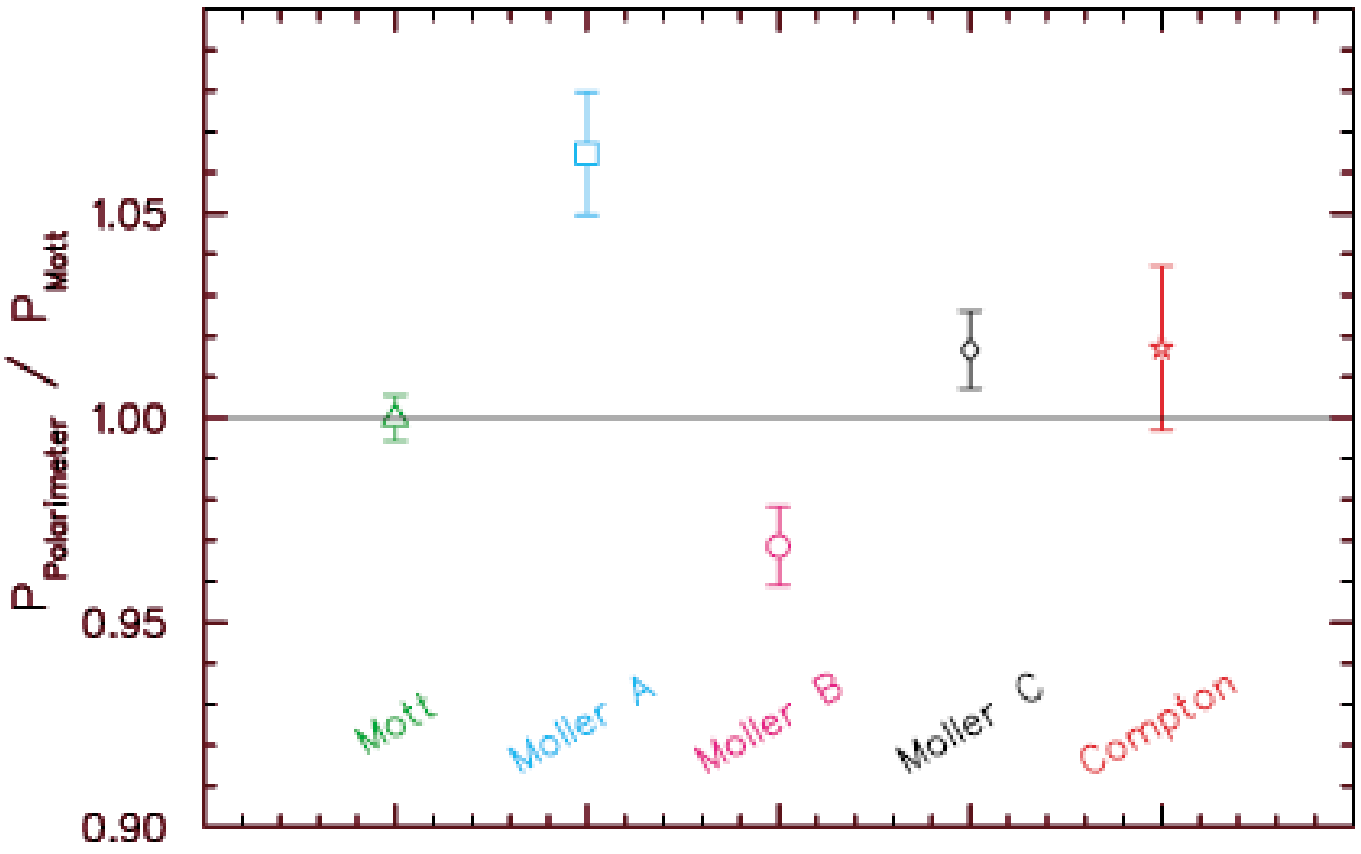
Optical Electron Polarimetry

T.J. Gay
University of Nebraska

The Problem: the CEBAF Spin Dance



J.M.Grames *et al.*, Phys. Rev. Spec. Top. Acc. Beams **7**, 042802 (2004)

SYSTEMATICS

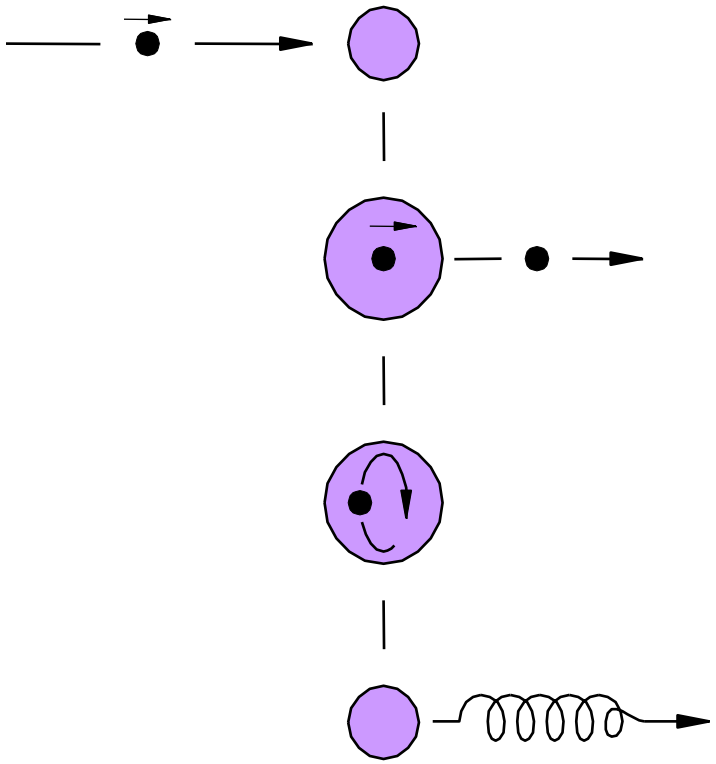
- Mott: 1%
- Möller A: 4%
- Möller B: 1%
- Möller C: 1%
- Compton: 3%

5 MeV State-of-the-Art Theory is carried out for the CEBAF Mott Polarimeter!

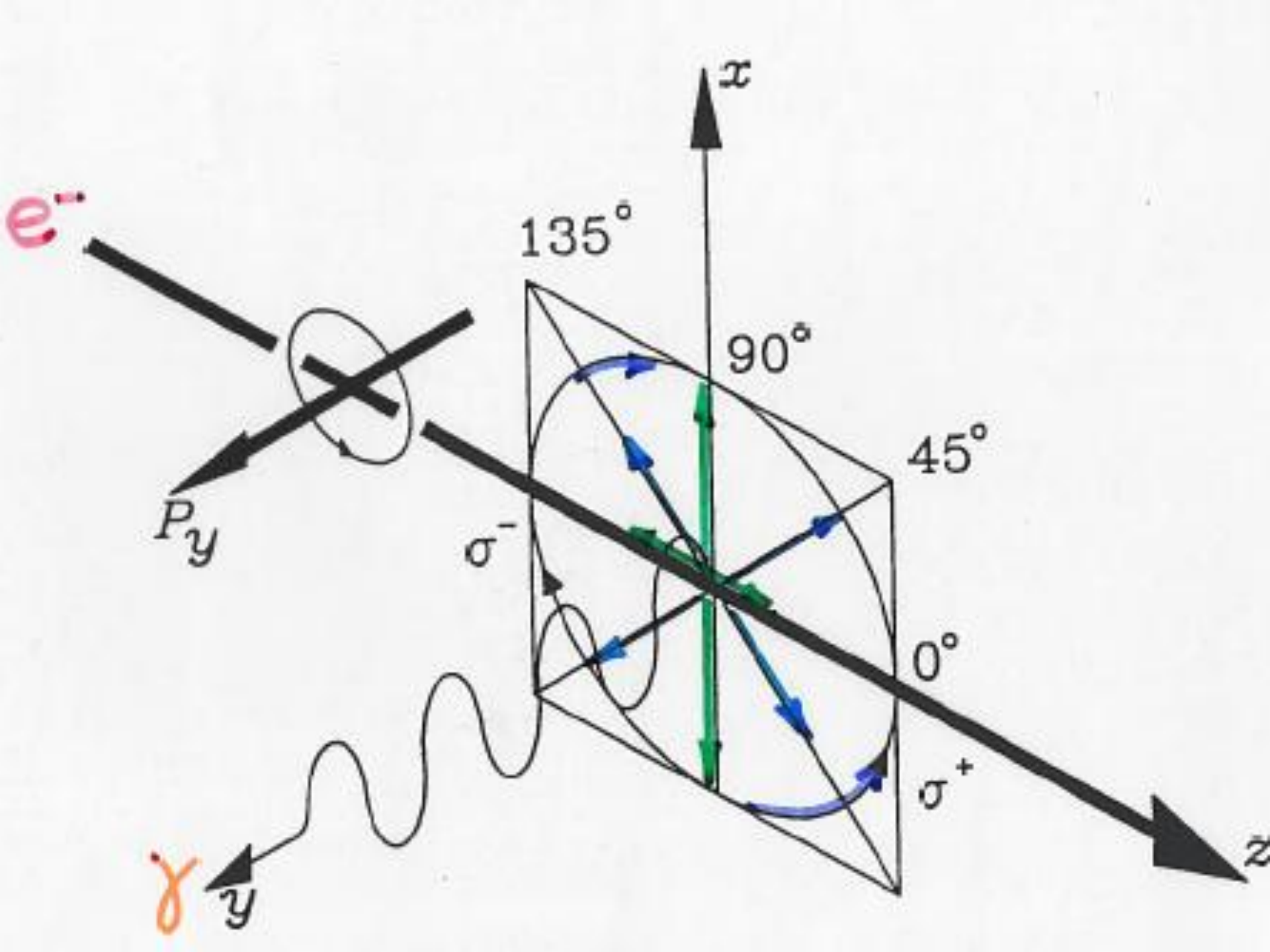
In 1956, with the goal of improving thermonuclear weaponry, Noah Sherman uses the UNIVAC, a high-speed electronic digital computer with tens of kilobytes of memory, to calculate the Mott scattering analyzing power. These calculations, which quote an accuracy of 1%, assume

- A point-like nucleus
- No K-shell (or any other) electrons in the target
- No QED effects, e.g., bremstrahlung
- Spherical extensions by Ugincius (1964), Motz (1970)

Exchange excitation of atomic fluorescence



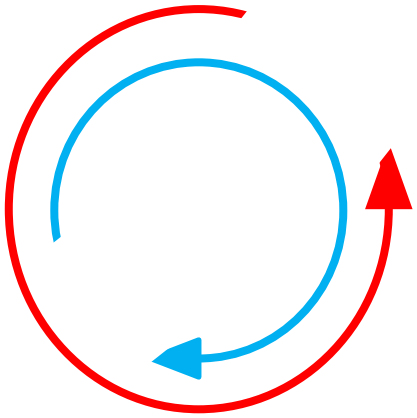
Dayhoff (<1956)

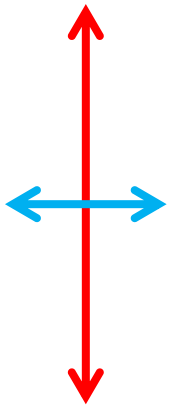

x
e⁻
135°
90°
45°
P_y
σ⁻
0°
σ⁺
γ
y
z

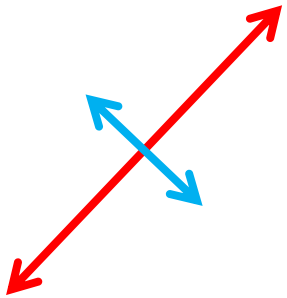
The general electron optical polarimeter equation

$$P_e = \frac{P_3}{[a + bP_1]}$$

NB – a,b, exactly computable







P_3 → Electron polarization in the direction of the emission direction

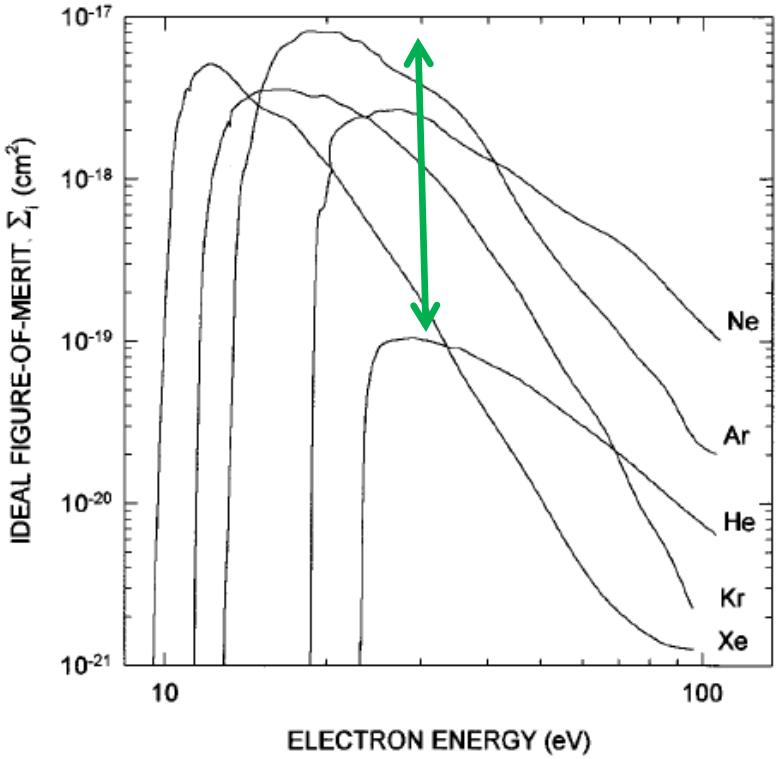
P_1 → Analyzing Power

P_2 → Validity of the kinematic assumptions

TABLE I. Polarimetric transitions for the noble gases (see text). Values of γ, β, and A (threshold) are taken from Refs. [5] and [9].

Target	Transition	E_t (eV)	E_c (eV)	First cascading state	σ_{max} (10^{-19} cm^2)	γ	β	A (threshold)
He	$3\,^3P \rightarrow 2\,^3S$ (3889 Å)	23.00	23.59	$4\,^3S$[a]	7.0 (Ref. [13])	0.5000	−0.3333	0.4390
Ne	$3\,^3D_3 \rightarrow 2\,^3P_2$ (6402 Å)	18.55	19.66	$4\,^3P_2^o$	91 (Ref. [14])	0.6663	0.2230	0.7315
Ar	$4\,^3D_3 \rightarrow 3\,^3P_2$ (8115 Å)	13.07	13.90	$3d_3$	260 (Ref. [15])	0.6667	0.2222	0.7317
Kr	$5\,^3D_3 \rightarrow 4\,^3P_2$ (8112 Å)	11.44	12.11	$3d_3$	120[b] (Ref. [16])	0.6214	0.2768	0.6959
Xe	$6\,^3D_3 \rightarrow 5\,^3P_2$ (8819 Å)	9.72	9.94	$5\,^3F_4^o$	280[b] (Ref. [16])	0.6322	0.3098	0.7080

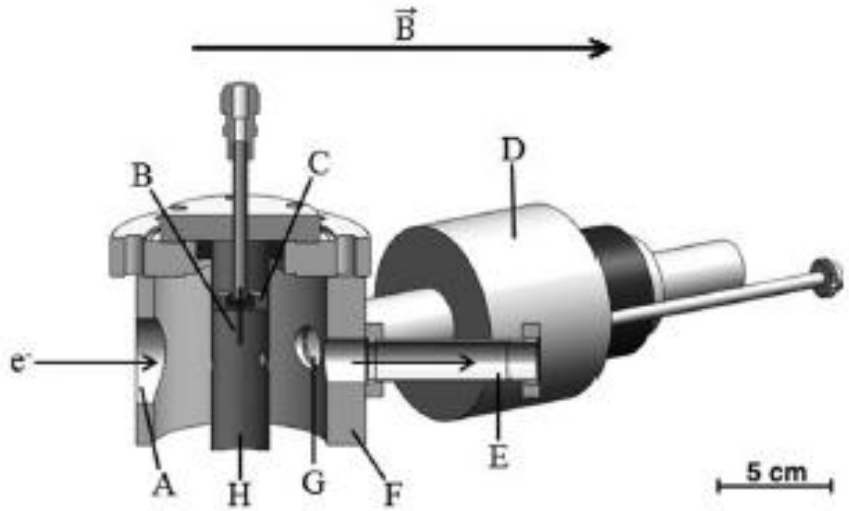
[a]The $3\,^3D$ state decays almost exclusively to the $2\,^3P$ state (see text).
[b]Extrapolated to zero target pressure.

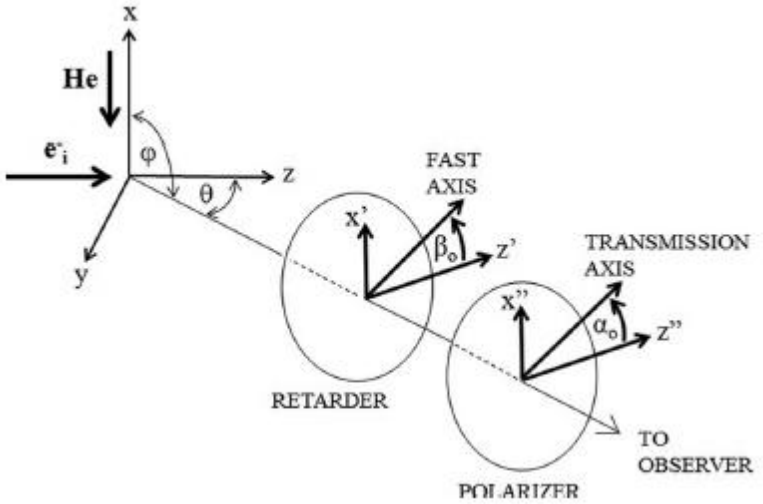


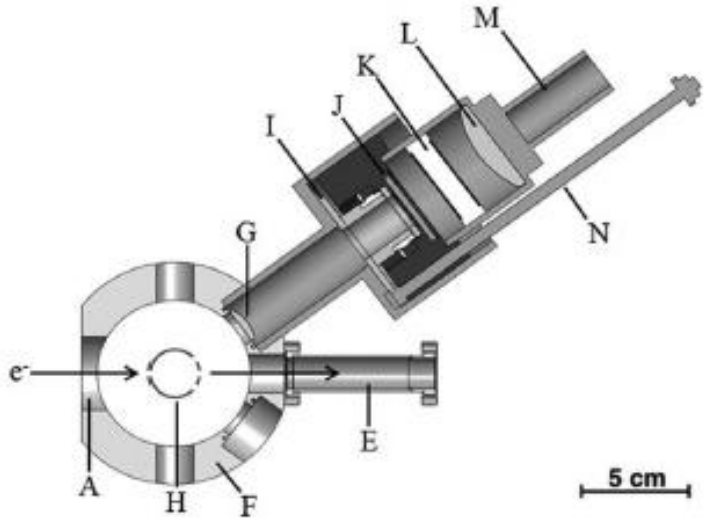
Advantages of the Optical Method

- Larger analyzing power (>2/3 for the neavy noble gases vs. 0.4-0.5 for Mott scattering)
- Omnidirectional
- Compact
- Absolute

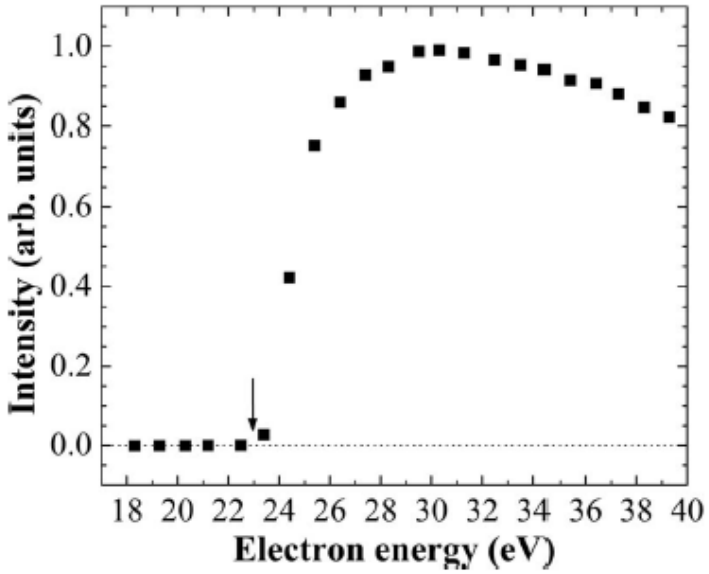
M. Pirbhai *et alii*, RSI **84**, 053113 (2013)

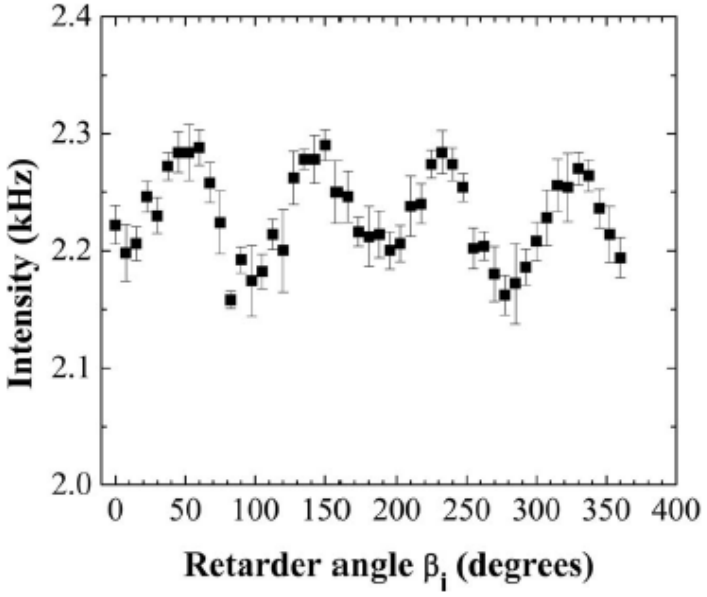


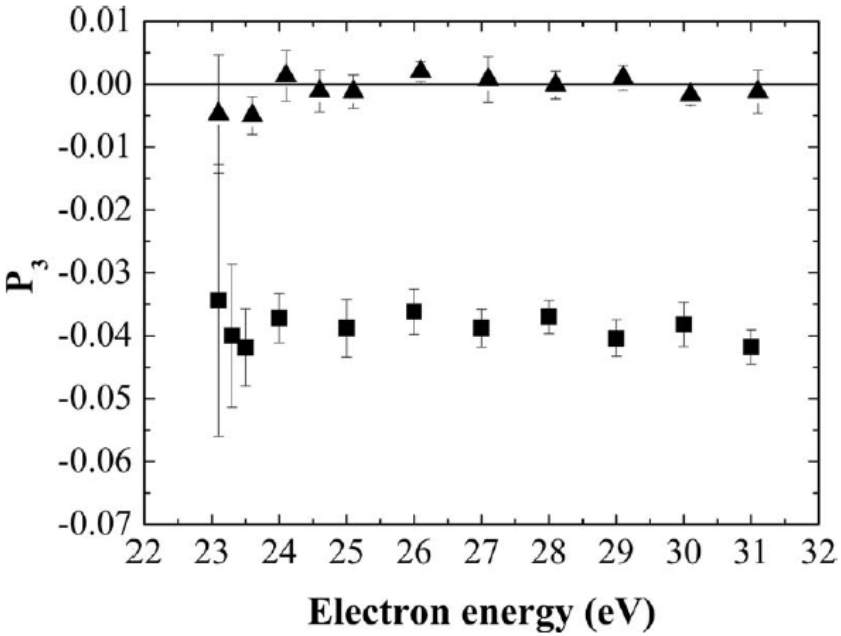




Data





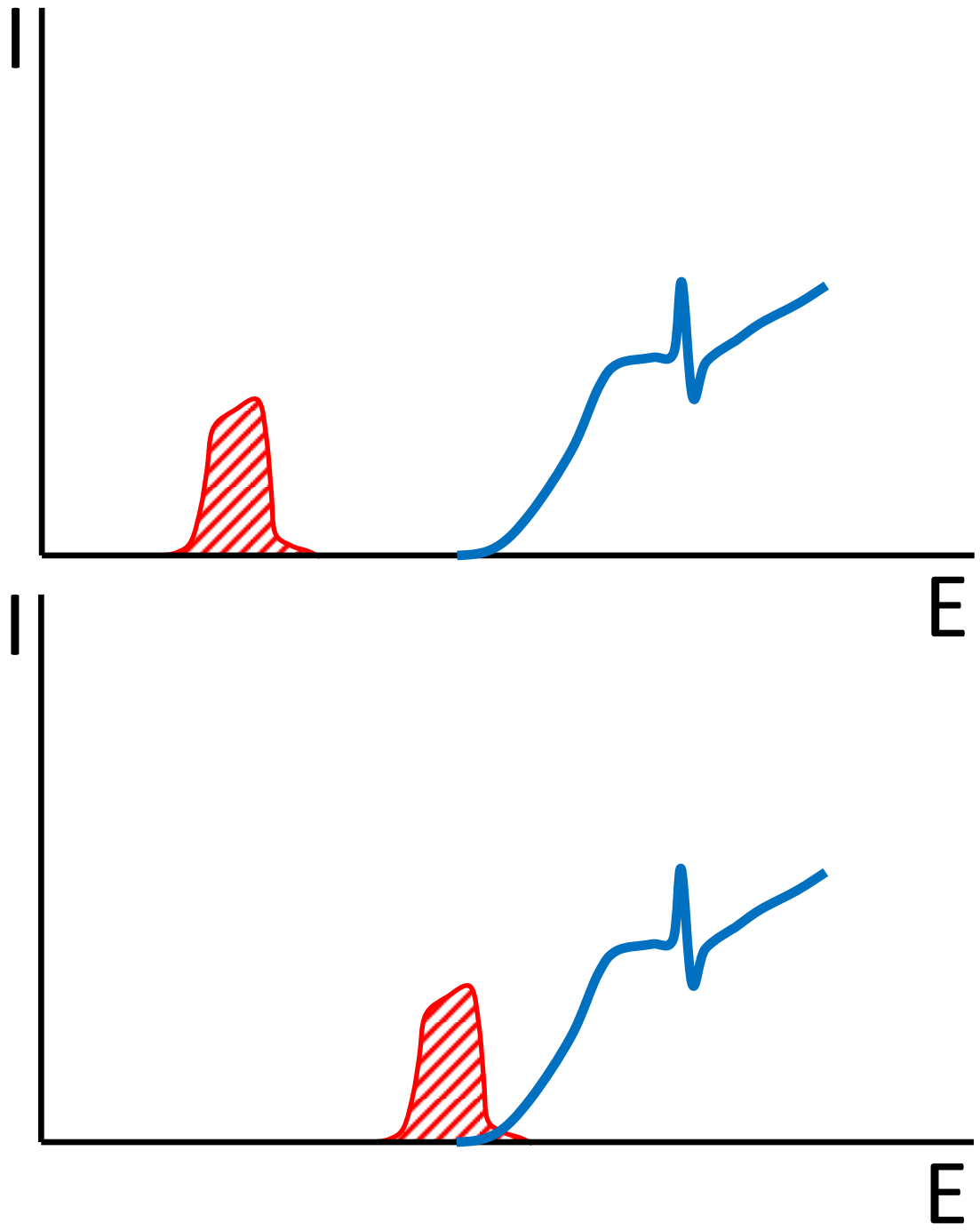


Argon Polarimetry

- Analyzing power = 0.73
- Efficiency = 500 Hz/nA
- Figure of merit = 270 Hz/nA
- 1 μA → Pe = 0.200(2) in 0.5 s

Skeletons

- Low efficiency compared with Mott scattering
- Rogue gas loads
- Cascades
- Energy dependence of efficiency $\oplus$ energy dependence of polarization within the beam width
- Hanle depolarization
- Pressure dependence of the Stokes parameters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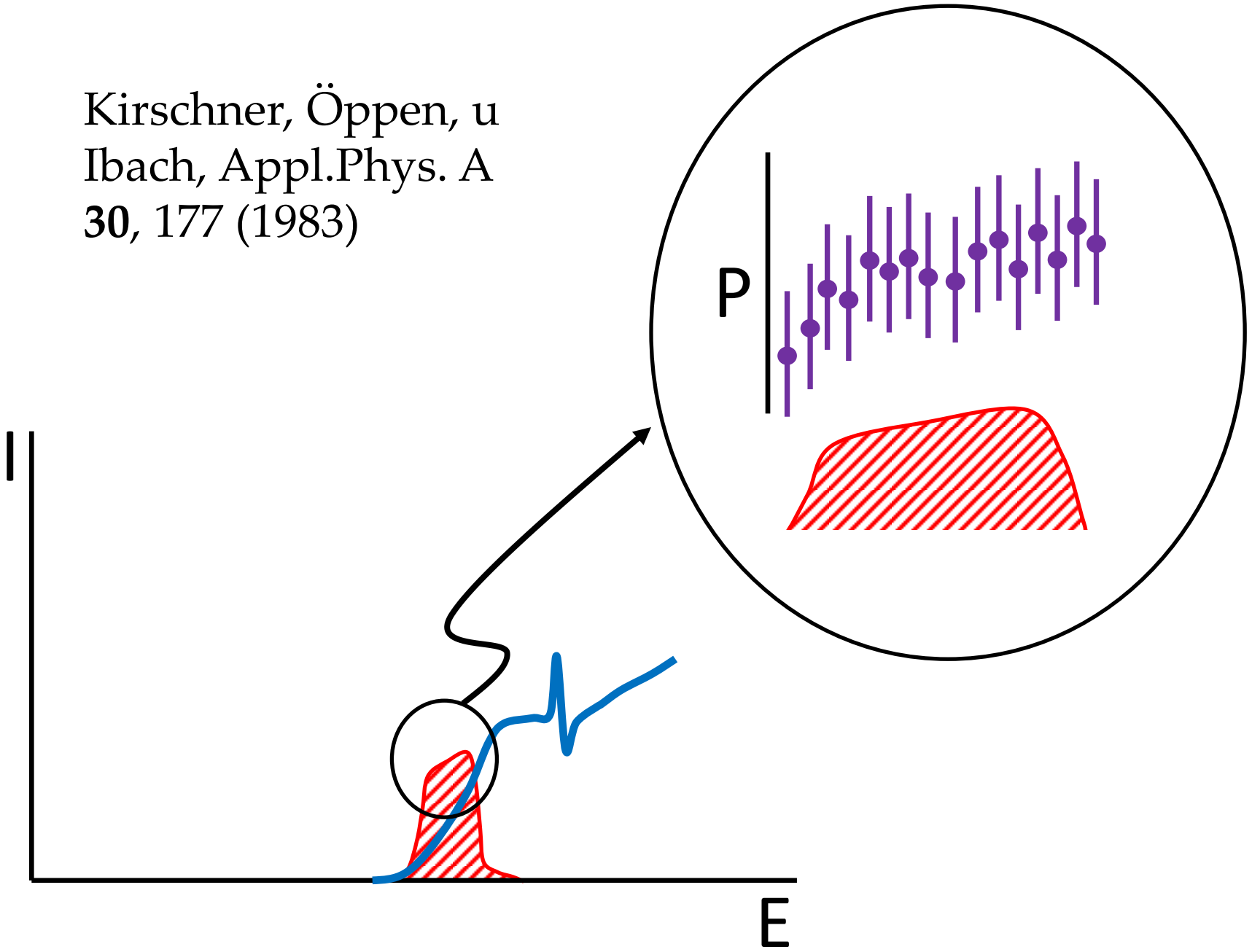
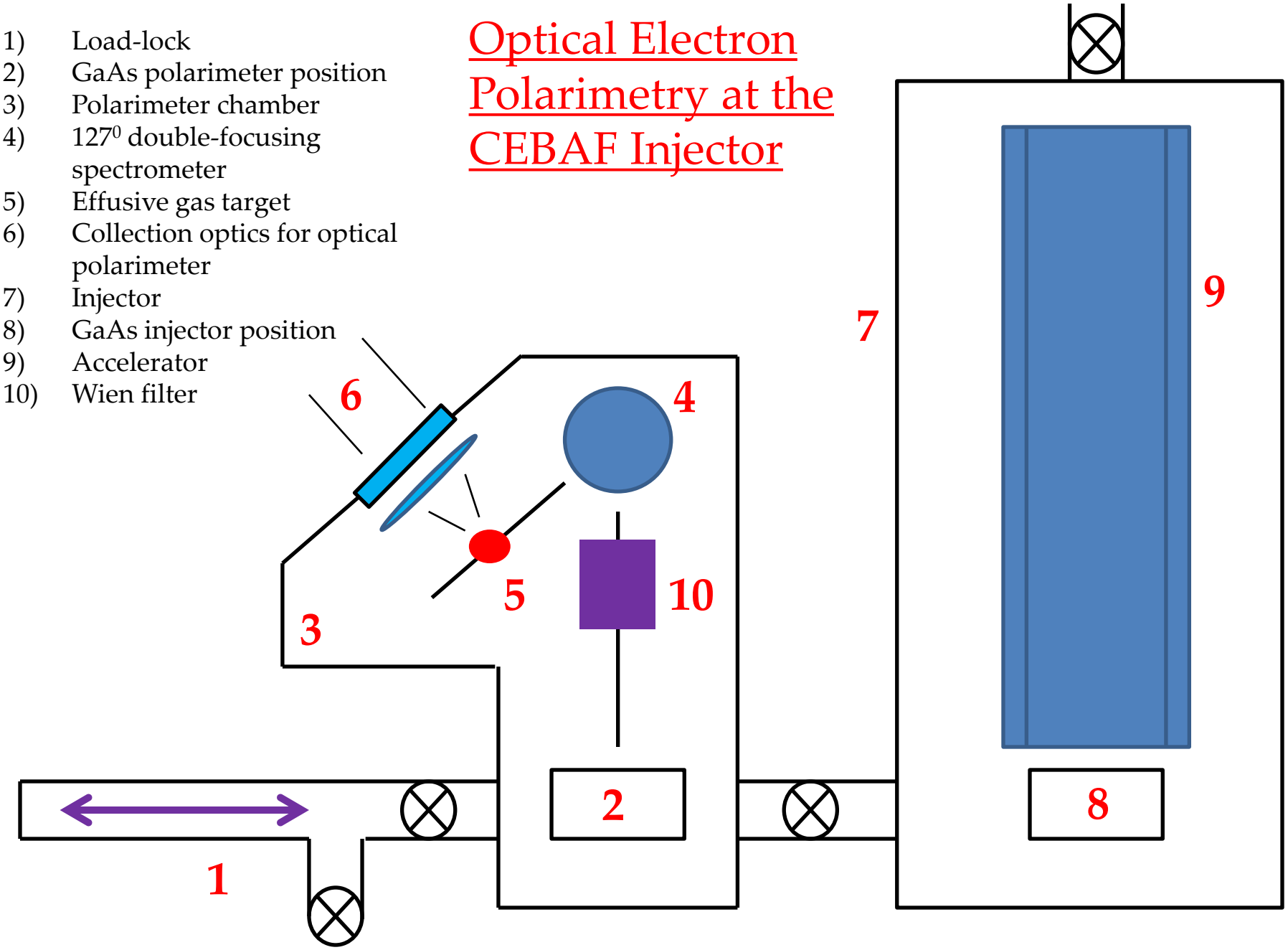
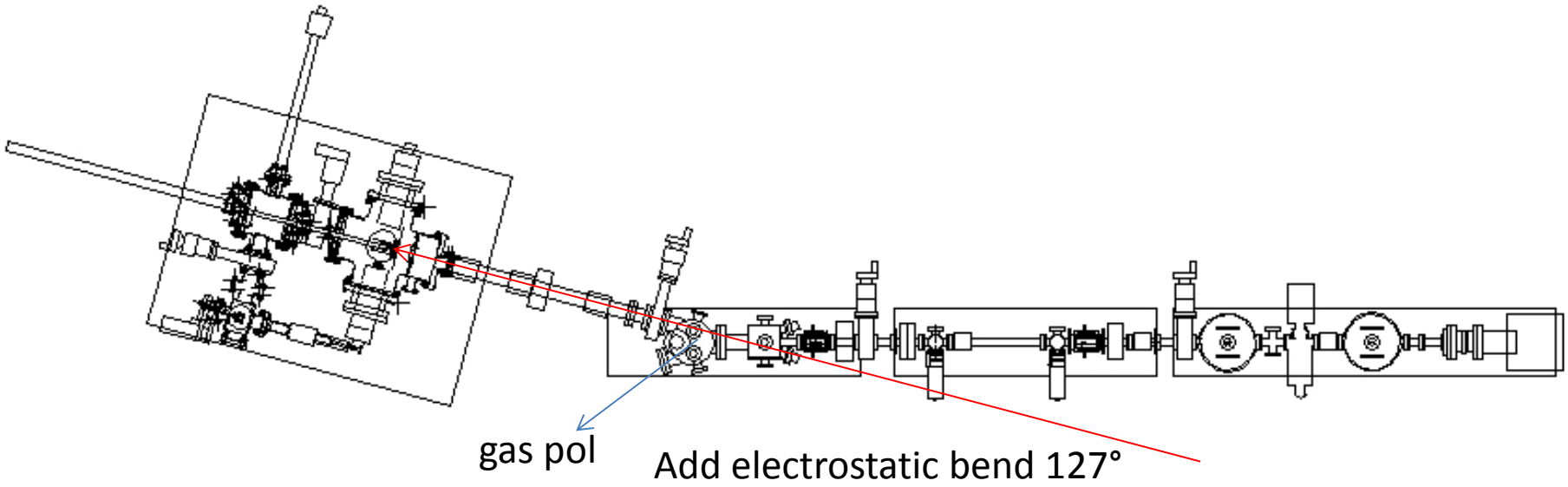
Kirschner, Öppen, u Ibach, Appl.Phys. A **30**, 177 (1983)



Optical Electron Polarimetry at the CEBAF Injector

1) Load-lock
2) GaAs polarimeter position
3) Polarimeter chamber
4) 127^0 double-focusing spectrometer
5) Effusive gas target
6) Collection optics for optical polarimeter
7) Injector
8) GaAs injector position
9) Accelerator
10) Wien filter

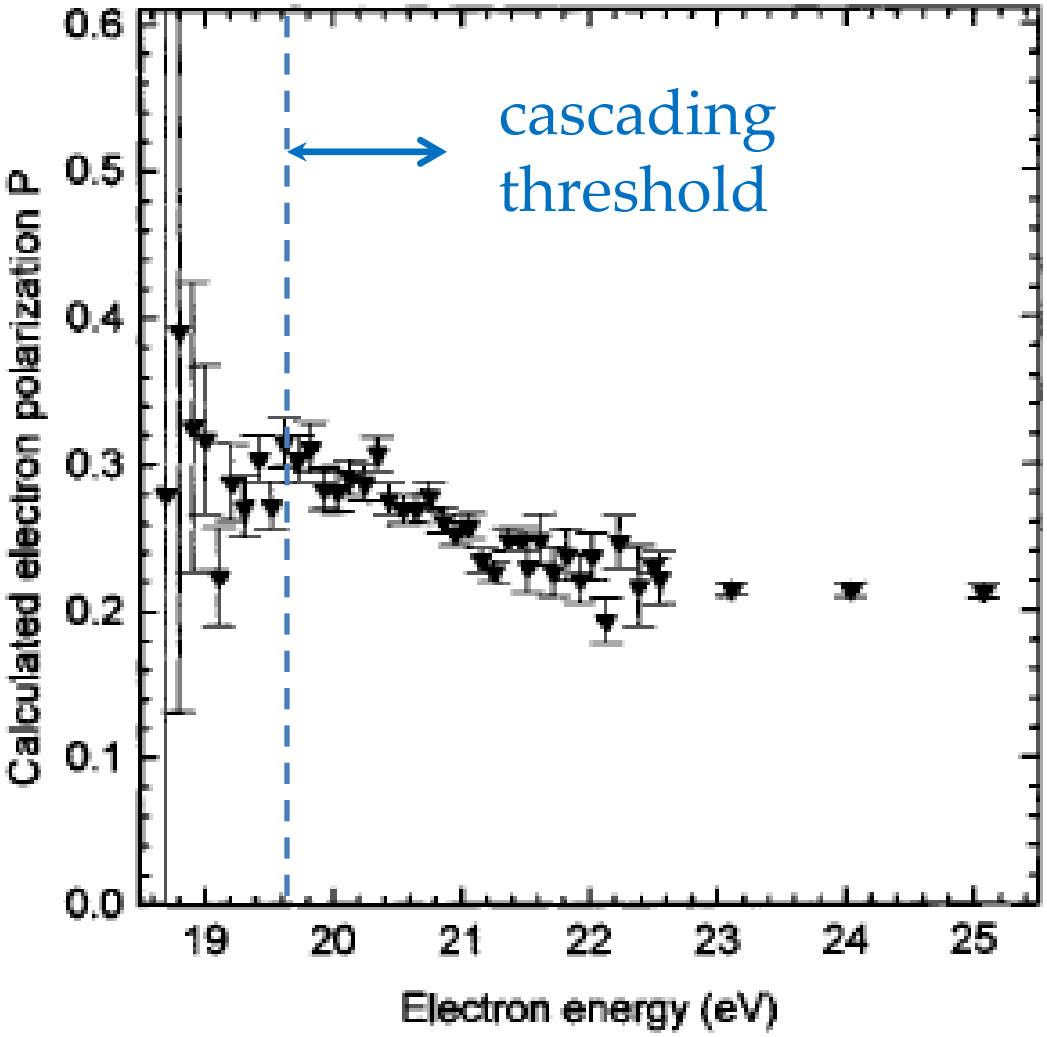



gas pol
Add electrostatic bend 127°

POLO @ MAMI

- Used in 2004 with an effusive argon target and deceleration from 50 keV of the beam to be measured.
- Measured P_e with a precision of < 2%
- Very high backgrounds
- "Self calibration" not attempted
- B.Collin *et al.*, NIM A **534**, 361 (2004)

Accuracy (preliminary)



- $P_e = 0.273(4)$
- 1.5% absolute
- < 100 s acquisition time