Detector Overview

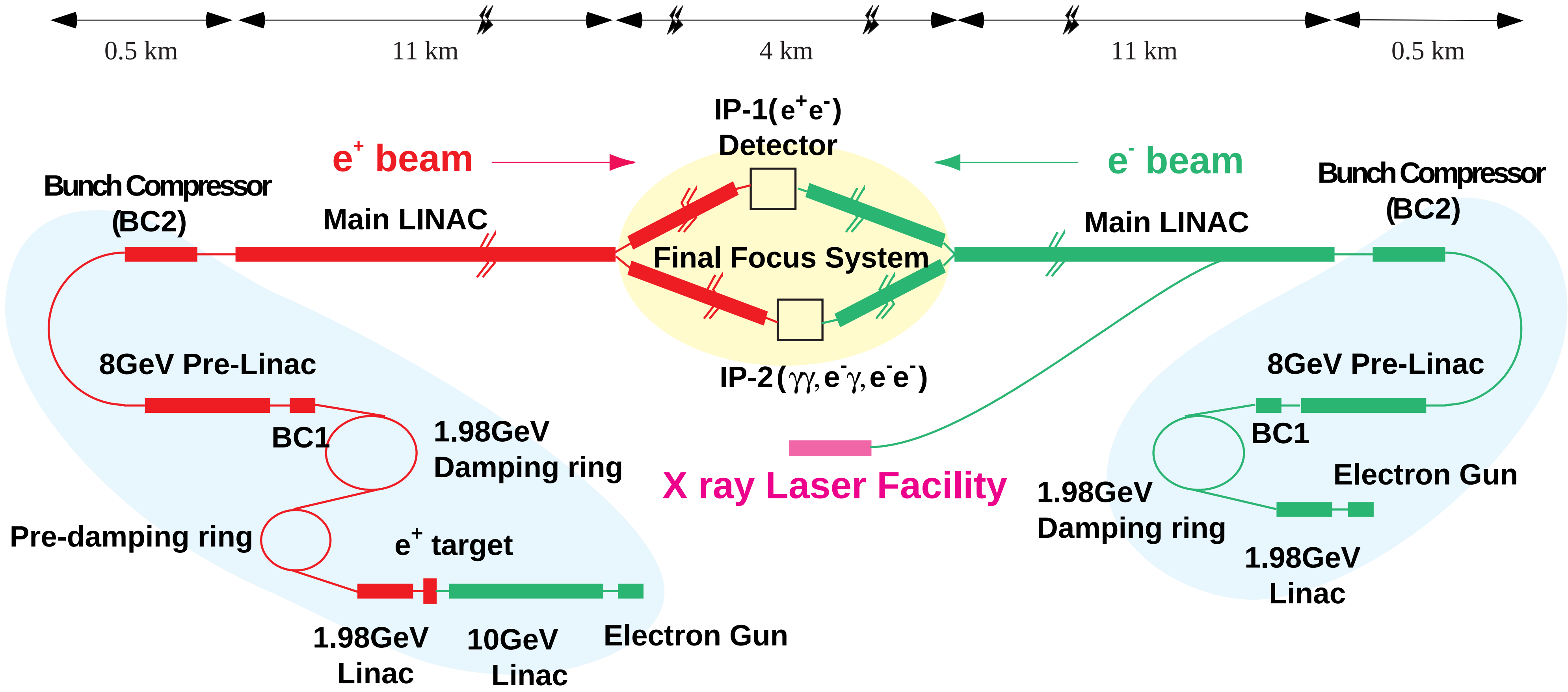
focused on interaction region

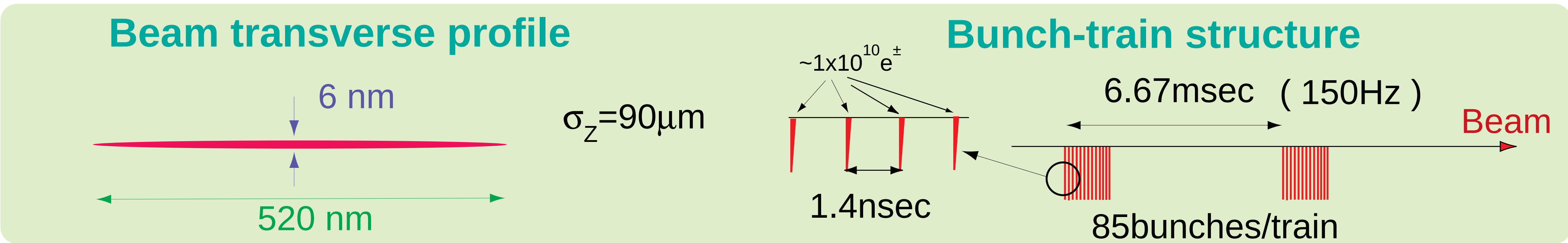
The 1st ACFA Workshop on Physics/Detector at the Linear Collider
Tsinghua University, Beijing

T. Tauchi (KEK), November 27, 1998

Contents

Schematics of JLC accelerator complex





JLC Parameters

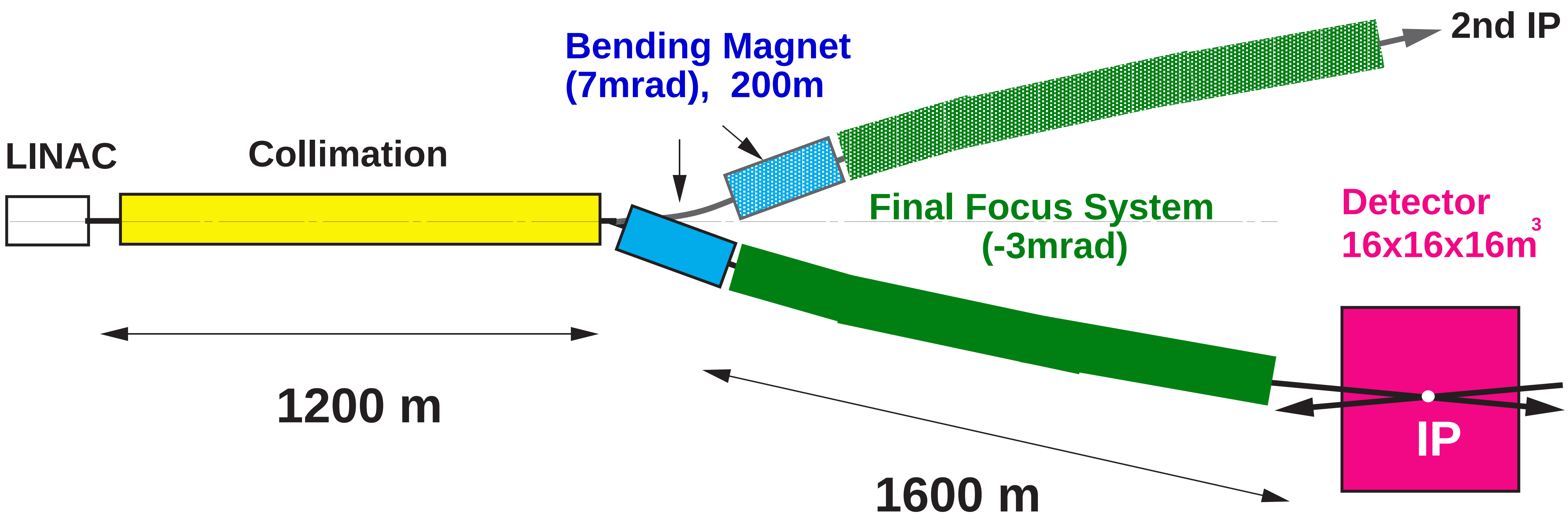
based on the X-band Main Linac (April, 1997)

RF frequency	11.4 GHz (λ=2.6 cm)
#Electrons/Bunch	7.0×10^{9} (6.45×10^{9} at IP)
#Banches/Train	85
Bunch separation	1.4 nsec
G(loaded)	55.6MeV/m
Normalized emittance	3(H) / 0.03(V) 10^{-6} rad m LINAC
	3.3(H) / 0.048(V) 10^{-6} rad m IP
Horizontal crossing angle	8 mrad

Ecm=	250 GeV	500 GeV	1.0 TeV	
#Klystrons/beam	1053	2197	4485	
Length/linac	2.07	4.32	8.81	km
AC-power(wall-plug)	55	115	234	MW
	assuming 28% WP $\rightarrow$ RF efficiency			
Rep.rate	150	150	150	Hz
β_x^*(mm) / β_y^*(μm)	10 / 100	10 / 100	10 / 100	
σ_x^*(nm) / σ_y^*(nm)	367 / 4.43	260 / 3.14	184/2.28	
$\Delta E/E$ due to BS	1.34	3.40	6.90	%
Pinch enhancement	1.581	1.585	1.599	
Luminosity $\times10^{33}$	4.13	8.28	16.72	$cm^{-2}\ s^{-1}$

The numbers are those with crab crossing. Luminosities are 3.15, 5.18, 7.66 x $10^{33}/cm^2/s$ for Ecm=250, 500, 1000GeV, respectively, with no crab crossing.

JLC : Beam Delivery System for $\sqrt{s}$ = 0.3 - 1.5 TeV



Muon

collimate beam-tail

$6\sigma_x \times 40\sigma_y$

Synchrotron Light

from collimated beam

$$\sigma_{\theta x(y)} = \sqrt{\varepsilon_{x(y)}/\beta_{x(y)}}$$

$$\sigma_{x(y)} = \sqrt{\varepsilon_{x(y)} \cdot \beta_{x(y)}}$$

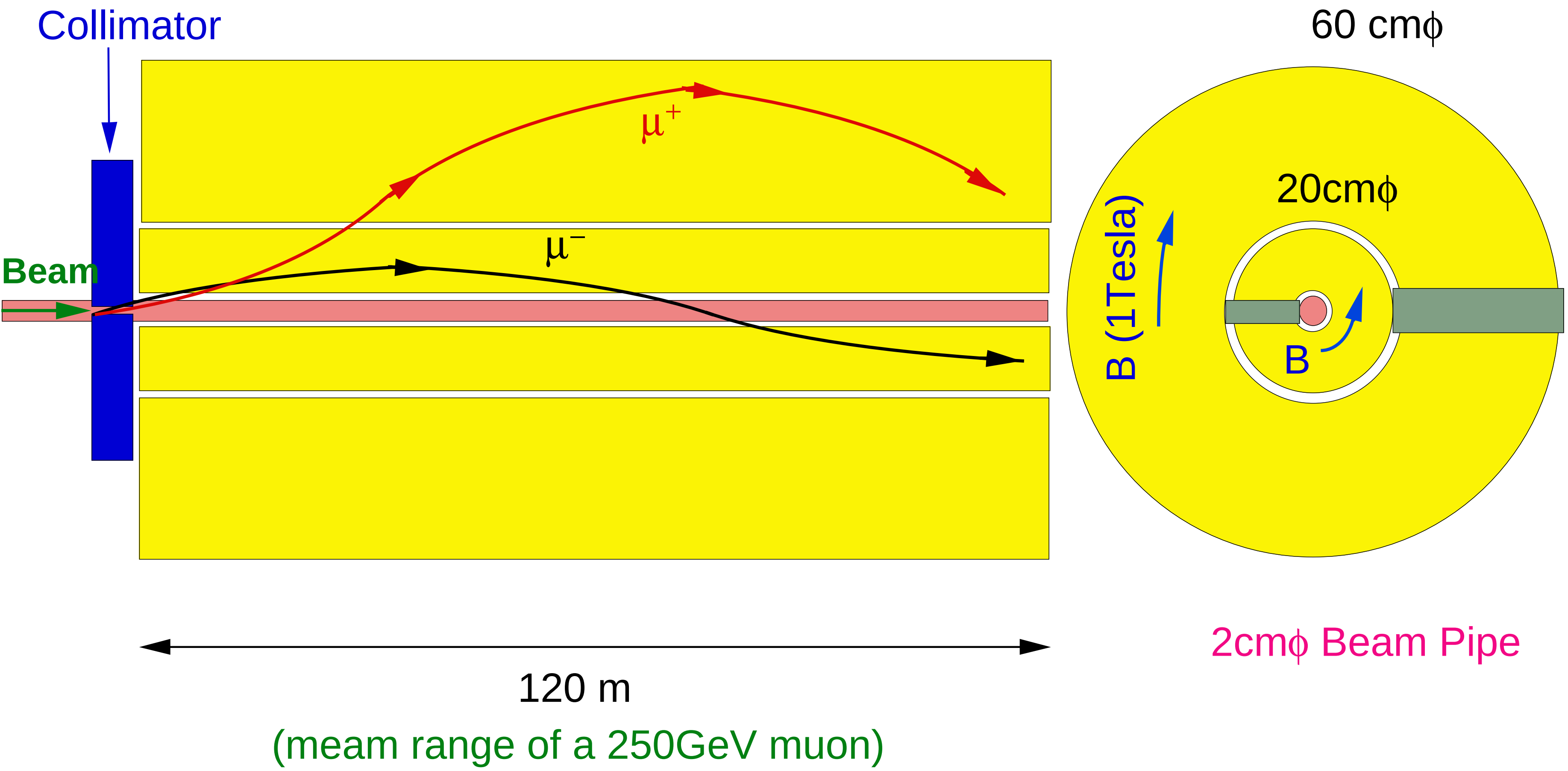
e^+e^- pairs

Minijets

$\theta_c = 8$ mrad

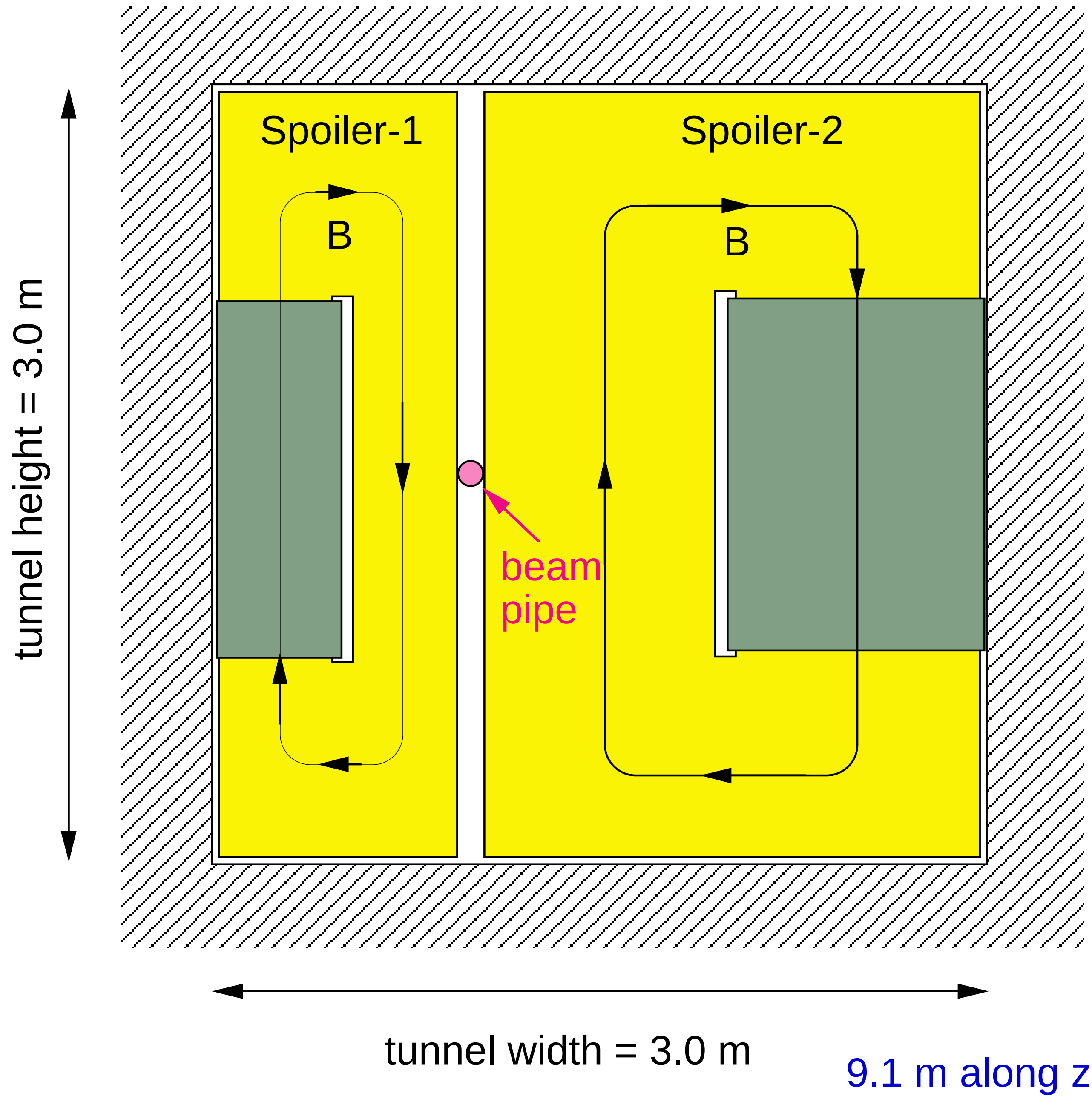
Muon Attenuator

E.A.Kushnirenko, LC92



Muon Spoiler

L.Keller,LC93

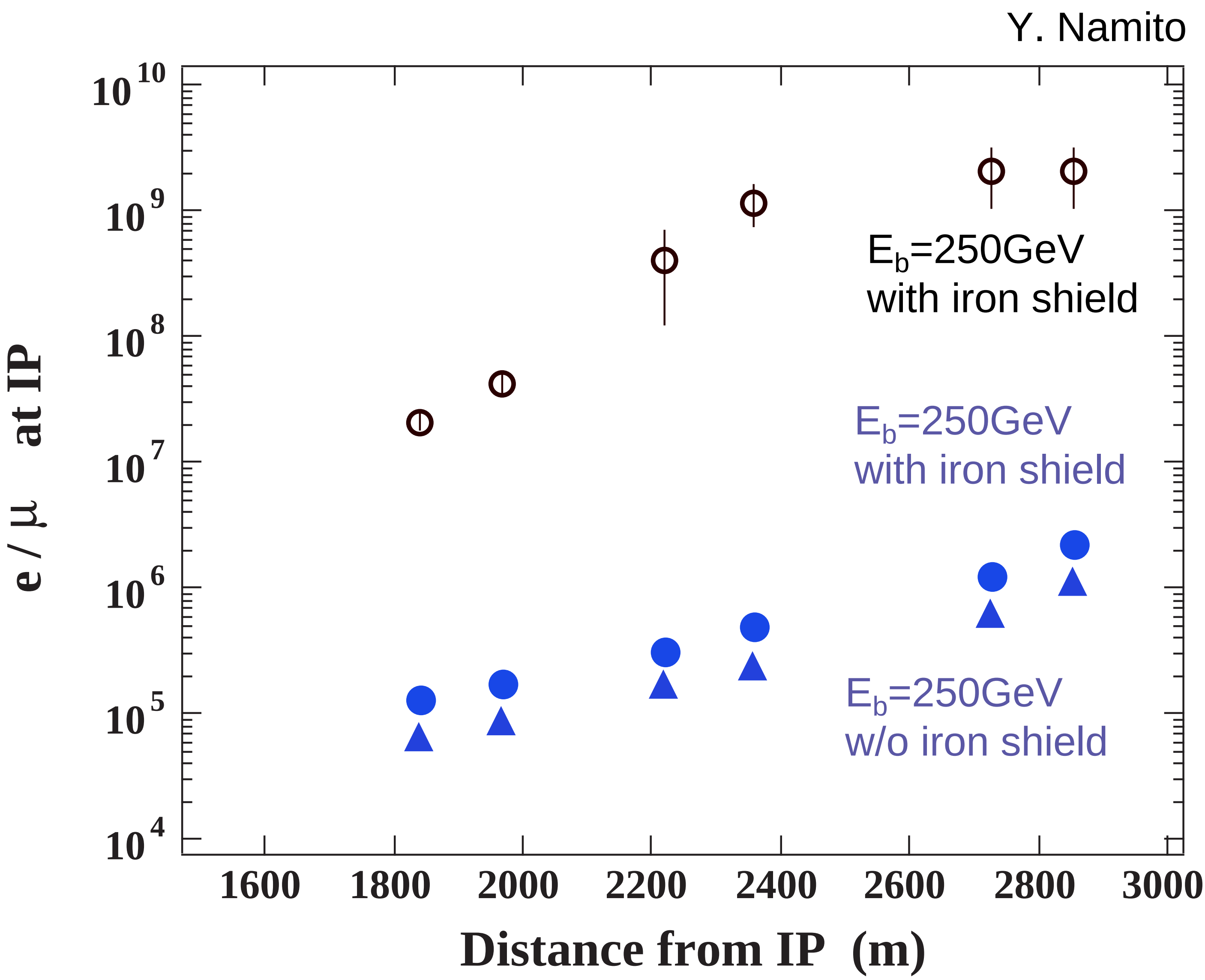


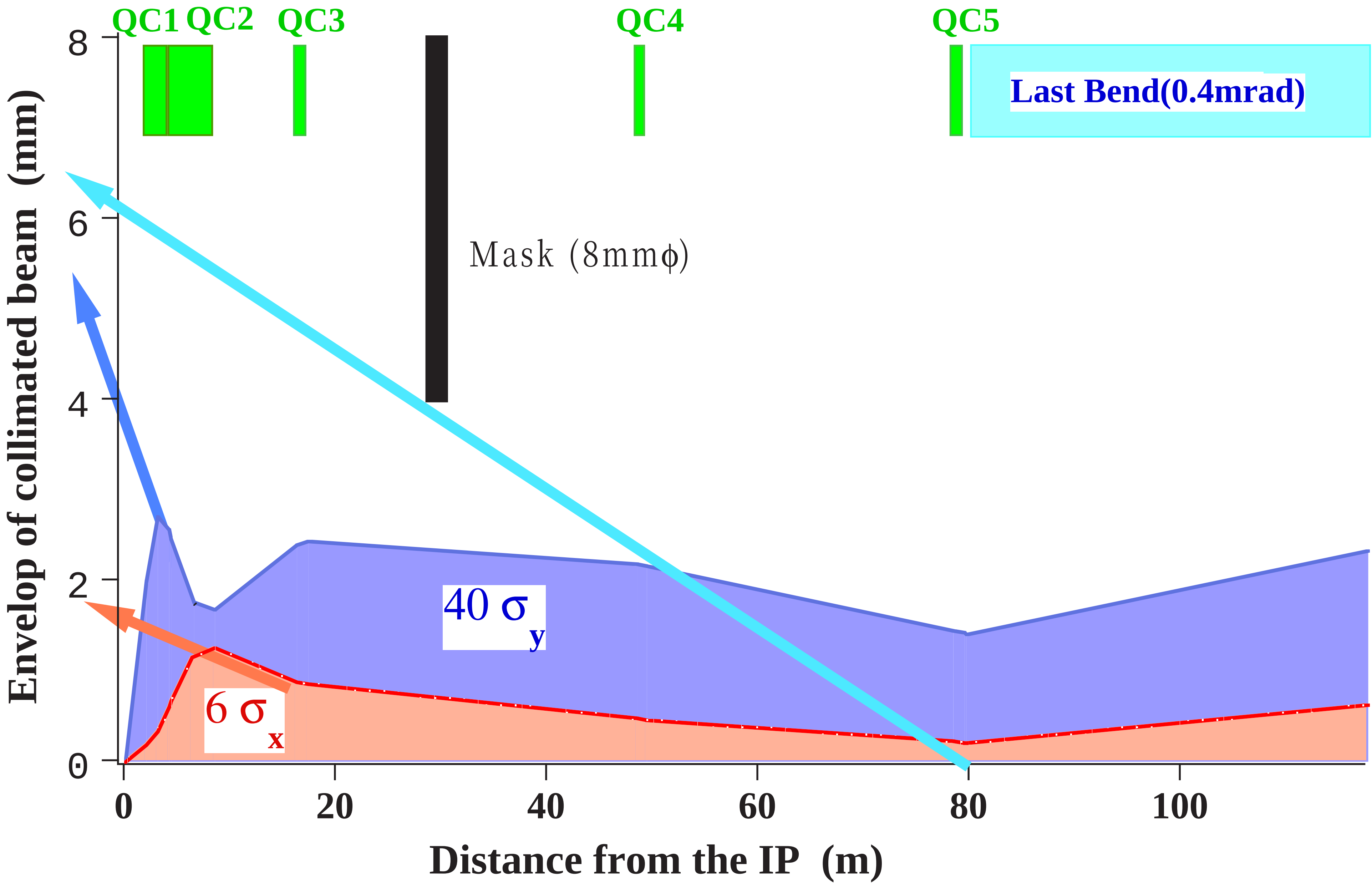
9.1 m along z
weight = 750 tons

Muon Background

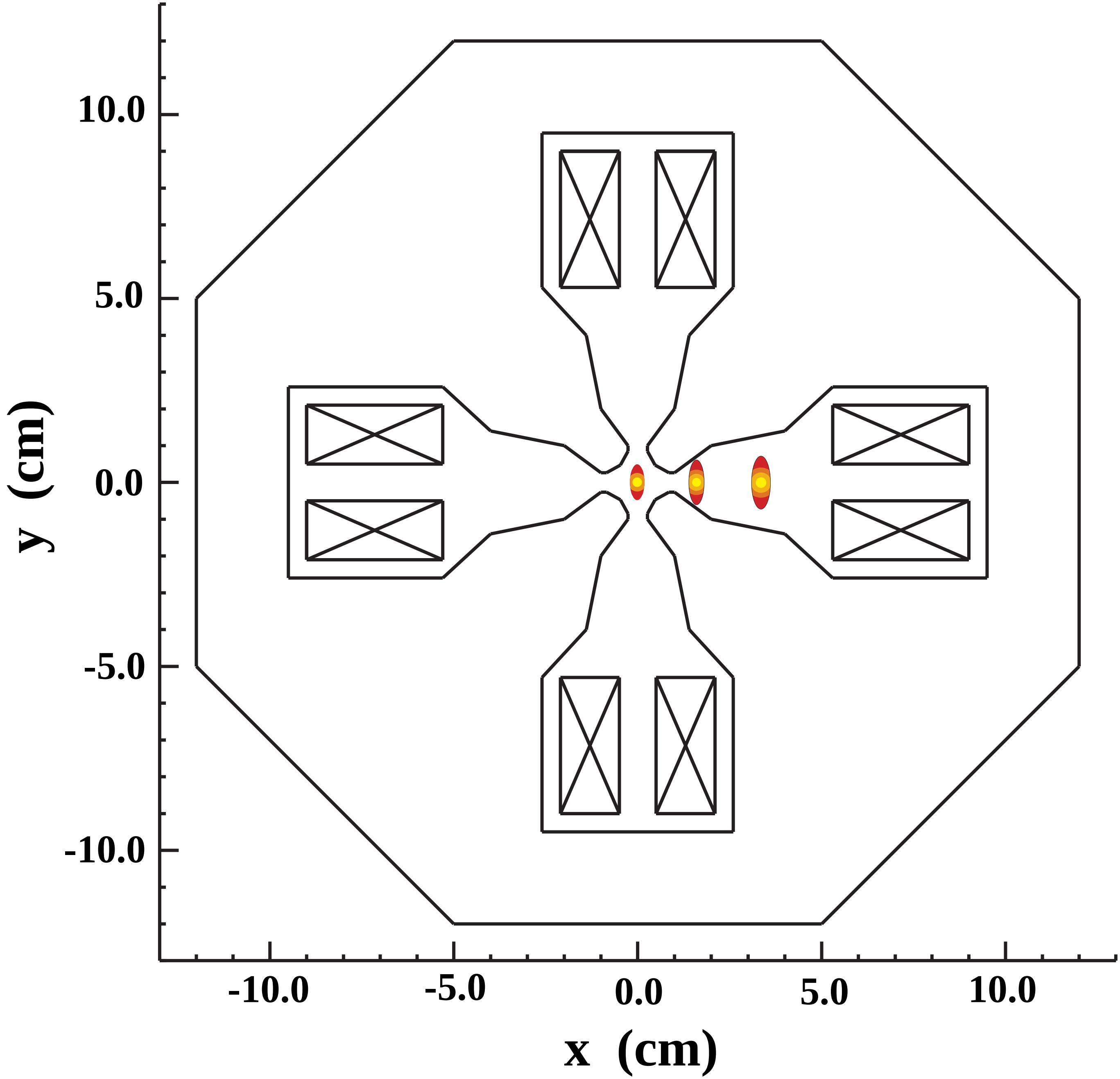
10^8(1% tail) x 10^2(bunches) electrons
may hit collimators at 150 Hz

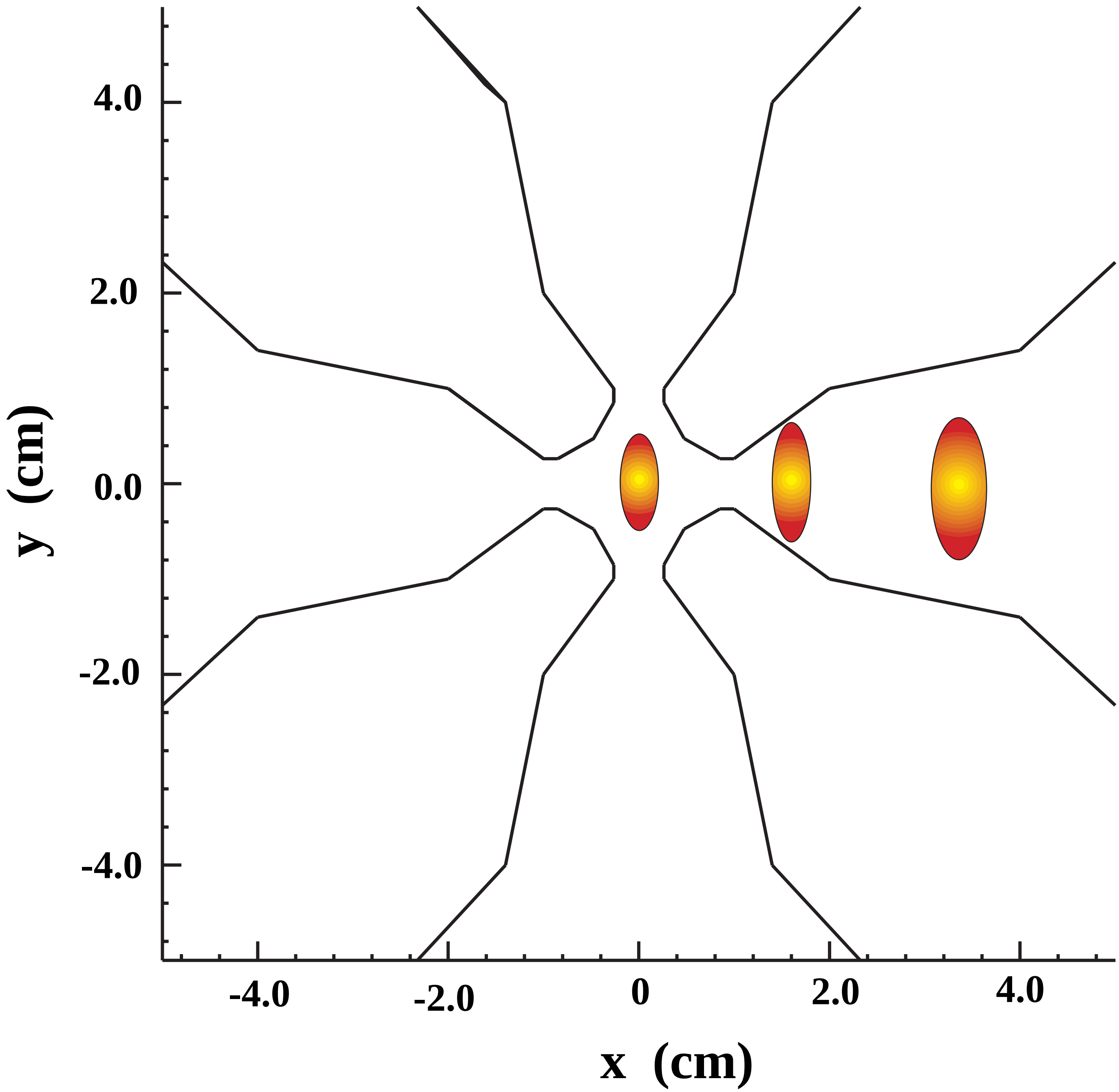
10 muons may be observed in the detector of
16x16x16 m^3.





QC1
QC2
QC3
QC4
QC5
Last Bend(0.4mrad)
Mask (8mmϕ)
40 σ y
6 σ x
Envelop of collimated beam (mm)
Distance from the IP (m)
0
2
4
6
8
0
20
40
60
80
100


10.0
5.0
0.0
-5.0
-10.0
y (cm)
-10.0
-5.0
0.0
5.0
10.0
x (cm)


4.0
2.0
0.0
-2.0
-4.0
y (cm)
-4.0
-2.0
0
2.0
4.0
x (cm)

Incoherent $e^{\pm}$ pairs

Pair creation by virtual and real (beamstrahlung) photons;

$e^+e^- \rightarrow e^+e^-e^+e^-$: LL $\sigma(cm^{-2})$~$O(10^{-26})$

$\gamma e^{\pm} \rightarrow e^+e^-e^{\pm}$: BH $\sigma(cm^{-2})$~$O(10^{-25})$

$\gamma\gamma \rightarrow e^+e^-$: BW $\sigma(cm^{-2})$~$O(10^{-27})$

Typical scattering angles ~ $m_e/E_e = 1/\gamma_e$ (small), however, the pairs are kicked by the strong magnetic field produced by comming beam.

$\Rightarrow$ Background !

$$\theta_{x(y)}^{kick} \sim \frac{2Nr_e}{\gamma_e} \frac{x\ (y)}{\sigma_{x(y)}(\sigma_x+\sigma_y)} \sim O(10^{-1}) \gg \frac{1}{\gamma_e}$$

$\gamma_e \sim \gamma_{beam} \cdot 10^{-3}$

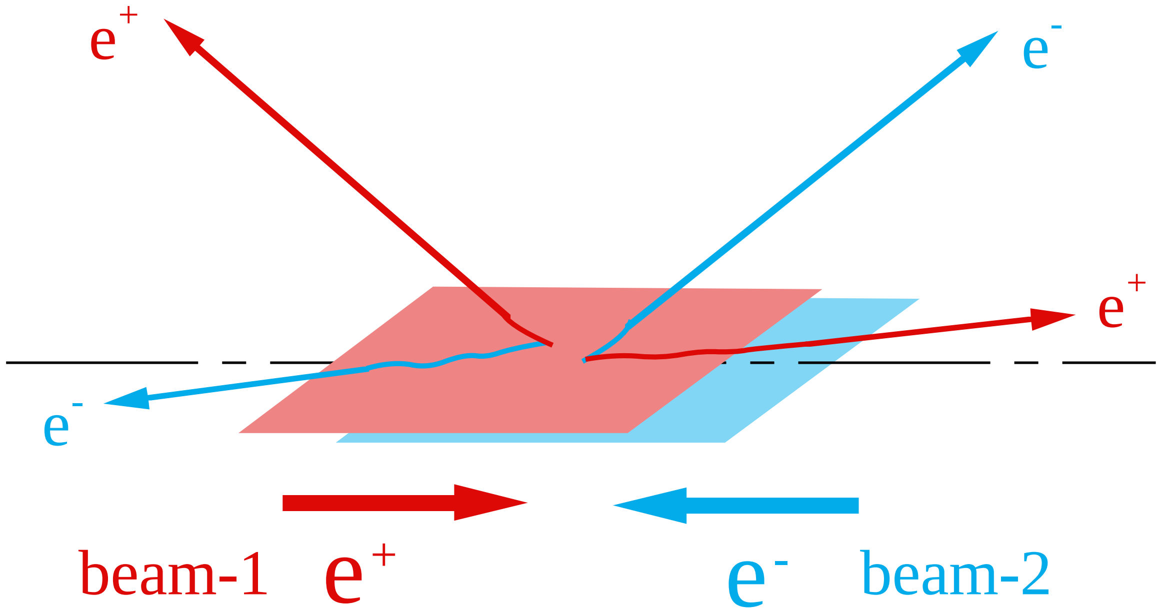
N : number of particles/bunch ~ 10^{10}

r_e (electron classical radius) = $2.8 \cdot 10^{-15}$m

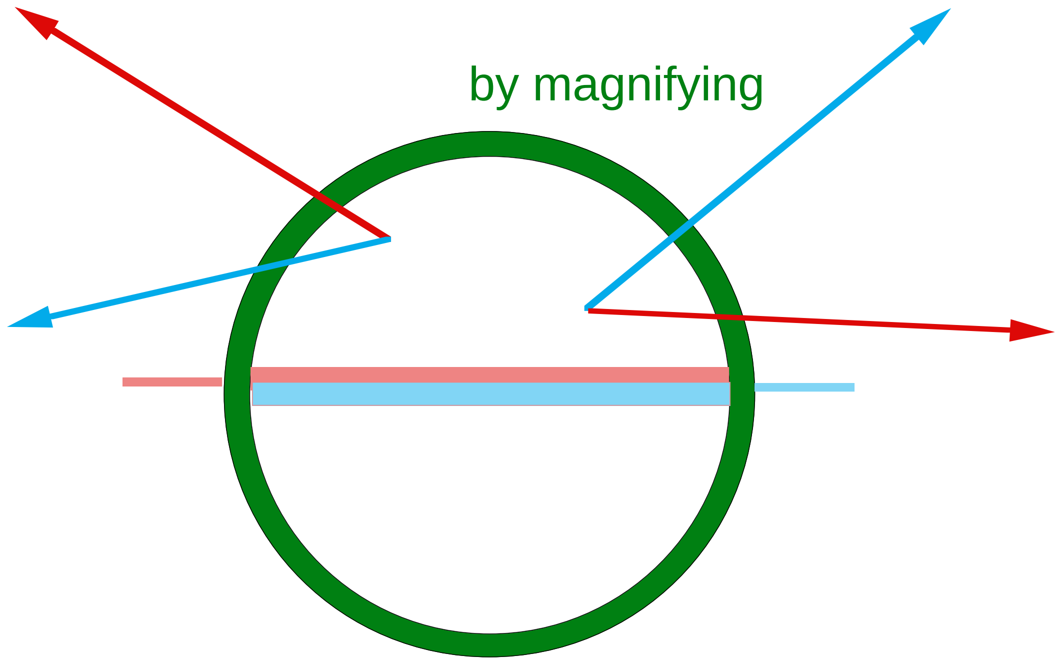
$x \sim \sigma_x \sim 10^{-7}$ m

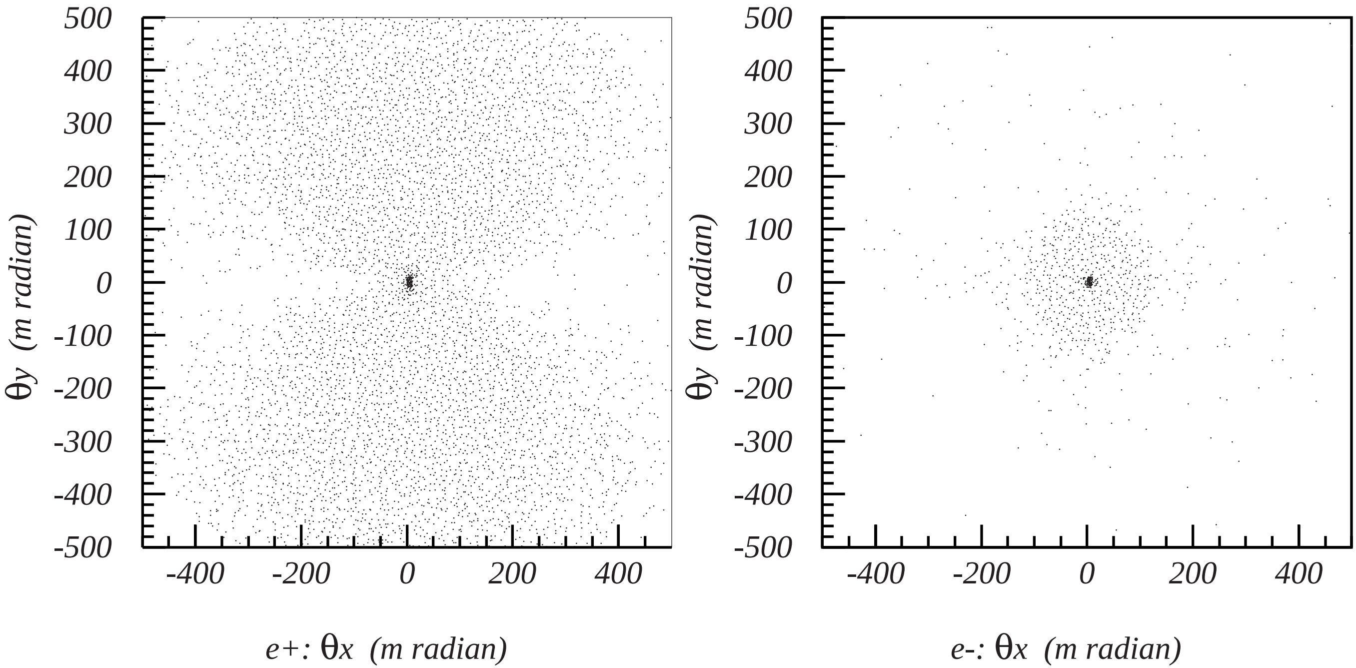
$y \sim \sigma_y \sim 10^{-9}$ m

$e^{\pm}$ pair creation and deflection during a collision

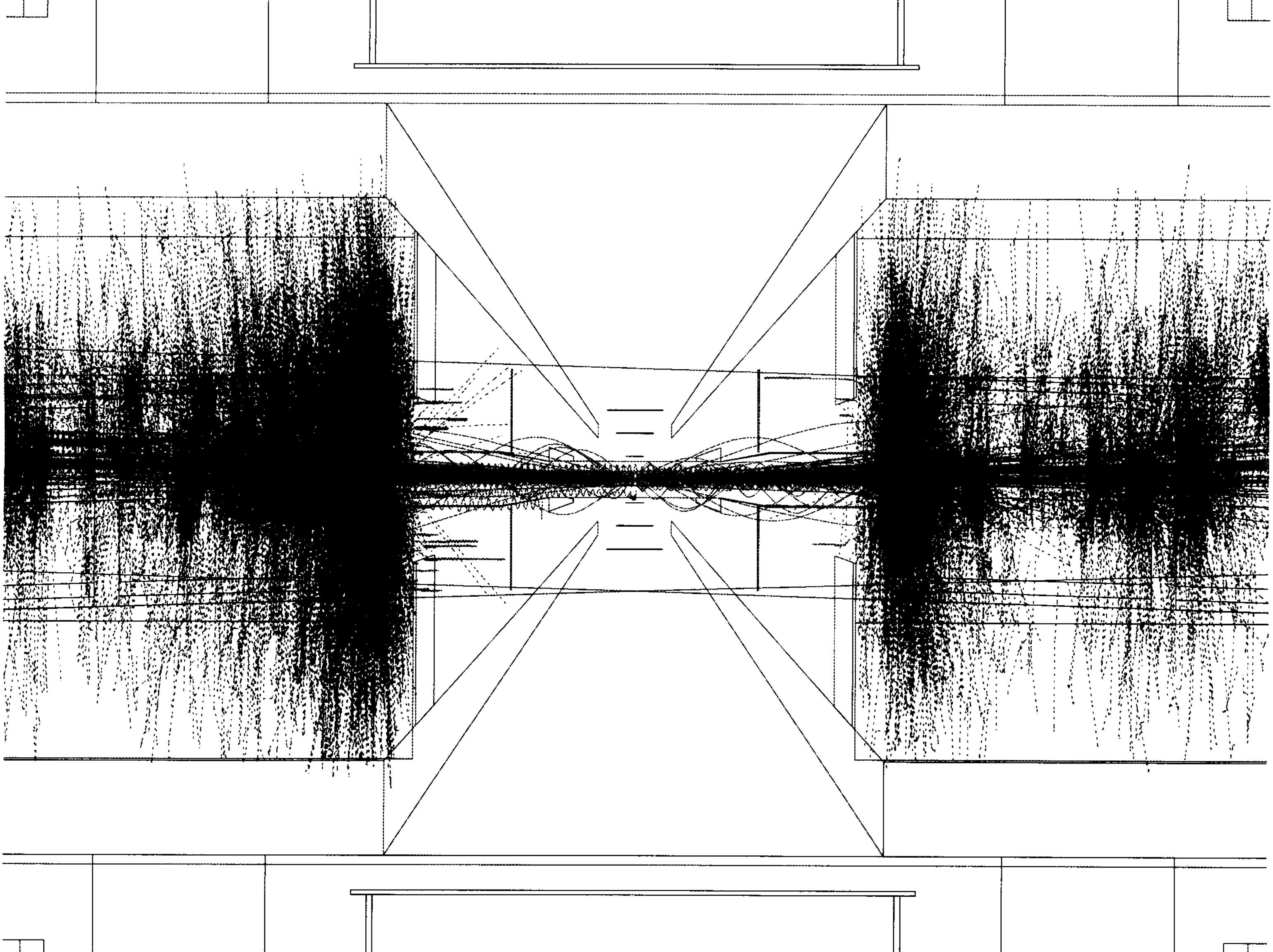


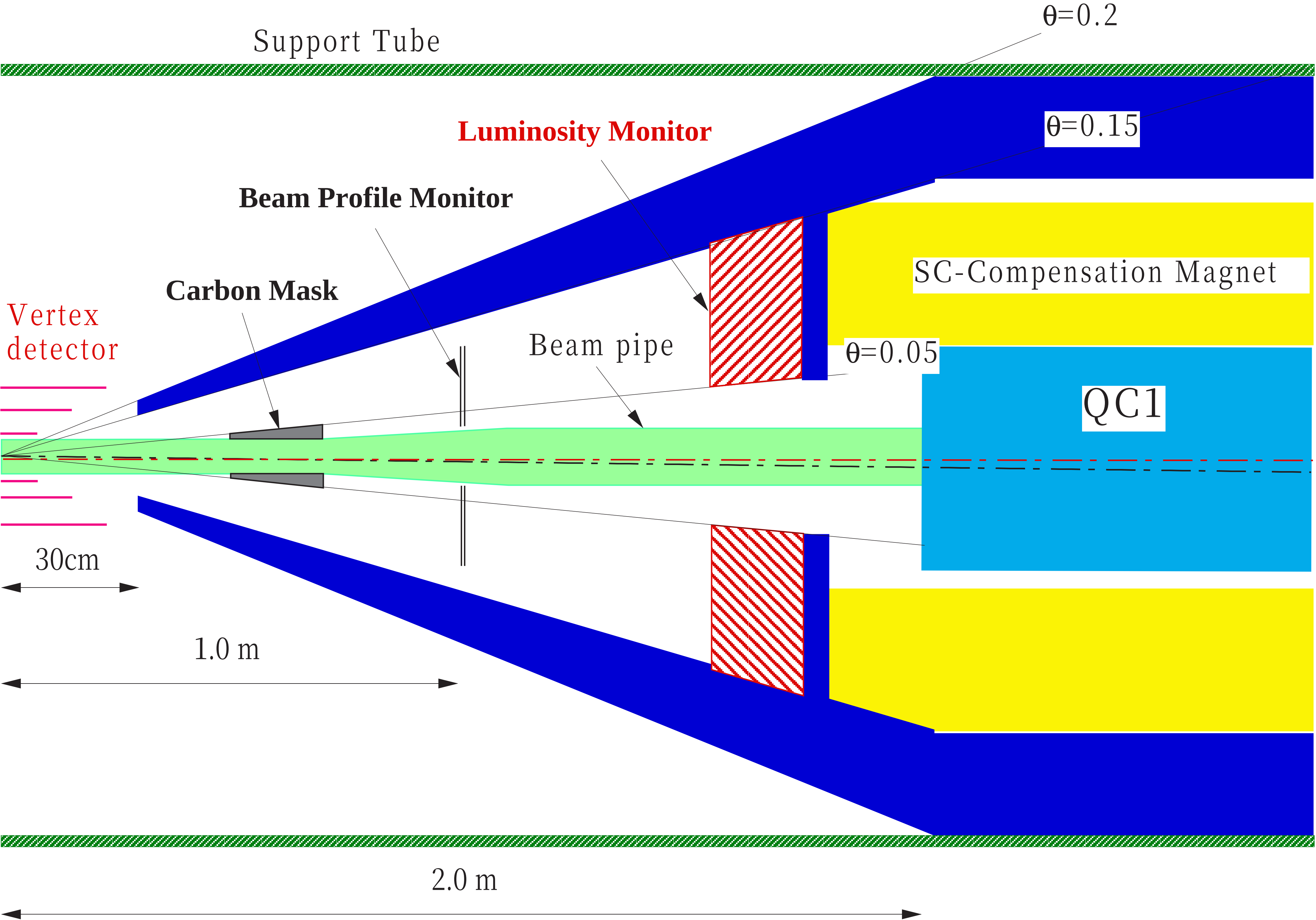
side view



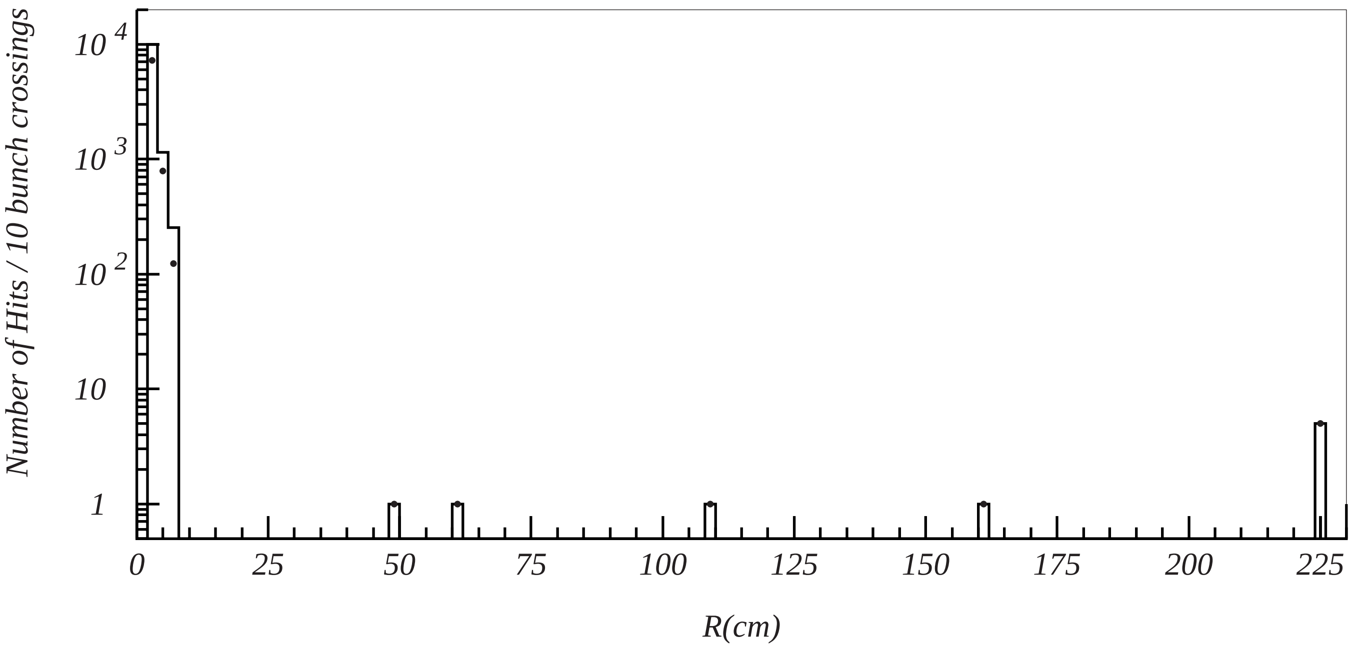


500
400
300
200
100
0
-100
-200
-300
-400
-500
θy (m radian)
-400
-200
0
200
400
e+: θx (m radian)
e-: θx (m radian)




θ=0.2
Support Tube
θ=0.15
Luminosity Monitor
Beam Profile Monitor
SC-Compensation Magnet
Carbon Mask
Vertex detector
Beam pipe
θ=0.05
QC1
30cm
1.0 m
2.0 m

Background hits per 10 bunch crossings due to e^+e^- pairs



Hits rates for a train of 85 bunches at 150Hz

VTX-layer	r (cm)	z (cm)	hits/mm^2
1	2.5	±7.5	3.6
2	5.0	±15.0	0.1
3	7.5	±22.5	0.01

tolerable hit rate = 1.0/mm^2

note: A track produces 20 hits at the VTX.

Neutron Background

$N_n \sim 0.13\ \Sigma E_e$ (GeV)

then

10^6 n/pulse at 150Hz

in total

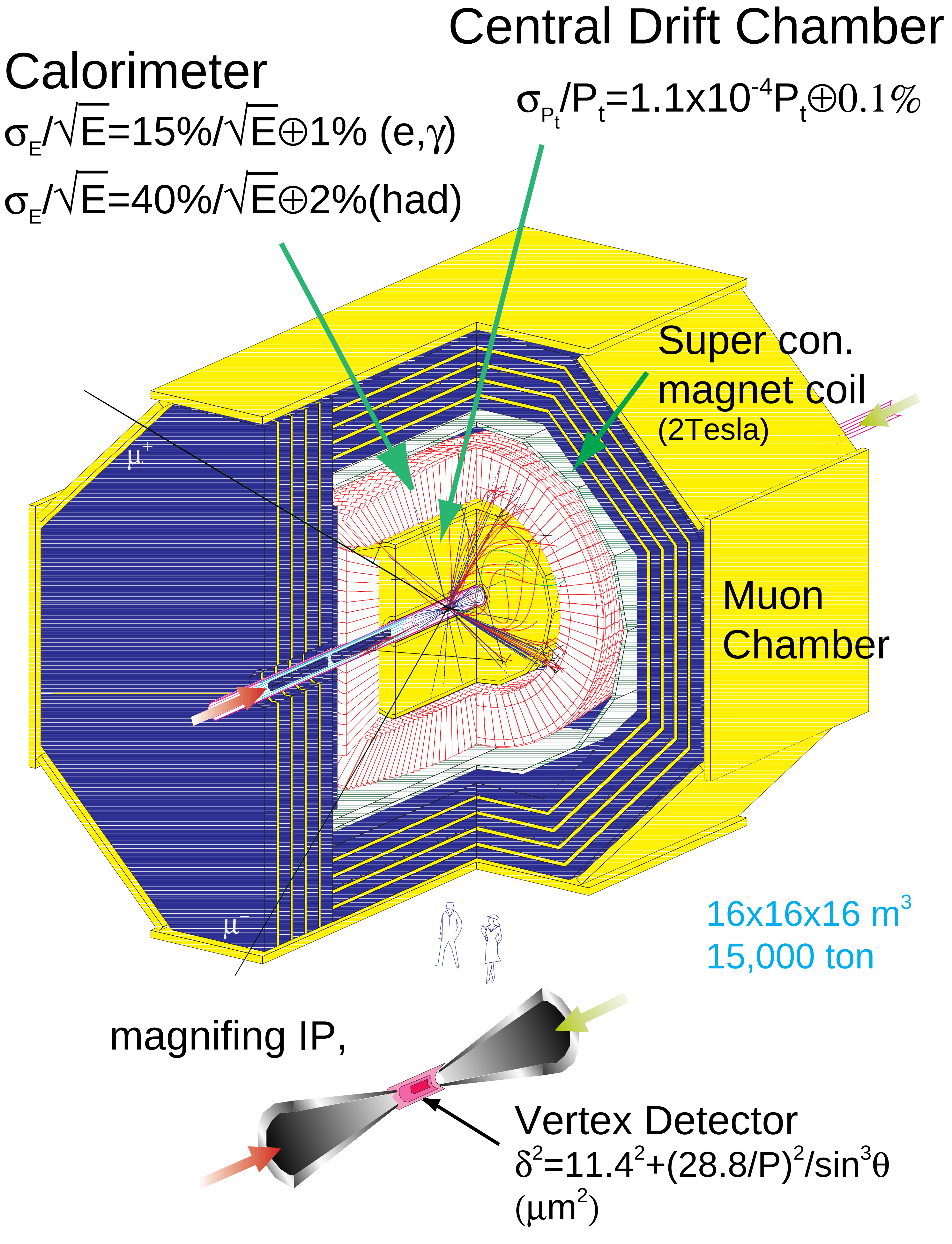
$$\underset{\text{n/pulse}}{10^6} \cdot \underset{\text{Hz}}{10^2} \cdot \underset{\text{s/year}}{10^7} = 10^{15}\text{n/year}$$

at the 1st layer of the VTX,

$$\underset{\text{n/year}}{10^{15}} \cdot \underset{/\text{cm}^2}{5 \cdot 10^{-3}} \cdot \underset{\Delta\Omega_{VTX}}{10^{-3}} \sim 5 \cdot 10^9\text{n/year/cm}^2$$

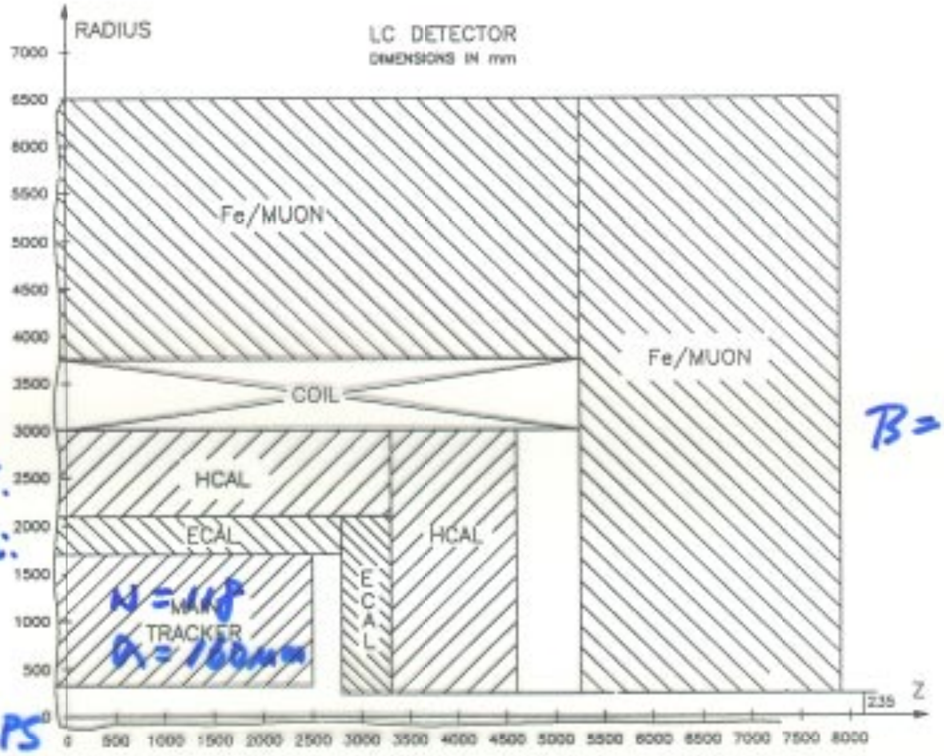
Is this accepable?

JLC detector



Tesla

shashlik.
had. Cu + scinti.
em. Pb + scinti.
TPC
CCD or APS



B = 3 Tesla

Figure 2.1.1: *Schematical layout of one quadrant of the LC Detector.*

note:

	λ cm
Pb	17.1
Cu	15.1
W	9.6

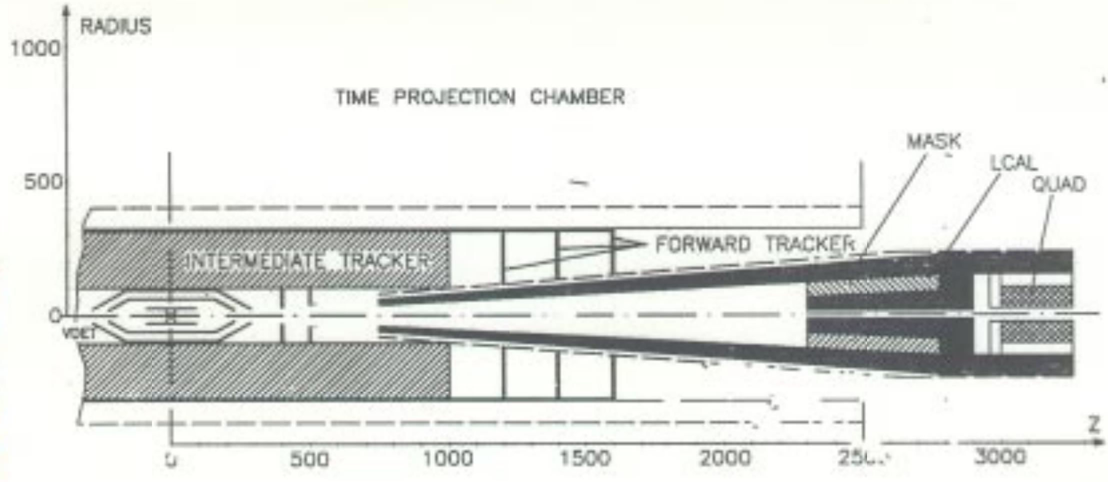


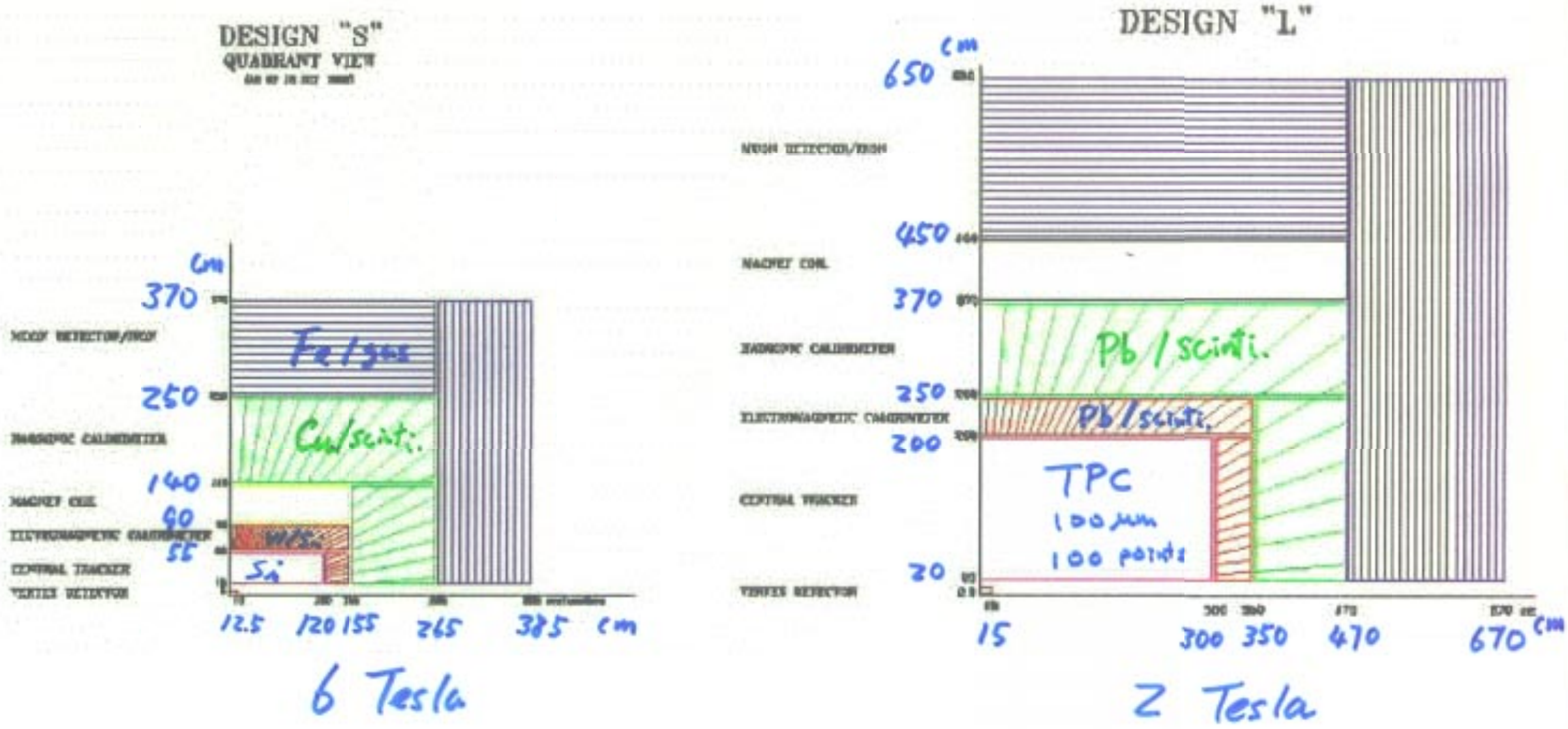
Figure 2.1.2: *Schematic layout of the inner region of the detector.*

VTX : $10\,\mu m \oplus \frac{30\,\mu m}{p \sin^{3/2}\theta}$

TPC : $\frac{\delta p}{p^2} < 1 \cdot 10^{-4}$

CAL : $10\%/\sqrt{E} \oplus 1\%$ [e.m.], $50\%/\sqrt{E} \oplus 4\%$ [had]

NLC



Quadrant Views of Designs S and L on same scale

VTX : $4.5\,\mu m \oplus \frac{5.5\,\mu m}{p \sin^{3/2}\theta}$ $\qquad 10\,\mu m \oplus \frac{30\,\mu m}{p \sin^{3/2}\theta}$

Si-strip : $\delta p/p^2 \sim 1.6 \times 10^{-4}$ $\qquad \delta p/p^2 \sim 5 \times 10^{-5}$

CAL : $12\%/\sqrt{E} \oplus 1\%$ (e.m.), $50\%/\sqrt{E} \oplus 2\%$ (had) $\qquad 15\%/\sqrt{E} \oplus 1\%$ (e.m), $40\%/\sqrt{E} \oplus 2\%$ (had)

Summary: General issues to be discussed

1. Detector size

Large

CDC: 4.6m ϕ x 4.6m (z)
jet-type or TPC
long wire wire-less
good matching between tracks and CAL-clusters
note: $R_{95\%} \sim \lambda$ for hadrons

Small (compact)

CDC: 1.1m ϕ x 2.4m (z)
micro-strips
robust against background
FF-Q can be outside of detector

2. Electromagnetic calorimeter

Better energy resolution (< 5%/$\sqrt{E}$) is needed ?
such as $PbWO_4$ crystals.... for measurement of $H \to \gamma\gamma$.

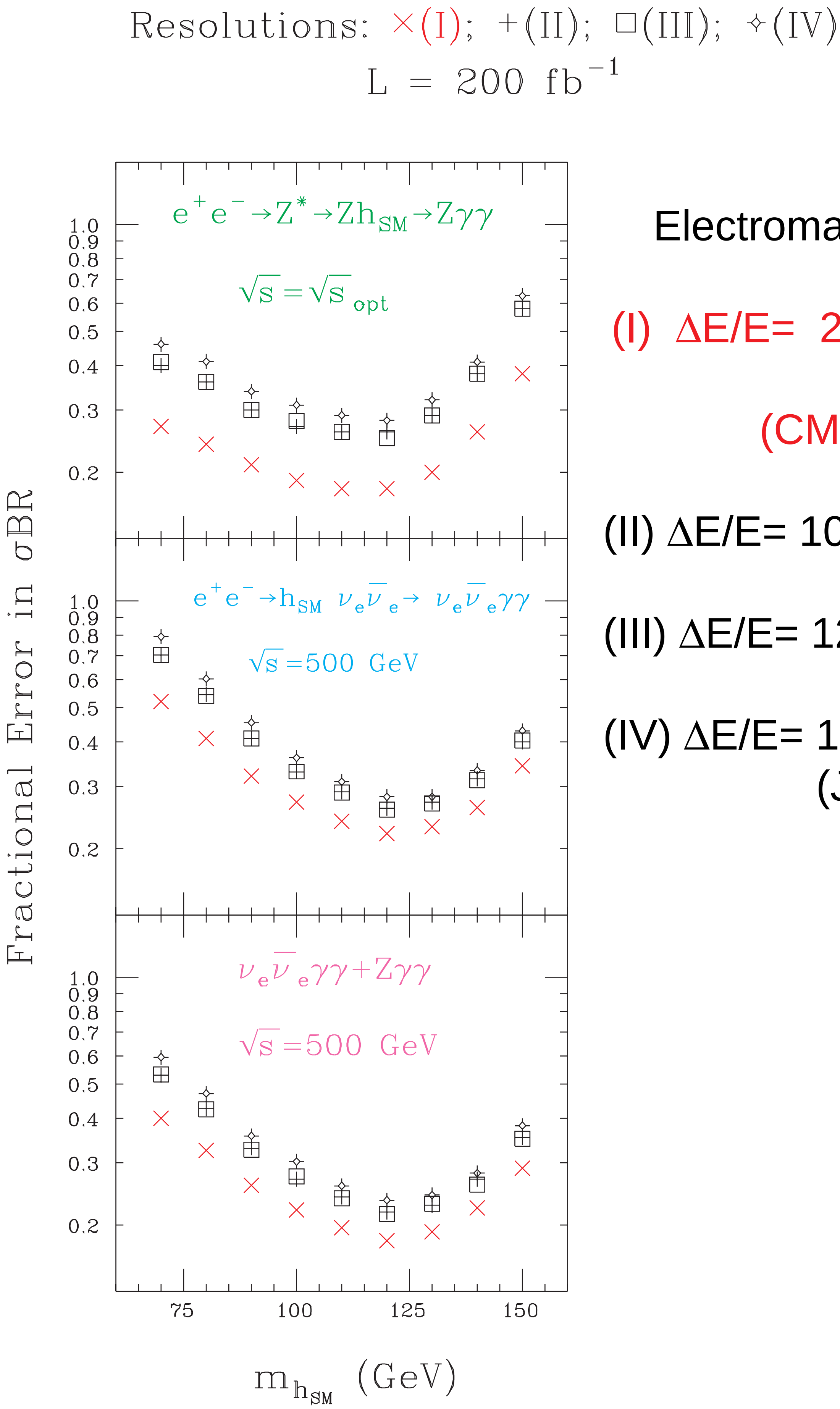
3. Hadron calorimeter

The same response ($e/\pi=1$) is necessary ?
Offline (software) compensation may work.

4. Vertex detector: CCD or pixel

CCD : radiation hardness (> 10^9 n/cm^2)
fast readout of 10^8 channels (100MHz)
Pixel : spatial resolution is enough ?
Minimal radius should be 1cm with B =4 Tesla ?
optimum r_{VTX} and B ?

J.F. Gunion and P.C. Martin,
Phys. Rev. Letters, 78 (1997), 4541-4544



Electromagnetic Cal.

(I) $\Delta E/E = 2\%/\sqrt{E} \oplus 0.5\% \oplus 20\%/E$
(CMS, $PbWO_4$)

(II) $\Delta E/E = 10\%/\sqrt{E} \oplus 1\%$

(III) $\Delta E/E = 12\%/\sqrt{E} \oplus 0.5\%$

(IV) $\Delta E/E = 15\%/\sqrt{E} \oplus 1\%$
(JLC)

CCD/VTX

C. Damerell

Present(SLD) **LC**

$$\sigma_{xy} \approx 11\mu m \oplus \frac{29\mu m}{p \cdot \sin^{3/2}\theta} \qquad \sigma_{xy}(\sigma_{RZ}) \approx 3\mu m \oplus \frac{5.5\mu m}{p \cdot \sin^{3/2}\theta}$$

$$\sigma_{RZ} \approx 18\mu m \oplus \frac{29\mu m}{p \cdot \sin^{3/2}\theta}$$

$$\sigma \approx (\text{pixel size, } R_{min}) \oplus (\text{multiple scattering})$$

	Present(SLD)	LC
R_{min} :	3 cm	~ 1 cm (B=4 Tesla)
X_0 :	0.35% rl/layer	0.12% rl/layer
	(Si : 200 μm^t	20 μm^t)
	(βe : 0.38 mm^t	0.38 mm^t)

↓

Significantly improves 3D topological vertex reconstruction

↓

Primary, Secondary, Tertiary Verteces

Charm and bottom quark ID

5. Minimum veto angle

θ_{veto} = 200 mrad ?

= 50 mrad ? even smaller ?

in order to veto two-photon process for SUSY studies such as stau pair production.

The mask shall be active, and calorimeter inside of the mask must work.

6. Intermediate tracker

in order to link charged tracks between CDC and VTX, where there is space from r=7.5cm to r=40cm.

How is it important?

What kind of device is appropriate?

7. Endcap tracker

in order to measure forward(backward) scattering angles precisely, especially for Bhabha scattering to measure the acollinearity angles which deterime the luminosity as a function of Ecm.

Is it necessary ? If so, what is detector-type ?

8. Particle identification

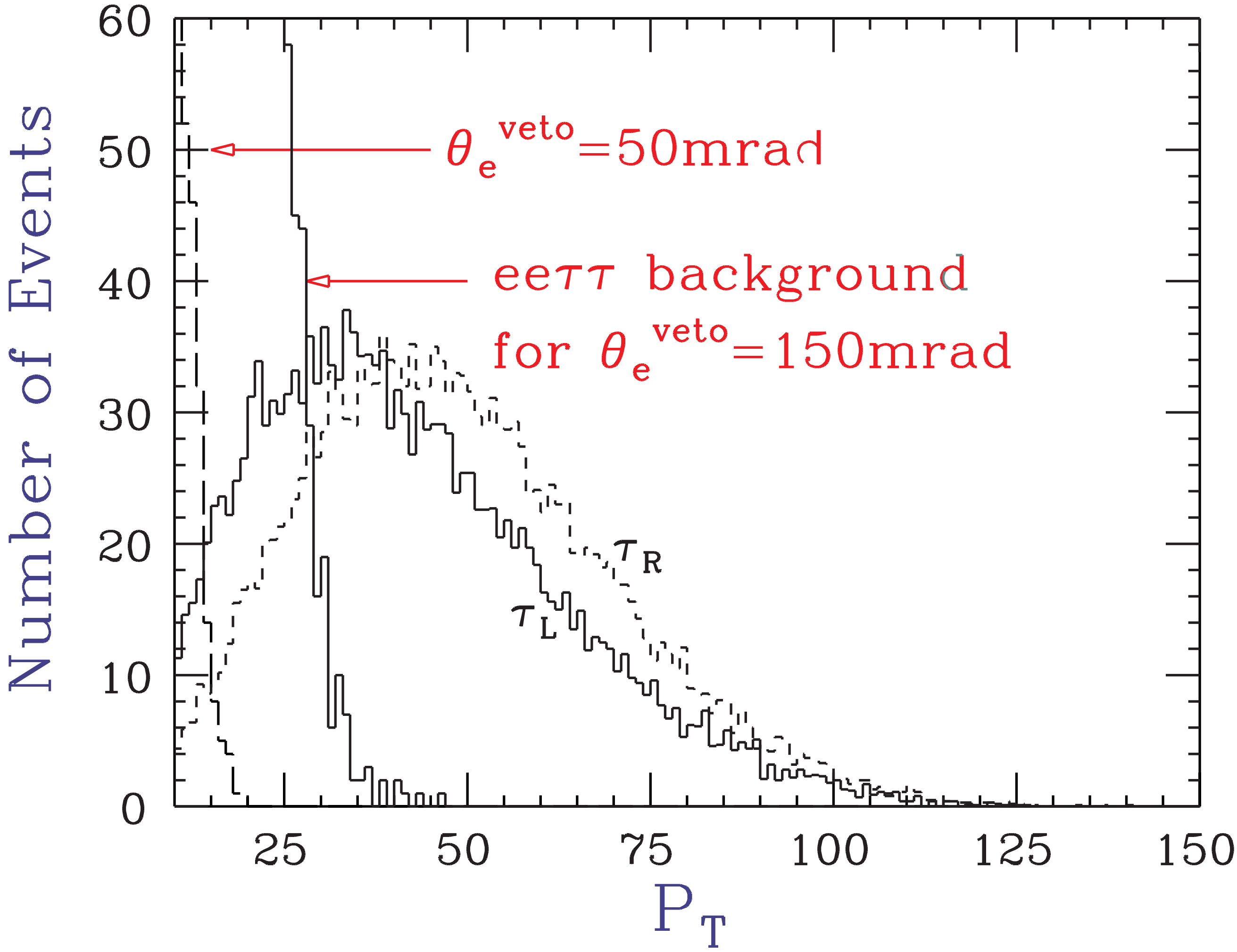
dE/dX measurement in CDC is necessary?

Any detector dedicated to particle-ID is necessary?

for NLSP of gauge mediated SUSY

Importance of small veto angle for

$$e^+e^- \rightarrow \tilde{\tau}^+_{L(R)}\tilde{\tau}^-_{L(R)}$$



9. Good timing information(CDC,CAL,VTX)

The goal is to identify an event in a specific bunch, where the bunch separation is 1.4-2.8 nsec,

in order to discriminate a physics event from minijets etc. .

For an example, if a physics event with a minijet,

σ_{jj}(2 jet mass)=3.9GeV $\rightarrow$ 5.4GeV

$c\bar{c}$ minijet is serious background for $h \rightarrow b\bar{b}$?

10. Trigger

Do we need a hardware trigger?

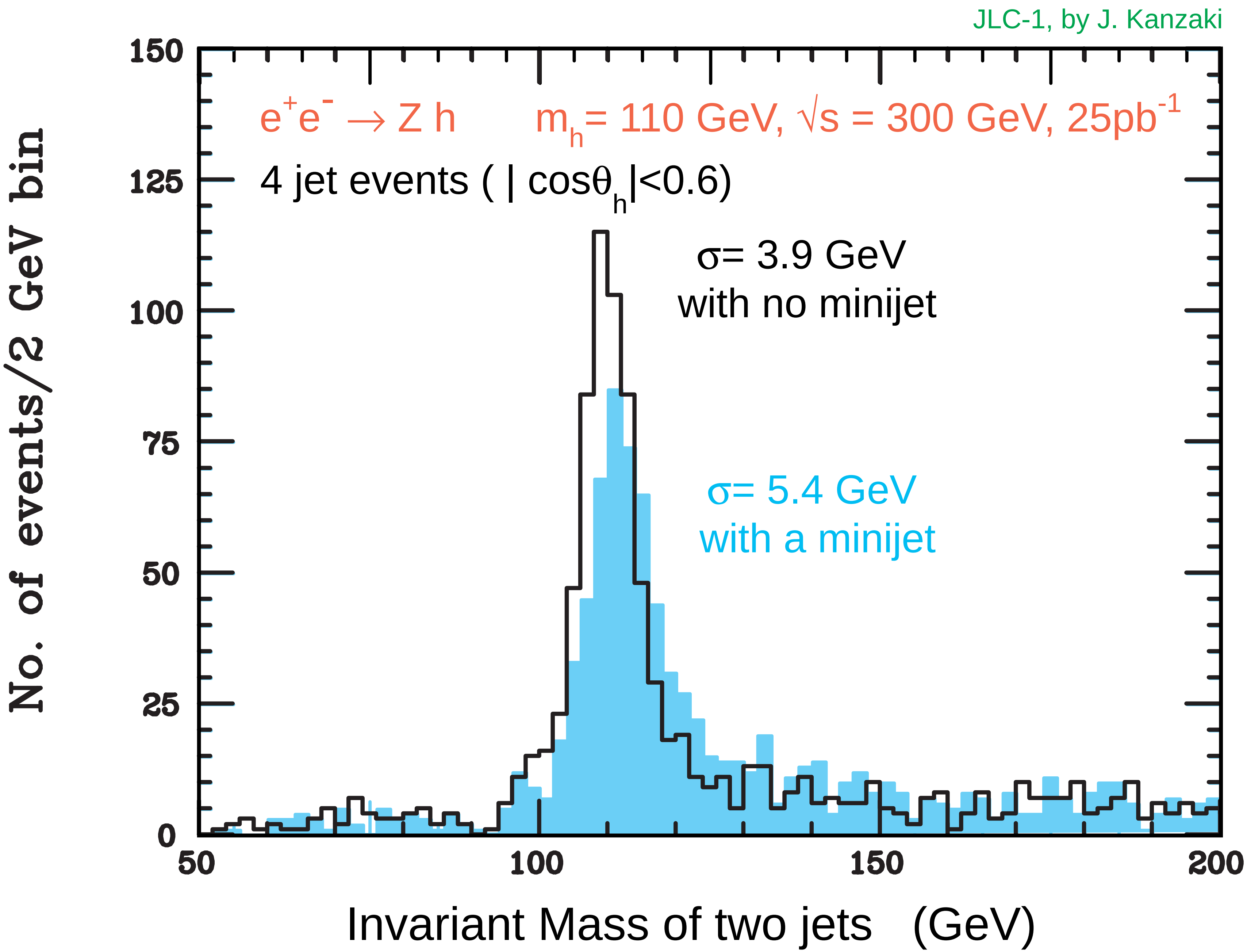
A software trigger is of-course needed, however what is the difference?

11. Data aquisition

For the JLC-1 detector;

Typical data size: 12 Mbyte/hadronic event

Readout speed (no data save on tapes): 150 Hz max.



JLC-1, by J. Kanzaki
e+e- → Z h
mh= 110 GeV, √s = 300 GeV, 25pb-1
4 jet events (| cosθh|<0.6)
σ= 3.9 GeV
with no minijet
σ= 5.4 GeV
with a minijet
No. of events/2 GeV bin
Invariant Mass of two jets (GeV)
0
25
50
75
100
125
150
50
100
150
200

Sizes and Electronics for the JLC detector

total size: 16 x 16 x 16 m^3, 14,783 tons

Detector	Total channels	Typical data size	Method	weight	Power consumption
Vertex	$6x10^3$	68 kbytes/bunch-crossing	Flash ADC		12kW 0.5kW(preamp)
CDC	$1.8x10^4$	12 Mbytes/hadronic-event	500MHz,8bit Flash ADC(22W/ch)	3 tons	397kW
	r=0.3-2.3m, 4.5mlong,	73.5m^3 of CO2-isobutane(90:10)			1.0kW****(preamp)
CAL	$3x10^4$	30kbytes//hadronic-event	FASTBUS-ADC	1,500(barrel) +1,280(endcap) tons	12.4kW**
	$2x10^6$ of Si pads				300kW***(preamp)
MDC	$1.25x10^4$	40kbytes	Conventional TDC		9.4kW*
	~4x10m long(barrel), ~4x15m long (endcap),		745m^3 of HRS gas		0.7kW****(preamp)
Magnet	9m diameter x 10m long			12,000tons with iron	500kW
Liq.Helium	500 liters			(coil:52x3tons; 720tons without iron)	

*FASTBUS-TDC(LecRoy1879) 71.8W/96ch

**FASTBUS-ADC(LecRoy1885) 39.6W/96ch

***preamplifier(TOPAZ-FCL type) 150mW/ch

****preamplifier(TOPAZ-VTX type) 50mW/ch

Utilities for the JLC detector

1) total size: 16 x 16 x 16 m^3, 14,783 tons

2) Largest component

(a) Magnet coil 9m diameter x 10m long

It can be divided into 3 coils of 3.2m long; 52 x 3 tons

(b) MDC 7m x 15m

It can be divided into 2.

3) Electric power consumption

(a) Electronics Hut	430.8kW
(b) Detector side	302.2kW
(c) Magnet	500kW
Total	**1233kW**

4) Cooling water*

(a) Electronics Hut	90 liters/sec
(b) Detector side	75.4 liters/sec
(c) Magnet	125 liters/sec
Total	**299.4 liters/sec**

5) Liquid He

500 liters

*50 kcal/sec=50 kg/sec=50 liters/sec corresponding to 200 kW cooling