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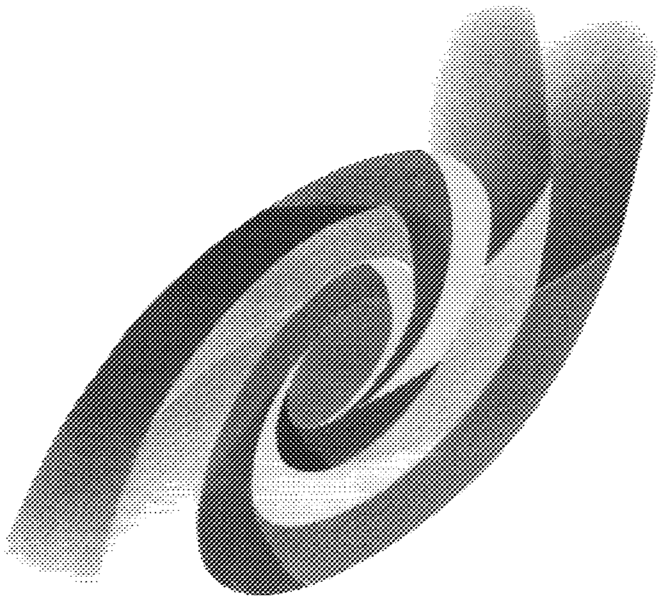

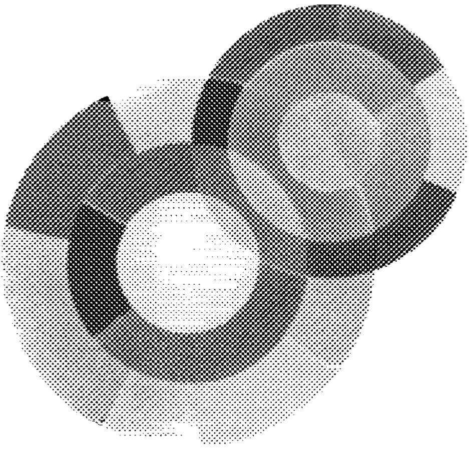

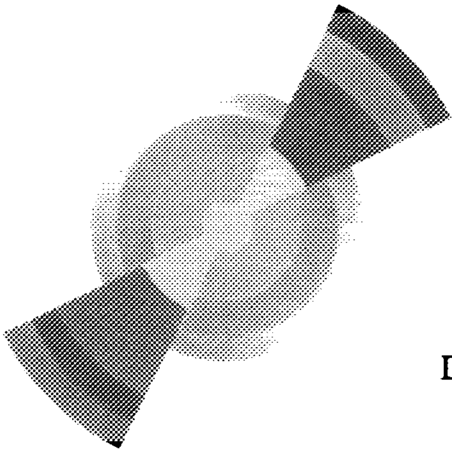

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A 4 - 8 *GeV* Compton Polarimeter for TJNAF

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A 4 – 8 *GeV* Compton Polarimeter for TJNAF

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ABSTRACT

We are building a new type of Compton Polarimeter for a few *GeV* electron beam. To increase the efficiency of the polarimeter, the electron-photon interaction occurs inside an optical cavity used to amplify the IR laser beam intensity. We aim at a photon beam power of 1000 *W* in the cavity, using a 300 *mW* laser. We describe the general design of this polarimeter and we discuss its expected performances.

The physics program at the Hall A of the Thomas Jefferson National Accelerator Facility includes several experiments using a 4 – 8 *GeV* polarized electron beam. These experiments need a high accuracy and non-destrutive beam polarization measurement for currents ranging from $100nA$ to $100\mu A$ (CW). Several Compton polarimeters have been already used at higher electron beam energies (CERN, DESY, SLAC...). However, their efficiencies are not sufficient for measuring the polarization of a 4 *GeV* electron beam in a reasonable time. The Compton polarimeter aim to monitor the longitudinal polarization of the beam with a statistical error of 1% in several minutes. It will be installed in a 15 meters straight line, before the Hall A entrance.

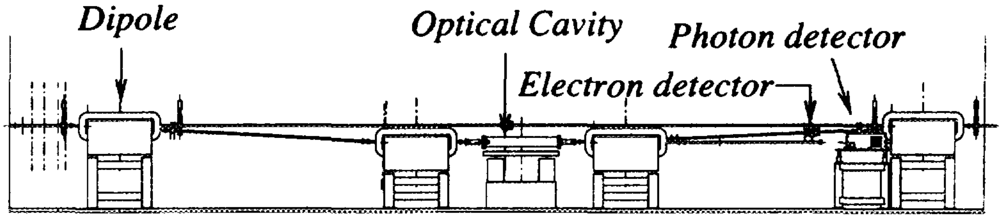

Figure 1: Design of the polarimeter: The vertical deviation allowed by the symmetric 4 dipole magnetic chicane is $30cm$. The direct beam pipe will be use when the polarimeter is not running.

In Compton polarimetry, the longitudinal polarization P_e is extracted from the measurement of the experimental asymmetry A_{exp}, in the scattering of circulary polarized photons off 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 the electron beam is polarized parallel (resp. anti-parallel) to the laser beam polarization. and P_γ is the photon beam polarization. The scattered photons are emitted with a mean angle of $130\mu rad$ while the electron are emitted with an angle smaller than $5\mu rad$. To allow scattered photons detection, a magnetic chicane will be used to separate the scattered particles from the incident beam (fig. 1).

The time needed for a $\frac{\Delta P_e}{P_e} = 1\%$ measurement of the electron polarization is given by $t = \left(\mathcal{L}\left(\frac{\Delta P_e}{P_e}\right)^2 P_e P_\gamma < A_l^2 > \sigma\right)^{-1}$. $\mathcal{L}$ is the luminosity and σ the unpolarized cross-section, which varies smoothly as a function of particles energies. But the theoretical longitudinal asymmetry decreases strongly with the energy of incident particles: The maximum asymmetry is 0.8 with SLAC condition ($50GeV$ electron beam, green laser), while the maximum asymmetry is 0.02 for a $4GeV$ electron beam, and a $1064nm$ laser. With a $0.5W$ laser of this type, the time needed to get a 1% level on the polarization measurement is about 5 days.

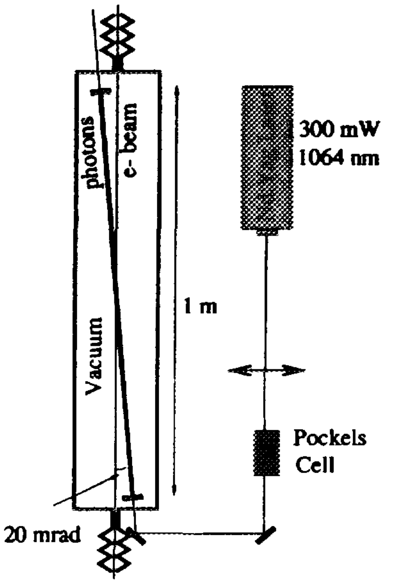

Figure 2: Principle of the cavity used as light amplifier

To increase performances of the system, one can use a high power UV laser. But such devices are not reliable and have to be installed in a dedicated room with a UV transport to the interaction point. An elegant alternative is to use a classical laser coupled with a Fabry-Pérot optical cavity in order to amplify the light intensity. In this solution, the laser beam is trapped between two highly-reflective concave mirrors and the Compton interaction occurs in the center of the cavity (Fig. 2). Due to constructive interference, the light power circulating inside the cavity will be enhance by a gain G. This gain depends on mirrors intrinsic characteristics (reflection R, transmission T, diffraction and absorption losses D and A, with the relation $R + T + D + A = 1$) and is a periodic function of the difference between laser frequency and cavity resonant frequency $\Delta\nu$: $G = G_M \frac{1}{1+\left(\frac{2\mathcal{F}}{\pi}\right)^2 \sin^2\left(\frac{\Delta\nu}{FSR}\right)}$. We have introduced the maximum gain $G_M = \frac{T}{(1-R)^2}$, the finesse $\mathcal{F}$ of the cavity, $\mathcal{F} = \pi\frac{\sqrt{R}}{1-R}$, and the Free Spectral Range $FSR = \frac{c}{2L}$, where L is the length of the cavity. The higher the finesse of the cavity is, the smaller the bandwidth of the resonance peak is and the higher the gain of the cavity at resonance is. The LPN Lyon, where the VIRGO[2] mirrors are realized, will built our mirrors. These multi-layer SiO_2/Ta_2O_5 mirrors will have a transmission $T \simeq 100ppm$, and total losses of less than $10ppm$. With such mirrors, the bandwidth of the cavity is small with respect to the laser frequency drift and the frequency noise due to

Mirror type	$1-R$	T	P_{cav}	During
MELLES GRIOT	$3000ppm$	$\sim 400ppm$	$1.5W$	$1\ h$
NEWPORT SuperMirror	$\simeq 100ppm$	$\sim 85ppm$	$150W$	$\sim 5\ min$
LPN Lyon mirror	$110ppm$	$100ppm$	$2500W$	several hours

Table 1: Mirrors characteristics and test results. The last line summarizes the main characteristics of final mirrors and the maximum power inside the cavity reachable with these mirrors.

mechanical vibration. It is necessary to control the laser frequency in order to keep the tuning between the laser frequency and the cavity resonance frequency. In order to design this feed-back control, based on Pound-Drever method[3], we have built an in air cavity at Saclay, with mirrors from the industry. For these tests, we use a $300mW$(CW) $1064nm$ laser. Characteristics of this mirrors and the power inside the cavity obtained during this test have been measured and are given table 1.

Both scattered photons and scattered electrons will be detected to measure the experimental asymmetry. For beam energies from $4GeV$ to $8GeV$, the photon detector must measure photon energies for $10Mev$ to $1GeV$, with a resolution close to 10%. This photon calorimeter will be located just before the fourth dipole of the chicane, below the direct beam line. The expected counting rate with a $100\mu A$ and a cavity gain of 9000 is close to $800kHz$. Beside, the third dipole of the chicane will produce synchrotron radiation ($\sim 30mW$, with an averaged photon energy of $400keV$ for a [$4Gev$, $100\mu A$] beam). Therefore this photon detector have to be radiation hard. A possible candidate is the $PbW0_4$ crystal, chosen by the CMS experiment for the electromagnetic calorimeter[4]. Test and simulation are running at Saclay to determine the resolution of a $PbW0_4$-based calorimeter for the energy range of $[10;100]MeV$.

To measure the energies of the scattered electrons, we will use the third dipole of the chicane as spectrometer magnet and the location of the electron will be measured before the fourth dipole using silicon-strip detector. This detector is under study at LPC Clermont-Ferrand.

It is planed to install the polarimeter at TJNAF at the end of 1997. The first run will be in 1998.

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