Jefferson Lab polarized electron source

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Plan

- Basics of polarized photoemission
- Experimental setup:

    photocathodes

    guns

    lasers

    beam quality controls
- Laser for G0 experiment
- New generation of gun
- Conclusions & outlook

Polarized electron sources

Polarized electron beam to probe nuclear structure

⇒ development of polarized e- sources

First e- source on an accelerator: PEGGY, at SLAC (1978)

Semiconductor sources introduced in 1975 via optical pumping of GaAs

Introduction of strained GaAs to reach higher beam polarization

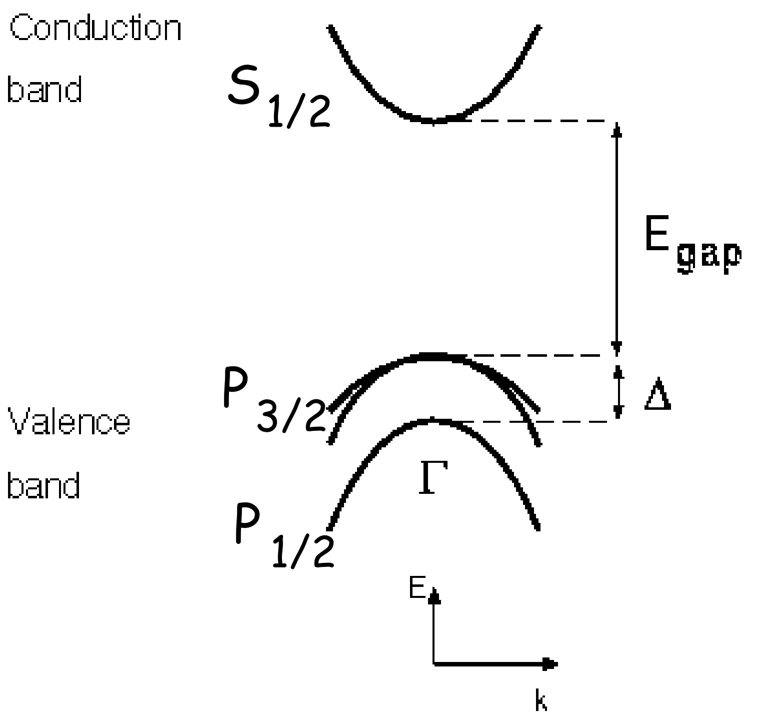
in early 90's (SLAC)

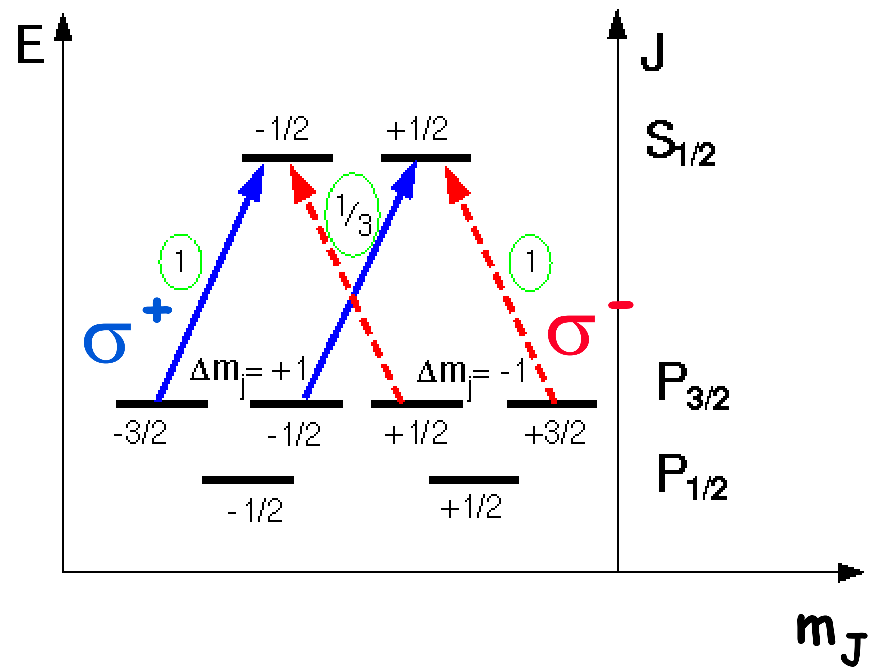
Nowadays, many accelerator facilities use strained GaAs sources:

SLAC, MAMI, ELSA, CEBAF

Photoemission from GaAs

Optical pumping between $P_{3/2}$ and $S_{1/2}$





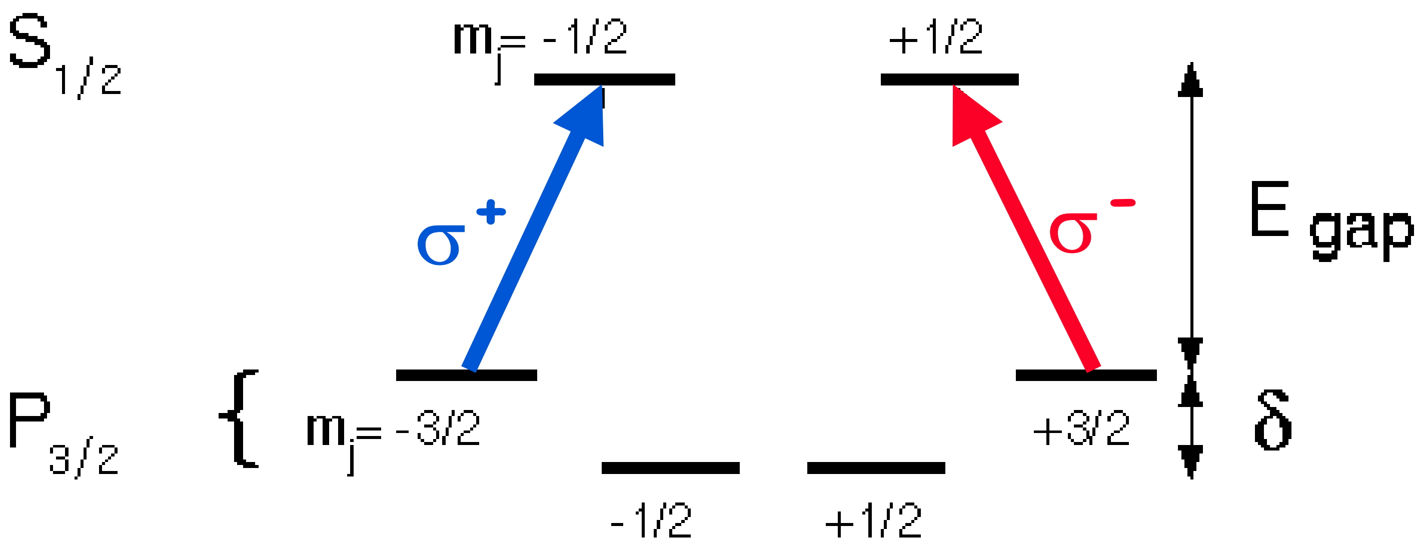
$$E_{gap} < E_{\gamma} < E_{gap+\Delta}$$

$$P_e = \frac{3-1}{3+1} = +/- \ 50\%$$

Photoemission from strained GaAs

Split degeneracy of $P_{3/2}$

& optical pumping between $P_{3/2}$ and $S_{1/2}$



P_e = +/- 100%, with $E_{gap} < E_\gamma < E_{gap+\delta}$

NEA Activation

- Electrons, pumped to the conduction band, must be emitted in vaccum

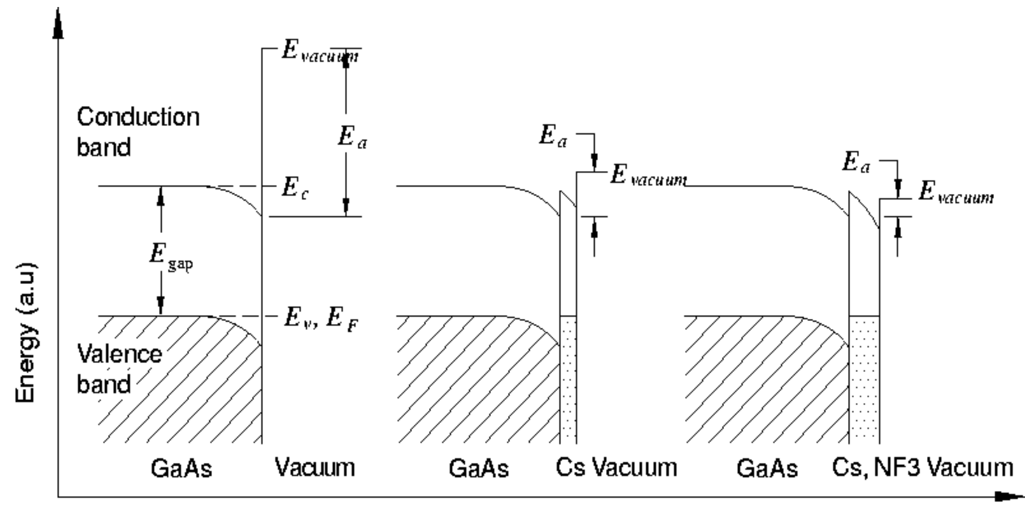
- Reduce surface e^- affinity

$\Rightarrow E_{conduction} > E_{vacuum}$

using alkali (Cs) and oxidant (NF3)

- Electrons emitted in vacuum & accelerated by some voltage

$E_a > 0$ $E_a \approx 0$ $E_a < 0$



Polarized source requirements

- High QE and P_e photocathode
- Gun

  Load and support photocathode

  Accommodate NEA activation of photocathode & optical port

  Hold high voltage

  Have good vacuum

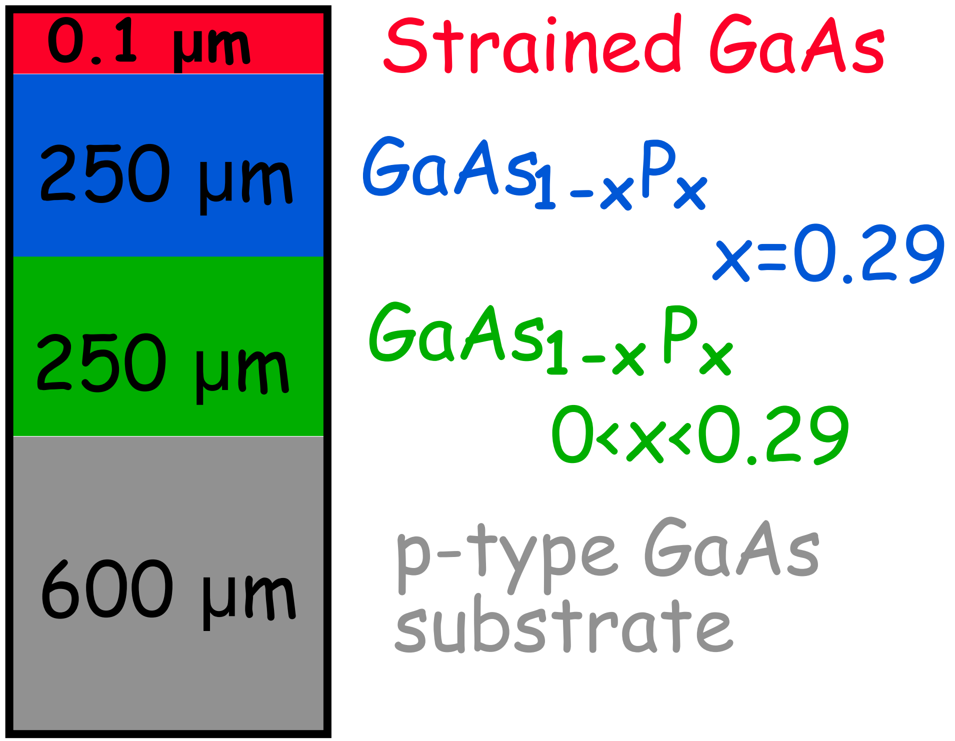
- Light source
  - Polarization (>99%)
  - Beam quality controls (intensity, position)

Strained layer GaAs photocathode

Bandwidth Semiconductor (formerly *SPIRE*)

- MOCVD-grown epitaxial spin-polarizer wafer
- Lattice mismatch

$\Rightarrow$ split degeneracy of $P_{3/2}$



QE & polarization

Quantum Efficiency

0.2 % at 840 nm yields 1 μA/mW

1.0 % at 780 nm yields 6 μA/mW

Polarization

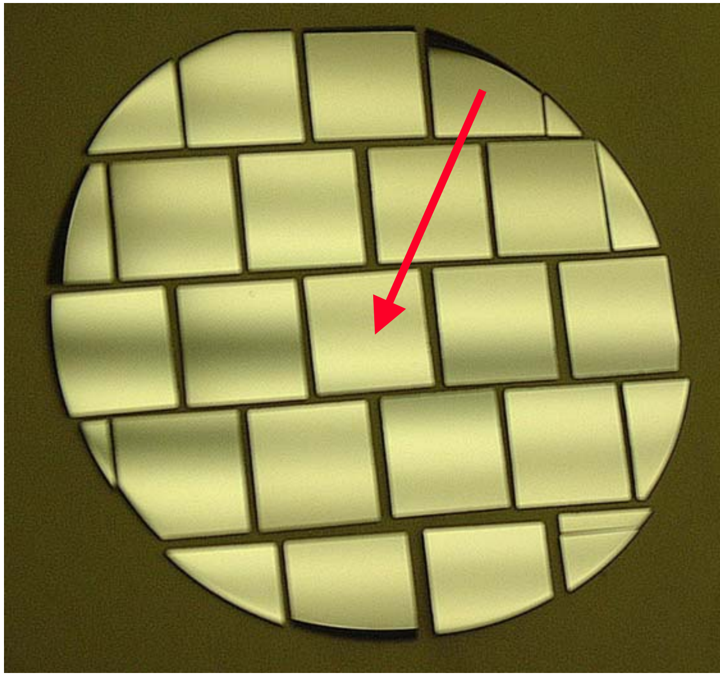
$P_e \sim$ 75 % at 840 nm

$P_e \sim$ 35 % at 780 nm

With laser polarization >99.5%, flipped at 30 Hz

$$\mathbf{FOM} \propto I\,P^2$$

Photocathode preparation

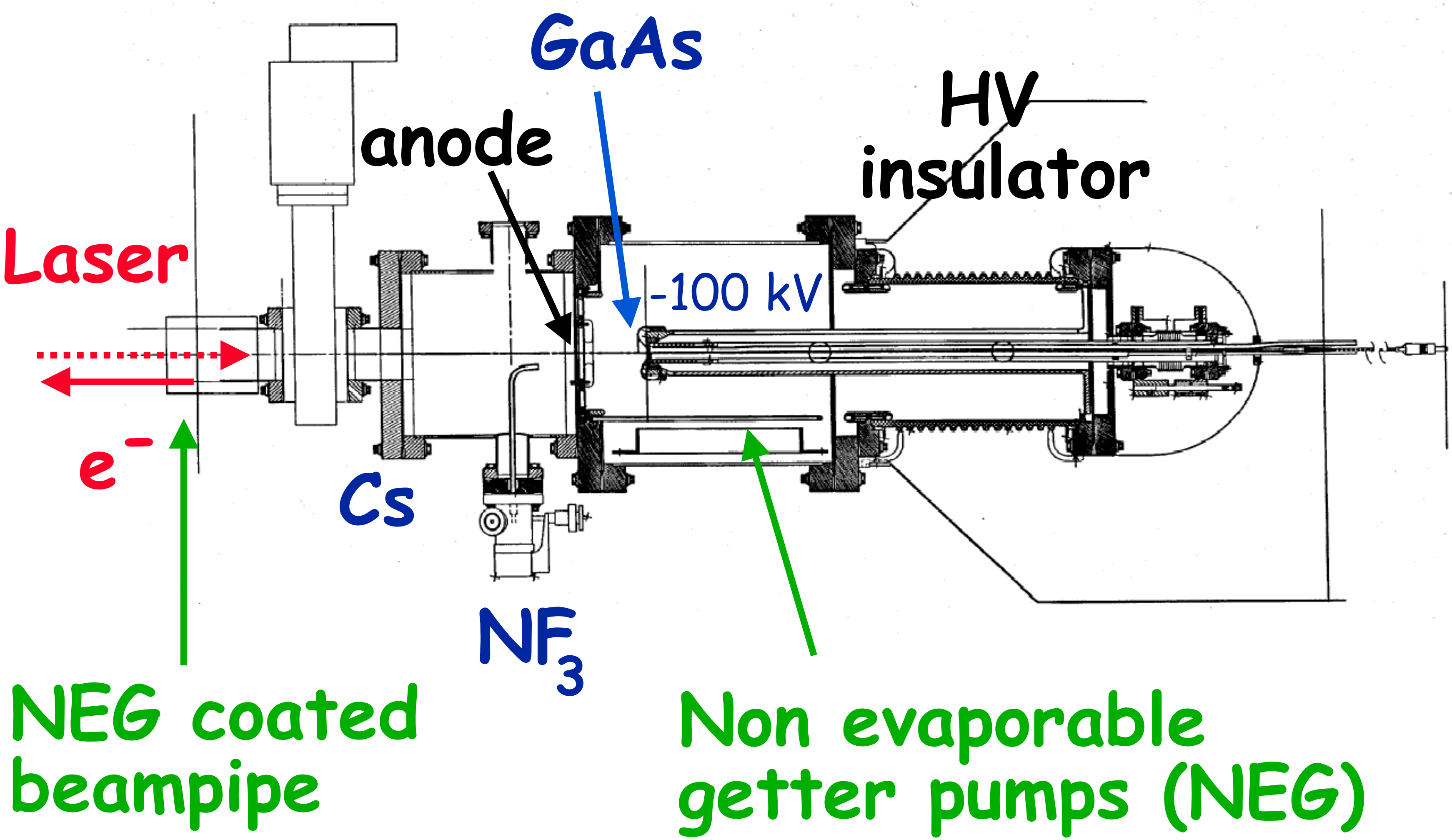


- 3" wafer cleaved (15.5 mm)
- Reduce active area: **anodization**

  ie: kill QE by anodizing in an electrolytic bath of weak phosphoric acid beyond a ~ 5 mm disk

- Mount sample on stalk
- Clean surface by a short exposure to atomic Hydrogen

JLab polarized gun design



JLab polarized guns

- No load-lock system

  $\Rightarrow$ bake after each wafer loading (3 days)

- Two identical guns

  switch within < 1 hour

- Excellent vacuum (Ion Pumps + NEG pumps)

  4 000 liter/s pumping speed $\Rightarrow$ 5.10^{-12} Torr

  excellent lifetime

  $\Rightarrow$ Little downtime due to photocathode exchange

Lifetime (1/e)

Low current : lifetime ~ 600 C

beam to 3 halls for 3 months
with single activation

High current : lifetime ~ 300 C

uninterrupted beam for 3 weeks

One year with only 3 activations!

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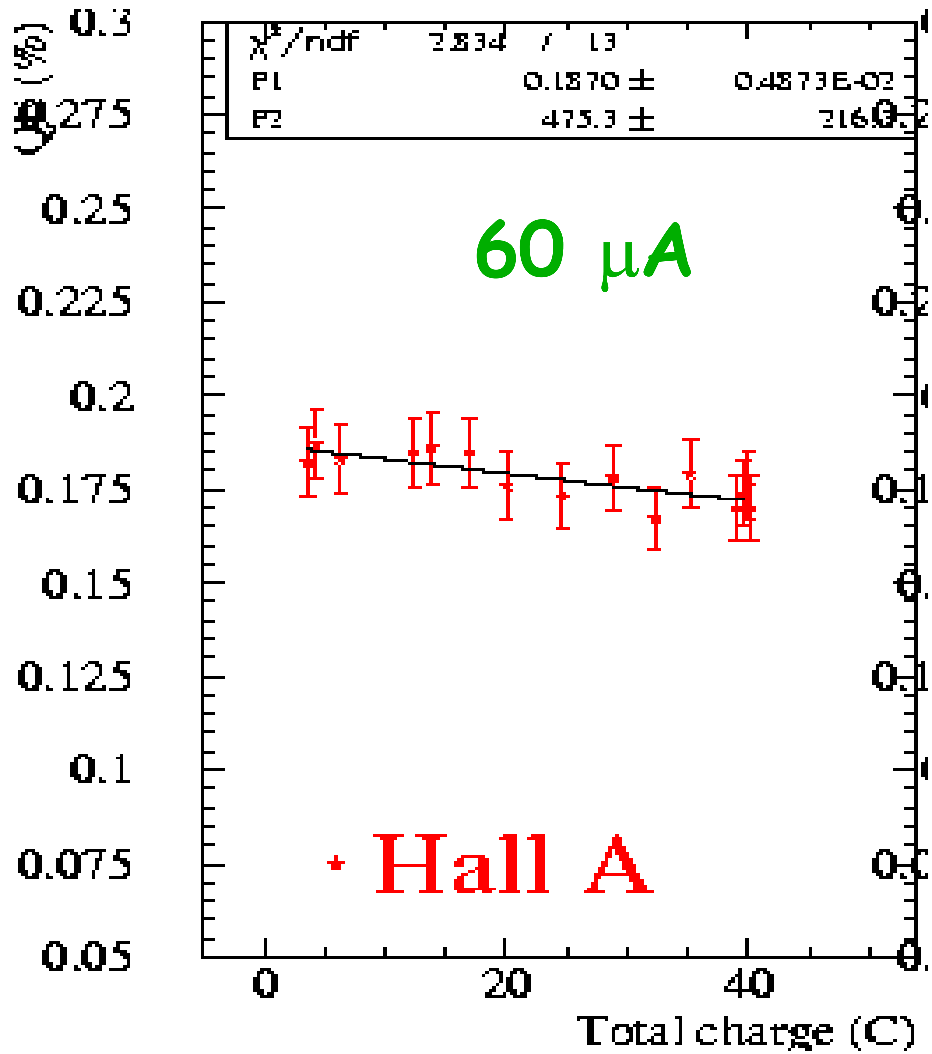
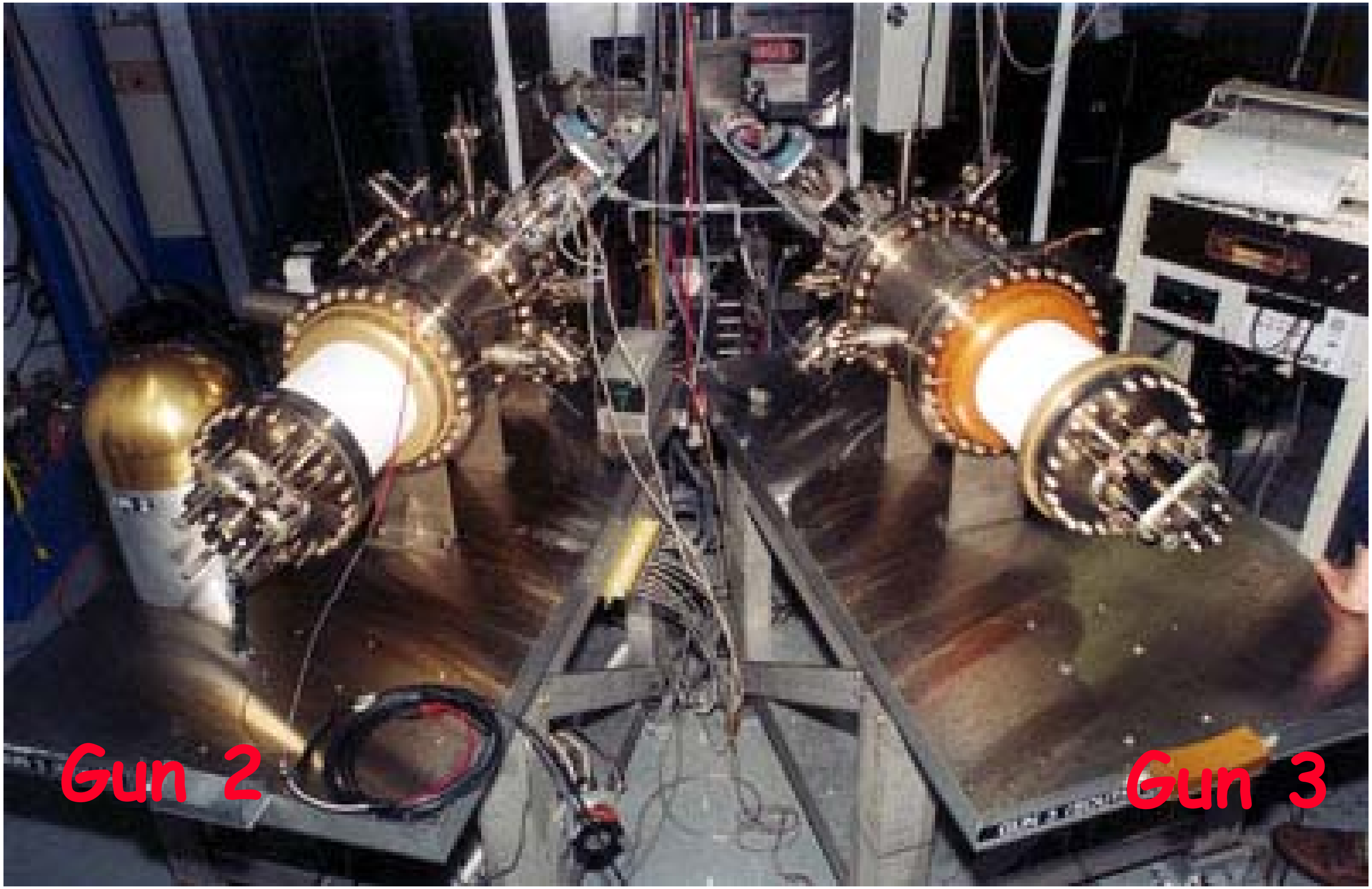


Two identical polarized guns



Light source requirements

Must satisfy 3 users simultaneously

Reliable system, remotely controlled

<u>what</u>	<u>how</u>
Light source	Laser
Control light intensity	Attenuator
Polarizing light	Pockels cell
Combining 3 beams	Beam splitter, dichroic mirror
Steering beams	Movable lens
Transport	Mirrors

Laser options

Diode

- easy, low maintenance, reliable
- low noise ~ 0.1% @ 30Hz
- low power < 100 mW
- wavelength fixed
- DC light => leakage

Ti:Sap

- high power ~500 mW
- wavelength adjustable
- higher maintenance
- homebuilt lasers were noisy (1%)
- now have low noise: 0.2% @ 30Hz

Diode lasers provide either high polarization (840 nm) or high current (780 nm)

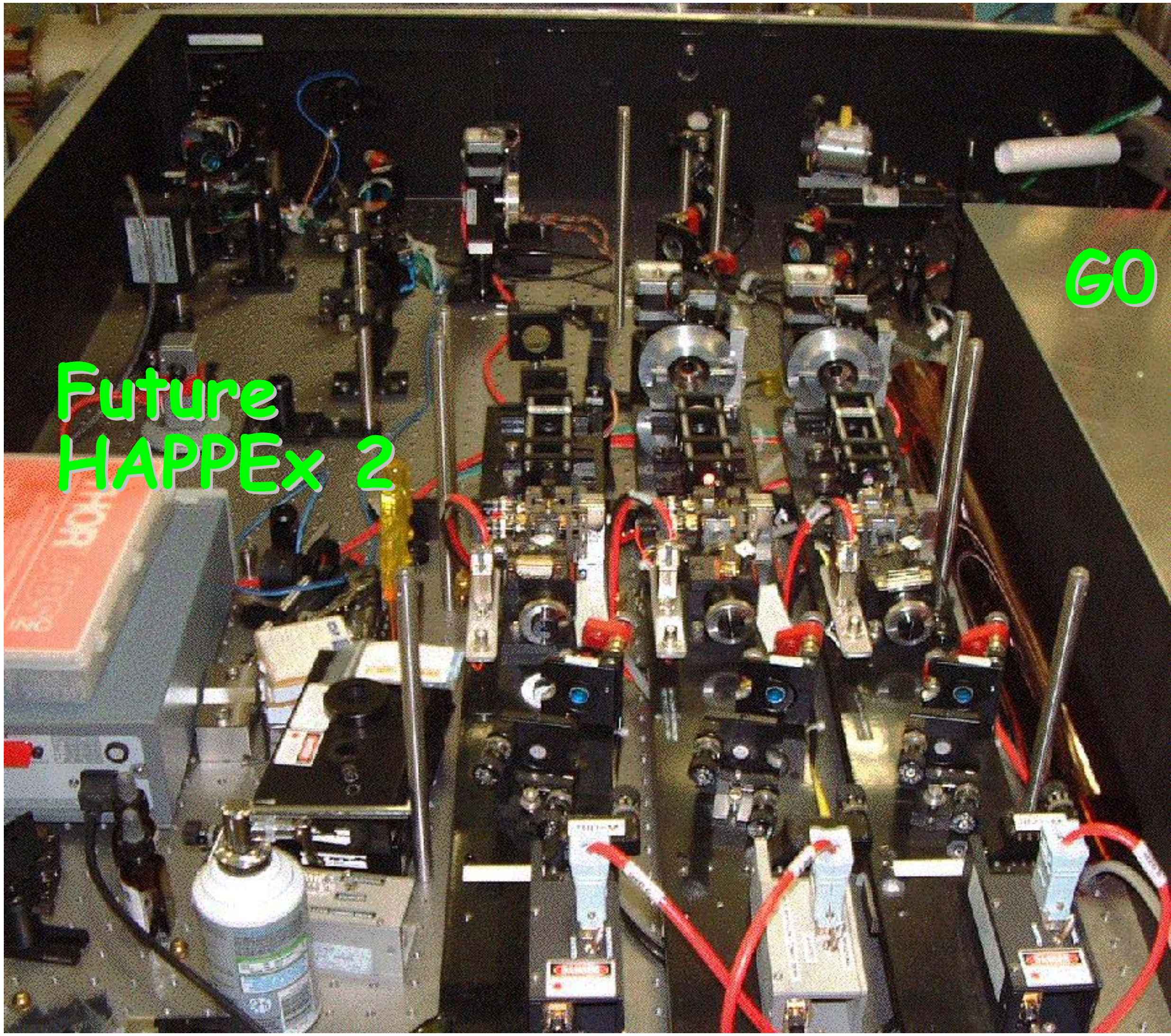
Ti:Sap lasers provide both high polarization and high current

Dynamic laser configuration

3 experimental halls
⇒3 lasers

Each laser mode-locked at 499 MHz (or 31 MHz for G0)

Each laser to meet each hall specific needs:
- intensity
- polarization
- beam quality



Beam quality controls

Users ask for increasingly better beam quality:

As beam helicity is reversed,
beam parameters (intensity, position) do not change

$\Rightarrow$ feedback systems to minimize those helicity correlations

Parity violation (PV) experiments measure $A_{exp} \sim 10^{-6}$ (1 ppm)

$\Rightarrow$ extreme constraints on helicity correlated beam parameters

charge asymmetry ~ ppm
position differences ~ nm

Independent control knobs for each hall

Level of control depends on the experiment

How we manage helicity correlations for ~~PV~~

- ***Charge asymmetry***

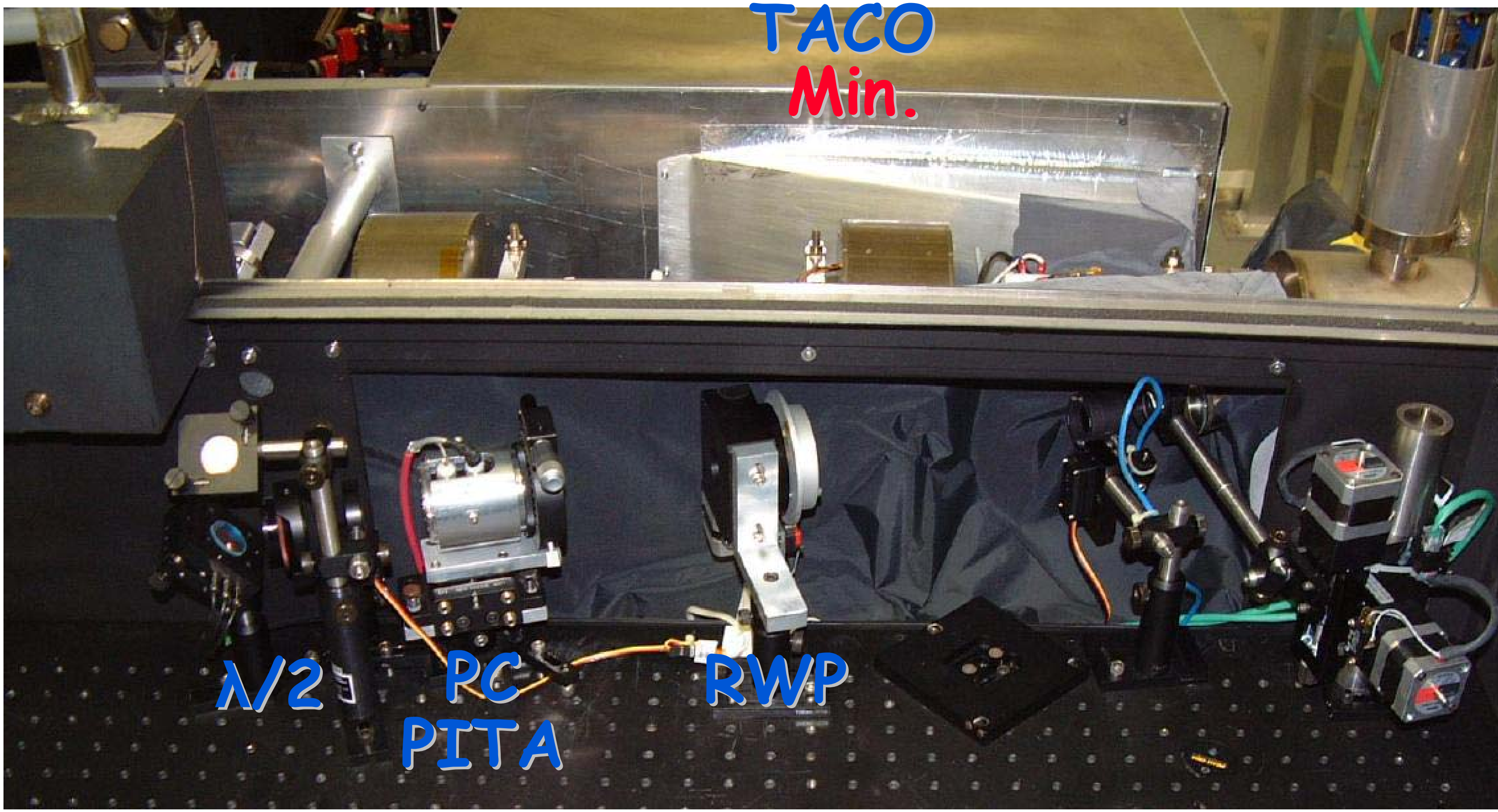
Pockels cell

	circular light	**PC**
	correction	**PITA**
Rotatable l/2-plate	(correction)	**RWP**
Seed laser power modulation	(correction)	**TACO**

- ***Overall systematics***

Insertable l/2-plate	(systematic reversal)	**λ/2**

Devices common to all lasers



Days Min. Hour

Some charge asymmetry results

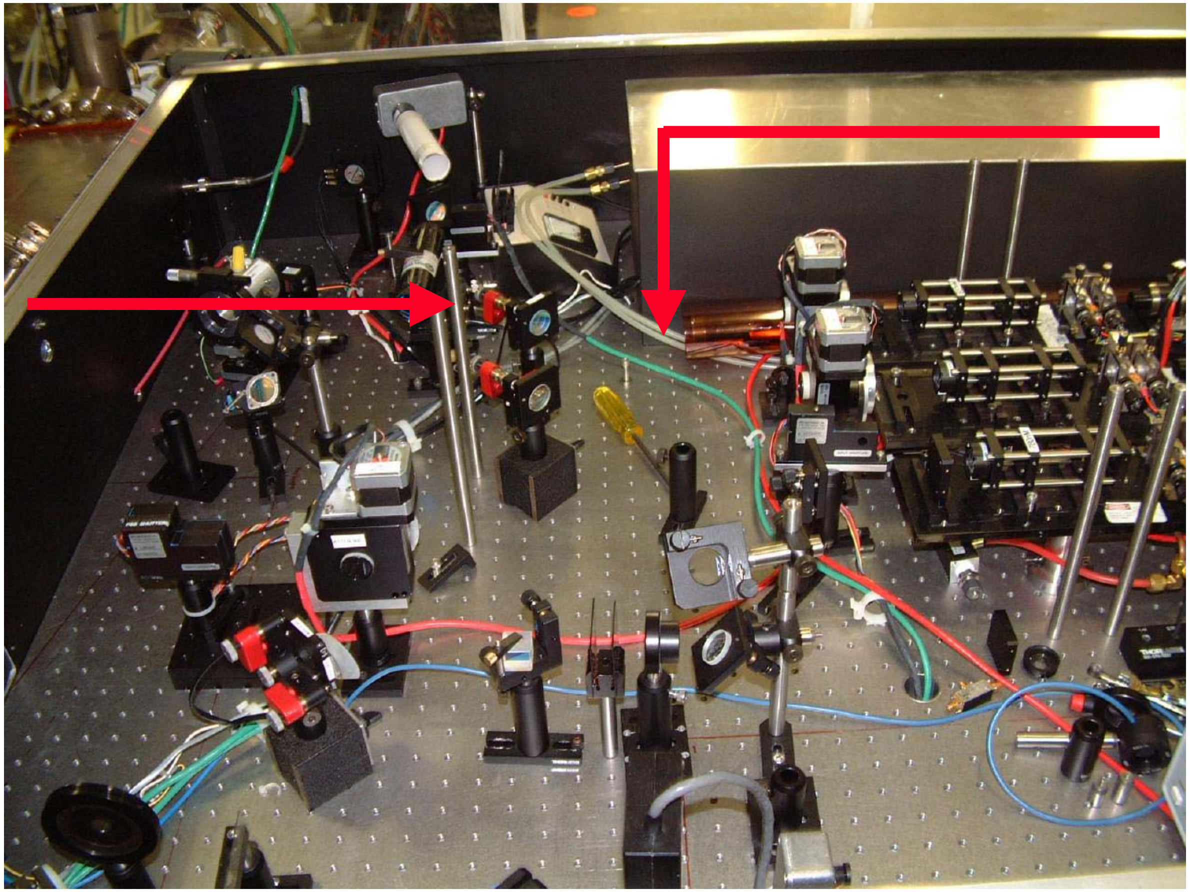
Experiments	Charge asymmetry (ppm) per physics run
Hall B	w/o TACO < 2000 w/ TACO < 500
GEn	TACO < 1000
GEp	< 1000
GDH	RWP 300 to 1000
g2n	RWP < 50

Independent parity devices

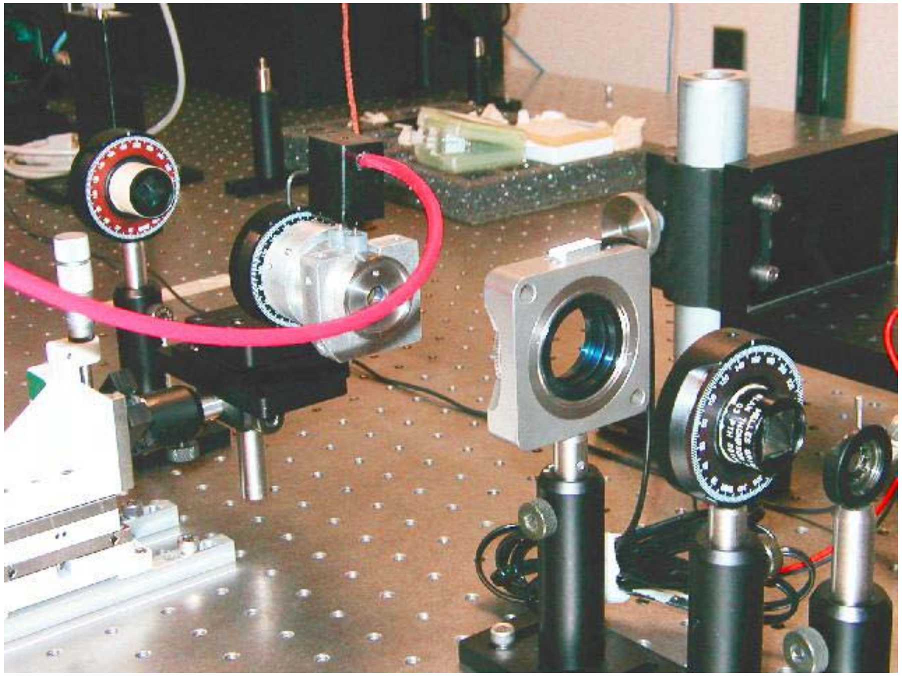
Installed upstream of the location where the 3 lasers are combined

Position modulation

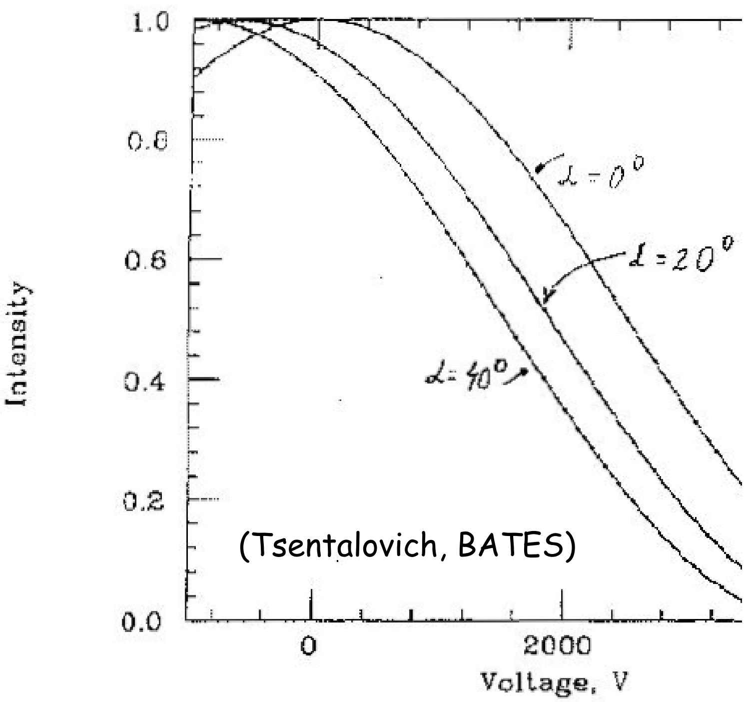
Intensity modulation



Independent intensity control : IA



- Low voltage PC + λ/10
- Low insertion loss
- Compact footprint



Stable slope ~200 ppm/V

Tests : A_i~ 3±3 ppm within 15 min.

G0 experiment

- Time structure

  31.2 MHz versus standard 499 MHz (16th subharmonic)

- Modest average current, but high peak current

  40 uA @ 31.2 MHz = transporting 640 uA @ 499 MHz

  ie: 8.10^{6} e^{-}/bunch

  $\Rightarrow$ **beam optics issues**

- Parity quality beam

- Two other halls running simultaneously

$\Rightarrow$ **mode-locked Ti:Sap Laser**

Ti:Sap Laser for G0

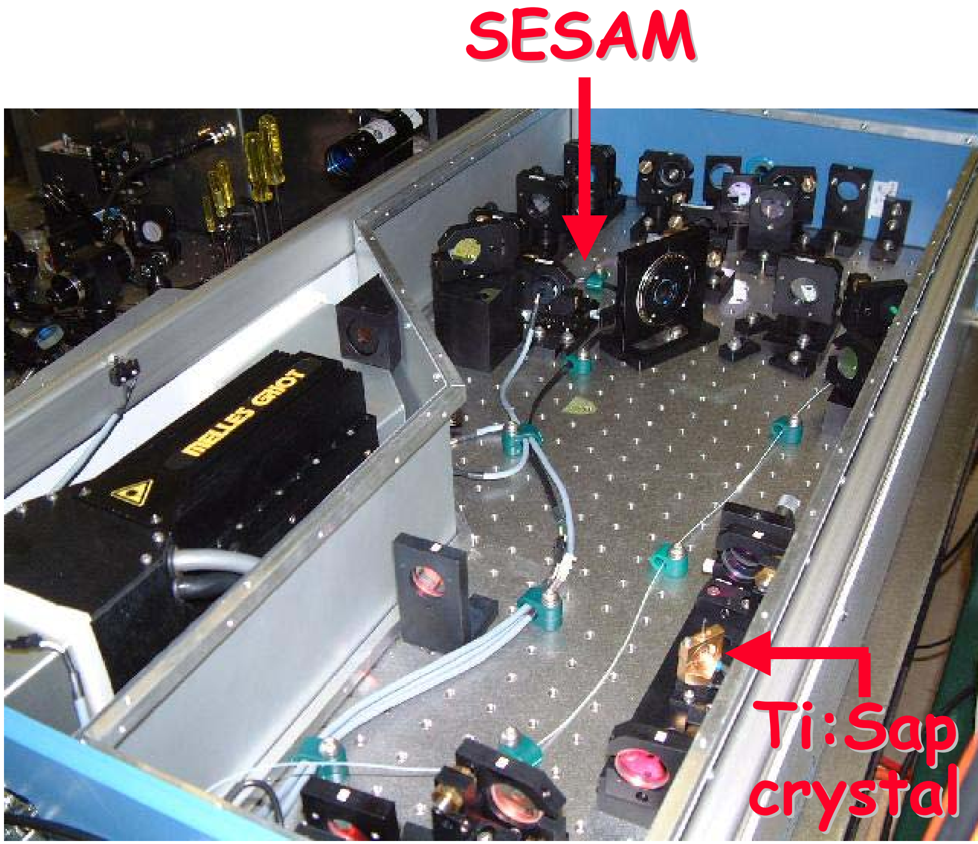
Homebuilt Ti:Sap
- diode seeded
- AOM

pulse width too large

Commercial Ti:Sap laser bought (TimeBandwith Product)

FWHM ~ 70 ps
phase noise < 1 ps

Installed early September, used since then for tests



40 μA to hall C
& parity quality beam !

Load lock design goals

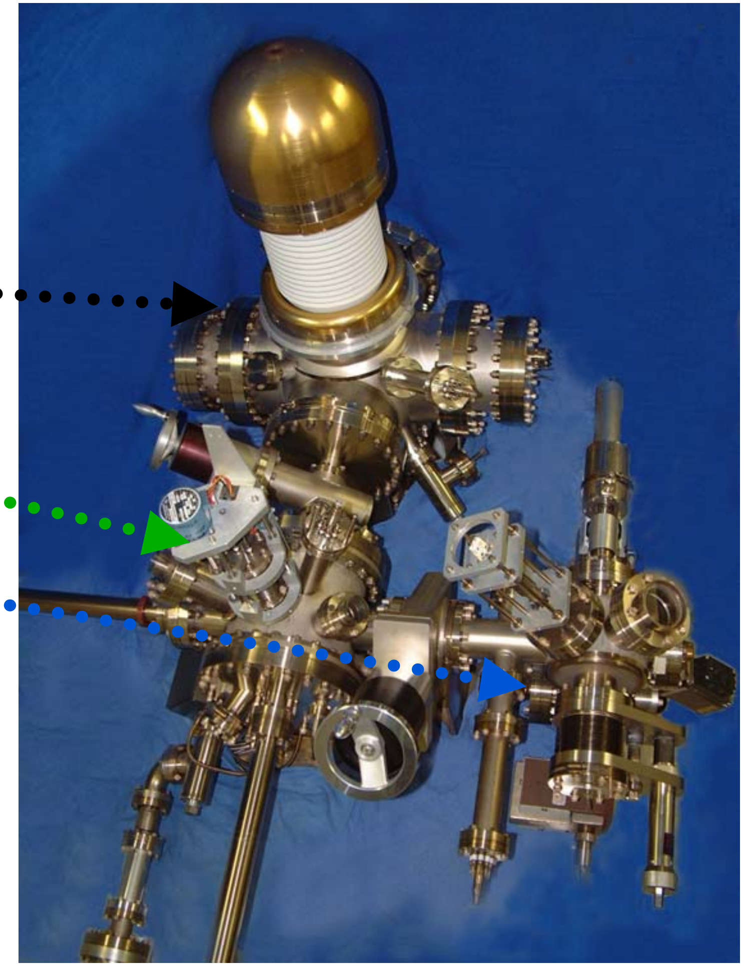
- Installation of cathode from air to HV in less than 8 hours
- Load-lock chamber at ground potential, no moving parts at HV
- Horizontal – compatible with tunnel configuration (15° bend)
- Maintain all good features of current horizontal guns
  - Electrode material
  - Electrostatic optics
  - Excellent vacuum, pumping conductance

Best Technology Load Lock Polarized Electron Gun

3 Chambers:

- High Voltage Chamber
- Preparation Chamber
- Load/Heat/Hydrogen Chamber

and 2 manipulators

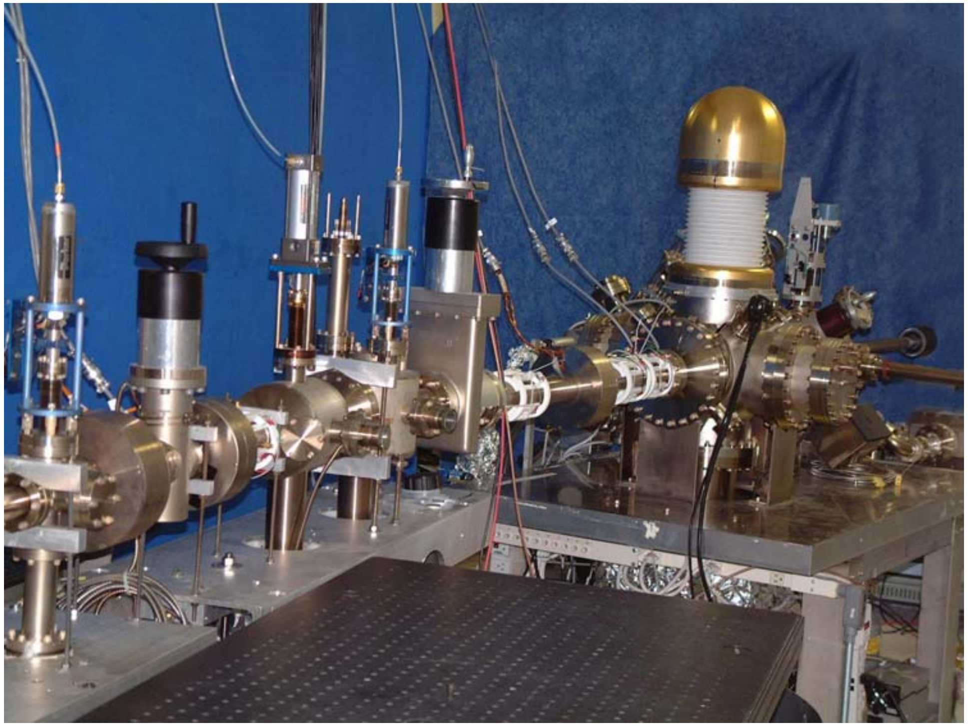


BTLLPEG under test

Installed in testcave in same configuration as production beamline

Instrumented beamline (viewers, BPM, harp scanner)

Plans for Wien filter, Mott Polarimeter



- **Goal reached to load, Hydrogen clean, activate and bring to HV chamber within 8 hours with good QE**
- **Ready for beam**

Conclusions

- Polarized source for production:

  Two operational guns

  high polarization (70-80%)
  high lifetime (300-600 C)
  high current (100 μA)

  Independent controls of beam quality for each hall

Outlook (1)

- 2002-2003 : high profile year for parity violation experiments at JLab (HAPPEx 2, G0)
    - *Ti:Sap*

      commercial G0 laser appears to be good

      a 499 MHz model ordered for HAPPEx 2, etc…
    - *Helicity correlations controlled at parity level*

      independent knobs validated for halls A & C
- This coming period will help us prepare the future of PV

Outlook (2)

- Test lab studies on Vertical gun to deliver P_e > 80%

reliable and powerful Ti:Sap would help

- Load lock gun studies to improve lifetime

Qweak experiment asks for 200 μA in 2006

high P_e and parity quality beam