cea
C.E. SACLAY
DSM

CEA/DAPNIA 94 08 09/1994

A COMPTON POLARIMETER FOR *CEBAF* HALL A

G. Bardin, C. Cavata, B. Frois, M. Juillard,
S. Kerhoas, J.C. Languillat, J.M. Le Goff,
P. Mangeot, J. Martino, S. Platchkov,
P. Rebourgeard, P. Vernin, C. Veyssière

DAPNIA

Adresse : DAPNIA, Bâtiment 141
CEA Saclay
F - 91191 Gif-sur-Yvette Cedex

Communication à 11th International Symposium

"High Energy Physics"

Bloomington, Indiana, U.S.A.

du 15 au 22 septembre 1994

A COMPTON POLARIMETER FOR CEBAF HALL A

G. Bardin[a,b], C. Cavata[a,b], B. Frois[a,b], M. Juillard[b],S. Kerhoas[a,b], J. C. Languillat[b], J.M. Legoff[a,b], P. Mangeot[b],J. Martino[b],S. Platchkov[a,b],P. Rebourgeard[b], P. Vernin[a,b],C. Veyssiere[b]

[a] CEBAF Hall A Collaboration
[b] CEA/DAPNIA , Saclay , F91191 France

The Physic program at CEBAF Hall A includes several experiments using $4\,GeV$ polarized electron beam [6]: Parity Violation in electron elastic scattering from proton and ^{4}He , electric form factor of the proton by recoil polarization , neutron spin structure function at low Q^2 , ...Some of these experiments will need beam polarization measurement and monitoring with an accuracy close to $\frac{\Delta P_e}{P_e} \leq 4\%$, for beam currents ranging from $100\,nA$ to $100\,\mu A$. We present a project of a Compton Polarimeter that will meet these requirements.

With a Compton Polarimeter, the longitudinal polarization , P_e , of an electron beam is extracted from the measurement of the experimental asymmetry, A_{exp} , in the scattering of circularly polarized photons on the electron Beam : $A_{exp} = \frac{N^{\rightarrow}_{\Rightarrow}-N^{\leftarrow}_{\Rightarrow}}{N^{\rightarrow}_{\Rightarrow}+N^{\leftarrow}_{\Rightarrow}} = P_e P_\gamma A_l$. $N^{\rightarrow}_{\Rightarrow}$ (resp $N^{\leftarrow}_{\Rightarrow}$) is the number of compton scattering events when electrons are polarized parallel (resp. antiparallel) to the LASER beam polarization. These counting rates can be expressed as :

$$\frac{dN^{\rightarrow}_{\Rightarrow}}{d\rho} = \frac{d\sigma}{d\rho}\epsilon(\rho)\,(1 + P_e P_\gamma A_l(\rho)) \;\; ; \;\; \frac{dN^{\leftarrow}_{\Rightarrow}}{d\rho} = \frac{d\sigma}{d\rho}\epsilon(\rho)\,(1 - P_e P_\gamma A_l(\rho))\,. \qquad (1)$$

In these equations, ρ is the scattered photon energy (normalized to the maximum scattered photon energy), $\frac{d\sigma}{d\rho}$ is the unpolarized Compton scattering cross section (See Eq. 2), $\epsilon(\rho)$ is the acceptance of the polarimeter, P_γ is the photon beam polarization and A_l is the longitudinal theoretical cross section asymmetry given by Eq. (3). A_{exp} and P_γ are measured quantities, and A_l is calculated in the framework of the standard model [3], so that the only unknown quantity is the electron beam longitudinal polarization P_e. This method is a well established technique [7] and is currently used at several high energy machines [5].

For an incident electron with energy E and momentum $\vec{p} = (0, 0, p)$ along (z) axis , an incident photon with energy k, crossing angle α and momentum $\vec{k} = (0, -k\sin\alpha, -k\cos\alpha)$, and a scattered photon with energy k', scattering angle θ_γ , the scattered photon energy is given by $k' = k\frac{E+p\cos\alpha}{E+k-p\cos\theta_\gamma+k\cos(\alpha-\theta_\gamma)}$. This gives at $\alpha = 0$ crossing angle, using $\gamma = E/m$, $\frac{k'}{k} \simeq \frac{4a\gamma^2}{1+a\theta_\gamma^2\gamma^2}$, with $a = \frac{1}{1+\frac{4k\gamma}{m}}$. The maximum scattered photon energy is $k'_{max} = 4ak\gamma^2$. The photon scattering angle at which $k' = k'_{max}/2$ is $\theta_{\gamma 1/2} = \frac{1}{\gamma\sqrt{a}}$. These kinematic parameters are listed in table 1. Backscattered photons have a very small opening angle ($\simeq 150\mu rad$). In the CEBAF Hall A beam tunnel, only 10 meters are available for the Compton Polarimeter. To allow scattered photon detection one then needs to separate the scattered photons from the incident electrons. This will be done by a magnetic chicane that will deflect the electrons and let room for the photon detector. The proposed setup (See Fig. 1) consists of 4 magnets with magnetic field $B = 1\,T$, $1\,m$ length , and $1\,m$ between two successive dipoles. This gives at

A COMPTON POLARIMETER FOR CEBAF HALL A

G. Bardin[a,b], C. Cavata[a,b], B. Frois[a,b], M. Juillard[b],S. Kerhoas[a,b], J. C. Languillat[b], J.M. Legoff[a,b], P. Mangeot[b],J. Martino[b],S. Platchkov[a,b],P. Reboургeard[b], P. Vernin[a,b],C. Veyssiere[b]

[a] CEBAF Hall A Collaboration
[b] CEA/DAPNIA , Saclay , F91191 France

The Physic program at CEBAF Hall A includes several experiments using $4\,GeV$ polarized electron beam [6]: Parity Violation in electron elastic scattering from proton and ^{4}He , electric form factor of the proton by recoil polarization , neutron spin structure function at low Q^2 , ... Some of these experiments will need beam polarization measurement and monitoring with an accuracy close to $\frac{\Delta P_e}{P_e} \leq 4\%$, for beam currents ranging from $100\,nA$ to $100\,\mu A$. We present a project of a Compton Polarimeter that will meet these requirements.

With a Compton Polarimeter, the longitudinal polarization , P_e , of an electron beam is extracted from the measurement of the experimental asymmetry, A_{exp} , in the scattering of circularly polarized photons on the electron Beam : $A_{exp} = \frac{N^{\rightarrow}_{\Rightarrow} - N^{\leftarrow}_{\Rightarrow}}{N^{\rightarrow}_{\Rightarrow} + N^{\leftarrow}_{\Rightarrow}} = P_e P_\gamma A_l$. $N^{\rightarrow}_{\Rightarrow}$ (resp $N^{\leftarrow}_{\Rightarrow}$) is the number of compton scattering events when electrons are polarized parallel (resp. antiparallel) to the LASER beam polarization. These counting rates can be expressed as :

$$\frac{dN^{\rightarrow}_{\Rightarrow}}{d\rho} = \frac{d\sigma}{d\rho}\epsilon(\rho)\left(1 + P_e P_\gamma A_l(\rho)\right) \ ; \ \frac{dN^{\leftarrow}_{\Rightarrow}}{d\rho} = \frac{d\sigma}{d\rho}\epsilon(\rho)\left(1 - P_e P_\gamma A_l(\rho)\right). \qquad (1)$$

In these equations, ρ is the scattered photon energy (normalized to the maximum scattered photon energy), $\frac{d\sigma}{d\rho}$ is the unpolarized Compton scattering cross section (See Eq. 2), $\epsilon(\rho)$ is the acceptance of the polarimeter, P_γ is the photon beam polarization and A_l is the longitudinal theoretical cross section asymmetry given by Eq. (3). A_{exp} and P_γ are measured quantities, and A_l is calculated in the framework of the standard model [3], so that the only unknown quantity is the electron beam longitudinal polarization P_e. This method is a well established technique [7] and is currently used at several high energy machines [5].

For an incident electron with energy E and momentum $\vec{p} = (0, 0, p)$ along (z) axis , an incident photon with energy k, crossing angle α and momentum $\vec{k} = (0, -k\sin\alpha, -k\cos\alpha)$, and a scattered photon with energy k', scattering angle θ_γ , the scattered photon energy is given by $k' = k\frac{E + p\cos\alpha}{E + k - p\cos\theta_\gamma + k\cos(\alpha - \theta_\gamma)}$. This gives at $\alpha = 0$ crossing angle, using $\gamma = E/m$, $\frac{k'}{k} \simeq \frac{4a\gamma^2}{1 + a\theta_\gamma^2\gamma^2}$, with $a = \frac{1}{1 + \frac{4k\gamma}{m}}$. The maximum scattered photon energy is $k'_{max} = 4ak\gamma^2$. The photon scattering angle at which $k' = k'_{max}/2$ is $\theta_{\gamma 1/2} = \frac{1}{\gamma\sqrt{a}}$. These kinematic parameters are listed in table 1. Backscattered photons have a very small opening angle ($\simeq 150\mu rad$). In the CEBAF Hall A beam tunnel, only 10 meters are available for the Compton Polarimeter. To allow scattered photon detection one then needs to separate the scattered photons from the incident electrons. This will be done by a magnetic chicane that will deflect the electrons and let room for the photon detector. The proposed setup (See Fig. 1) consists of 4 magnets with magnetic field $B = 1\,T$, $1\,m$ length , and $1\,m$ between two successive dipoles. This gives at

$E(GeV)$	1	4	6	8
a	0.96	0.87	0.82	0.77
$k'_{max}(GeV)$	0.035	0.500	1.058	1.776
$\theta_{\gamma 1/2}(\mu rad)$	521	136	94	73
$\sigma(barn)$	0.64	0.58	0.55	0.52
$A_l^{max}(\%)$	3.7	15.6	24.0	32.6
$< A_l > (\%)$	0.9	3.4	4.9	6.2
$\mathcal{L}(barn^{-1}s^{-1})$	300	300	300	300
$N_t(10^6)$	513	37	18	11
$t(hours)$	730	57	29	19

$E(GeV)$	1	4	6	8
a	0.98	0.93	0.90	0.87
$k'_{max}(GeV)$	0.018	0.266	0.580	0.999
$\theta_{\gamma 1/2}(\mu rad)$	515	132	89	68
$\sigma(barn)$	0.67	0.62	0.60	0.58
$A_l^{max}(\%)$	1.8	7.4	11.2	15.2
$< A_l > (\%)$	0.5	1.7	2.5	3.3
$\mathcal{L}(barn^{-1}s^{-1})$	440	440	440	440
$N_t(10^6)$	1900	135	62	36
$t(hours)$	1890	140	66	40

Table 1: *Kinematic Parameters , Cross section, maximum and mean longitudinal Asymmetry , Luminosity, number of events and time to get* 1% *statistical error on* $P_e = 50\%$. *For different electron beam energies* E *at* $100\,\mu A$, *for a* $0.5\,W$ *Laser , at* $\alpha = 20mrad$ *crossing angle, with* $k = 2.4\,eV$ *for* 0.6cm *interacting length and a waist beam size* $d_0 = 116\mu$ *(left, Green Argon) and* $k = 1.16\,eV$ *and* 0.8cm *interacting length and* $d_0 = 164\mu$ *(right, IR NdYAg)*

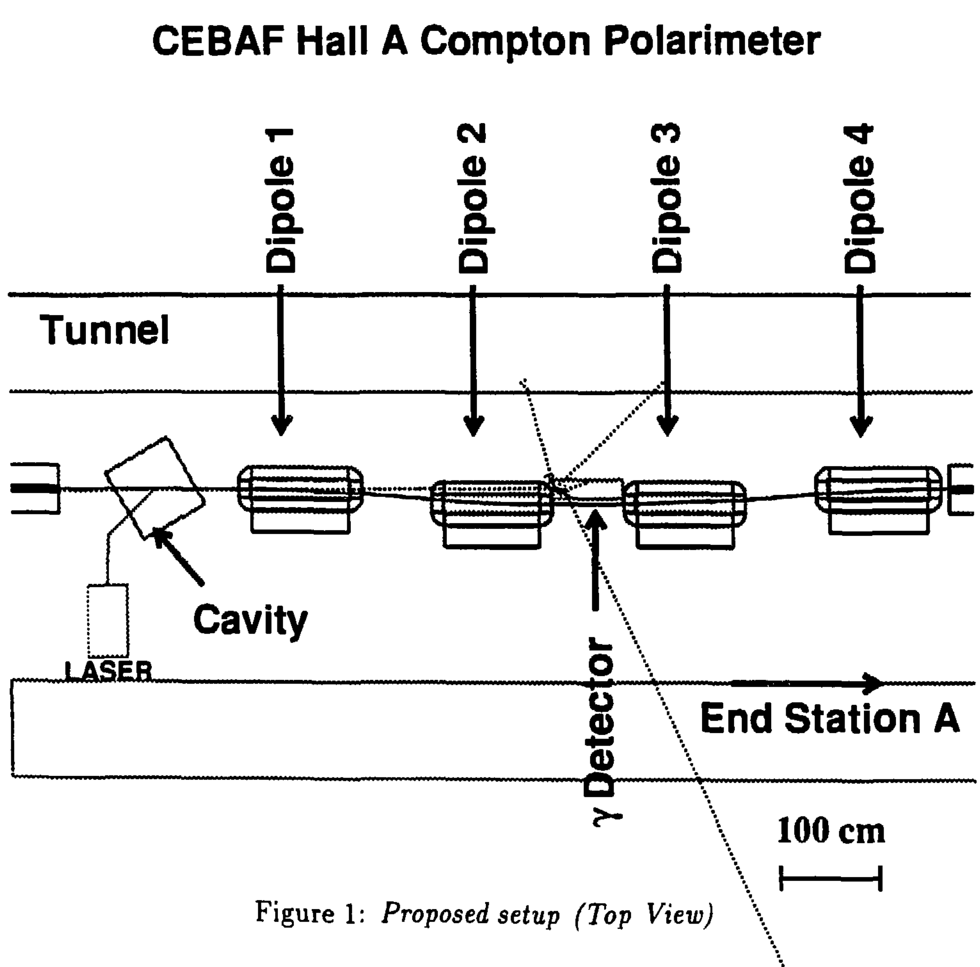

Figure 1: *Proposed setup (Top View)*

$4\,GeV$ a transverse deflection of $\simeq 15cm$. For $\alpha = 0$ crossing angle, the differential unpolarized cross section is [4]

$$\frac{d\sigma}{d\rho} = 2\pi r_0^2 a \left[\frac{\rho^2(1-a)^2}{1-\rho(1-a)} + 1 + \left(\frac{1-\rho(1+a)}{1-\rho(1-a)} \right)^2 \right], \tag{2}$$

whereas the longitudinal asymmetry is given by

$$A_l = \frac{\sigma_{\Rightarrow}^{\rightarrow} - \sigma_{\Rightarrow}^{\leftarrow}}{\sigma_{\Rightarrow}^{\rightarrow} + \sigma_{\Rightarrow}^{\leftarrow}} = \frac{2\pi r_0^2}{\frac{d\sigma}{d\rho}} (1-\rho(1+a)) \left[1 - \frac{1}{(1-\rho(1-a))^2} \right]. \tag{3}$$

(r_0 is classical electron radius). The longitudinal asymmetry is maximum for $\rho = 1$, i.e $k' = k'_{max}$ (high energy scattered photon, see table 1). For a Laser with diameter d (with a negligible divergence), frequency ν, power P_L and an electron beam at intensity I_e (whose size is small with respect to the Laser beam size), the luminosity for an interacting length L, at $\alpha = 0$ crossing angle, is [9] $\mathcal{L} = \frac{I_e}{e}\frac{2}{c}\frac{P_l}{h\nu}\frac{4L}{\pi d^2}$. For polarization $P_\gamma = 100\%$ and $P_e = 50\%$, at $4GeV$, with a $0.5W$ $532\,nm$ Laser and $0.6\,cm$ interacting length, this corresponds to a 2.5 hours measurement at $\frac{\Delta P_e}{P_e} = 1\%$ (See table 1). But this Polarimeter will also be used at lower current, especially for experiments using polarized target. For $I_e = 100\,nA$, a 1% measurement is out of reach.

To increase the counting rates, one can use a high power UV Laser, emitting at higher energy such as a pulsed Excimer $80W$ (KrF), $\lambda = 248nm$, $k = $ 5eV. These types of Laser are expensive (at least 100 k\$), difficult to run and not reliable. One would then need to install the Laser in an accessible room (outside the beam region) and setup a transport for the Laser light. On the other hand, with standard continuous Laser (Green Argon or InfraRed NdYag), the available power is poor (limited to 10 W for Argon , and to $0.5W$ for NdYaG), but they are widely used system, cheap and very reliable, so that one can avoid the Laser beam transport problem. Their weak point being their low power one has to find amplification. An elegant solution was proposed by B. Norum et al.[1] : The Laser light is trapped in a cavity made of 2 highly reflective mirrors. In such cavity a "given" incident photon will perform a certain number of round trips inside the cavity. Setting the interaction region of the Laser with the electron beam inside this cavity gives the wanted gain. Optical Cavities fed by visible Laser light with a gain $G \simeq 10000$ are currently used for gravitational wave detection by Laser interferometry [8].

We will use a symmetric cavity consisting of two identical mirrors M_1 and M_2. Let z be the cavity axis , and the mirror radius of curvature be $R_1 = R_2 = R$. The mirror are located at $z_1 = -L/2$ and $z_2 = L/2$, using $g = 1 - \frac{L}{R}$ (with $0 \leq g^2 \leq 1$, for the cavity stability), it can be shown [2] that the allowed *transverse modes* in the cavity have a (complex) electric field given by

$$E(x,y,z)_{mn} = A\frac{d_0}{d(z)} e^{-ikz} e^{i\omega t} e^{i(m+n+1)\Psi(z)} e^{-ik\frac{x^2+y^2}{2R^2(z)}} e^{-\frac{x^2+y^2}{d^2(z)}} H_m(\sqrt{2}\frac{x}{d(z)}) H_n(\sqrt{2}\frac{y}{d(z)}), \tag{4}$$

where H_m and H_n are Hermite Polynomials. The phase $\Psi(z)$, the beam diameter $d(z)$ and the curvature radius $R(z)$ obey the evolution equations $\Psi(z) = \tan^{-1}\frac{z}{z_R}$, $d(z) = d_0\sqrt{1 + \frac{z^2}{z_R^2}}$, and $R(z) = z(1 + \frac{z^2}{z_R^2})$. The waist beam diameter d_0, the Rayleigh range z_R and the diameters d_1, d_2 of the beam on each mirror are (for a wave length $\lambda = 2\pi/k$)

$$d_0^2 = \frac{\lambda}{\pi}\frac{L}{2}\sqrt{\frac{1+g}{1-g}} \;;\quad d_0^2 = \frac{\lambda}{\pi} z_R \;;\quad d_1^2 = d_2^2 = \frac{\lambda}{\pi} L \sqrt{\frac{1}{1-g^2}} = \frac{2d_0^2}{1+g}. \tag{5}$$

For a given transverse mode (m,n), the allowed *longitudinal modes* or frequencies are given by [2] $\omega_l(mn) = 2\pi\frac{c}{2L}\left(l + \frac{1}{\pi}(m+n+1)\cos^{-1}\sqrt{g^2}\right)$, where l is a positive integer. The adaptation of the Laser modes to the cavity modes is a delicate work for which we will closely work with VIRGO specialists. To reach high cavity gain, mirrors with high reflectivity, low absorption and low scattering are used. High reflectivity is obtained using multilayer "$\lambda/4$ " mirrors. To compute the cavity gain, we introduce the reflexion and transmission coefficients of one mirror [10] $r = \frac{E_R}{E_I}$, $t = \frac{E_T}{E_I}$, where E_I, E_r and E_t are the incident, reflected and transmitted electric field. In terms of energy, the reflectivity R and the transmissivity T of this mirror are given by $R = \frac{J_R}{J_I}$, $T = \frac{J_T}{J_I}$, where (J_i) is the energy per unit area per second and is proportionnal to $|E_i|^2$: $R = |r|^2$; $T = |t|^2\frac{q_l}{q_1}$. For a Transverse Electric wave, at incident angle θ_i, q_i is given by $q_i = \sqrt{\frac{\epsilon_i}{\mu_i}}\cos\theta_i$, the indice l stands for the medium of the mirror. Let $g_{rt}(\omega)$ be the round trip gain of the gavity, so that the electric field circulating in the cavity E_{circ} is related to the incident electric field E_I by [2] $E_{circ} = it_1E_I + g_{rt}(\omega)E_{circ}$. Using α_0, the electric absorption coefficient of the medium inside the cavity, the electric field at $z = Z$ is related to field at $z = 0$ by $E(Z) = E(0)e^{-\alpha_0 Z}$, or in terms of power, $J(Z) = J(0)e^{-2\alpha_0 Z}$. This gives the intensity attenuation for a round trip , $Z = 2L$, $J(Z) = J(0)e^{-2\alpha_0(2L)} = J(0)e^{-\delta_0}$. Here $\delta_0 = 2\alpha_0(2L)$ represents the round trip absorption of the cavity medium. The mirrors themselves contribute to the absorption. Let $T_1 = |t_1|^2$ and $R_1 = |r_1|^2 = e^{-\delta_{r_1}}$ be the transmissivity and reflectivity of mirror M_1, and let A_1 (resp. D_1) be the absorption (resp. scattering) for that mirror, so that the fraction of energy loss by absorption (resp. scattering) is $A_1 = 1 - e^{-\delta_{a_1}}$ (resp. $D_1 = 1 - e^{-\delta_{d_1}}$). The energy conservation reads $1 = T_1 + R_1 + A_1 + D_1$. We then get for the round trip gain of the electric field $g_{rt}(\omega) = r_1r_2e^{-\frac{\delta_{a_1}+\delta_{d_1}+\delta_{a_2}+\delta_{d_2}+\delta_0}{2}}e^{-i2L\frac{\omega}{c}}$, and for the ratio of circulating and incident electric fields $\frac{E_{circ}}{E_I} = \frac{it_1}{1-r_1r_2e^{-\frac{\delta}{2}}e^{-i2L\frac{\omega}{c}}}$, with $\delta = \delta_{a_1} + \delta_{d_1} + \delta_0 + \delta_{a_2} + \delta_{d_2}$. For a symmetric cavity $r_1 = r_2 = r$ and $t_1 = t_2 = t$, and one gets $\frac{E_{circ}}{E_I} = \frac{it}{1-r^2e^{-\frac{\delta}{2}}e^{-i2L\frac{\omega}{c}}}$. In terms of power (with $R = r^2$ and $T = t^2$) the gain of the cavity is then :

$$G = \frac{J_{circ}}{J_I} = \frac{T}{1 - 2R\cos(\frac{\omega}{c}2L)e^{-\frac{\delta}{2}} + (Re^{-\frac{\delta}{2}})^2} = \frac{T}{(1 - Re^{-\frac{\delta}{2}})^2 + 4R\sin^2(\frac{\omega}{2c}2L)} \quad (6)$$

For frequencies $\omega_l = l\Delta\omega_{ax}, l = 1,2,3\ldots$, where $\Delta\omega_{ax} = \omega_{l+1} - \omega_l = \frac{2\pi c}{2L}$ is the axial mode interval, the cavity has maximum gain G_l, given by $G_l = \frac{T}{(1-Re^{-\frac{\delta}{2}})^2}$. Introducing the finesse $\mathcal{F}$ of the cavity, $\frac{\mathcal{F}}{\pi} = \frac{\sqrt{R}}{1-Re^{-\frac{\delta}{2}}}$, we then get for the gain $G(\omega) = G_l\frac{1}{1+\left(\frac{2\mathcal{F}}{\pi}\right)^2\sin^2\left(\pi\frac{\omega}{\Delta\omega_{ax}}\right)}$. The bandwidth of the cavity $\Delta\omega_{cav}$ is defined so that the gain G of the cavity is decreased by a factor 2 when the frequency is changed from the resonance $\omega = \omega_l$ to $\omega = \omega_l \pm \frac{\Delta\omega_{cav}}{2}$ and is related to the finesse by $\frac{\Delta\omega_{cav}}{\Delta\omega_{ax}} = \frac{2}{\pi}\sin^{-1}\left(\frac{\pi}{2\mathcal{F}}\right)$. For a high finesse cavity this equation becomes $\frac{\Delta\omega_{cav}}{\Delta\omega_{ax}} \simeq \frac{1}{\mathcal{F}}$. The maximum gain G_l at resonance can be written $G_l = \frac{\mathcal{F}}{\pi}\frac{1}{\sqrt{R}}\frac{T}{1-Re^{-\frac{\delta}{2}}}$, that , for a high finesse cavity, i.e with a high reflectivity $1 - R \simeq \delta_r \ll 1$ and with negligible scattering and mirror and medium absorption $\delta_d, \delta_a, \delta_0 \ll \delta_r$, leads to $G_l \simeq \frac{\mathcal{F}}{\pi} \simeq \frac{1}{\delta_r}\left(1 - 3\frac{\delta_a+\delta_d}{\delta_r} - \frac{\delta_0}{\delta_r}\right)$. The higher the finesse, the smaller the bandwidth of the resonance peaks and the higher the gain of the cavity at resonance.

J.M. Makowsky Laboratory at Lyon, where the VIRGO mirrors are constructed, will build and characterize our $\frac{1}{4}$ inch mirrors. The mirrors have the structure $LL(HL)_NHS$, where L (resp. H) stands for $\lambda/4$ layer of a Low (resp. Ligh) indice material, SiO_2 (resp. Ta_2O_5) with indice $n \simeq 1.47$ (resp. $n \simeq 2.1$) and S for the super polished silica substrate. To minimize scattering, the layers are made of amorphous deposit. The reflectivity of the mirror is governed by the design of the layers, we will use $(HL)_{14}$ mirrors with residual transmissivity $T = 1 - R - A - D \simeq \delta_r - (\delta_a + \delta_d) \simeq 100\,ppm$, Scattering $D \simeq \delta_d \simeq 2\,ppm$ (resp. $D \simeq 6\,ppm$) and Absorption $A \simeq \delta_a \simeq 3\,ppm$ (resp. $A \simeq 12\,ppm$) at $1064nm$ (resp. at $633nm$). The cavity medium will be vacuum to reduce absorption (e.g $\delta_0 = 0$, for comparison $50cm$ of air has an absorption of $3\,ppm$). We thus expect a cavity gain $G \simeq 8090$ at $1064\,nm$ and $G \simeq 4000$ at $633\,nm$. For the cavity gain, a $1064\,nm$ NdYag Laser is then more efficient than a $532\,nm$ Argon Laser. To keep scattering very low, perfect surface state is mandatory. Starting with a super polished substrate with RMS roughness $0.5A$ and a peak/valley of $15A$, one can obtain after coating an RMS roughness of $0.3A$ and a peak/valley of $4A$. We also plan to test the mirror damnage by irradiation at the ORSAY synchrotron facility (LURE).

Using a $1064\,nm$ NdYaG Laser, with $0.5\,W$, and a $1\,m$ cavity at $g = -0.95$, with a gain $G = 1000$, we expect at $\alpha = 20mrad$ crossing angle ($0.8cm$ interacting lenght), $100\mu A$ beam intensity and $4\,GeV$ energy, an integrated rate of $270kHz$. If the scattered photon energy is not measured, this corresponds to a 8 minutes measurement to get $\frac{\Delta P_e}{P_e} = 1\%$ for $P_e = 50\%$. In order to increase the figure of merit of the Polarimeter, we plan to measure the energy of the scattered photon. The size and the material (Lead Glass, BGO, CsI, ...) of the photon detector are currently under study. The background will come from bremsstrahlung in the 8 meters beam pipe upstream of the polarimeter and synchrotron radiation in the first dipole of the chicane. For an Energy threshold of 5 MeV, assuming a vacuum of 10^{-8} Torr, we expect an integrated bremsstrahlung photon rate of $5kHz$ at $100\mu A$. Synchrotron photons will have characteristic energy $\epsilon_c = 4keV$ with a power, at $100\mu A$, after $1\,cm$ collimator, of $0.1W$.

We plan to commission this Polarimeter in Spring 1997.

References

[1] B. Norum, T. Welch, *CEBAF LOI 93-012.*

[2] "Lasers", A. Siegman, University Science Book, Mill Valley, California (1986).

[3] A. Denner, S. Dittmaier, *Nucl. Phys. B407 (1993) 43*

[4] C. Prescott, SLAC internal report, *SLAC TN 73 1.*

[5] D.P. Barber, et al. *NIM A329 (1993) 79.* G. Shapiro, et al. *SLAC-PUB-6261 (1993).*

[6] P. Souder et al, *CEBAF E-91-004.* E. Beise et al, *CEBAF E-91-010.* R. Lourie et al, *CEBAF E-91-011.* C. Perdrisat et al, *CEBAF PR-93-027.* Z. Meziani et al, *CEBAF PR-94-010.* C. GLashausser et al, *CEBAF E-89-033.* V. Burkert et al, *CEBAF E-89-042.* P. Ulmer et al, *CEBAF E-98-049.* J.J. Kelly et al, *CEBAF E93-013.*

[7] "Compton Polarimeter at SLAC SPEAR", *NIM 165 (1979) 177* . " Compton Polarimeter at DESY Doris", *Phys. Lett. 135B (1984) 498)* .

[8] A. Abramovici et al. , Science 256 (1992) 325. C. Bradaschia et al. , *NIM A289 (1990) 519.*

[9] D. Marchand, P. Vernin, Private Communication.

[10] M. Born, and E. Wolf, "Principles of Optics", Pergamon Press, (1975).