Important Role of Polarized Positron Beam for Future Linear Colliders

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- **Development of Polarized e^+**
- **Application of the Polarized e^+ beam to Linear Colliders**

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1. Creation of Polarized e^+

(1) β^+ decay : helicity = v/c.

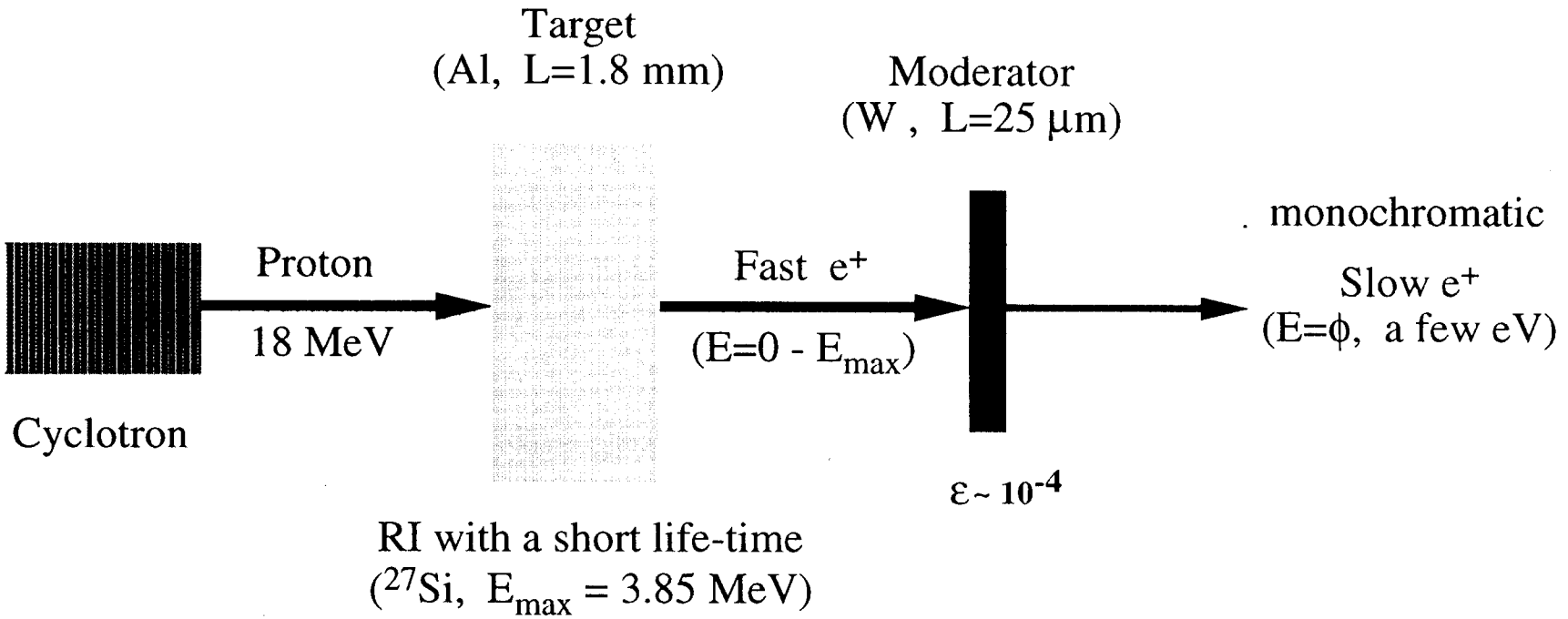
- New aspects
  - On-line production of radioisotopes.

- Possible polarization : 60~80 %

(2) Compton scattering of circularly polarized laser lights with 1.54 GeV e^- from ATF.

- Relatively simple method to produce highly polarized e^+ beams.
  (P > 80 %)

Production System of Polarized Slow e^+



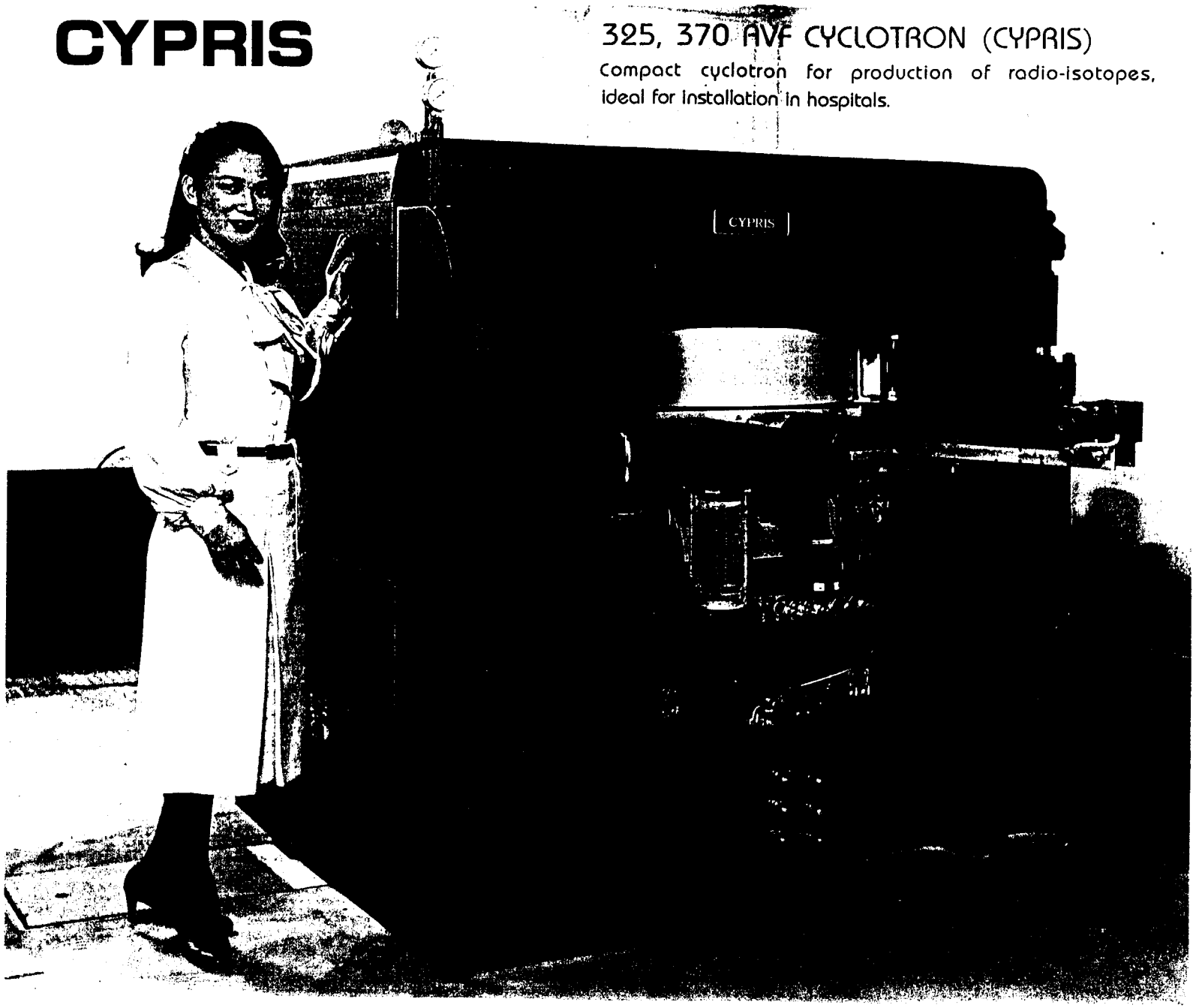
$$^{27}Al + p \rightarrow {}^{27}Si + n$$

$$^{27}Si \xrightarrow{\beta^+ \text{ decay}} {}^{27}Al + e^+ + \nu_e$$

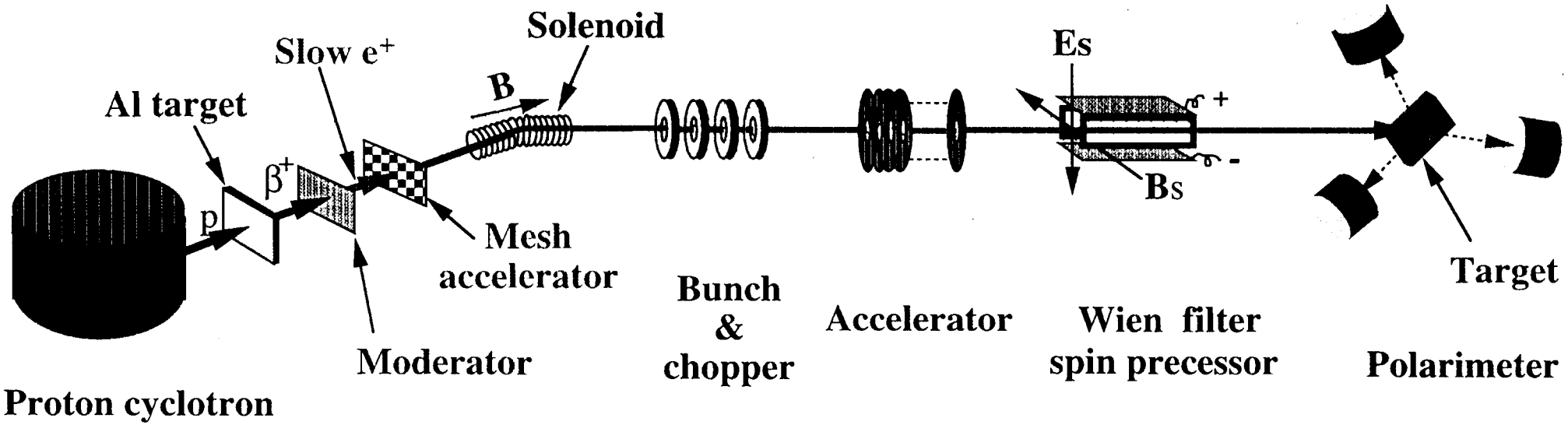
CYPRIS

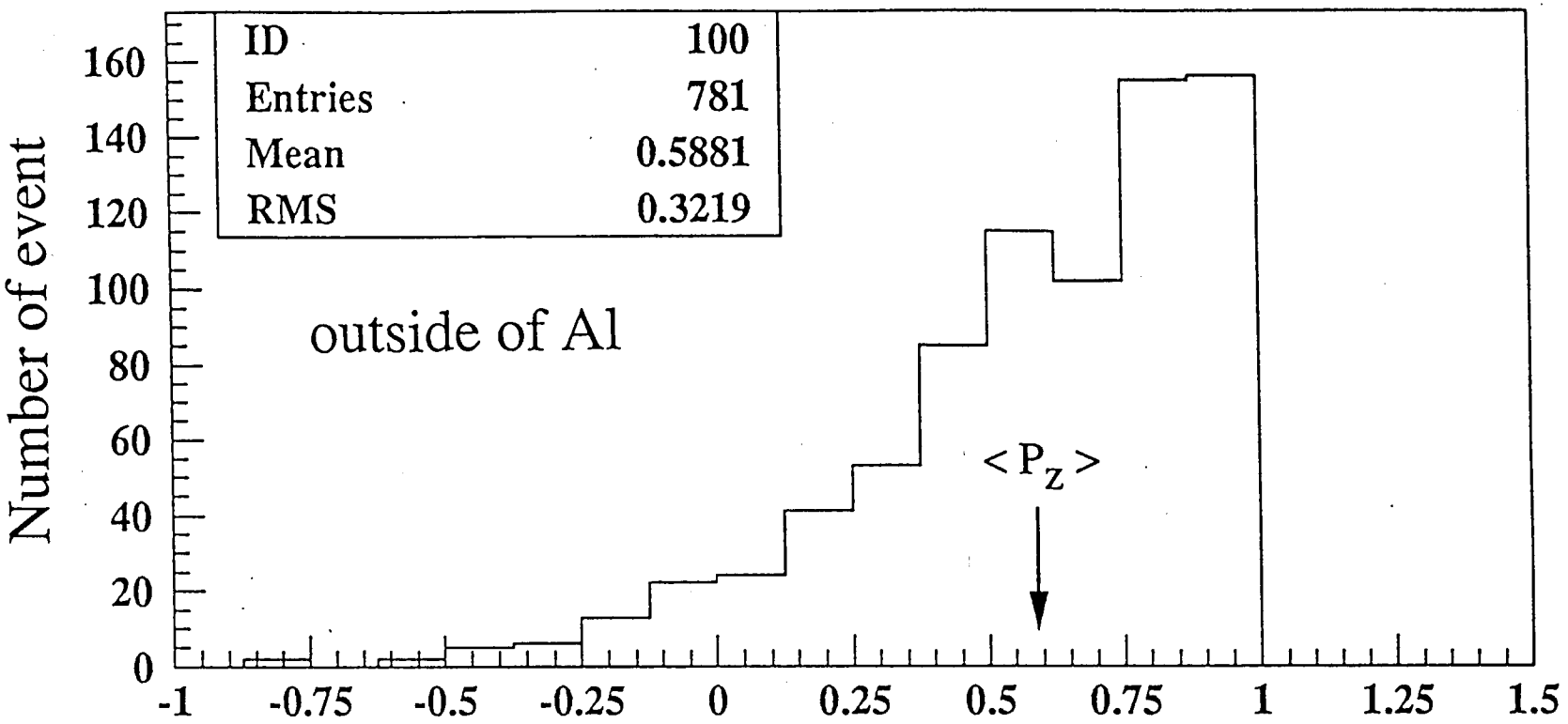
325, 370 AVF CYCLOTRON (CYPRIS)

Compact cyclotron for production of radio-isotopes, ideal for installation in hospitals.



Beam Line of Slow Polarized Positron Beam





$P_Z = (v/c)\cos\theta$

θ : angle between the e^+ spin and flight directions

Beam Intensity of Polarized Slow e^+

Proton current, I / Conversion efficiency of moderator, ε	1 μA	70 μA	1 mA
10^{-5}	4.3×10^4	3.0×10^6	4.3×10^7
10^{-4}	4.3×10^5	3.0×10^7	4.3×10^8
10^{-3}	4.3×10^6	3.0×10^8	4.3×10^9

$\varepsilon = 0.2$

$I = 100$ mA

10^{14} e^+/sec

2. Measurement of the Slow e^+ Polarization (β^+ method)

Mott and Bhabha scatterings are not effective

In an external magnetic field B

Ps state			Effect of B
singlet (para-Ps)	m=0	Ψs	Mixed
triplet (ortho-Ps)	m=0	$\Psi t(0)$	
	m=+1	$\Psi t(+1)$	Unperturbed
	m= -1	$\Psi t(-1)$	

Ψs and $\Psi t(0)$ are perturbed to form two mixed states

$$\Psi' t = \{\Psi t(0) + y\Psi s\}/\sqrt{1+y^2} \quad [\text{ ortho-like state }]$$

$$\Psi' s = \{\Psi s - y\Psi t(0)\}/\sqrt{1+y^2} \quad [\text{ para-like state }]$$

$$y = x / \{1+\sqrt{1+x^2}\}$$

$$x = 0.0276B \quad (\text{for B in KG})$$

The time spectrum of Ps decays

$$\frac{dN(t)}{dt} = \frac{1}{2}\lambda_t e^{-\lambda_t t} \qquad \text{ortho Ps}$$

$$+ \frac{1}{4}(1 - \varepsilon P\cos\theta)\lambda'_t e^{-\lambda'_t t} \qquad \text{ortho-like Ps}$$

$$+ \frac{1}{4}(1 + \varepsilon P\cos\theta)\lambda'_s e^{-\lambda'_s t} \qquad \text{para-like Ps}$$

P : Polarization of positron

θ : Angle between the spin direction and B

Life time

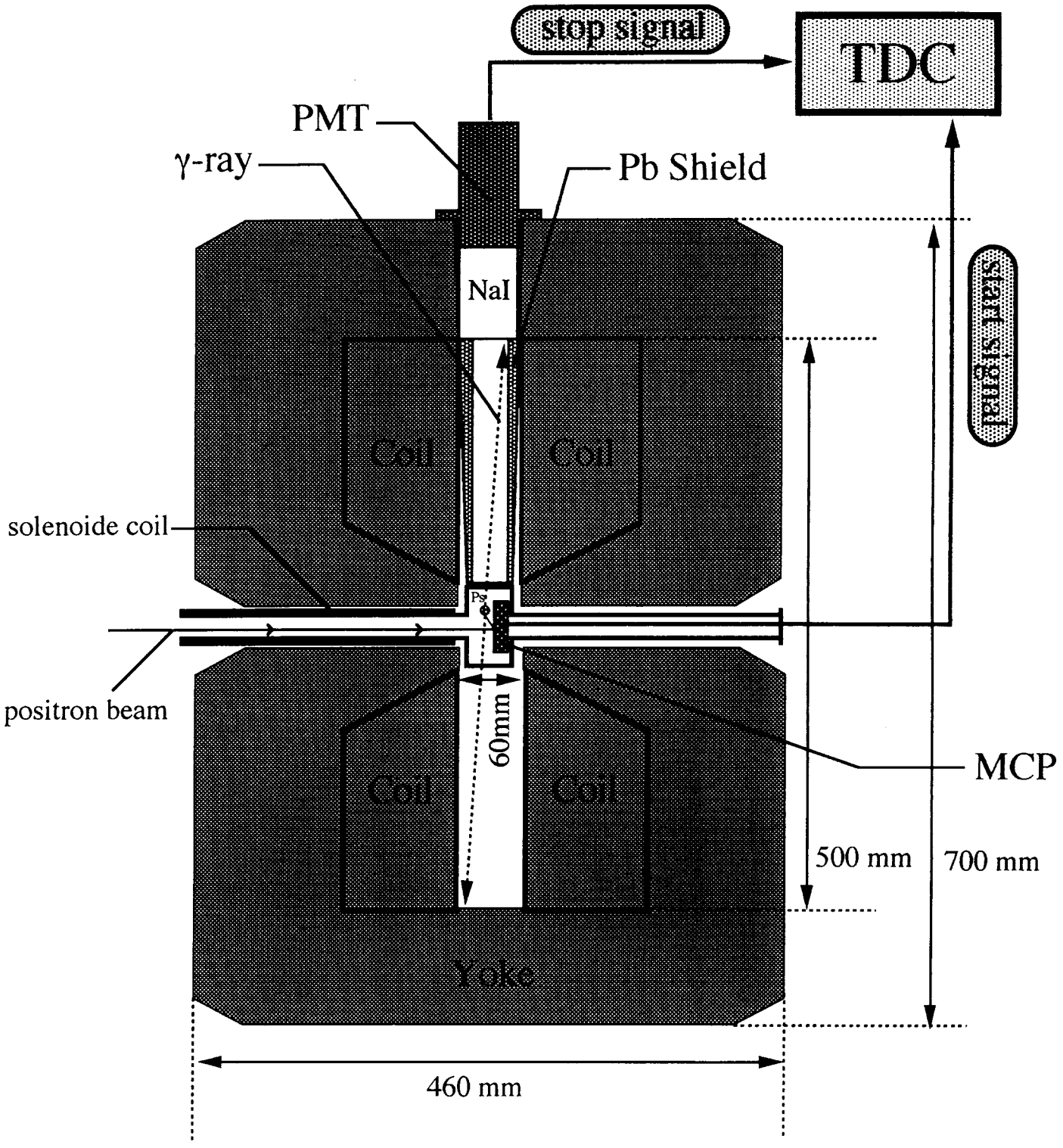
para Ps : $1/\lambda_s = 0.125\text{nsec}$

ortho Ps : $1/\lambda_t = 140\text{nsec}$

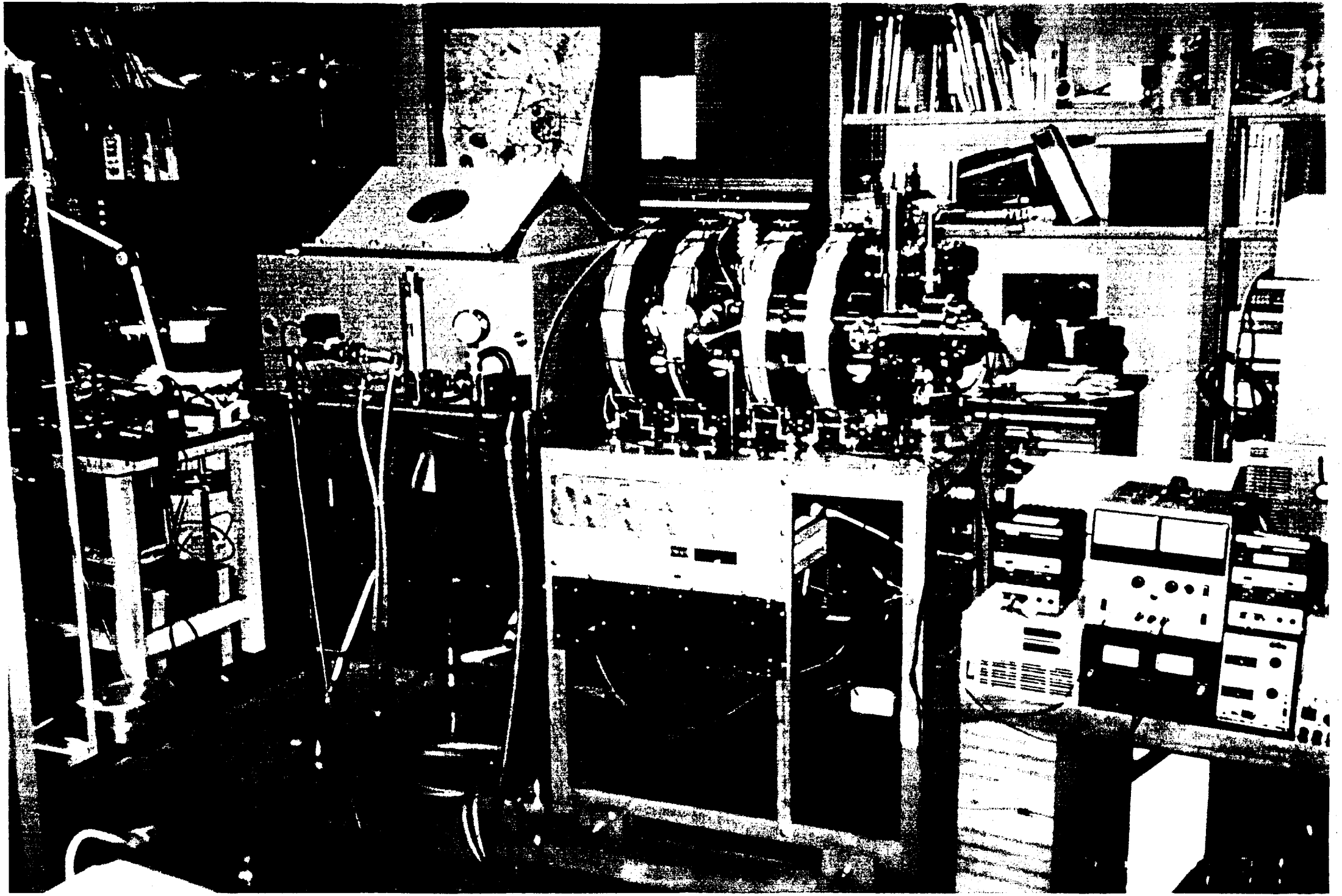
ortho-like Ps : $\lambda'_t = (\lambda_t + y\lambda_s)/(1 + y^2)$

para-like Ps : $\lambda'_s = (\lambda_s + y\lambda_t)/(1 + y^2)$

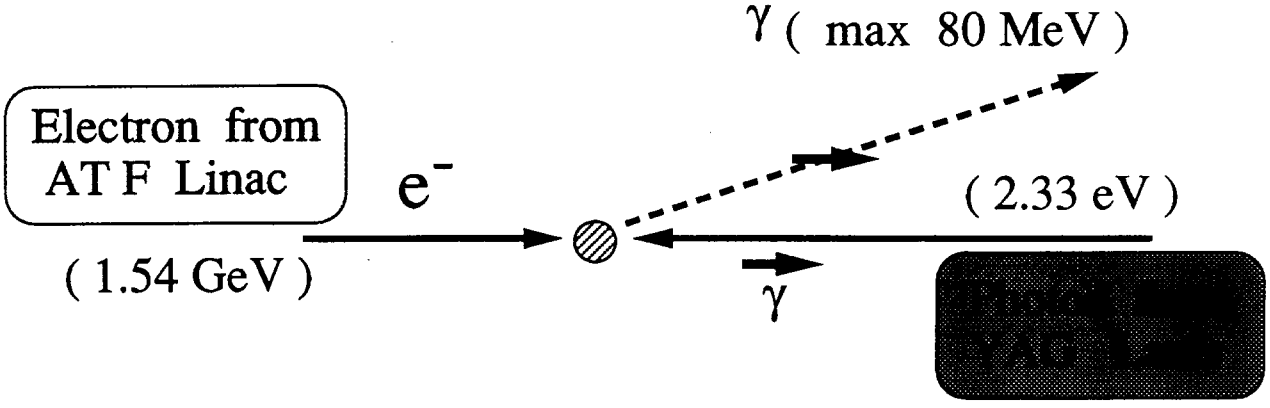
Schematic view



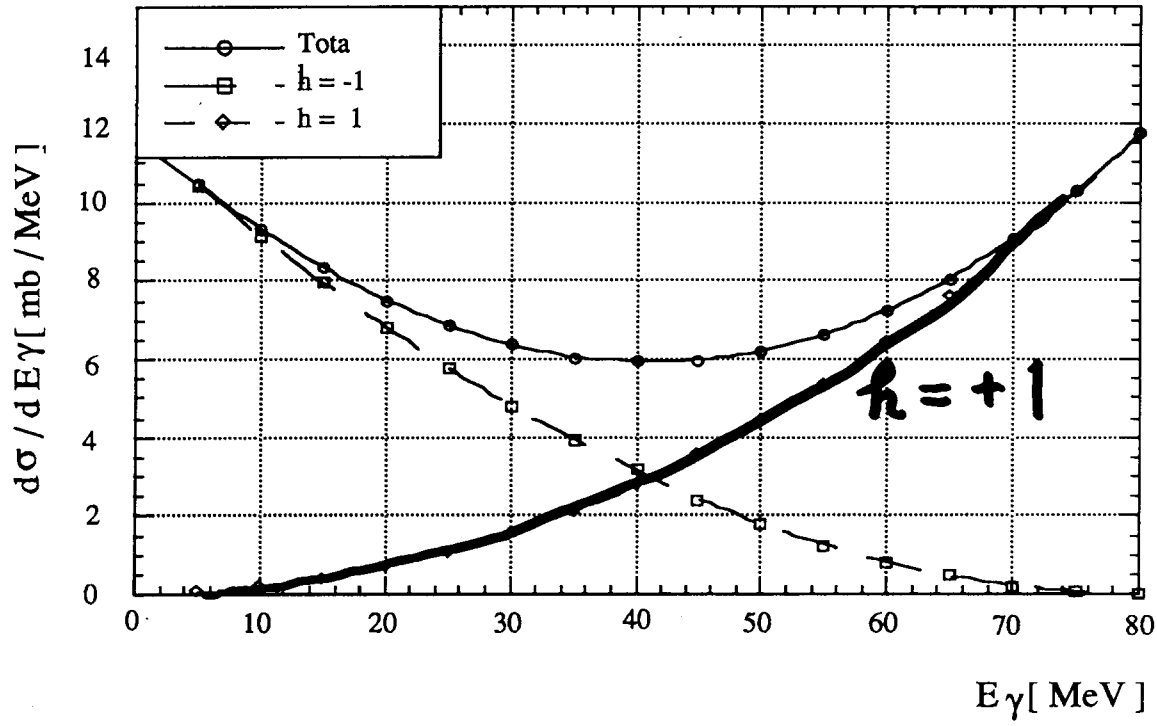
Weight : ~~450 kg~~
900 kg



Compton Scattering

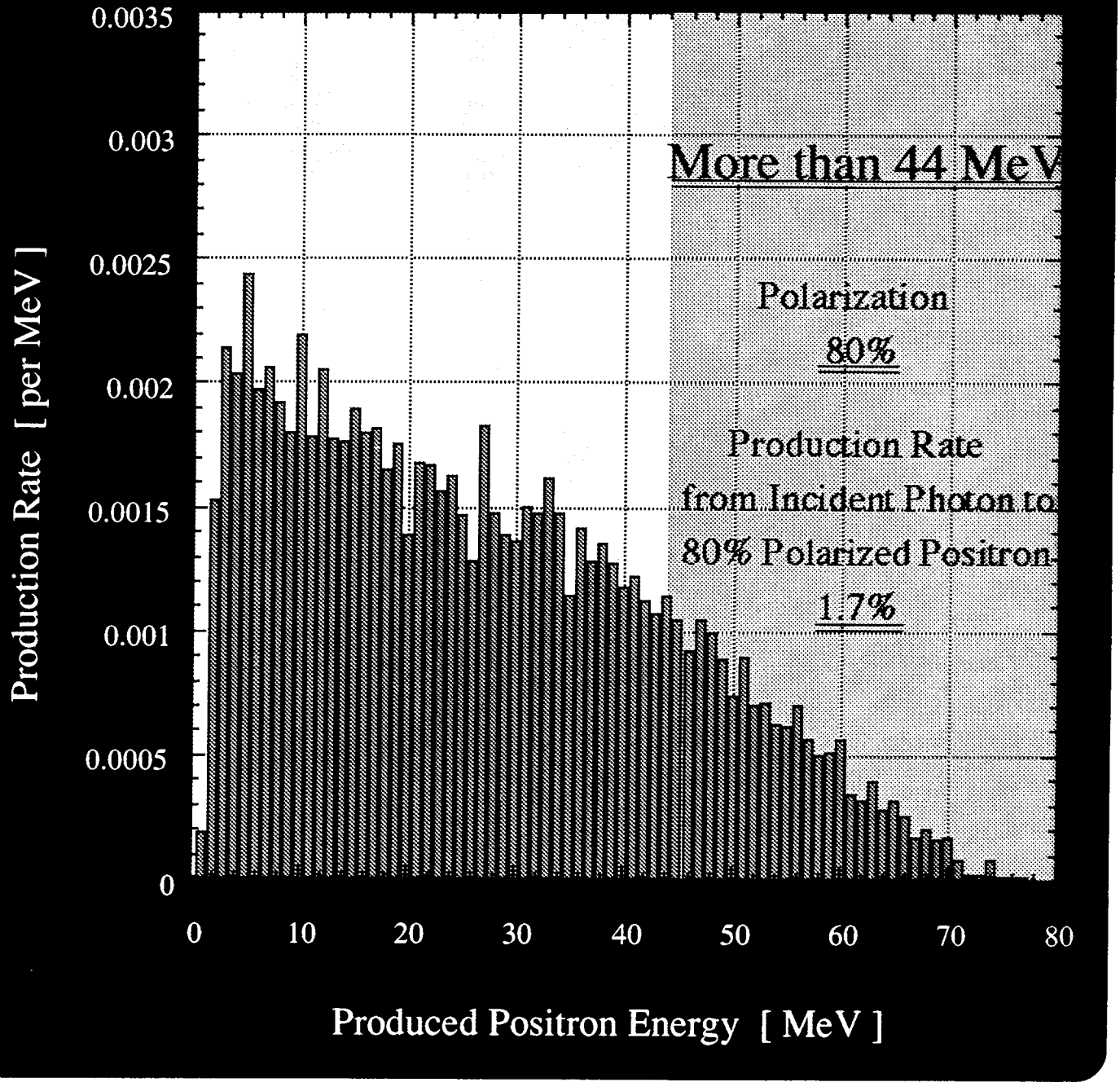


Differential Cross Section of Compton Scattering

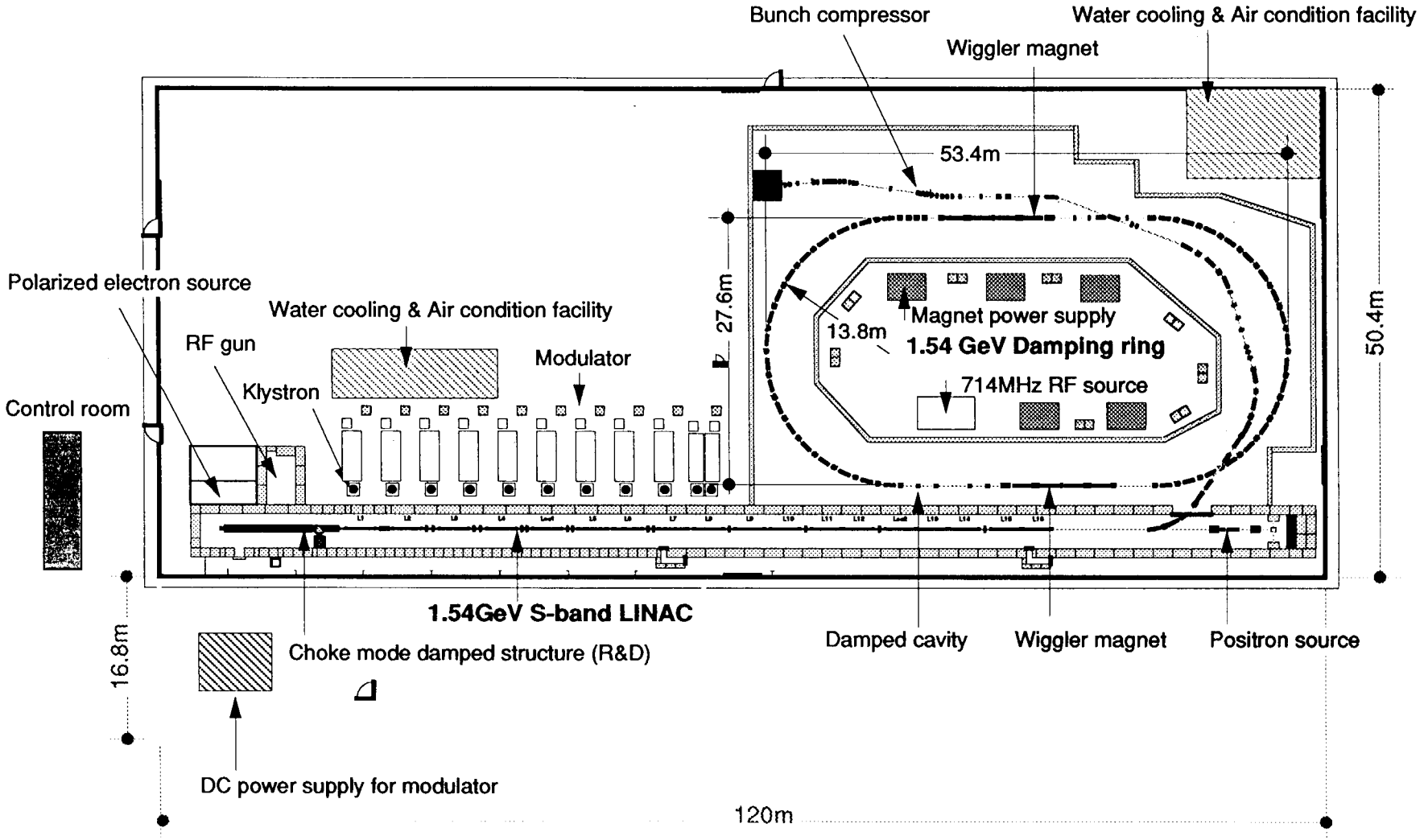


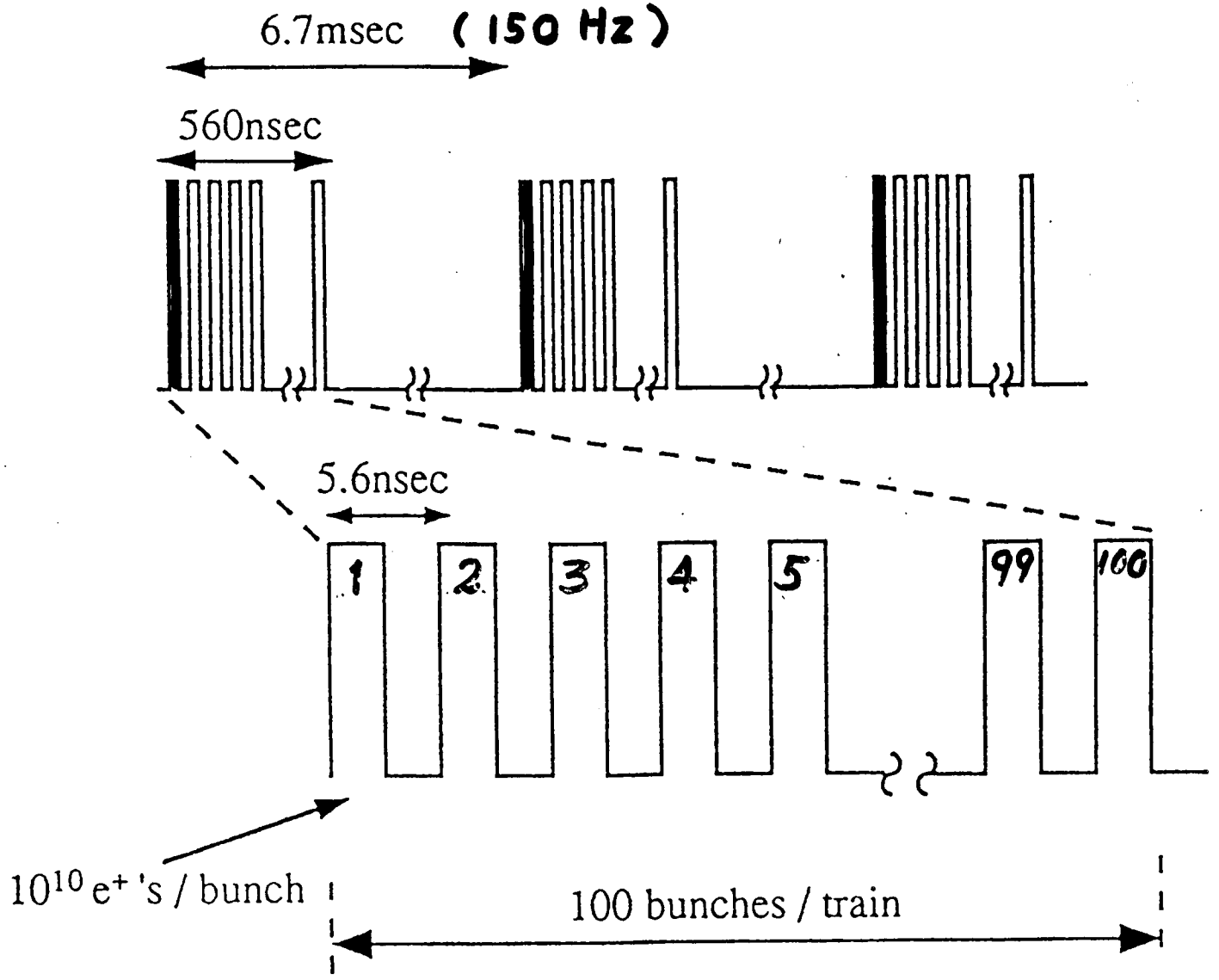
Pair Creation of Porarized Positron

(Positron with Helicity of +1/2)



ACCELERATOR TEST FACILITY FOR JLC (KEK JLC)




6.7msec (150 Hz)
560nsec
5.6nsec
1
2
3
4
5
99
100
10^{10} e^+'s / bunch
100 bunches / train

3. How to Obtain High Intensity Polarized e^+ Beam at LC

○ **Goal :**

1. Intensity of the polarized e^+ beam
   = 1.5×10^{10} / bunch (2.3×10^{14}/sec)
2. Sophisticated bunching system.

(1) β^+ decay.

○ **Proton linac : 100mA, 40MeV.**

○ **Field associated moderator.**
: good efficiency (~ 20 %).

(2) Laser-Compton scattering.

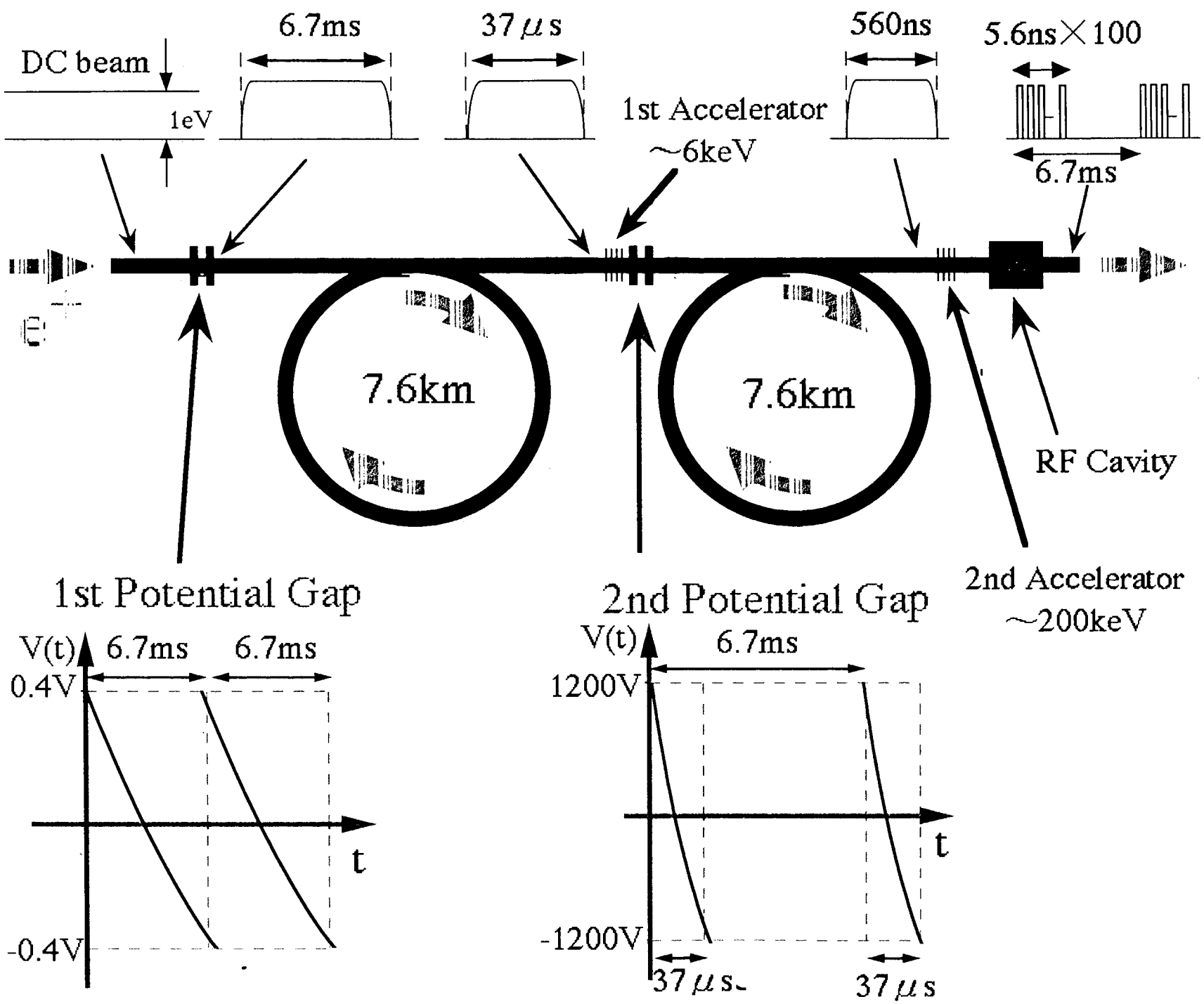
○ **Laser :**

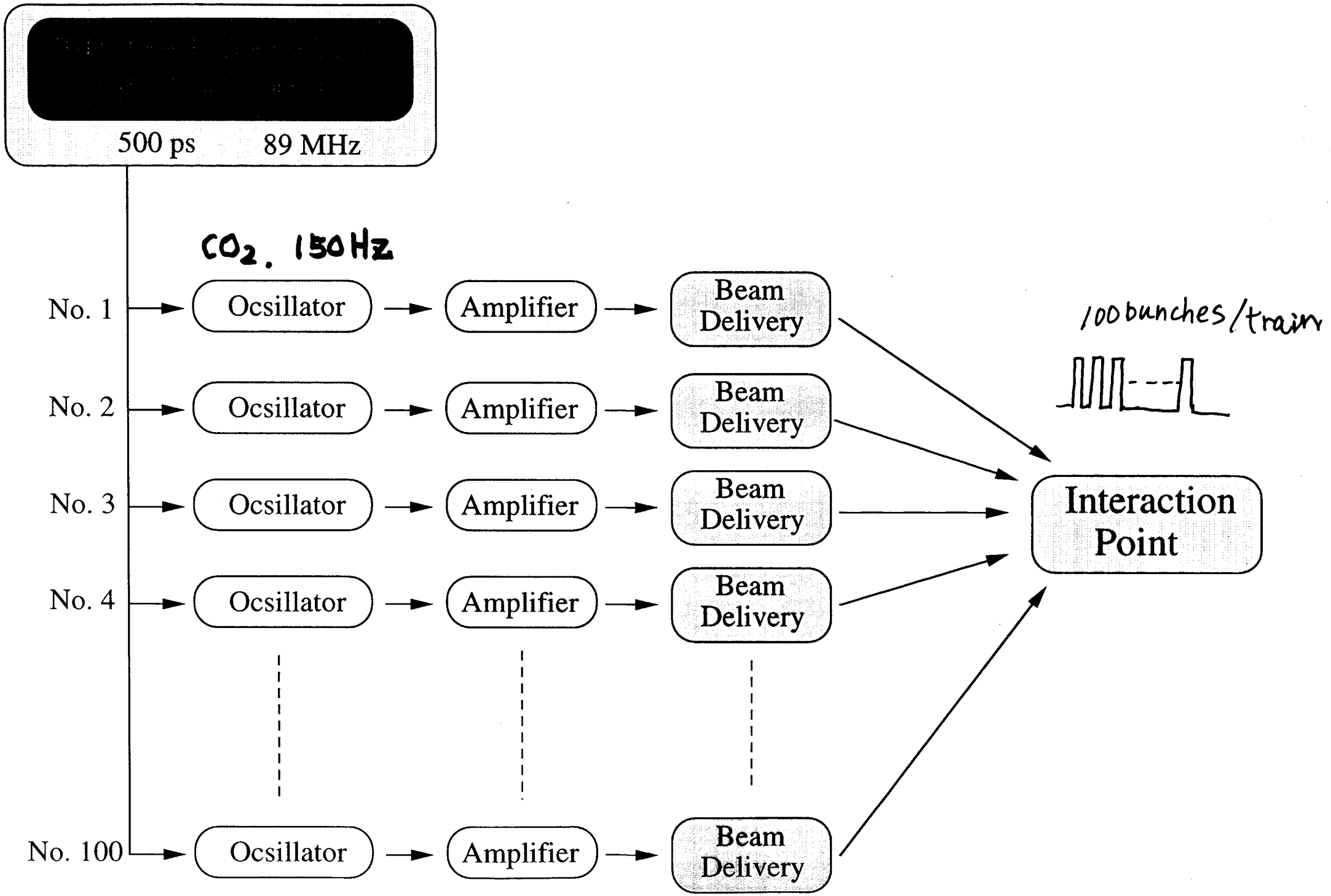
- **CO^2 laser : 5J / bunch, 100ns, 150Hz**
  100 Amplifier.
- **Control laser (Nd:YAG)**
  : 500ps, 89MHz.

○ **e^- linac : 5 GeV, I = $O(10^{12}$ /bunch)**
→ a multi-converter system.

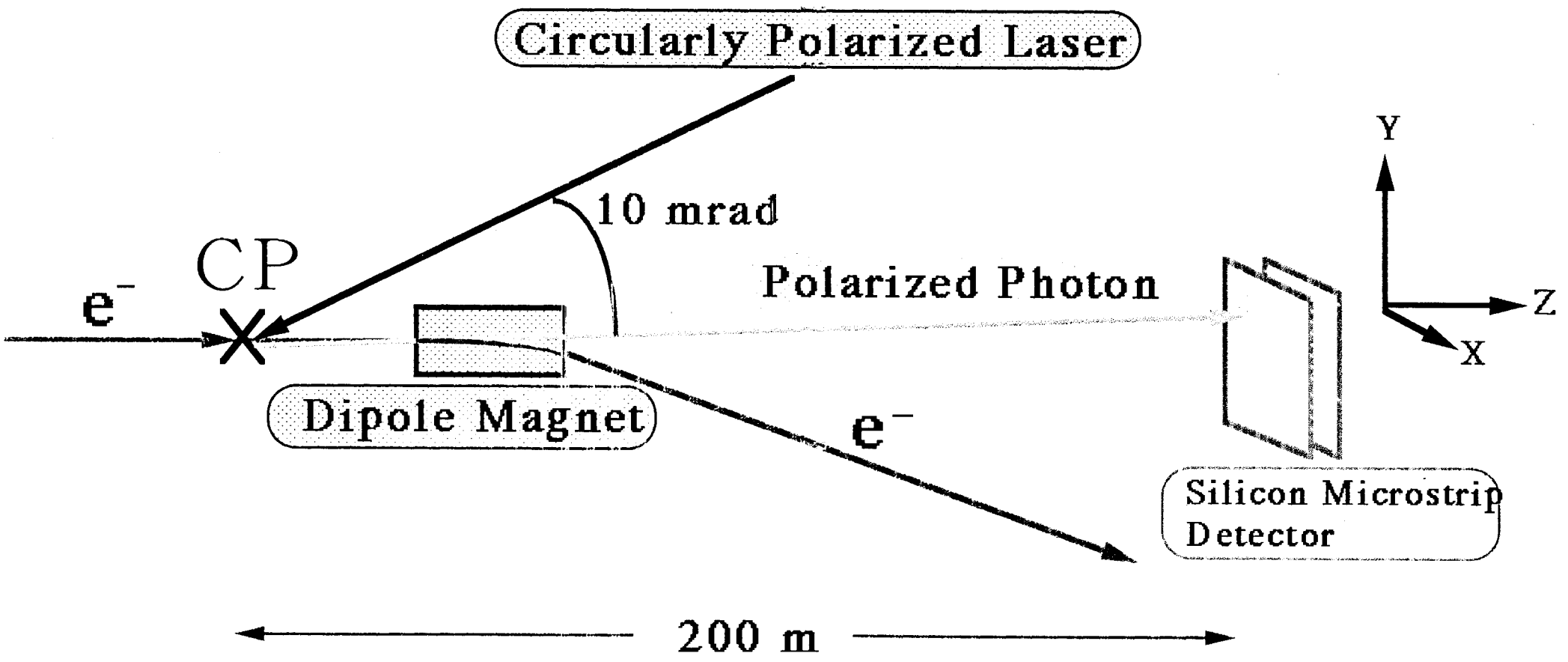
"Development of Polarized e^+ Beams for Future Linear Colliders" KST-Collaboration

KEK Preprint 95-92, July 1995

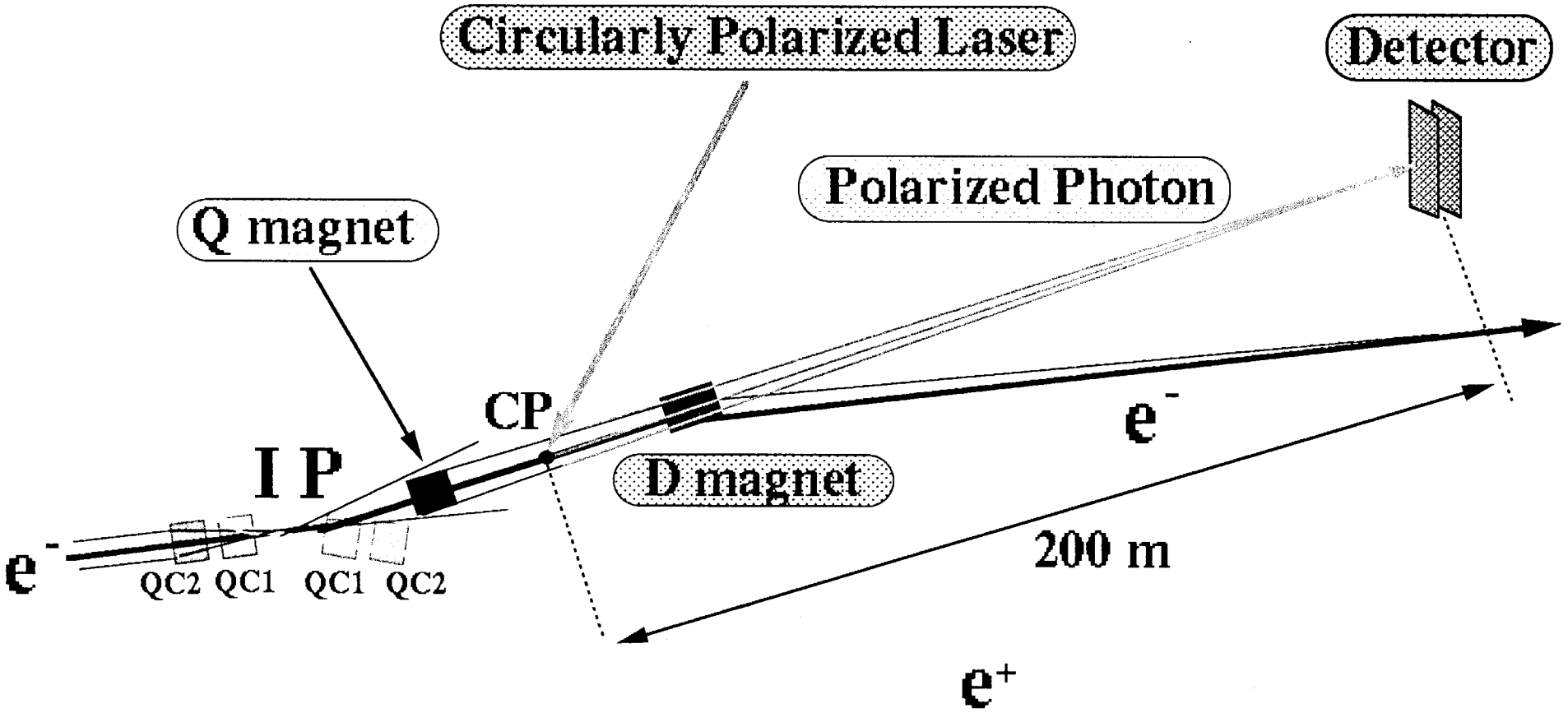

DC beam
1eV
6.7ms
37 μs
560ns
5.6ns×100
6.7ms
1st Accelerator
~6keV
7.6km
7.6km
RF Cavity
2nd Accelerator
~200keV
1st Potential Gap
V(t)
6.7ms
6.7ms
0.4V
-0.4V
t
2nd Potential Gap
V(t)
6.7ms
1200V
-1200V
t
37 μs
37 μs


500 ps
89 MHz
CO_2, 150Hz
No. 1
No. 2
No. 3
No. 4
No. 100
Ocsillator
Amplifier
Beam Delivery
100 bunches/train
Interaction Point

Polarimeter with Laser-Compton Scattering



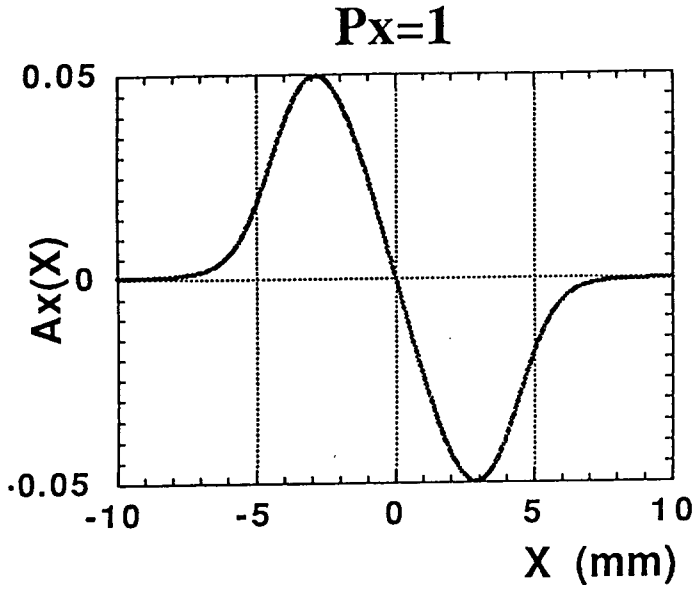
Application to the Future Linear Collider

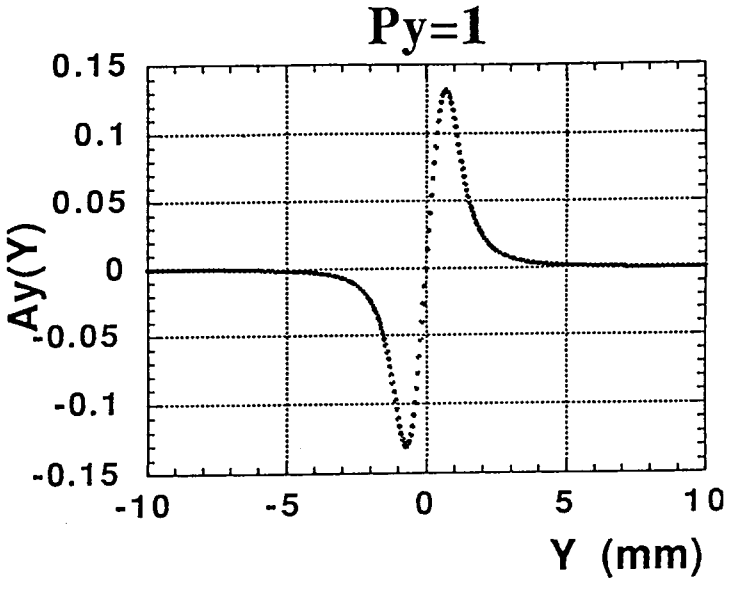


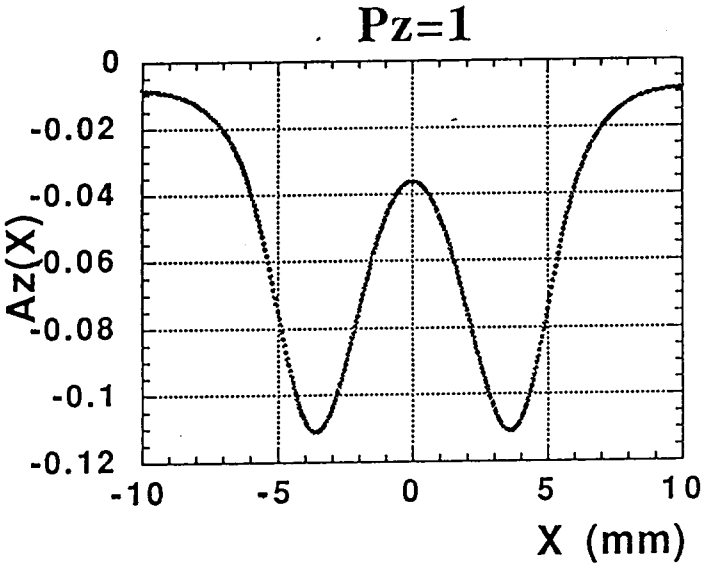
Asymmetry for the right handed and left handed laser beams

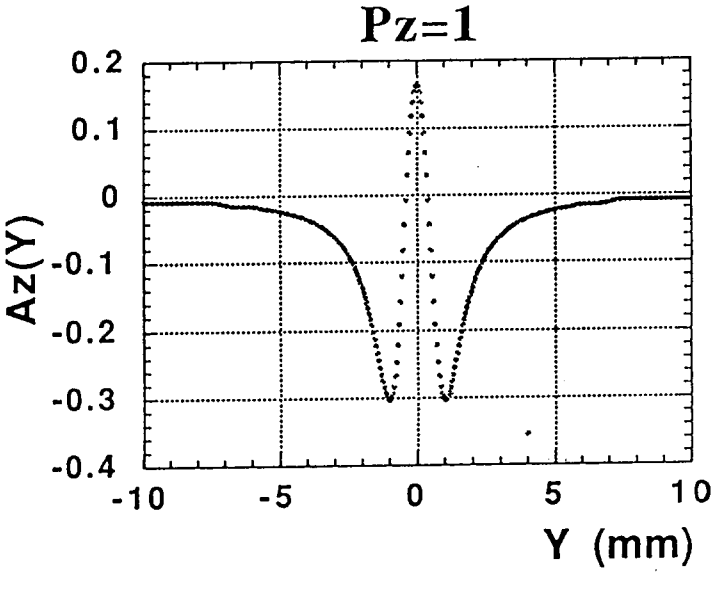
Spot Size : $\phi \approx 20\,\mu m$

Strip Pitch : $\Delta X, \Delta Y = 50\,\mu m$









4. How to Measure the $e^{\pm}$ Polarization at Linear Colliders

Goal : To measure the x-,y-,z-components of e+ (e-) spin during physics runs.

- **The laser-compton scattering can provide a possibility.**

→ **Focus scattered γ -rays at a distance of 200m downstream of the colliding point**

- **Backgrounds of synchrotron radiations.**

→ **Take advantage of large energy difference between scattered γ -rays and synchrotron radiations.**

$E_{\gamma,max}$ ~ 230 GeV

$E_{syn,max}$ ~ 200 MeV

5. Possible Physics at LC by using the Polarized e^+ Beam

(1) Standard theory

○ **Luminosity : Twice if both of e^- and e^+ are 100%-polarized.**

○ **Effective polarization :**

$$P_{eff} = (P^- - P^+) / (1 - P^- P^+)$$

1. $P^- = -90\%$, $P^+ = 0\%$ → $P_{eff} = -90\%$
2. $P^- = -90\%$, $P^+ = 80\%$ → $P_{eff} = -98.8\%$

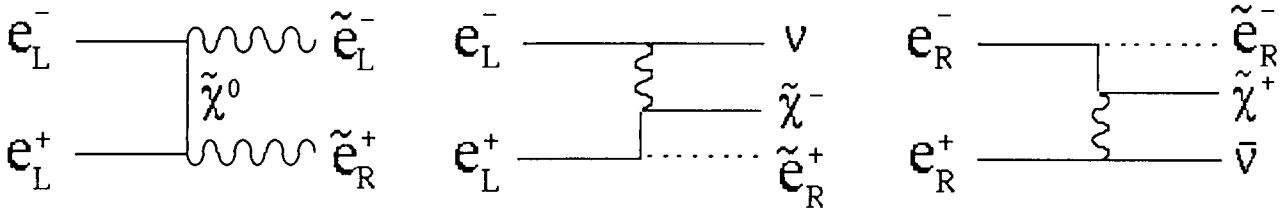
○ **Systematic errors of the left-right asymmetry for $e_R^+ e_L^- \to \bar{f} f$ is drastically suppressed.**
→ Accurate determination of $\sin\Theta_W$ on the Z-pole.

○ **Separation of γWW vertex**

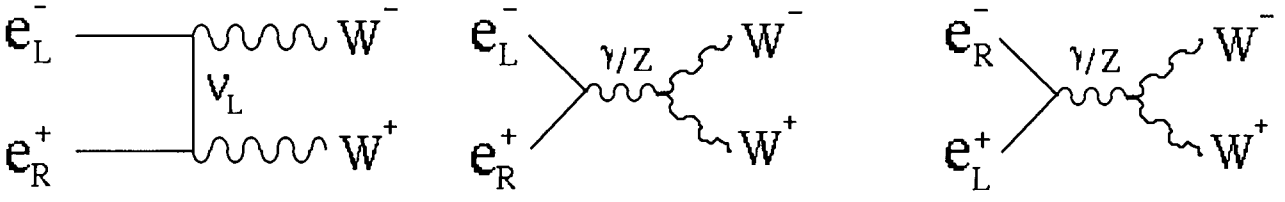
"On the Study of the Three-Gauge-Coupling via Single W Production at LC"
Short Note : Y. Kurihara et al.

(2) SUSY

- Unique possibilities of observing particular reactions of SUSY productions under the suppression of SM-backgrounds.



(SUSY)



(SM Backgrounds)

(3) Exotics

- Unknown particles or phenomena will be cleanly observed without being disturbed by the SM-backgrounds.

Polarized e^+ beam can bring out the full ability of linear colliders and plays important role to explore new physics beyond the standard model !!