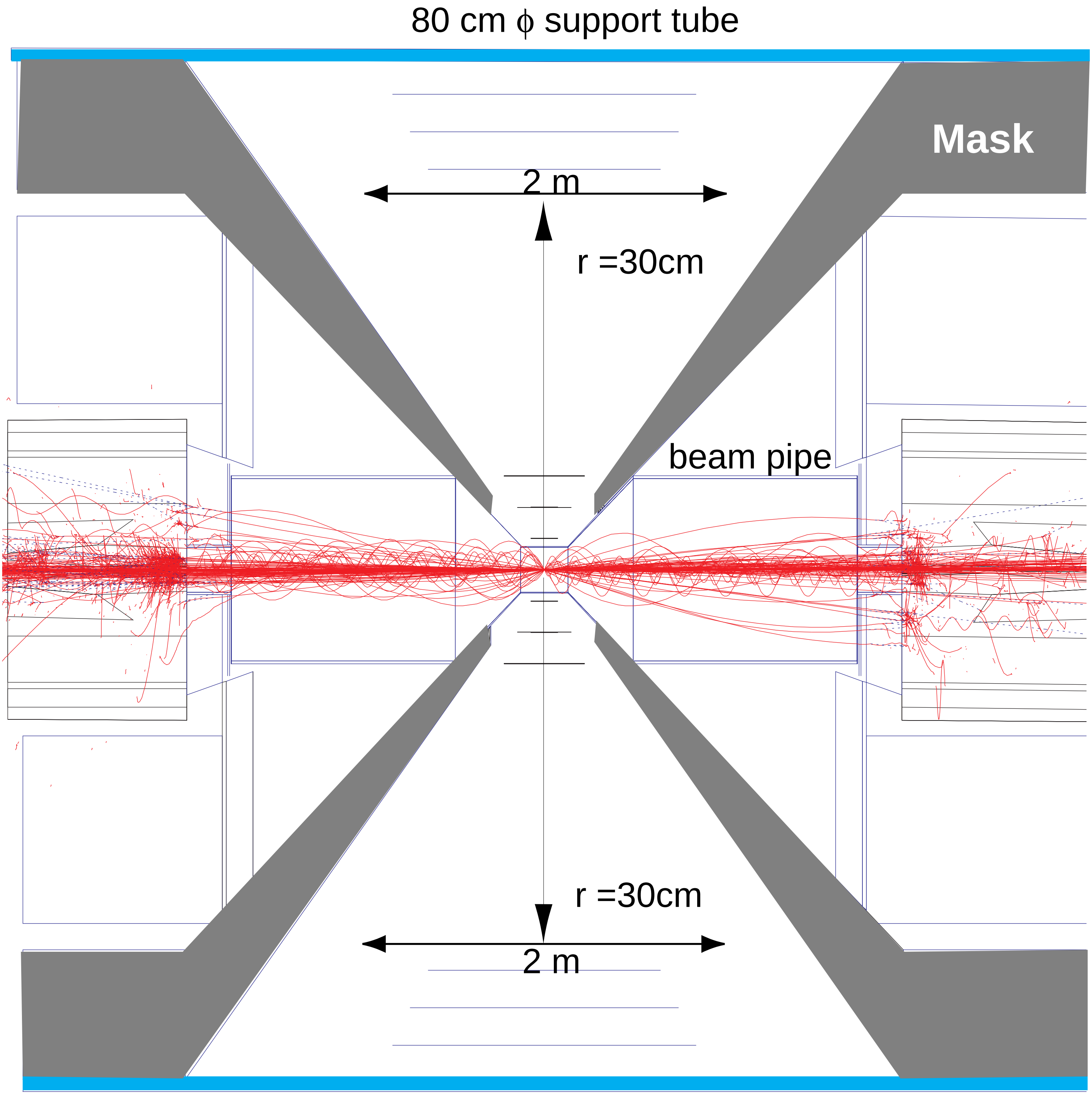
JLC Design Study, April,1997

QC1 and Synchrotron Radiation

note: 9cmϕ aperture for super conducting QC1, Jan.2000

note: 4cmϕ beam pipe just in front of QC1





1/100 bunch and E_γ>100MeV, E_e>10MeV for display purpose

JIM simulation for E_γ>10keV, E_e>200keV

Background tolerance

(1) CDC 10 % occupancy / train

r_{min} \ B	2 tesla	3 tesla
2.5 cm hit#/train	△ 1.2 k (2.4 k)	◎ 0.12 k (0.37 k)
1.8 cm		○ 0.72 k
1.5 cm hit#/train	× 4.2 k	× 2.6 k

(2) VTX 1hit / mm^2 / train

r_{min} \ B	2 tesla	3 tesla
2.5 cm hit#/mm^2/train	○ △ 0.9 (2.8)	◎ 0.4 (1.0)
1.8 cm		△ 1.6
1.5 cm hit#/mm^2/train	× 4.3	× 3.6

Values in ( ) are those of JLC-Y (high luminosity).

4,3 and 2cmϕ beam pipes for r_{min}=2.5,1.8 and 1.5 cm, respectively.

A.Miyamoto, LC99, Oct.,1999

Summary of Neutron Background in VTX

			Neutron yield at IP(/cm^2 /year)
e^+e^-:	Old (GEANT)		$3x10^7$
	New(Fluka98) w 2T solenoid		$5 x10^7$
	New(Fluka98) w. CC and QC		$7 x10^7$
beamstrahlung: from beam dump(340kW) (300m from IP)		Old(GEANT)	$1x10^7$
		New(Fluka98)	$2.5x10^7$

Statistical error of new estimate is roughly a few x 10^7 (guess)

New estimatebased on Fluka98 is well below the requirement,

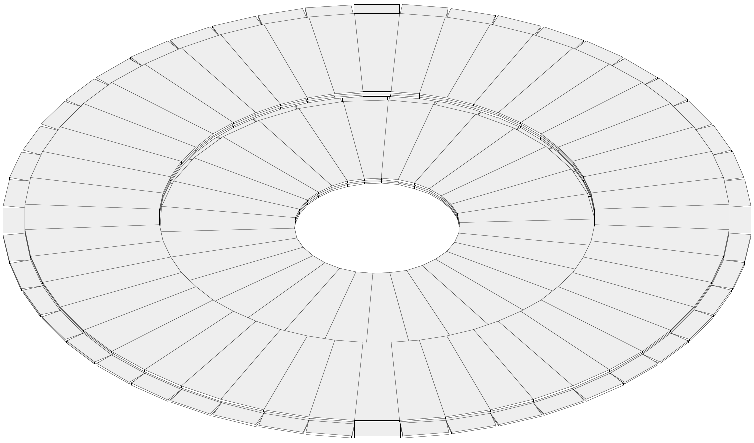
$< 1.5x10^{10}$ n/cm^2

for the CCD vertex detector

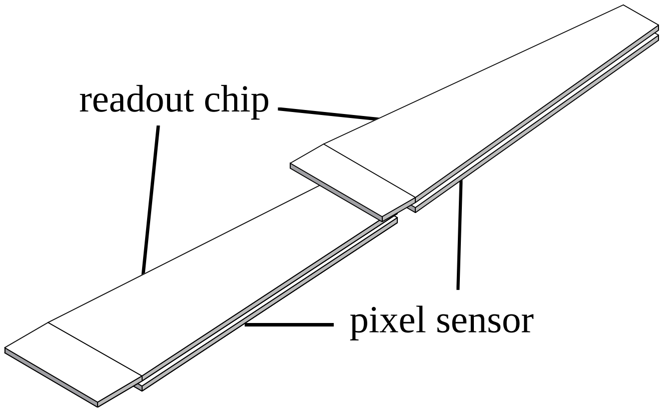
Neutron background from other sources in dump line are under study.

Pixel Beam Profile Monitor

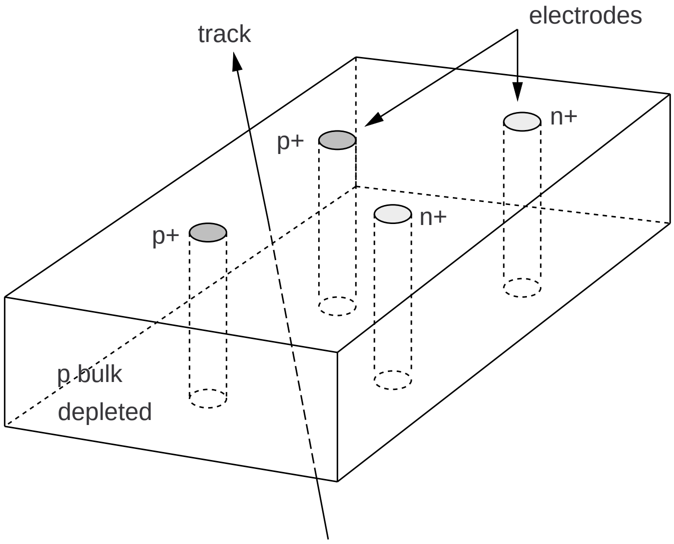
H. Yamamoto et al., University of Hawaii



The sensor arrangement; the top side faces the IP.



One 'segment' ; the bottom side faces the IP.



Schematic diagram of the 3D pixel concept

3D Pixel

1. Fast charge collection
   < 1 nsec :bunch separation

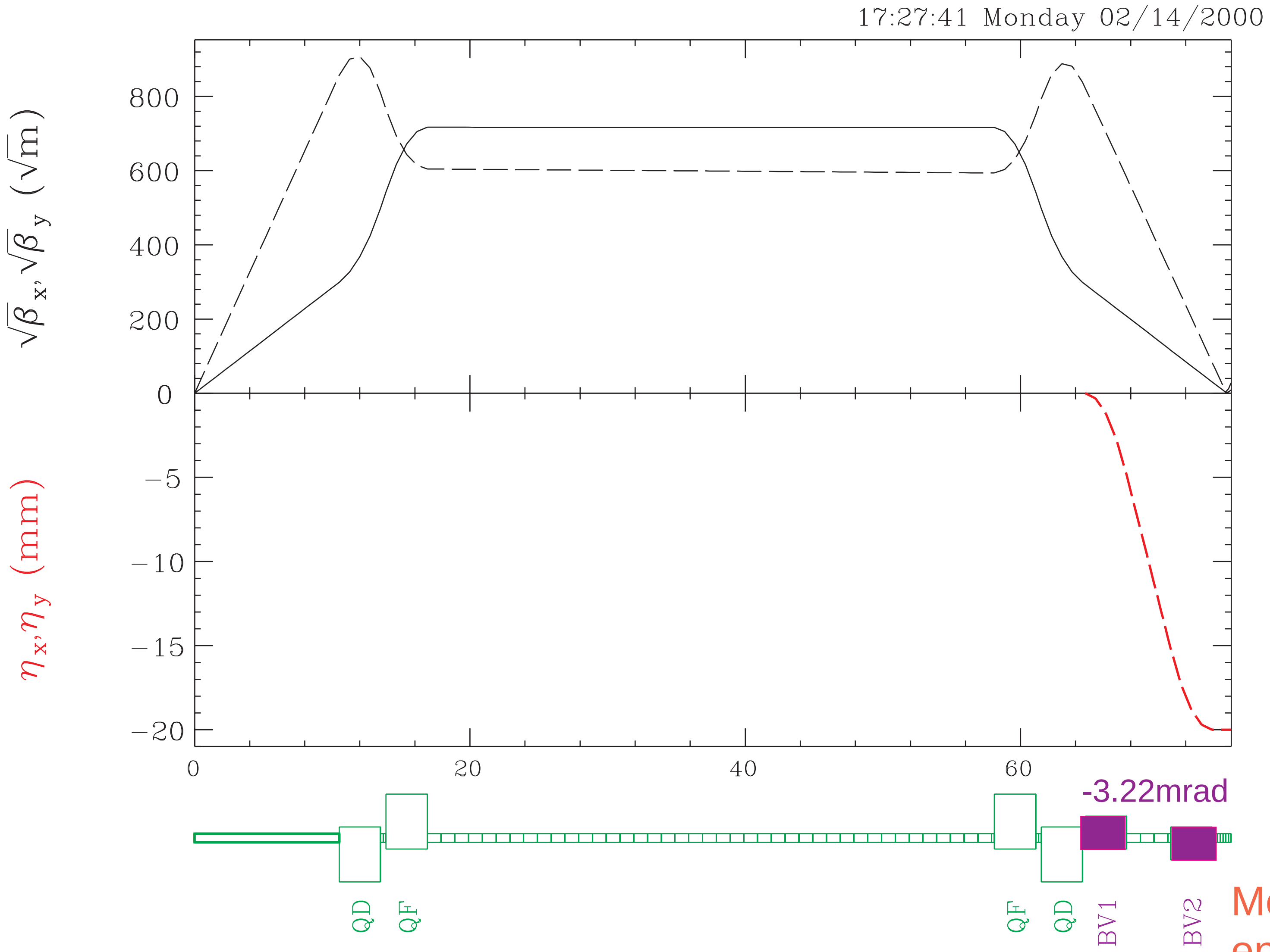
2. Radiation hard
   >>50kRad/year,10^7n/cm^2/year

3. Flexible geometry

4. Active edge

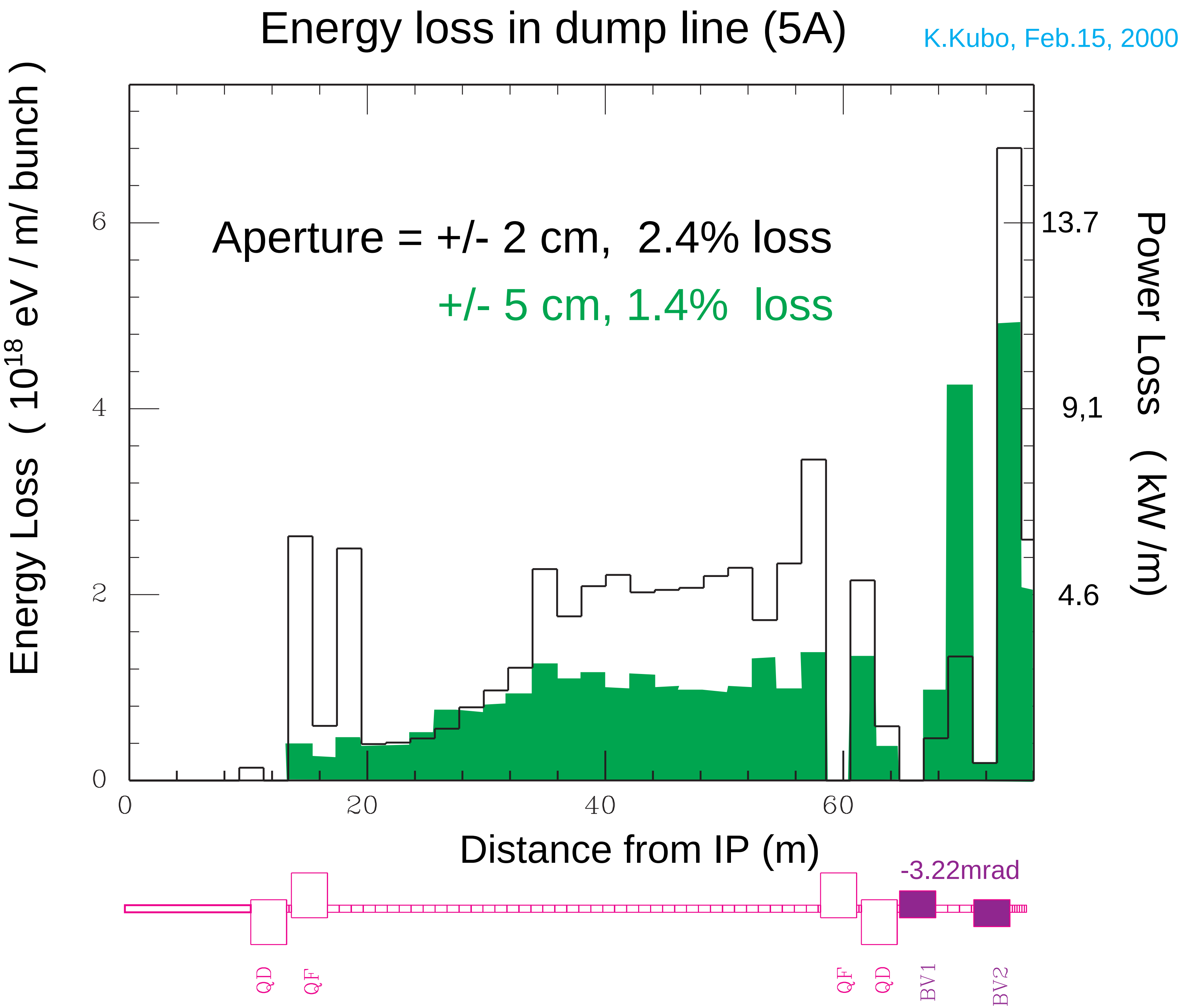
Optics of Dump Line (1 st version)

K.Kubo



2nd focus point

Measurements of energy distribution polarization


Energy loss in dump line (5A)
K.Kubo, Feb.15, 2000
Aperture = +/- 2 cm, 2.4% loss
+/- 5 cm, 1.4% loss
Energy Loss (10^{18} eV / m/ bunch)
Power Loss (kW /m)
0
2
4
6
13.7
9,1
4.6
0
20
40
60
Distance from IP (m)
-3.22mrad
QD
QF
QF
QD
BV1
BV2

IR issues	JLC	NLC	tools	R&D other choices
Collimation muon background	non-linear 1.2km/1.5TeV $6\sigma_x$ x $40\sigma_y$ 6 cylinders (iron or lead) 0.6ϕ x 120m	linear 2.4km/1TeV(1.5TeV?) $7\sigma_x$ x $35\sigma_y$ 4 spoilers tunnel filler 3 x 3 x $9m^3$	SAD, EGS MUCARLO	wake field measurement detail tunnel geometry shorter collimation radio-activation in tunnel optimization with two schemes exotic : laser, liquid metal collimation....
Final Focus System	1.6 (0.6) km/1.5 (0.5) TeV	2.5 km -> 1 km by Pantaleo's FF optics	SAD, MAD	Tunability, 2 IP, μ bkg.
Crossing angle Crab cavity	8mrad toward smaller angle limited by SR backgrounds option (lum. 40% up) why? higher luminosity without crab cavity.	20mrad toward larger angle,limited by "3 Tesla". must why? easier extraction of disrupted beam.	ABEL,CAIN, Guinea-Pig	tolerance for crab cavity requires 0.2^{o}phase stability needs prototype-cavity (measurement at SLAC, M.Ross) KEK B-factory crab cavity can be prototype?
Final focus Q-magnet	warm magnet, 2.2m long inner radius=6.85mm another option: superconducting QC1 w/o compensation magnet.	2 permanet magnets, 1m long each, + Q1SC(0.5m) inner radii=7 and 8 mm outer radii=2 and 2.5cm PEP-II experience 2m from IP, why?		warm magnet: water cooling w/o vibration permanet magnet: no beam-based alignment smaller angle: superconducting magnet how to extract beam?
	longer distance makes smaller dead cone and less background (back-scattered photons) and it must be benifit if it is set outside the conpact detector. if l^*=1m, 25% shorter final focuss system if l^*=3m, 20% longer final focuss system			optics with large l^*

IR issues	JLC	NLC	tools	R&D other choices
Superconducting compensation magnet	must	no for small detector, must for large detector. (permanet magnet has no advantage with this?)		thinner cryostat for smaller dead cone
Detector solenoid	2 -> 3 Tesla	6 -3Tesla for small/large D. 20mrad crossing angle OK?	GEANT	Optimization of mag. field, calorimeter performance
Support of FF-Q vibration	support tube no additional "anchor" is necessary at TRISTAN tunnel. prototype in 2000.	optical anchor compact detector with support tube (grounded)	ANSYS	their prototypes calculations with measured ground motion.
Feedback	Slow feedback(SLC type) **collisions:** can be corrected at <10Hz with BPM by using beam-beam deflection. O(nm) ground motion at >10Hz..... 5% lum. loss **nm beam spot size:** needs orbit correction by 10nm-res. BPMs	Slow feedback(<10Hz) fast feedback(2.8ns, <200Hz) by BPM with pilot beam and also by beam beam deflection.	SAD,TURTLE, MERLIN,CAIN	SLC and B-factory's experiences feedback simulations 10-100nm resolution BPM.
Background: synchrotron radiation (SR)	no problem because of collimation and mask (for that from last bend).	similar to JLC but... needs recalculation	MQRAD QSRAD GEANT	SLD experineces, that is large fluctuation of the background in CDC. What is a stability of beam?

IR issues	JLC	NLC	tools	R&D other choices
Pair background	VTX: 0.9-0.4hits/mm^2 /train by "electrons" at r=2.5cm for B=2-3 Tesla CDC: 121-12 hits /train by "photons" at Ecm=500GeV	VTX: 2-7 hits/mm^2/train at r=1.2cm for B=6-3 Tesla CDC: 3x10^4 photons/train no gas chamber allowed at Ecm=1TeV This result may be consistent with JLC because of "photon conversion" in the chamber and its higher beam energy.	ABEL,CAIN, Guinea-Pig GEANT,EGS	Detailed geometry at IP Tolerable background hits: VTX: $<$ 1hit/mm^2/train CDC: occupancy $<$ 1% radiation damage? need cross check with common background-rays and geometries. Comparison between ABEL, CAIN and Guinea-Pig.
neutron backgrounds from pairs, (disrupted beam and beam dump)	10^6 n/train (n/E_e=0.13/GeV) VTX: 7 x10^{7}hits/cm^2/year	VTX: 2.2-4.7 x10^{9}hits/cm^2/year	GEANT FLUKA98	Tolerable background hits: CCD/VTX $<$ 1.5x 10^{10} hits/cm^2 so, no problem.

Instruments

	IR issues	JLC	NLC	tools	R&D other choices
	Pair monitor	3D pixel detector Hawaii university	**???** Very big SR background! How does SR background fluctuate event by event inside masks at SLD ?	ABEL,CAIN, Guinea-Pig GEANT	pixel device(50x50μm^2) with dE/dX measurement. What's kind of feedback?
	Shintake monitor				Laser optics close to IP? σ_x measurement at least
	IP-BPM				O(10nm) resolution
	Luminosity meas.	acollinearity angle of Bhabha scattering		Toomi's program	How to measure luminosity distribution within a beam energy spread(1%) ? (toponium physics)
	Beamstrahlung monitor				
Exstraction Beam Line	Radiative Bhabha meas		There is a chicane in extraction beam line to separate electron beam and photons with a common dump.	ABEL,CAIN, Guinea-Pig SAD GEANT	Design extraction lines and beam diagnostic equipments for small(JLC) and large (NLC) crossing angles.
Exstraction Beam Line	Energy measurement	using vertical dispersion			
Exstraction Beam Line	Polarization measurement	Hirose's talk at LCWS95 (Appi, Morioka)			
	Beam dump				

Future Plan

1. IP layout will be optimized for the high luminosity upgrade.

   JLC-Y : 1.4nsec bunch spacing,
   190 bunches/train
   stronger beamstrahlung effects

2. "Pre-linac" collimation scheme must be established.

It means collimation before the main linac.
It may simplify the collimation system and the muon protection.

3. Superconducting QC1 is seriously considered.

The design shall be based on experiences of LHC-QC magnets, adding new features of correction magnets near the beam line for nano-meter beams.
Prototype of QC1 must be necessary.

4. More detailed study on the support system will be pursued with respect to ground motions.

Prototype system must be constructed to verify our estimations.

5. Background studies will continue based on detailed simulations with up-to-date geometries, especially for the neutron background.

6. The realistic design of the pair monitor shall be promoted by a collaboration between University of Hawaii and KEK. It will be finalized in this autumn.

7. R&D of active mask and luminosity monitor will be initiated by National Taiwan University group.

8. The "actual" dump line must be designed in order to control beam losses for the neutron backgrounds.
Experimental methods must be established for measurements of beam energy spread and polarization.

9. All efforts should be concentrated for the first draft of the CDR in this autumn.