

# Detector Overview

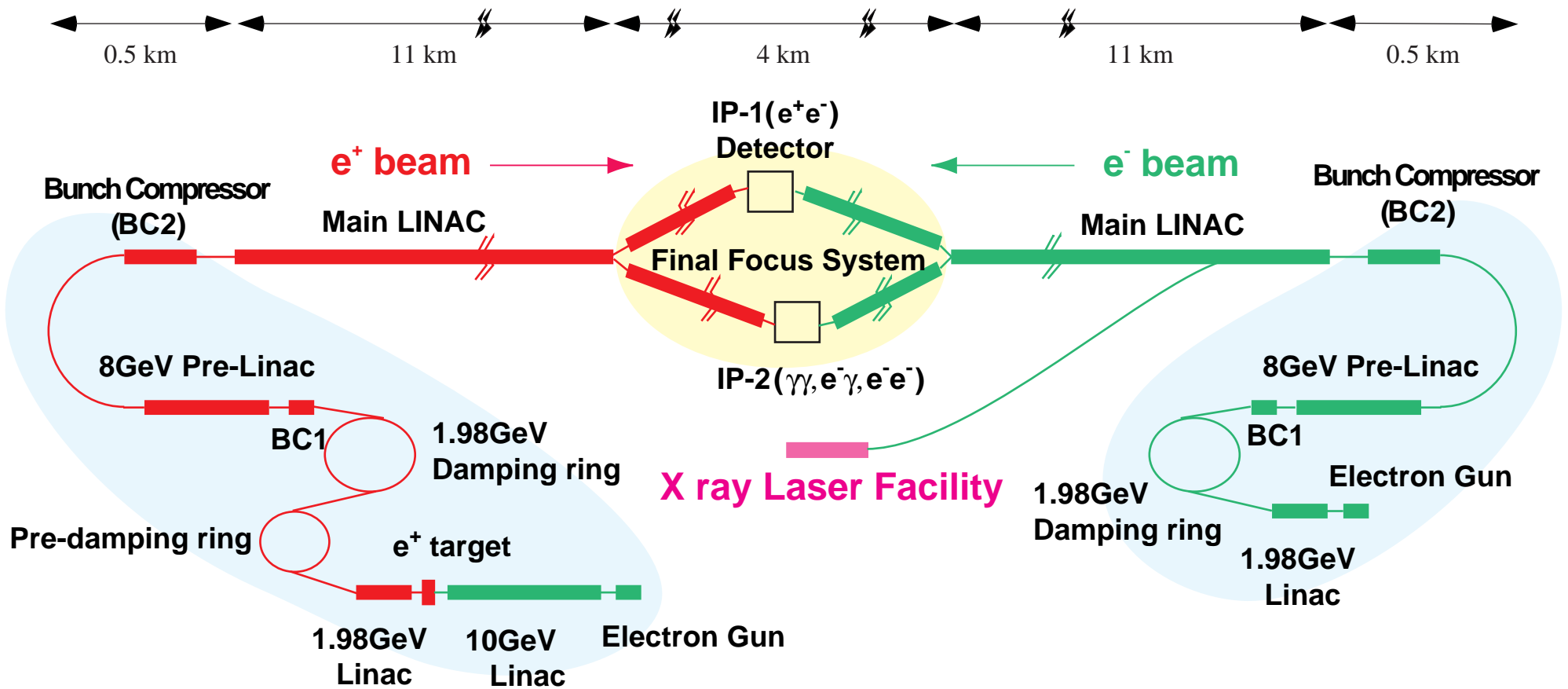
## focused on interaction region

The 1st ACFA Workshop on Physics/Detector at the Linear Collider  
Tsinghua University, Beijing  
T. Tauchi (KEK), November 27, 1998

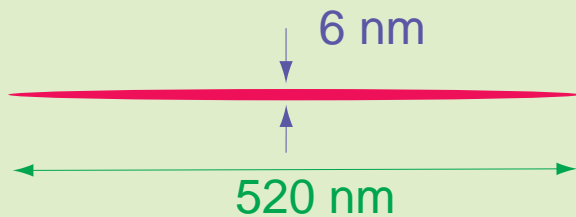
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# Schematics of JLC accelerator complex

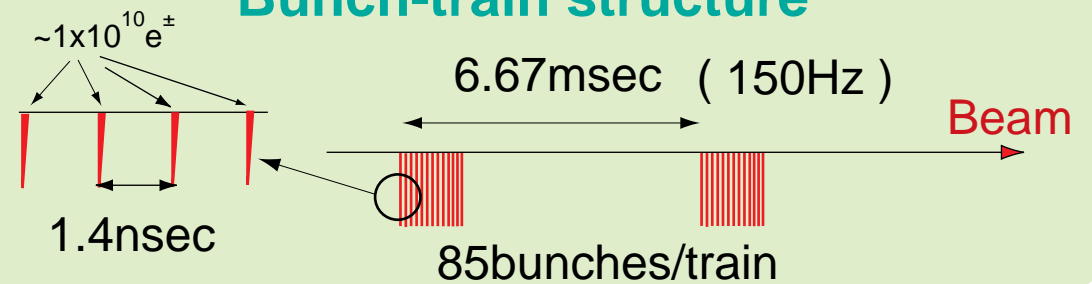


## Beam transverse profile



$$\sigma_z = 90 \mu\text{m}$$

## Bunch-train structure



# JLC Parameters

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

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RF frequency	11.4 GHz ( $\lambda=2.6$ cm )		
#Electrons/Bunch	$7.0 \times 10^9$ ( $6.45 \times 10^9$ at IP )		
#Banches/Train	85		
Bunch separation	1.4 nsec		
G(loaded)	55.6 MeV/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		

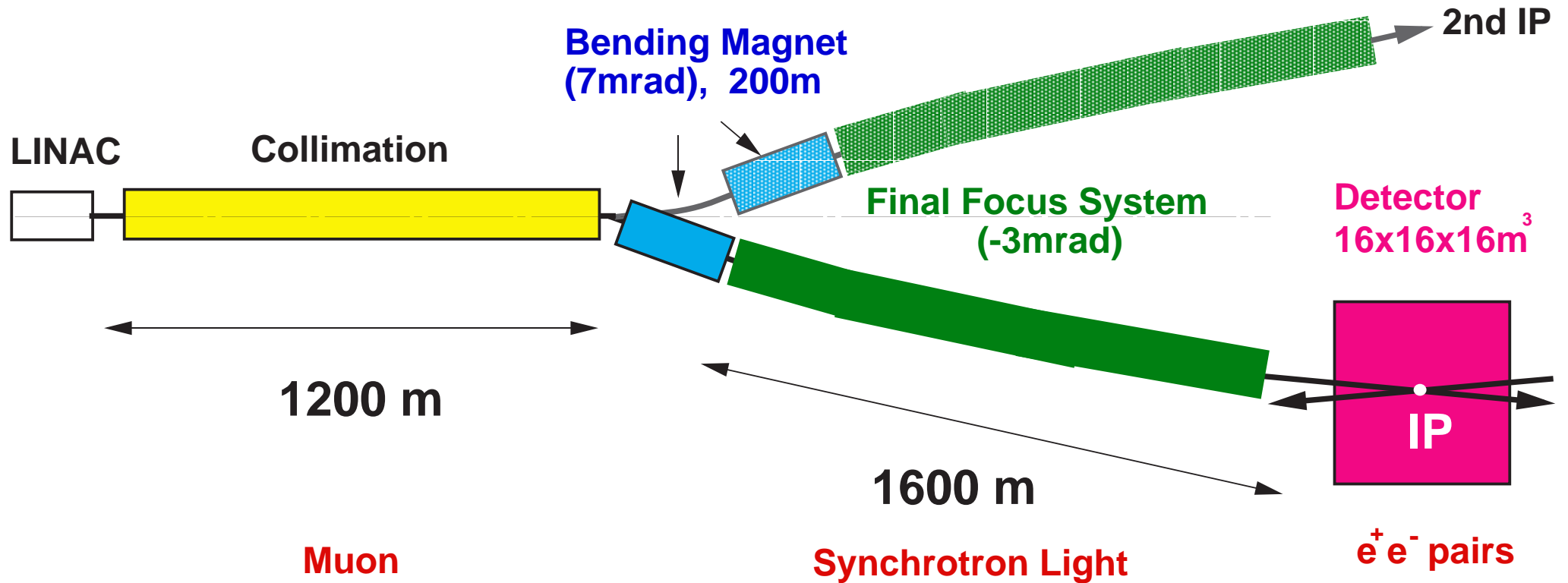
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	Ecm= 250 GeV	500 GeV	1.0 TeV	
#Klystrons/beam	1053	2197	4485	
Length/linac	2.07	4.32	8.81	km
AC-power(wall-plug)	55	115	234	MW
	assuming 28% WP $\rightarrow$ RF efficiency			
Rep.rate	150	150	150	Hz
$\beta_x^*$ (mm) / $\beta_y^*$ ( $\mu$ m)	10 / 100	10 / 100	10 / 100	
$\sigma_x^*$ (nm) / $\sigma_y^*$ (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 $\times 10^{33}$	4.13	8.28	16.72	$\text{cm}^{-2} \text{s}^{-1}$

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

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



collimate beam-tail  
 $6\sigma_x \times 40\sigma_y$

from collimated beam

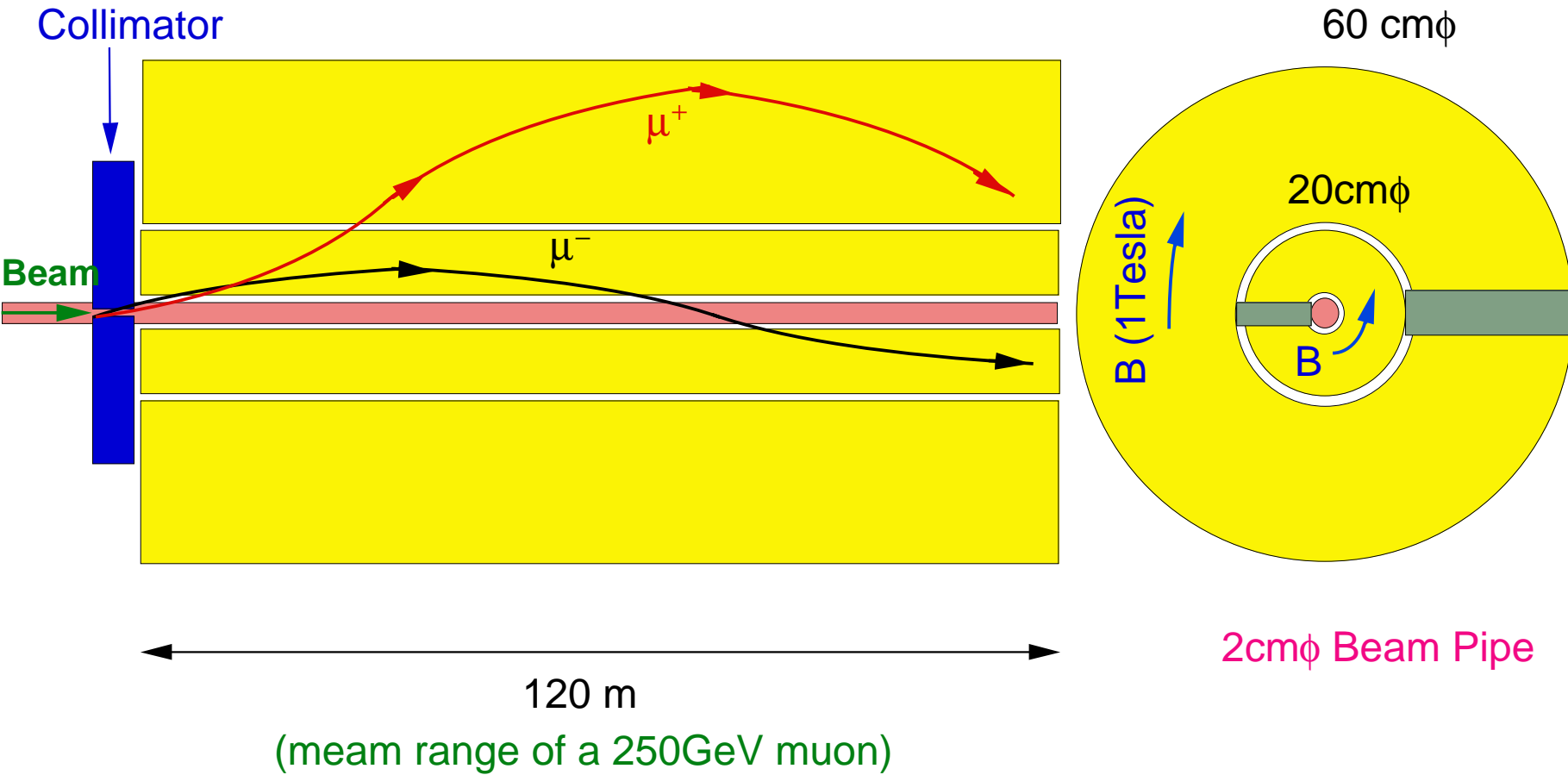
$$\sigma_{\theta_{x(y)}} = \sqrt{\varepsilon_{x(y)} / \beta_{x(y)}}$$

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

$\theta_c = 8$  mrad

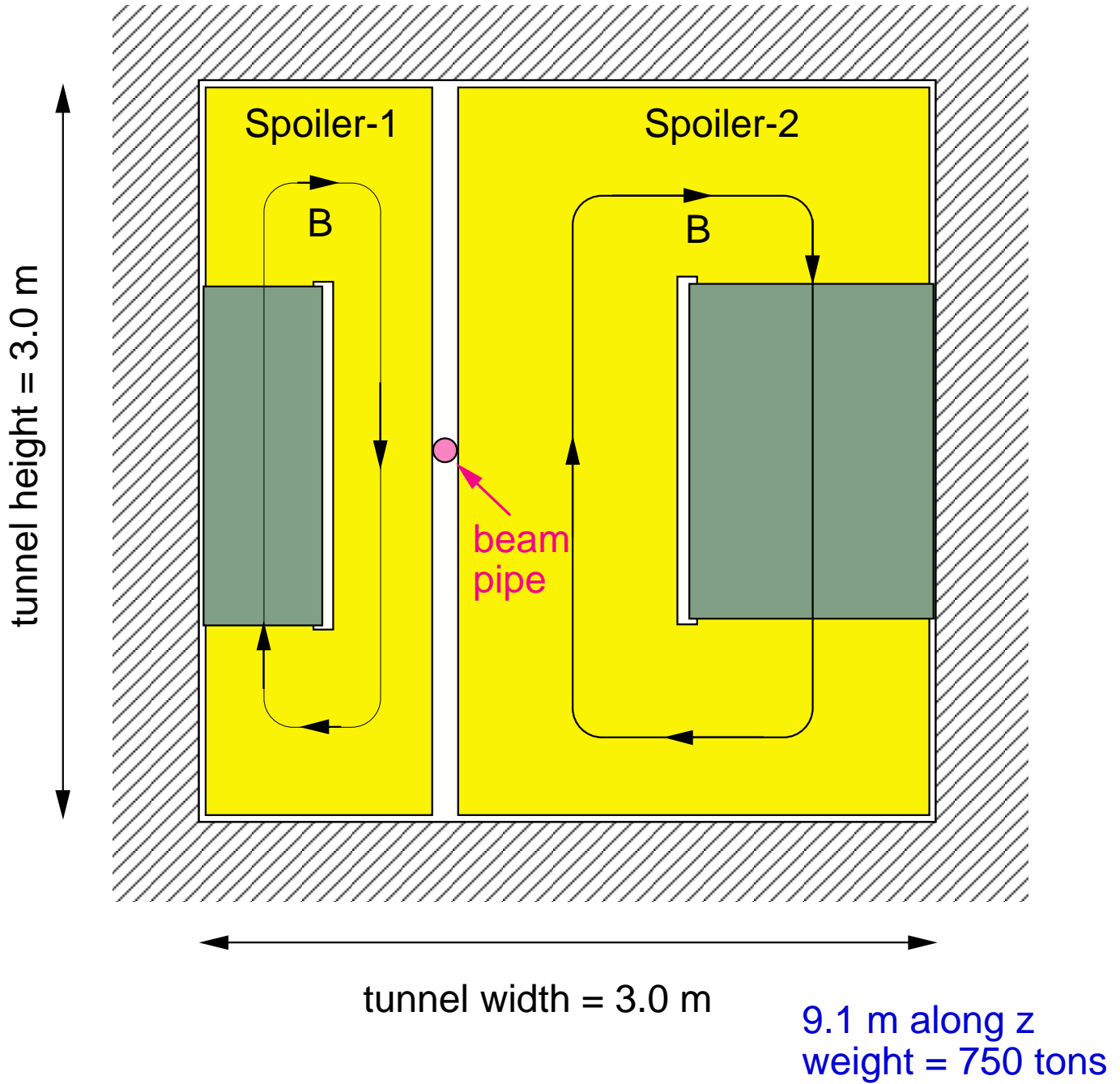
# Muon Attenuator

E.A.Kushnirenko, LC92



# Muon Spoiler

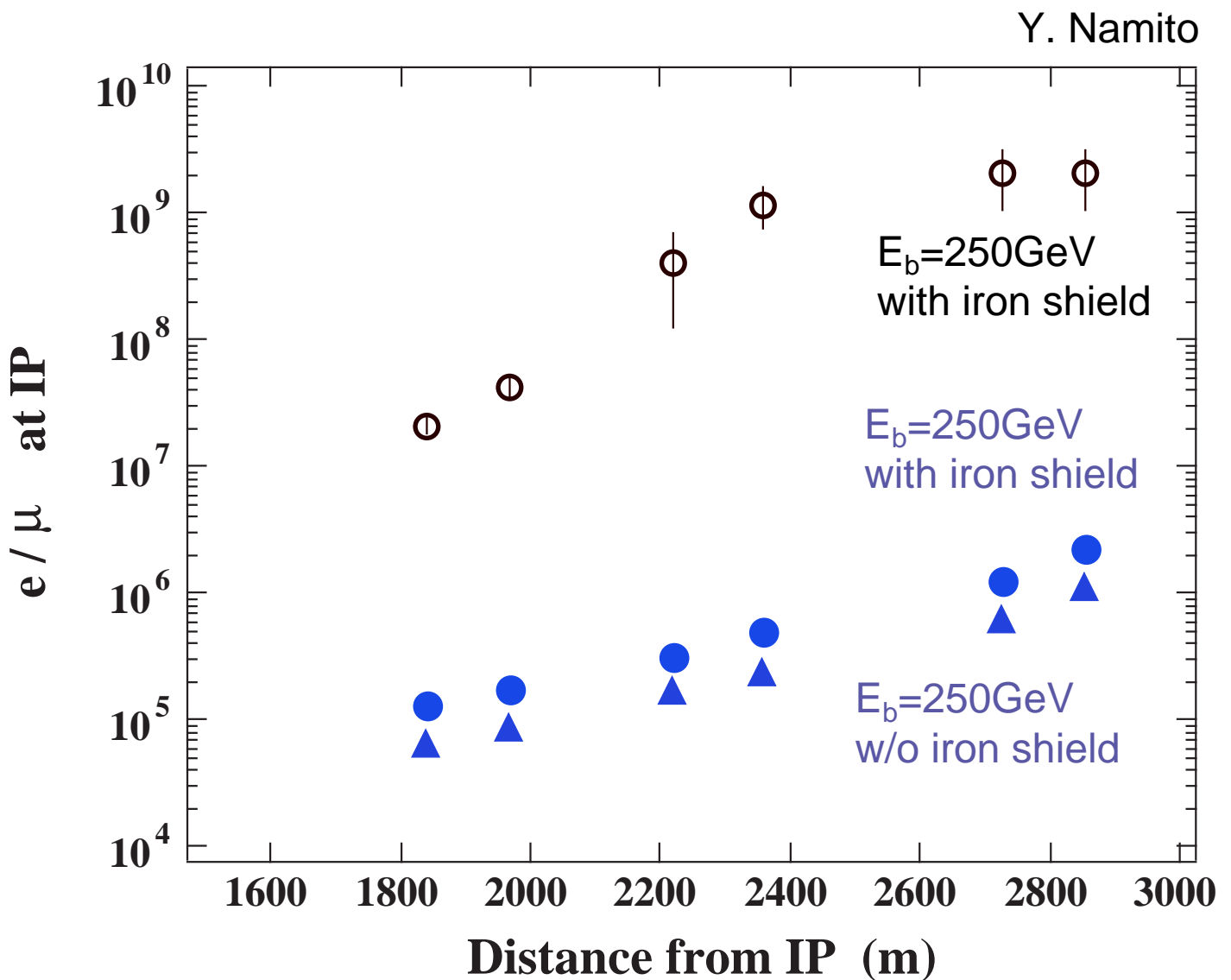
L.Keller,LC93

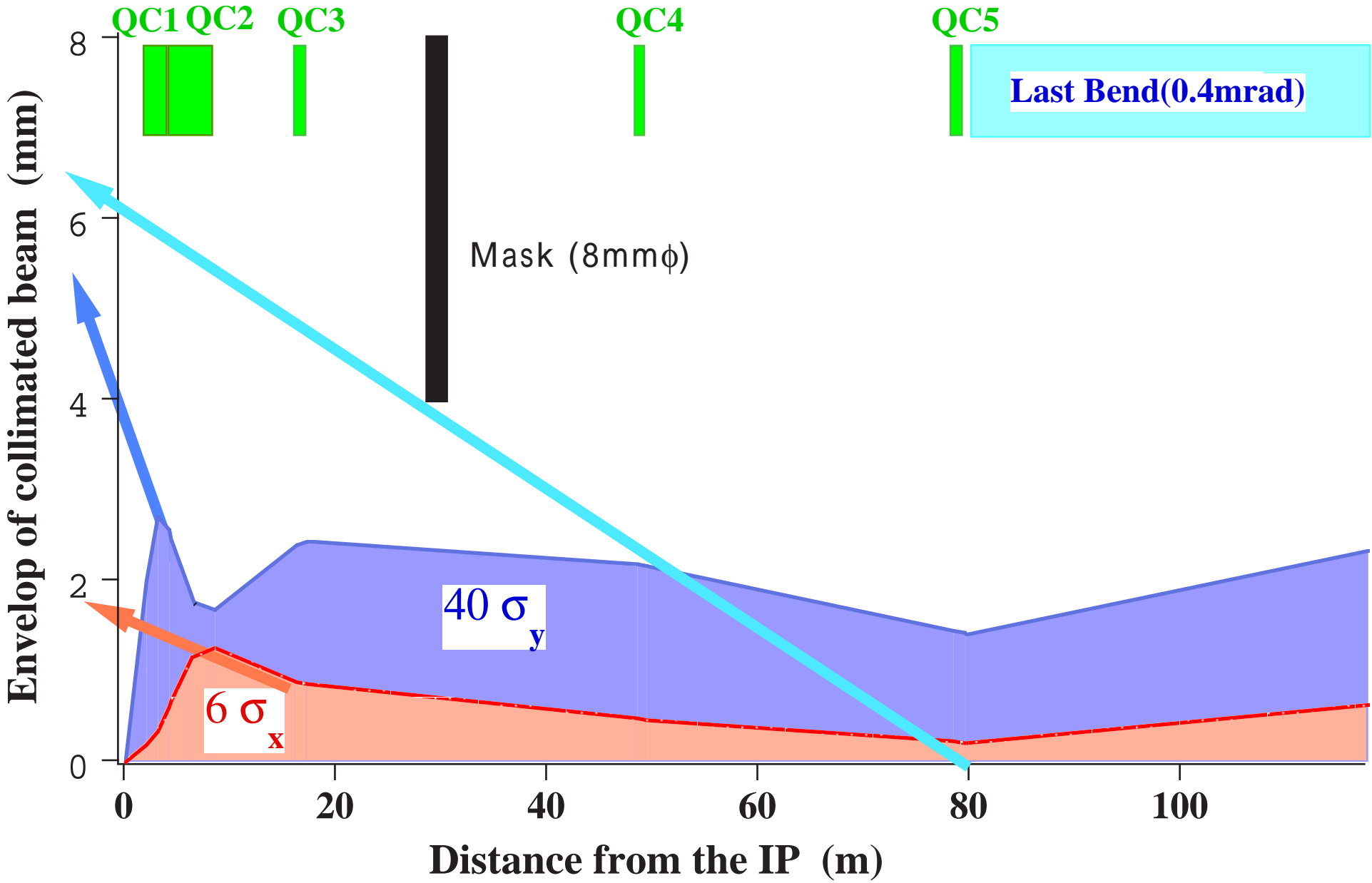


# Muon Background

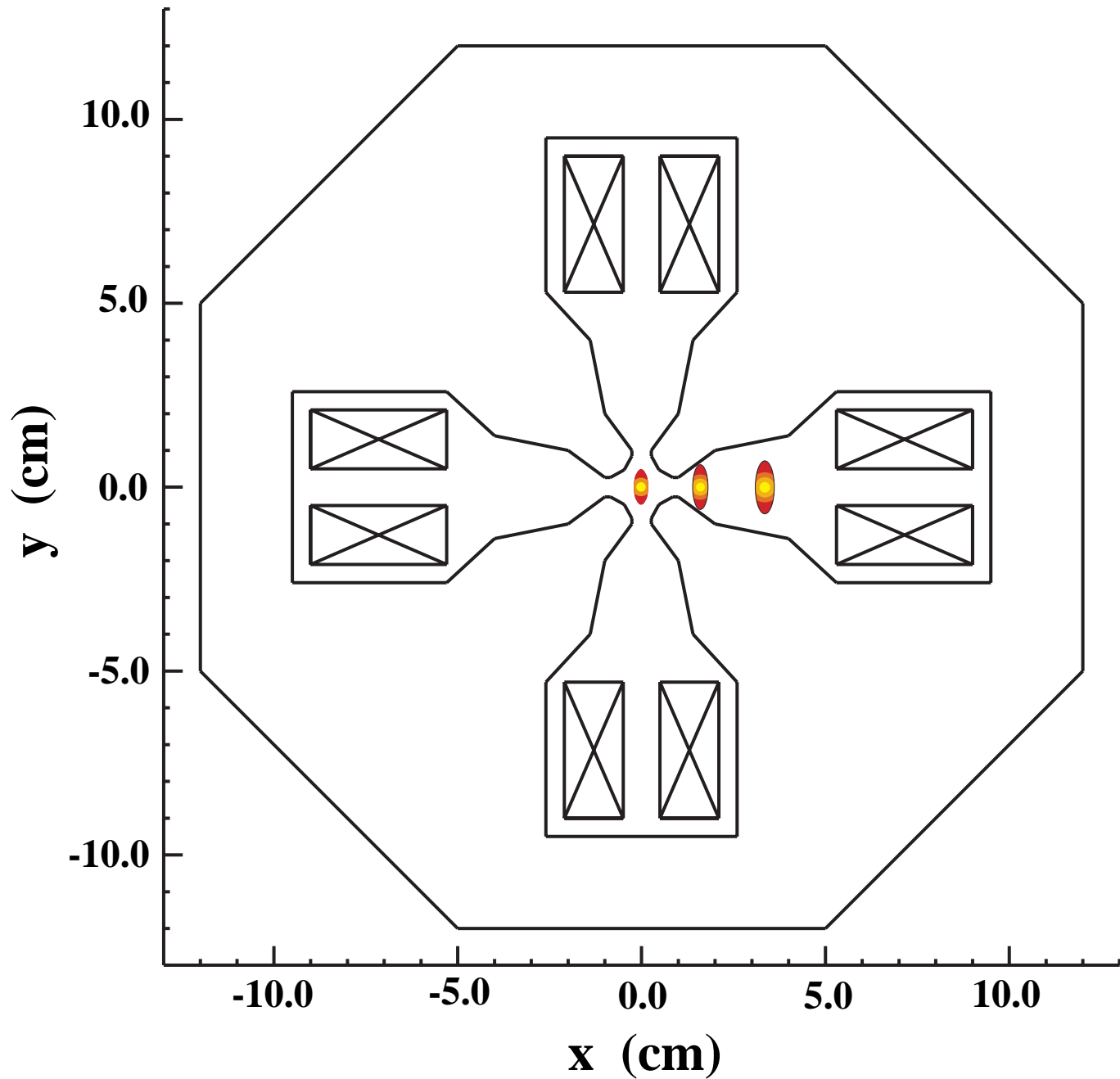
$10^8$ (1% tail) x  $10^2$ (bunches) electrons  
may hit collimators at 150 Hz

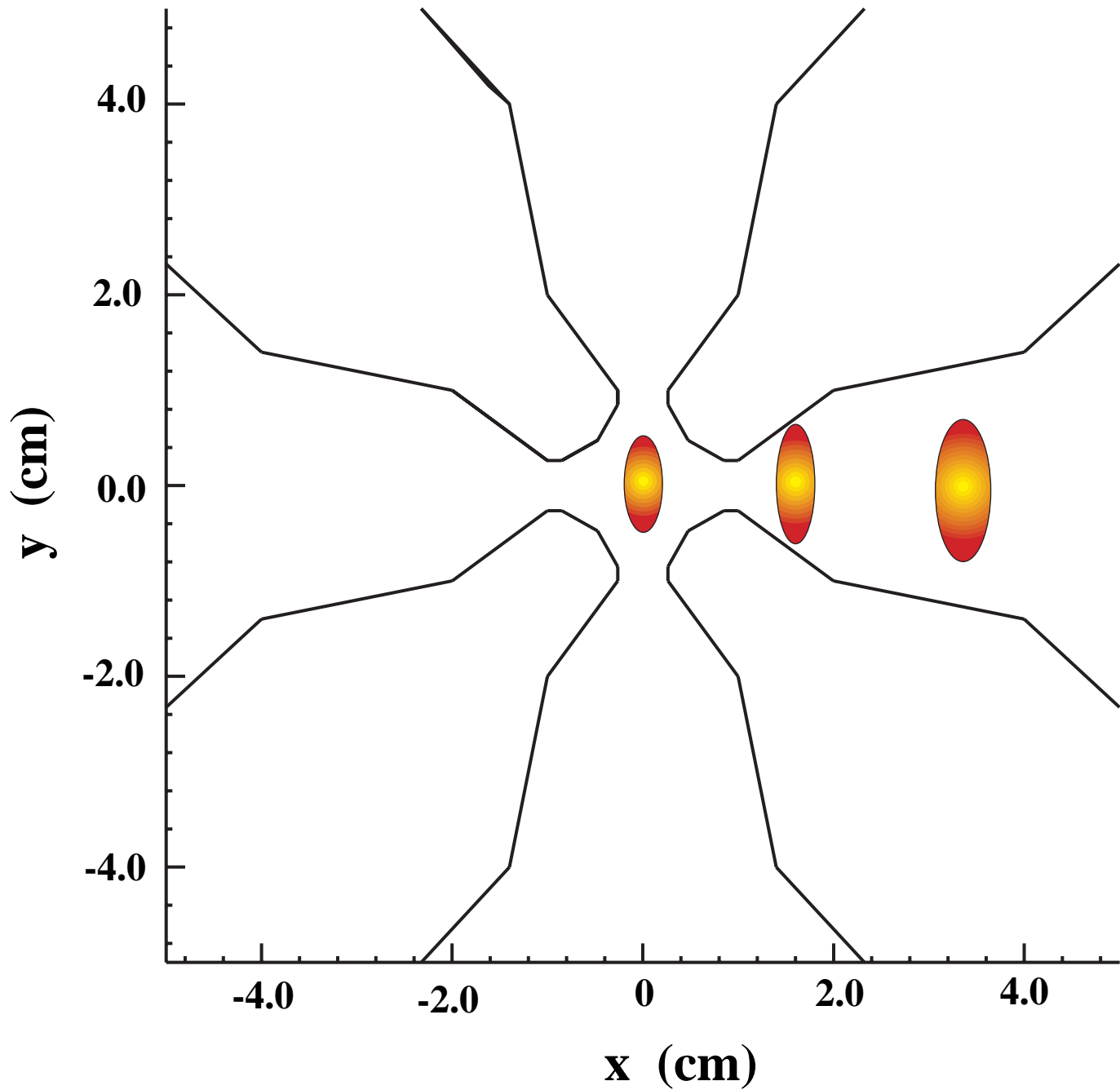
10 muons may be observed in the detector of  
 $16 \times 16 \times 16 \text{ m}^3$ .











# Incoherent $e^\pm$ pairs

Pair creation by virtual and real (beamstrahlung) photons;

$$\begin{array}{ll}
 e^+e^- \rightarrow e^+e^-e^+e^- & : \text{LL} \quad \sigma(\text{cm}^{-2}) \sim O(10^{-26}) \\
 \gamma e^\pm \rightarrow e^+e^-e^\pm & : \text{BH} \quad \sigma(\text{cm}^{-2}) \sim O(10^{-25}) \\
 \gamma\gamma \rightarrow e^+e^- & : \text{BW} \quad \sigma(\text{cm}^{-2}) \sim O(10^{-27})
 \end{array}$$

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

$\Rightarrow$  Background !

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

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

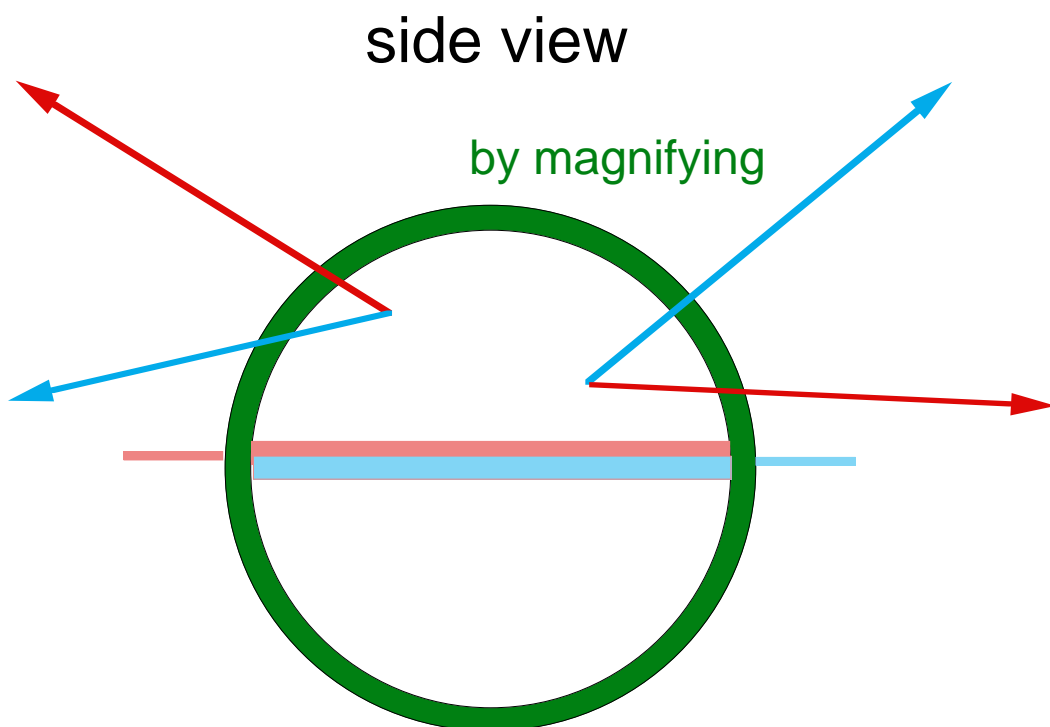
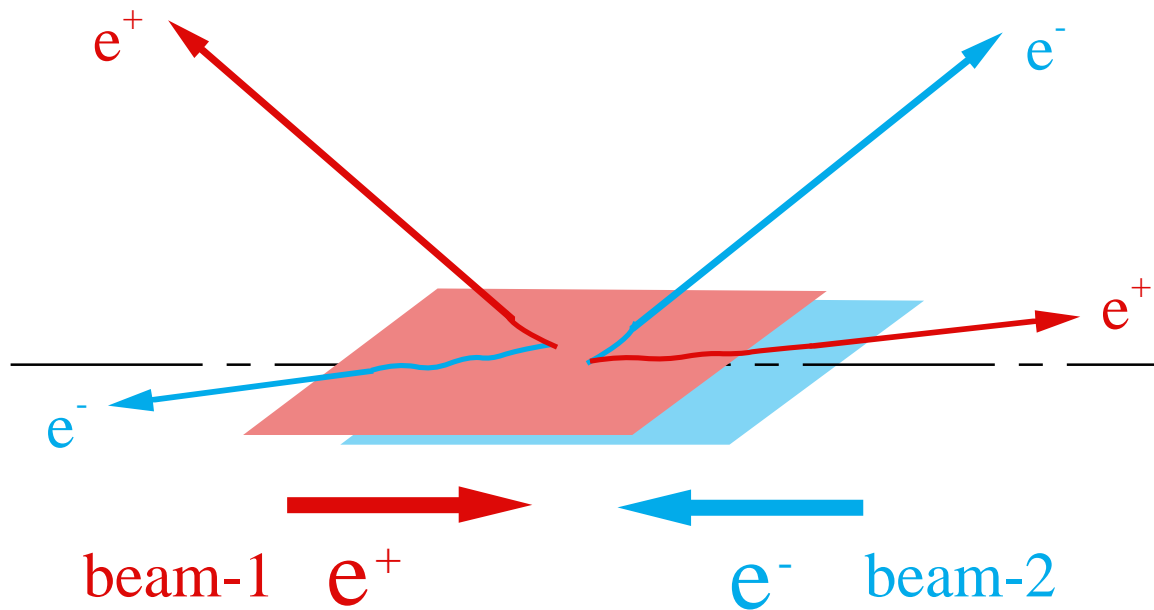
N : number of particles/bunch  $\sim 10^{10}$

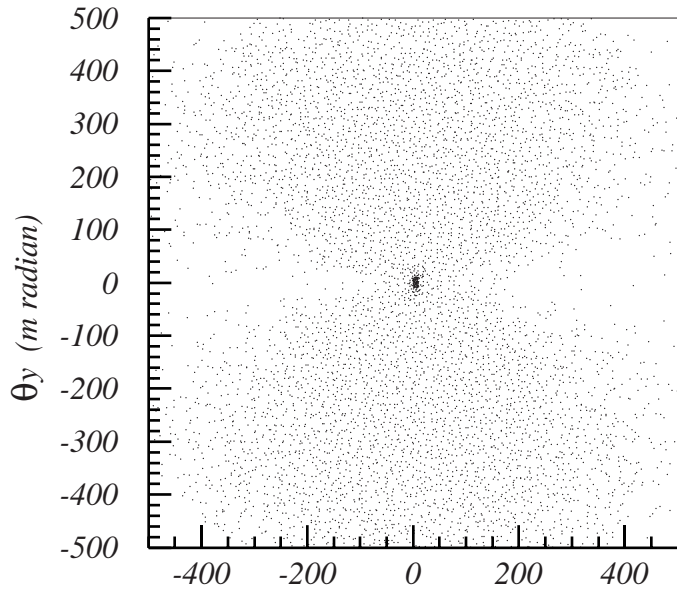
$r_e$  (electron classical radius) =  $2.8 \cdot 10^{-15}$  m

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

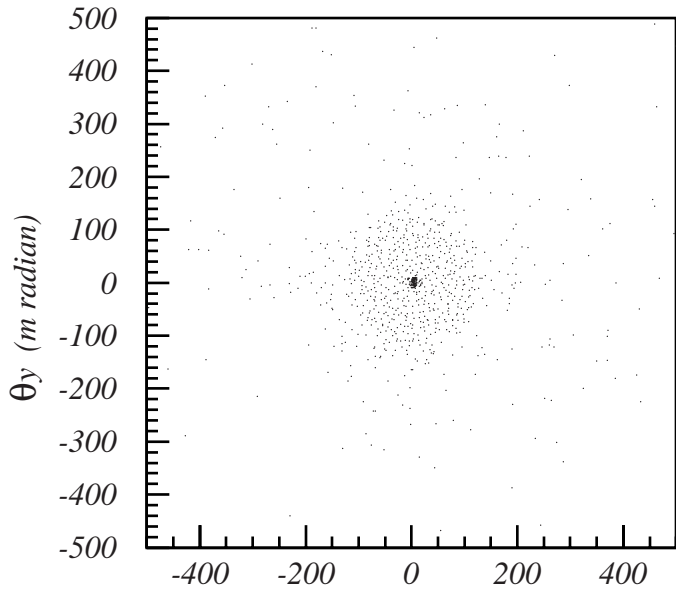
$$y \sim \sigma_y \sim 10^{-9} \text{ m}$$

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

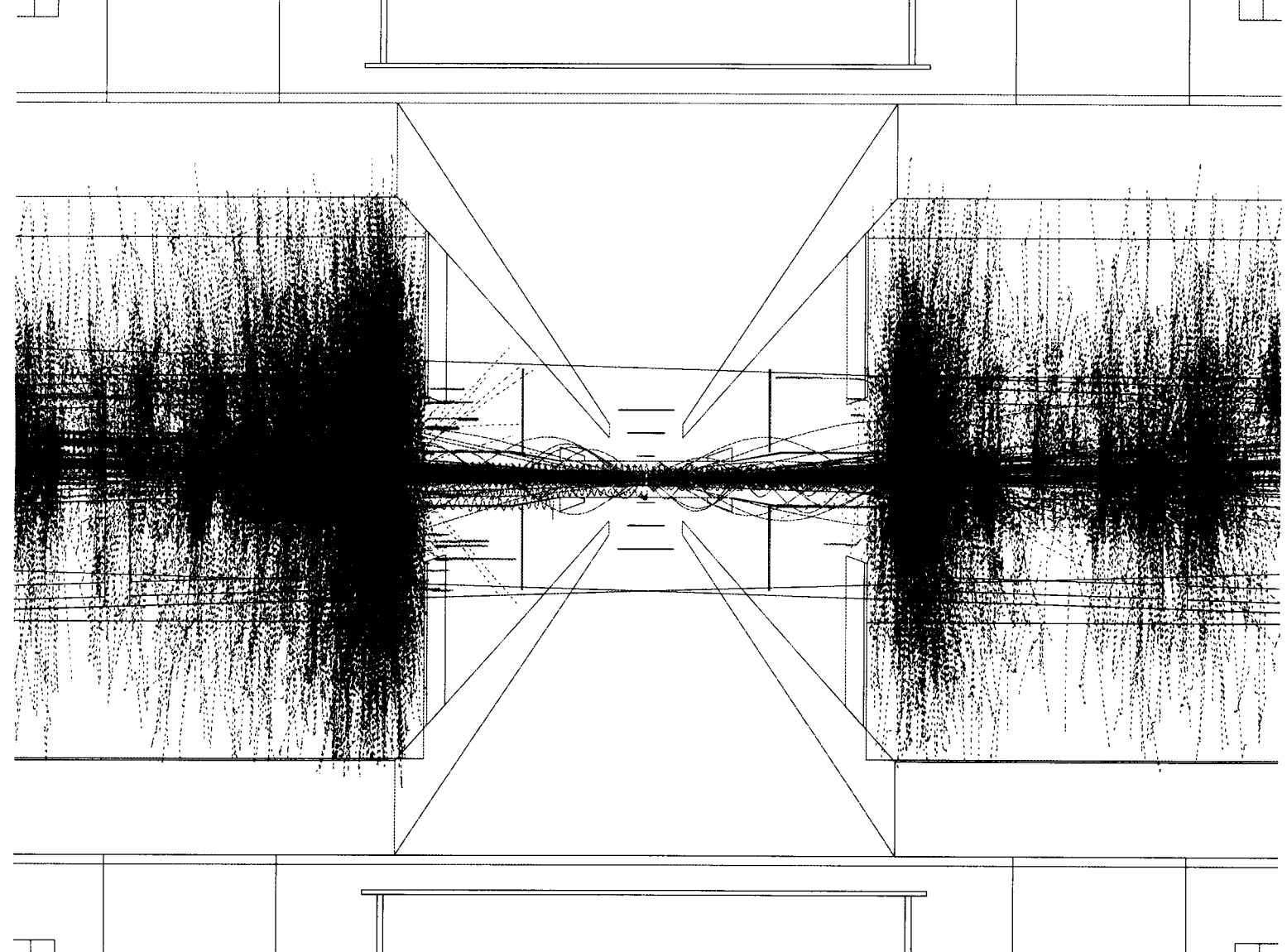


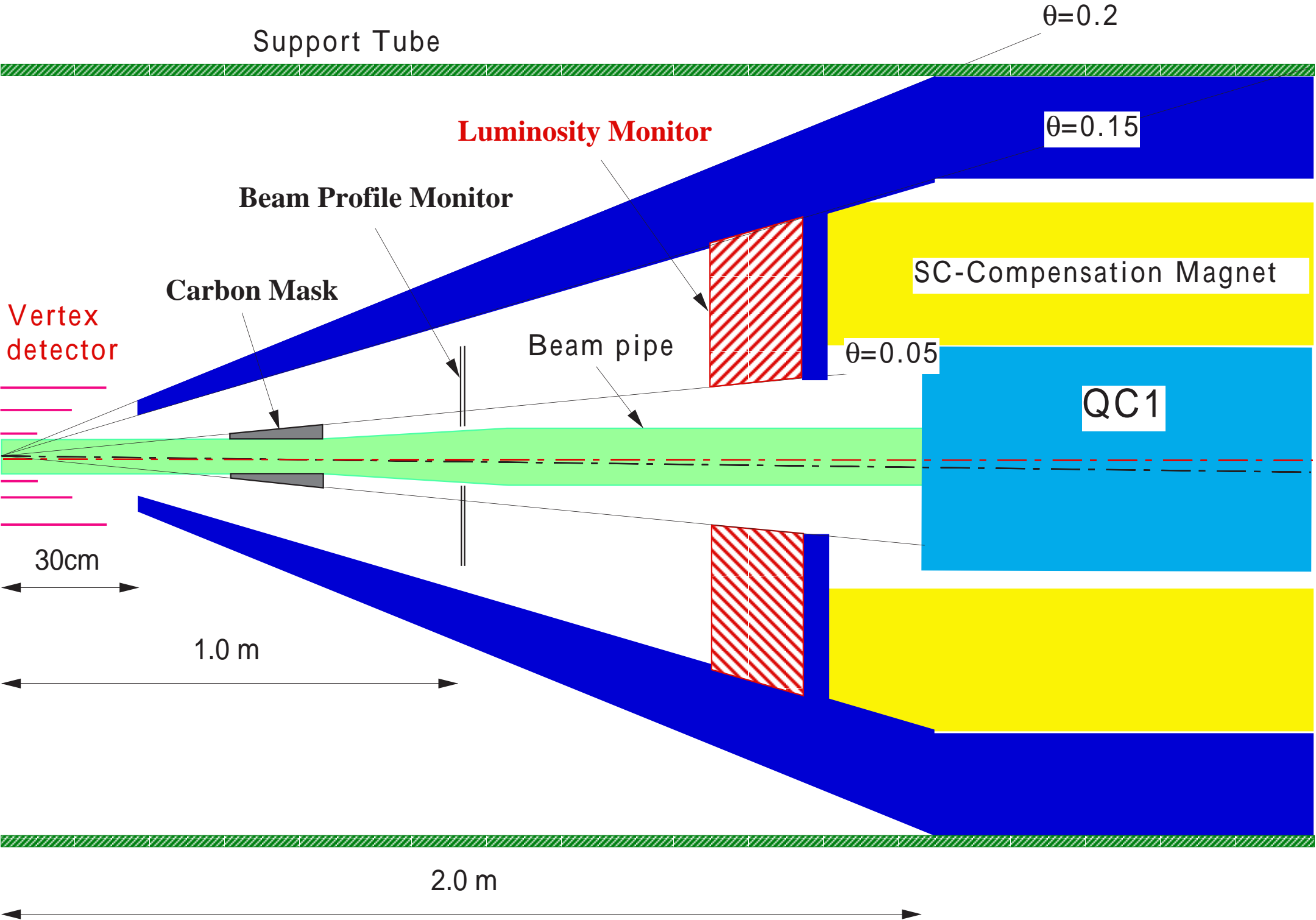


$e^+ : \theta_x$  (m radian)

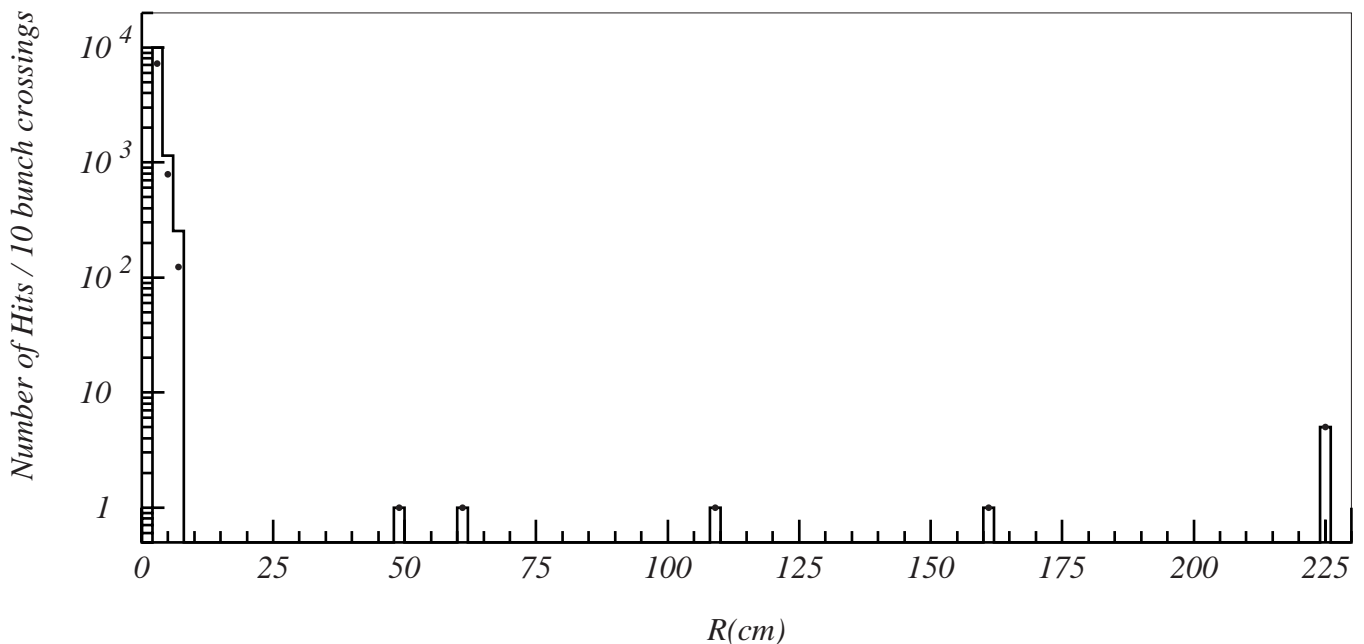


$e^- : \theta_x$  (m radian)





# 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 <sup>2</sup>
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<sup>2</sup>

note: A track produces 20 hits at the VTX.



# Neutron Background

$$N_n \sim 0.13 \Sigma E_e \text{ (GeV)}$$

then

$$10^6 \text{ n/pulse at } 150\text{Hz}$$

in total

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

n/pulse   Hz   s/year

at the 1st layer of the VTX,

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

n/year   /cm<sup>2</sup>    $\Delta\Omega_{\text{VTX}}$

Is this acceptable?

# JLC detector

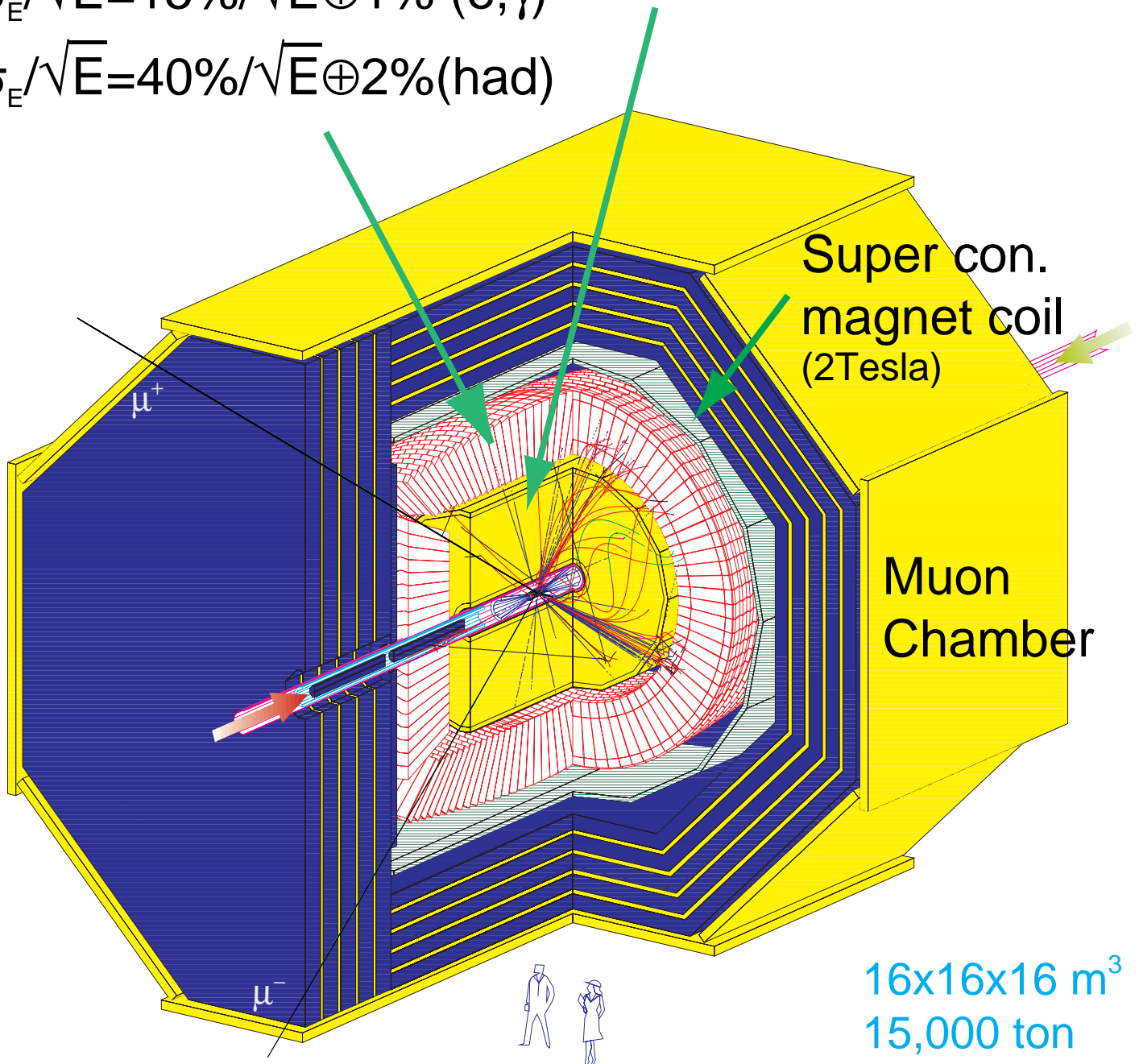
## Calorimeter

$$\sigma_E/\sqrt{E}=15\%/\sqrt{E}\oplus 1\% (e,\gamma)$$

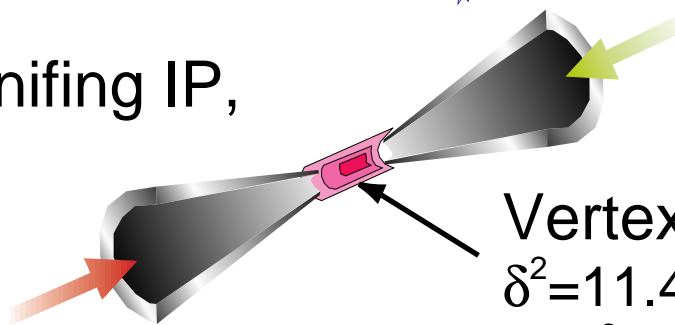
$$\sigma_E/\sqrt{E}=40\%/\sqrt{E}\oplus 2\%(\text{had})$$

## Central Drift Chamber

$$\sigma_{P_t}/P_t=1.1\times 10^{-4}P_t\oplus 0.1\%$$



magnifying IP,



Vertex Detector

$$\delta^2=11.4^2+(28.8/P)^2/\sin^3\theta$$

( $\mu\text{m}^2$ )

# Summary: General issues to be discussed

## 1. Detector size

### Large

CDC: 4.6m  $\phi$  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  $\phi$  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  $\text{PbWO}_4$  crystals.... for measurement of  $H \rightarrow \gamma\gamma$ .

## 3. Hadron calorimeter

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

## 4. Vertex detector: CCD or pixel

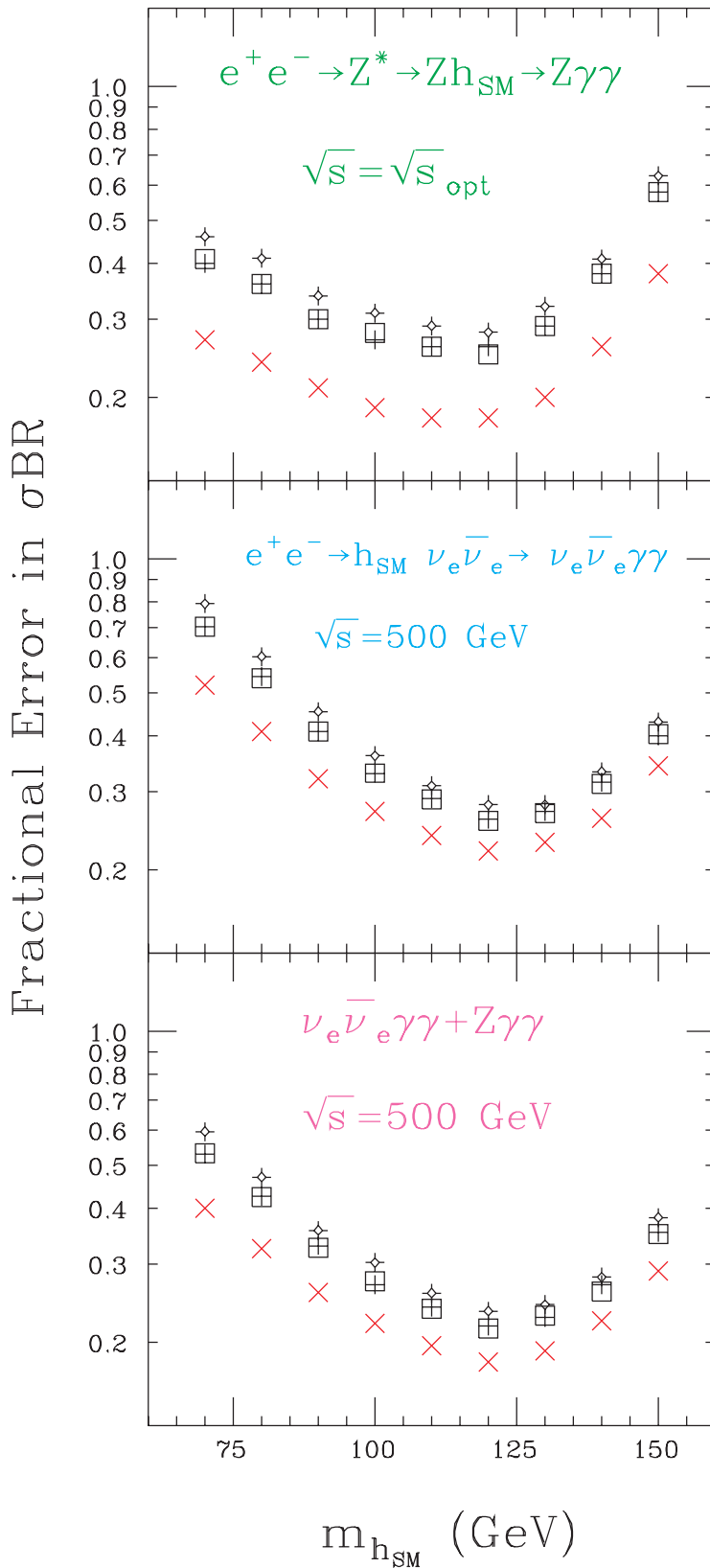
CCD : radiation hardness ( $> 10^9$  n/cm<sup>2</sup>)  
fast readout of  $10^8$  channels (100MHz)

Pixel : spatial resolution is enough ?

Minimal radius should be 1cm with  $B = 4$  Tesla ?

optimum  $r_{\text{VTX}}$  and  $B$  ?

Resolutions:  $\times$ (I);  $+$ (II);  $\square$ (III);  $\diamond$ (IV)  
 $L = 200 \text{ fb}^{-1}$



### Electromagnetic Cal.

(I)  $\Delta E/E = 2\%/\sqrt{E} \oplus 0.5\%$   
 $\oplus 20\%/E$   
 (CMS,  $\text{PbWO}_4$ )

(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**

$$\sigma_{xy} \approx 11\mu\text{m} \oplus \frac{29\mu\text{m}}{p \cdot \sin^{3/2} \theta}$$

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

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

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

$$R_{\min} : \quad 3 \text{ cm}$$

$$\sim 1 \text{ cm}$$

( B=4 Tesla)

$$X_0 : \quad 0.35\% \text{ rl/layer}$$

$$0.12\% \text{ rl/layer}$$

$$(\text{Si} : 200 \mu\text{m}^t)$$

$$20 \mu\text{m}^t)$$

$$(\beta\text{e} : 0.38 \text{ mm}^t)$$

$$0.38 \text{ mm}^t)$$



**Significantly improves 3D topological vertex reconstruction**



**Primary, Secondary, Tertiary Verteces  
Charm and bottom quark ID**

## 5. Minimum veto angle

$$\theta_{\text{veto}} = 200 \text{ mrad ?}$$

= 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  $r=7.5\text{cm}$  to  $r=40\text{cm}$ .

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 determine the luminosity as a function of  $E_{\text{cm}}$ .

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

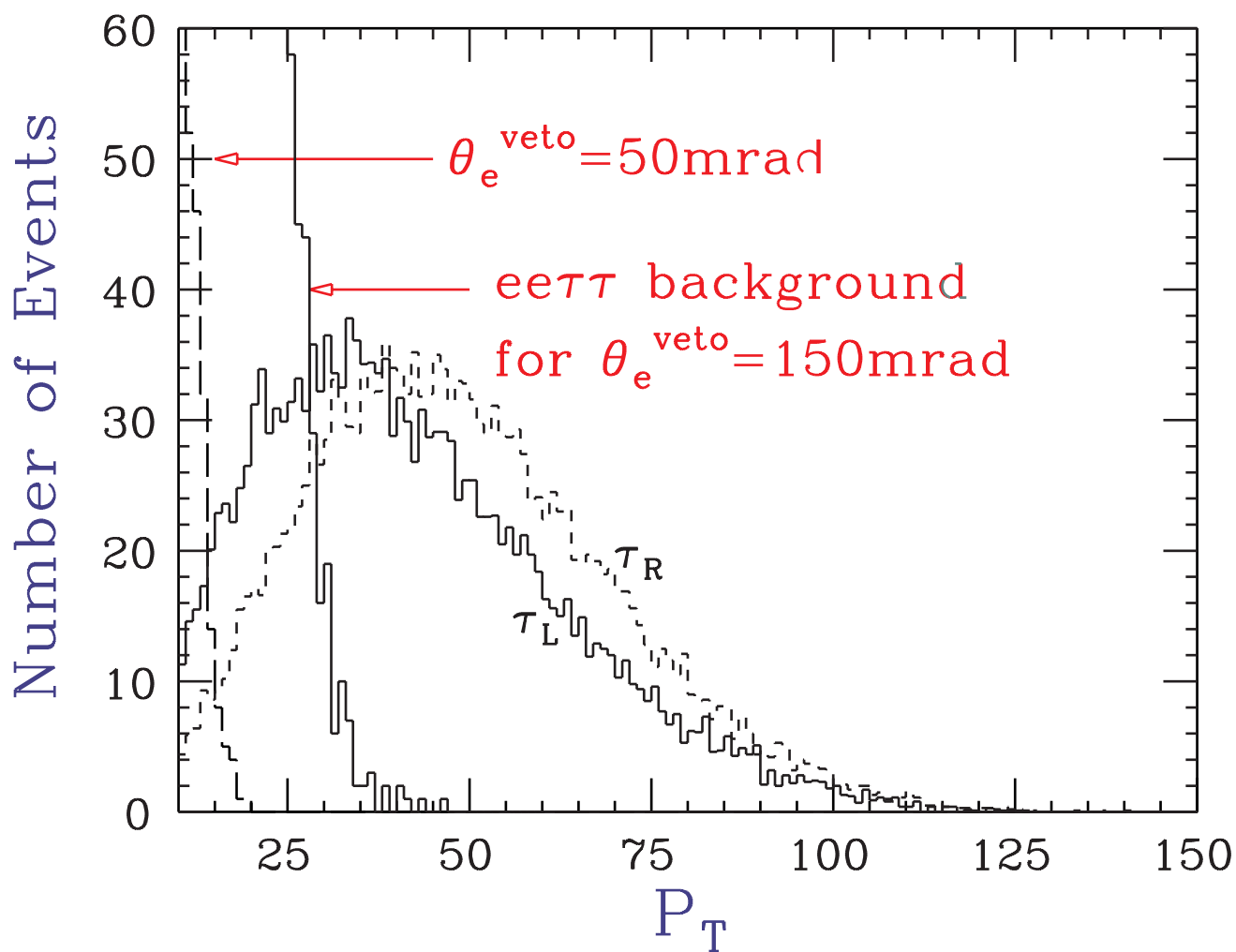
## 8. Particle identification

$dE/dX$  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,

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

$c\bar{c}$  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?

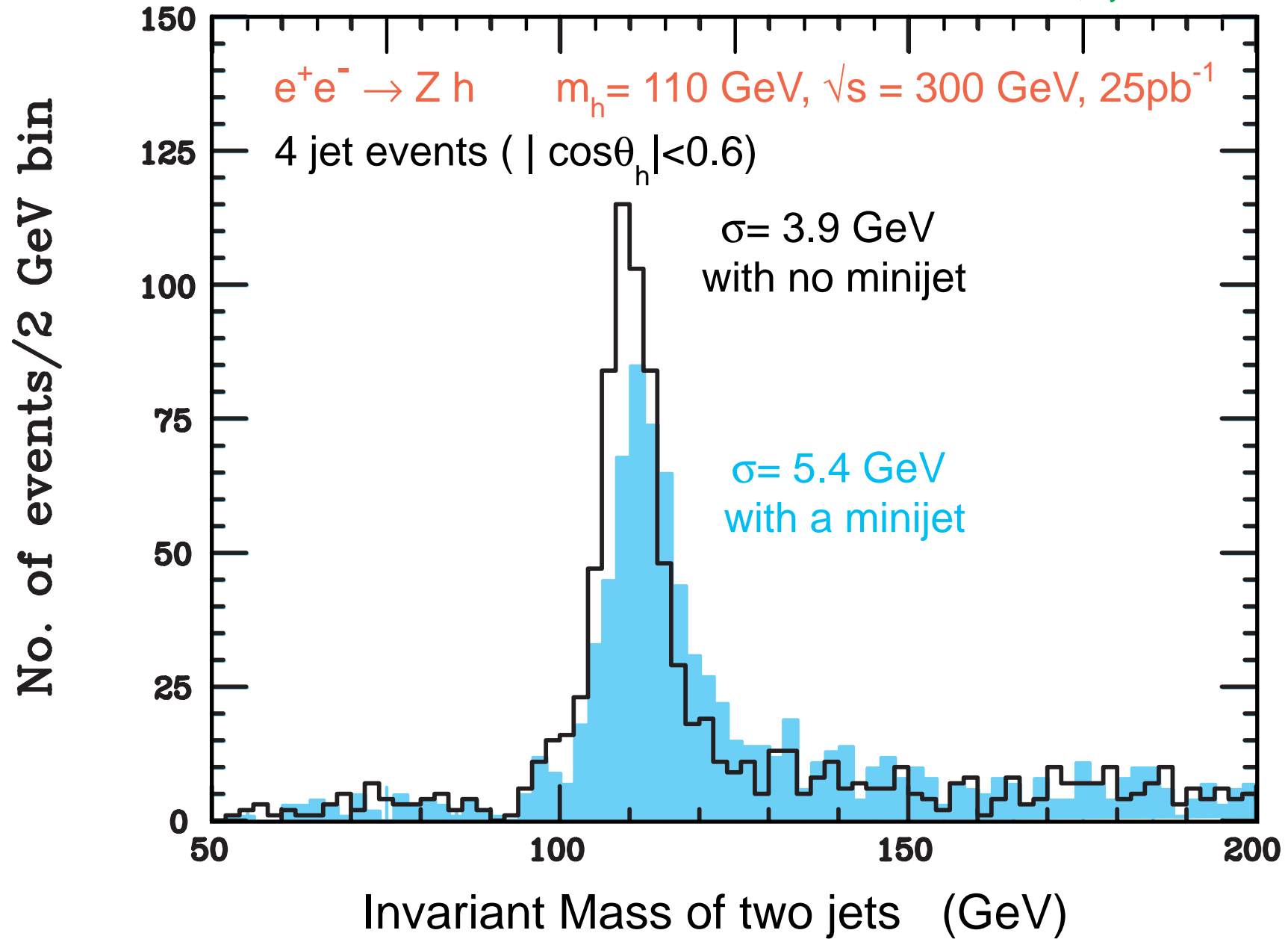
## 11. Data aquisition

For the JLC-1 detector;

Typical data size: 12 Mbyte/hadronic event

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





## Sizes and Electronics for the JLC detector

**total size: 16 x 16 x 16 m<sup>3</sup>, 14,783 tons**

Detector	Total channels	Typical data size	Method	weight	Power consumption
Vertex	6x10 <sup>3</sup>	68 kbytes/bunch-crossing	Flash ADC		12kW 0.5kW(preamp)
CDC	1.8x10 <sup>4</sup> r=0.3-2.3m, 4.5mlong,	12 Mbytes/hadronic-event 73.5m <sup>3</sup> of CO2-isobutane(90:10)	500MHz,8bit Flash ADC(22W/ch)	3 tons	397kW 1.0kW****(preamp)
CAL	3x10 <sup>4</sup> 2x10 <sup>6</sup> of Si pads	30kbytes/hadronic-event	FASTBUS-ADC	1,500(barrel) +1,280(endcap) tons	12.4kW** 300kW***(preamp)
MDC	1.25x10 <sup>4</sup> ~4x10m long(barrel), ~4x15m long (endcap),	40kbytes	Conventional TDC 745m <sup>3</sup> of HRS gas		9.4kW* 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<sup>3</sup>, 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