Electron Polarization Measurement with A Fabry-Perot Cavity at HERA

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WHAT? Overview of HERA machine and its polarimeters

Why? Necessities of having fast & precise P_e measurement

HOW? Principle of the polarization measurement

New polarimeter with a Fabry-Perot Cavity

Comparison of the new polarimeter with the existing ones

And Summary and outlook

Overview of HERA Machine and its Polarimeters

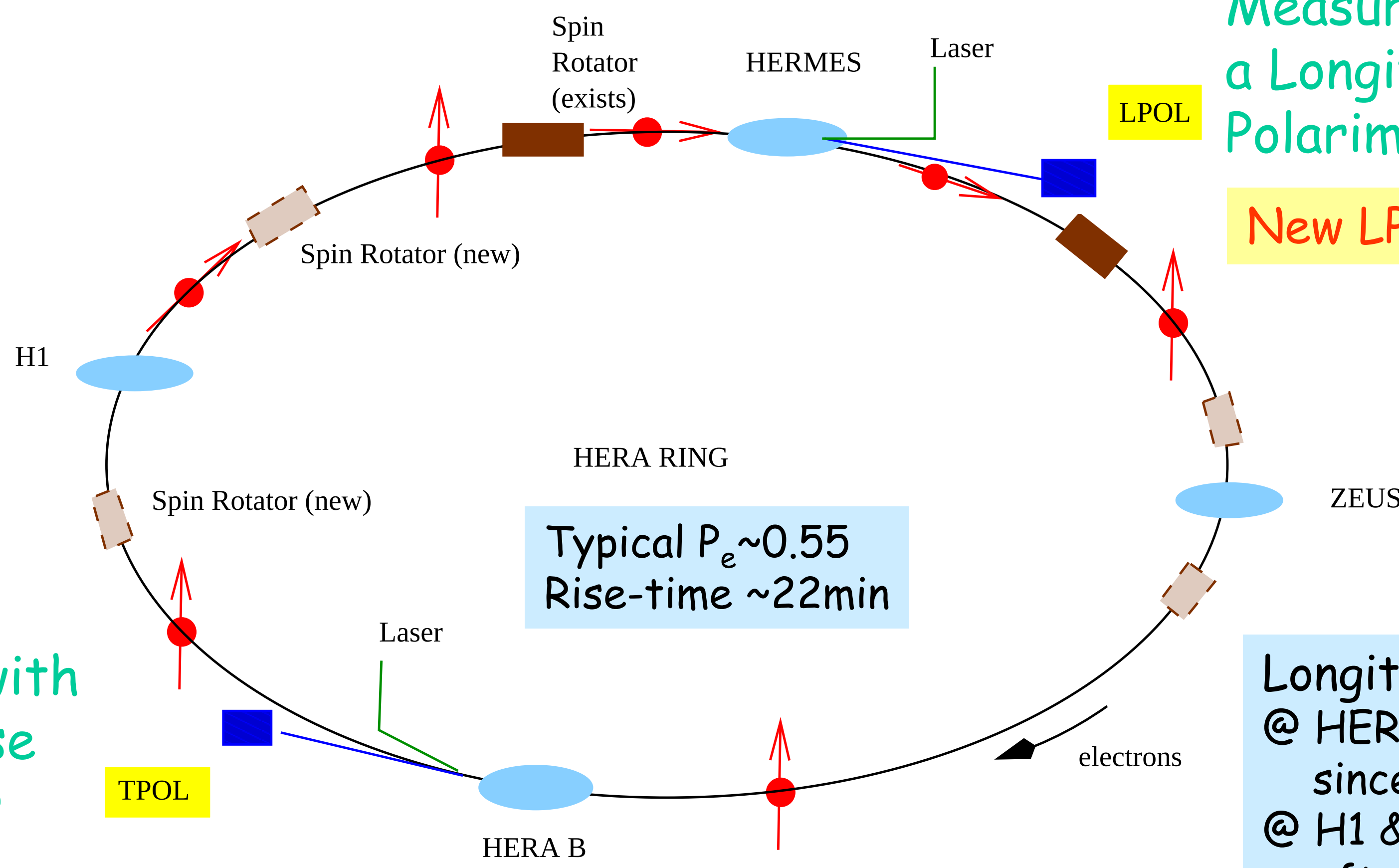
Sokolov-Ternov Effect

Spin Rotator

Natural transverse polarization → Longitudinal polarization

Measured with a Longitudinal Polarimeter

New LPOL



Typical P_e~0.55
Rise-time ~22min

Measured with a Transverse Polarimeter

Longitudinal P_e
@ HERMES
since 1995
@ H1 & ZEUS
after upgrade

Necessities of having Fast & Precise P_e Measurement
The Physics Consideration

Precision Measurements (QCD):

Neutral Current (NC) and Charged Current (CC) cross-sections very sensitive to P_e at high Q^2
→ Parton densities at large x

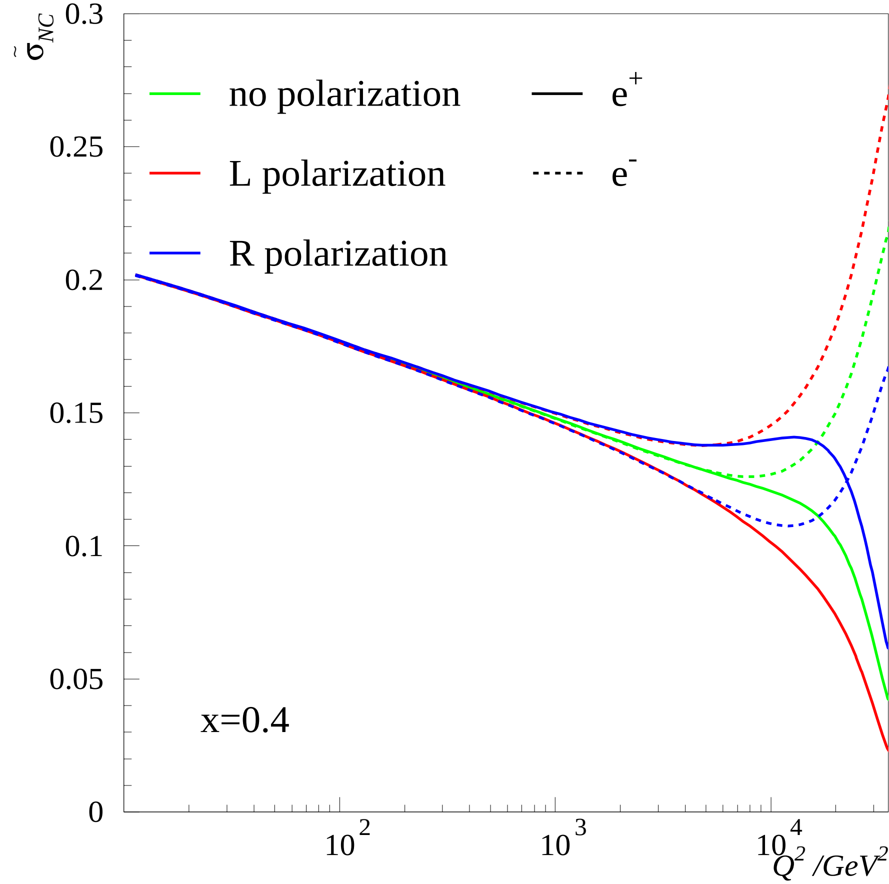
Electroweak Physics:

NC → qZ couplings: v_q, a_q
CC → W boson (propagator) mass

Physics Beyond Standard Model:

Right-handed CC interaction
Enhanced sensitivity for searching for Leptoquarks, R_p violating SUSY

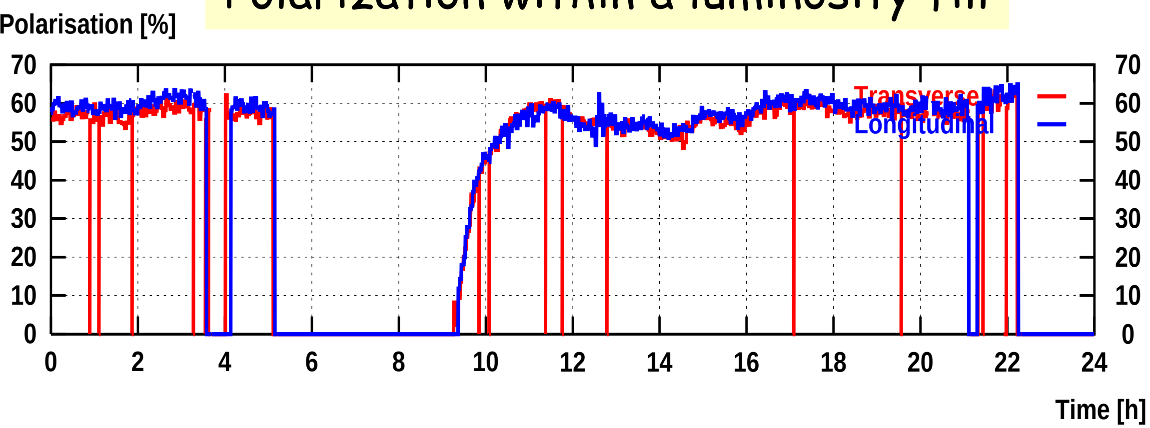
Example: NC cross-section



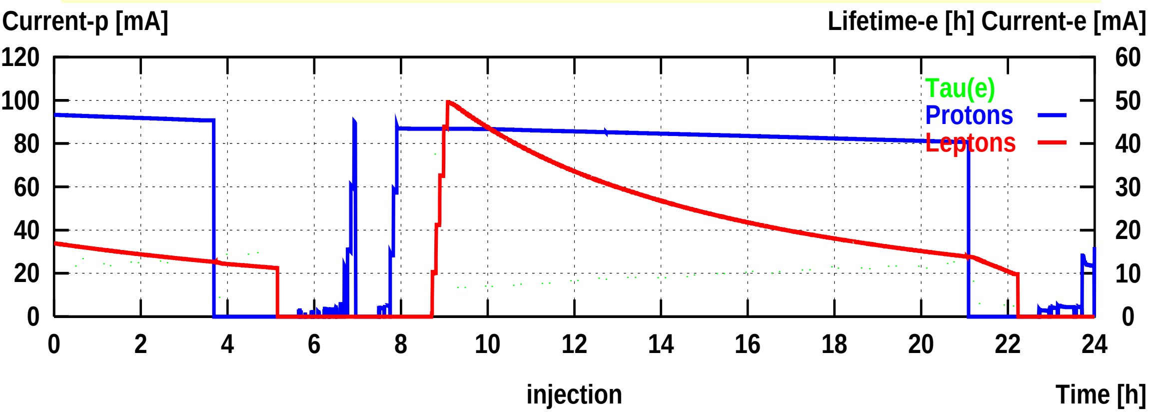
Up to $Q^2 = s = 10^5$

Necessities of having Fast & Precise P_e Measurement
Other considerations

Polarization within a luminosity fill



p and e beam currents within a luminosity fill



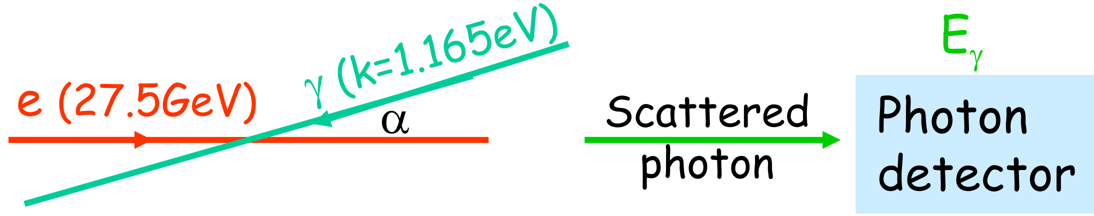
P_e varies ~10% and
P_e changes from bunch to bunch (not shown)

Need fast feedback to optimize and maintain maximum P_e

Luminosity largest at the beginning of a fill

Need P_e as precise as lumi. and their correlations to properly analyze data

Principle of the P_e Measurement with a Longitudinal Polarimeter



Compton Scattering:

$e+\gamma \rightarrow e+\gamma$

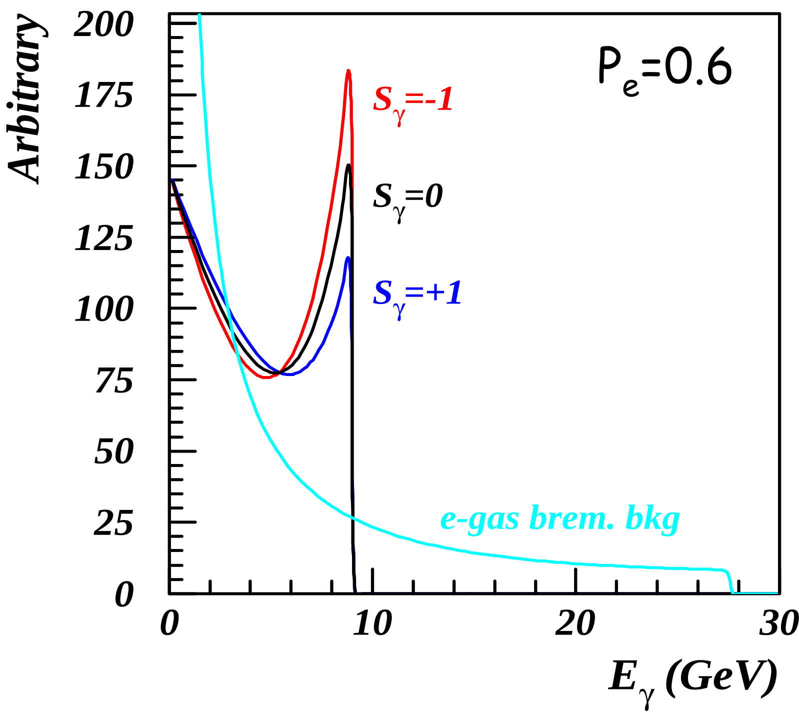
Cross Section:

$d\sigma/dE_\gamma = \sigma_0(E_\gamma) - P_e S_\gamma \sigma_1(E_\gamma)$

σ_0, σ_1: known (QED)

P_e: Polarization of the **e beam** to be measured

S_γ: Circular polarization (+-1) of the **laser beam**



Luminosity (electron-laser):

$$L \propto \frac{P_L I_e}{k\alpha\sqrt{\sigma_{e,y}^2 + \sigma_{\gamma,y}^2}}$$

I_e: e beam intensity

P_L: Laser beam power

A Comparison of Different Polarimeters

	P_L	e-γ rate	γ rate (n_γ)	$(\delta P_e)_{stat}$	$(\delta P_e)_{syst}$
LPOL:	33MW	0.1KHz pulse laser	1000 γ/pulse multi-γ mode i.e. 0.01 γ/bc (bc=bunch crossing)	1%/min (all bunches) 1%/(>30min) (single bunch)	~2%
TPOL:	10W	10MHz cw laser (cw=continuous wave)	0.01 γ/bc single-γ mode	1-2%/min (all bunches)	~4% → <2% (upgrade)
New LPOL:	5kW	10MHz cw laser	1 γ/bc few-γ mode	0.1%/6s (all bunches) 1%/min (single bunch)	per mill

Fabry-Perot Cavity

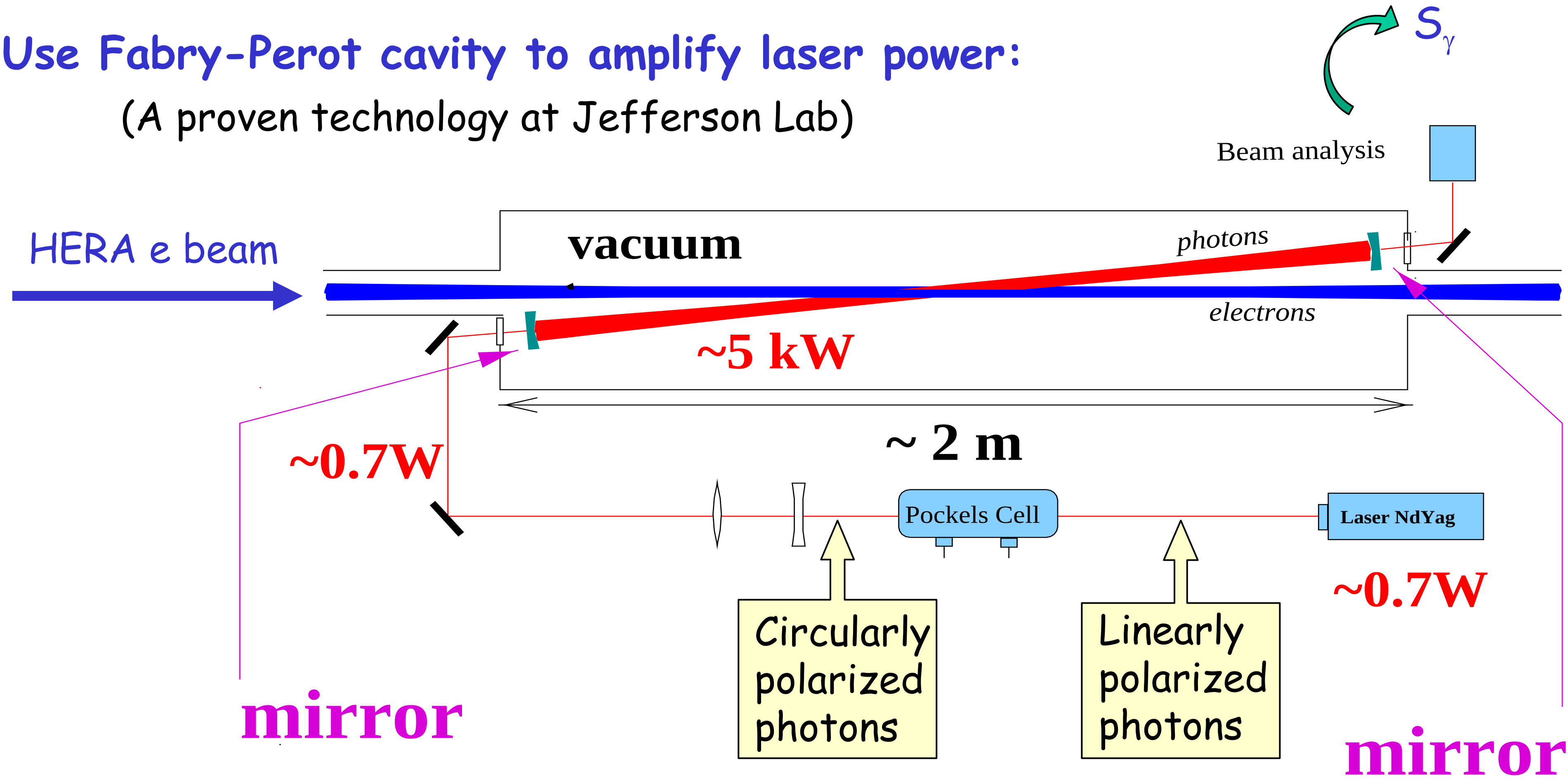
0.7W

Expected precision

A High Gain Fabry-Perot Cavity

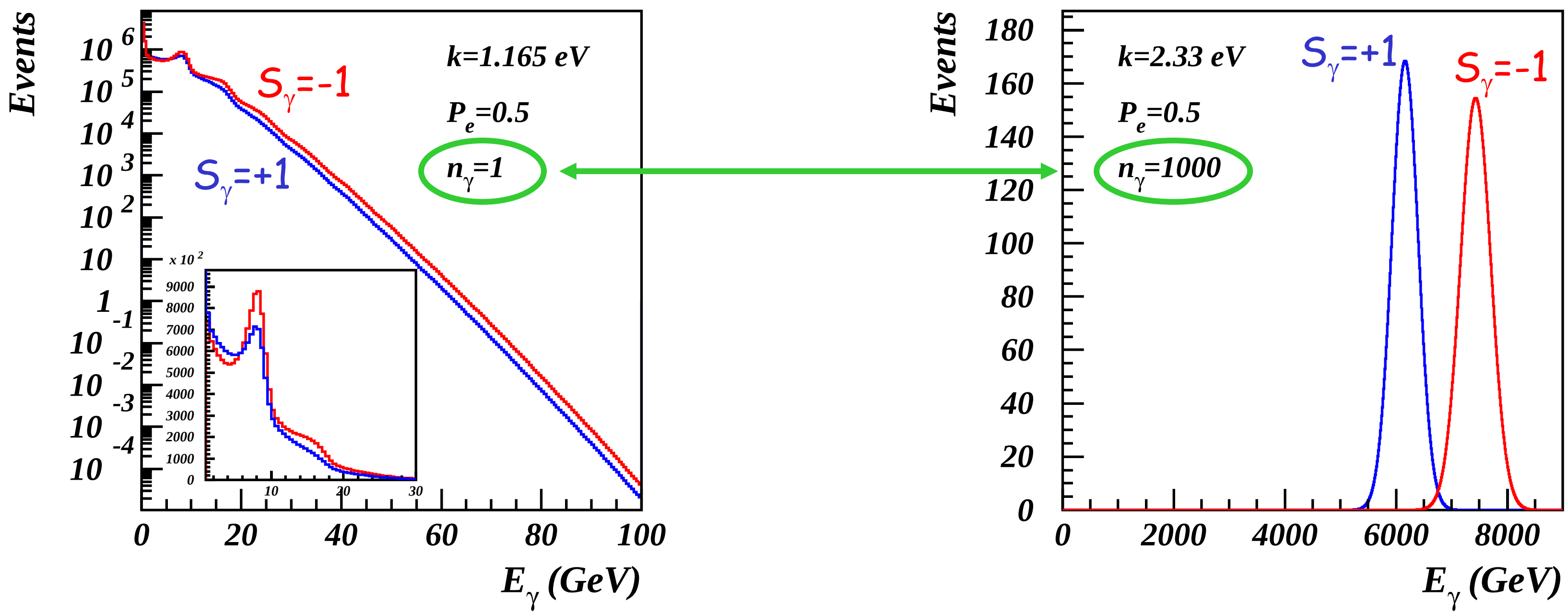
Use Fabry-Perot cavity to amplify laser power:

(A proven technology at Jefferson Lab)



All optical components are fixed rigidly on an optical table

Photon Detection and Systematic Uncertainty of P_e



Compton and Bremsstrahlung edges clearly visible

Background determination and Calibration easy

$(\delta P_e)_{syst}$: per mill level expected

Up to 1000 γ produced per pulse

Signal/background ratio improved

> 5TeV measured in the detector!

Calibration difficult

Non-linearity $\rightarrow$ main syst. error

Summary and Outlook

New polarimeter with a Fabry-Perot cavity:

High statistics precision: ← Large gain in cw laser power (~10^4)

0.1% every 6s (all bunches)
1% every minute (single bunch)

Small systematic uncertainties: ← Few-photon mode

Per mill level

Fast and precise measurement of P_e:

Valuable feedback for HERA machine to achieve maximum polarization
Necessary to fully exploit the physics potential at HERA after upgrade

Cavity prototype being tested at LAL, Orsay

Final set-up will be installed during the shutdown in spring 2002