Laser system for precision Compton polarimetry at 12 GeV

Dave Gaskell

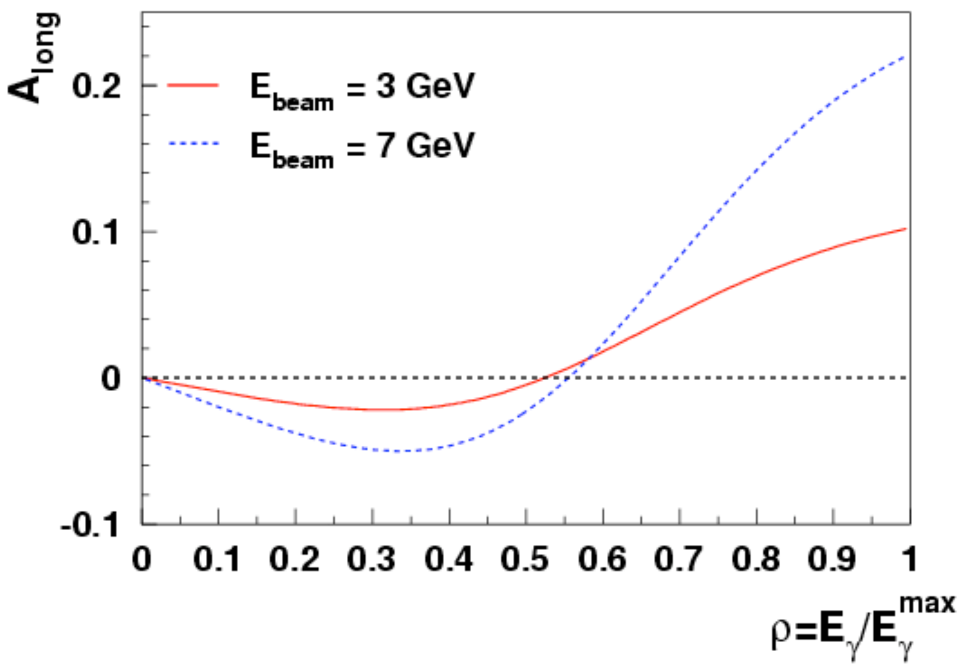
SOLID Collaboration Meeting
January 28, 2011

Compton Polarimetry at JLab

Main challenges for Compton polarimetry at JLab

Low beam currents (~100 μA)
→Measurements can take on the order of hours
→Makes systematic studies difficult

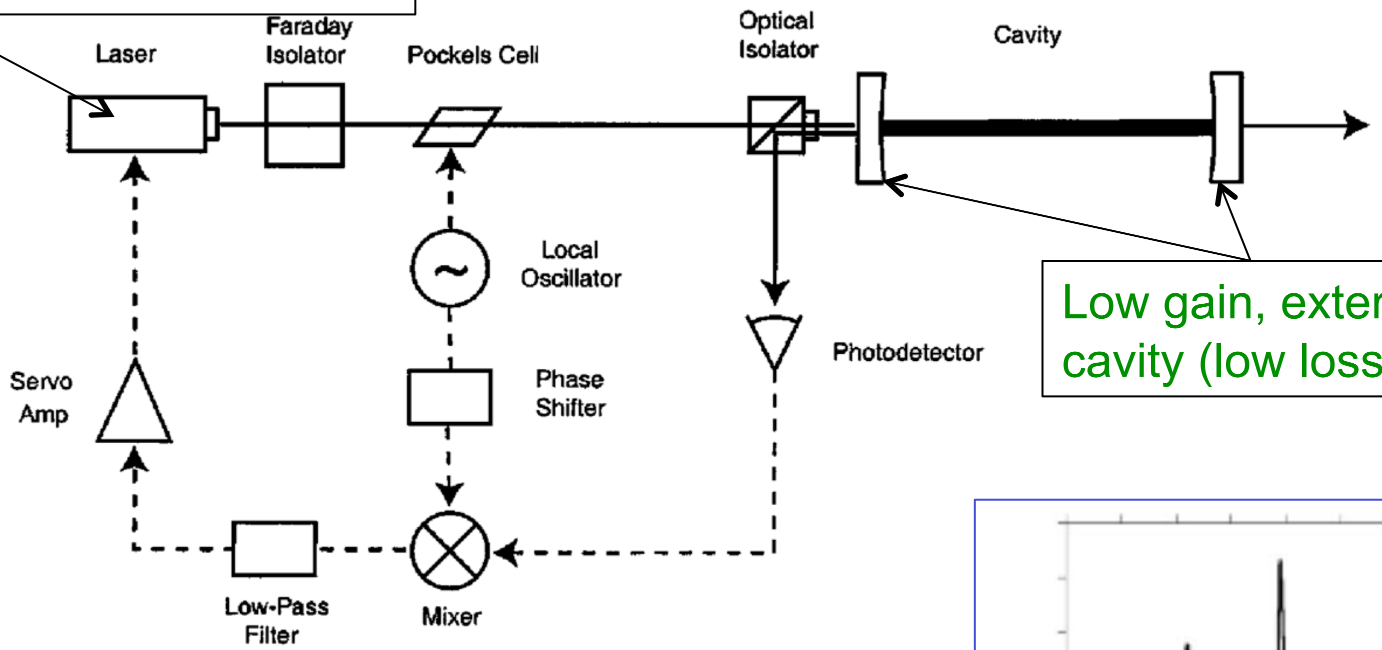
Relatively small asymmetries
→ Smaller asymmetries lead to harder-to-control systematics



Backgrounds can be significant; requires relatively large laser powers
→ Halls A and C use Fabry-Perot cavities

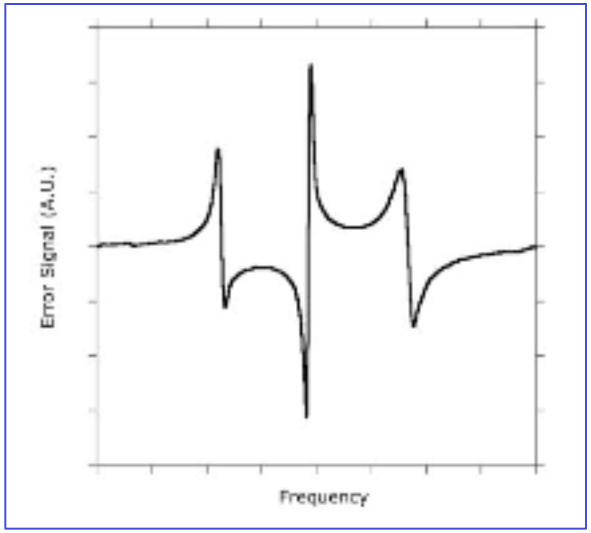
External Fabry-Perot Cavity

Hall C: Coherent VERDI-10



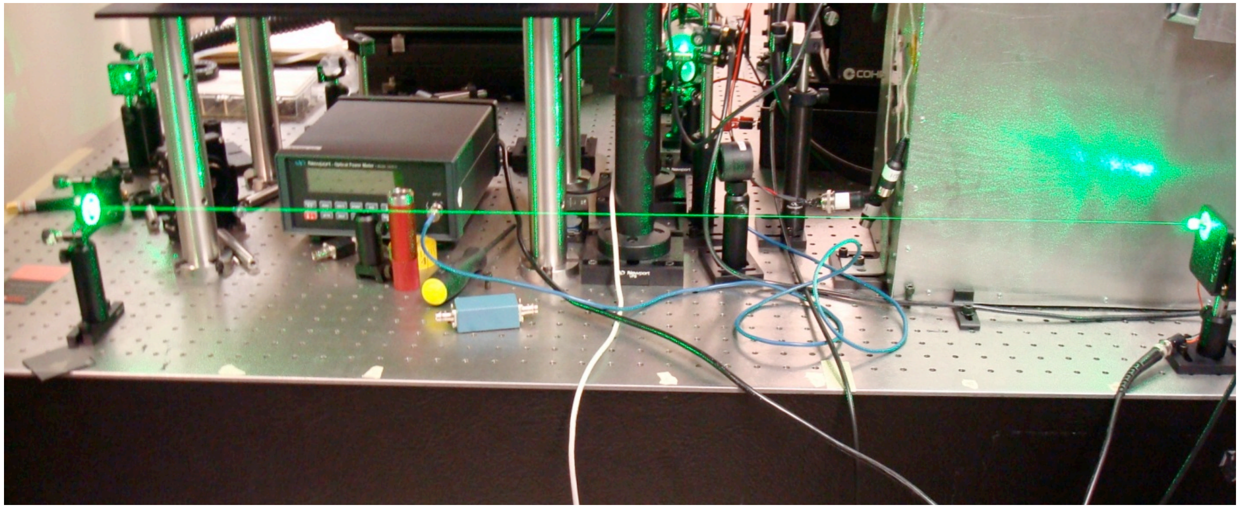
Low gain, external cavity (low loss mirrors)

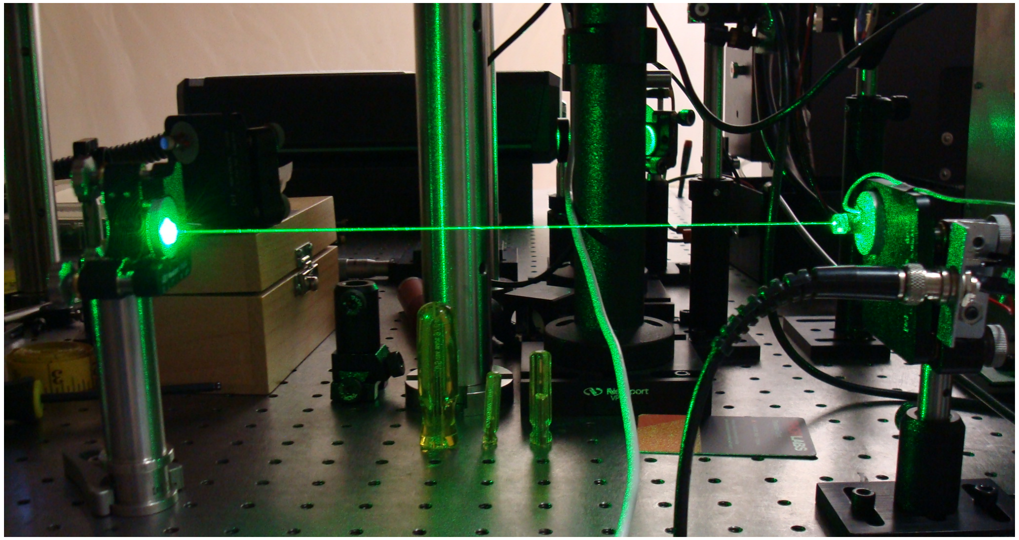
Laser locked to cavity using Pound-Drever-Hall (PDH) technique



Low gain cavity

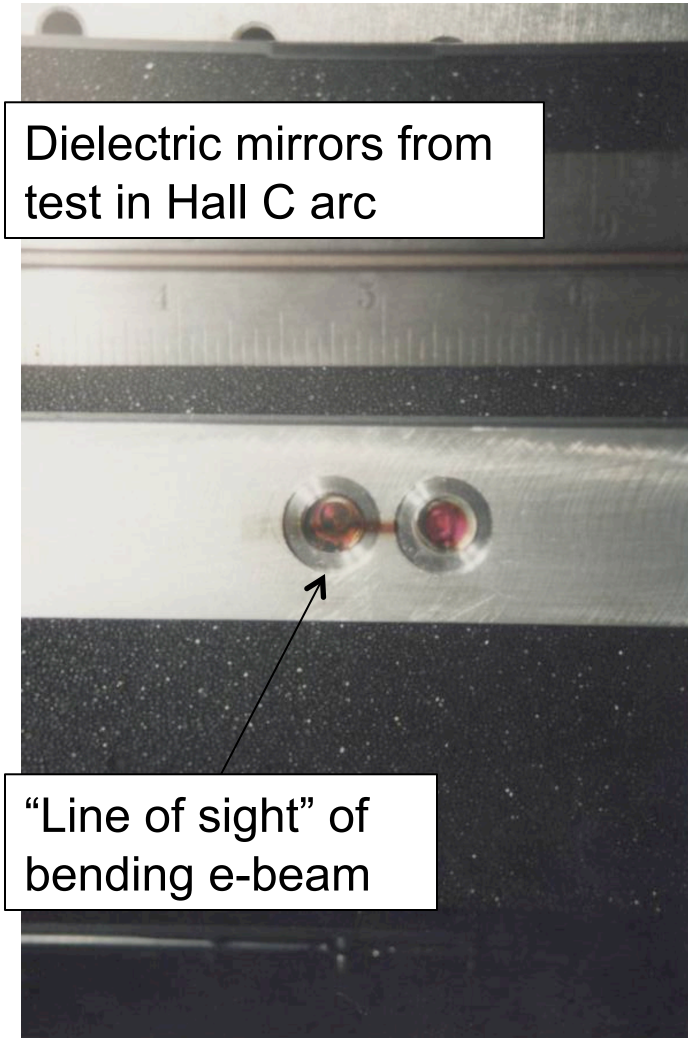
Gain 100 cavity
linewidth=400 kHz





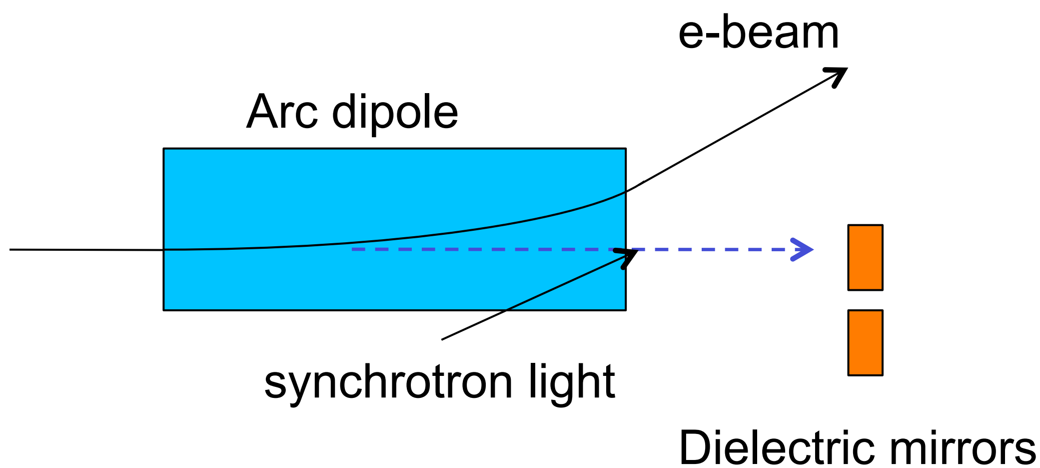
Gain 300 cavity
linewidth = 175 kHz

Dielectric Mirrors in the Beamline



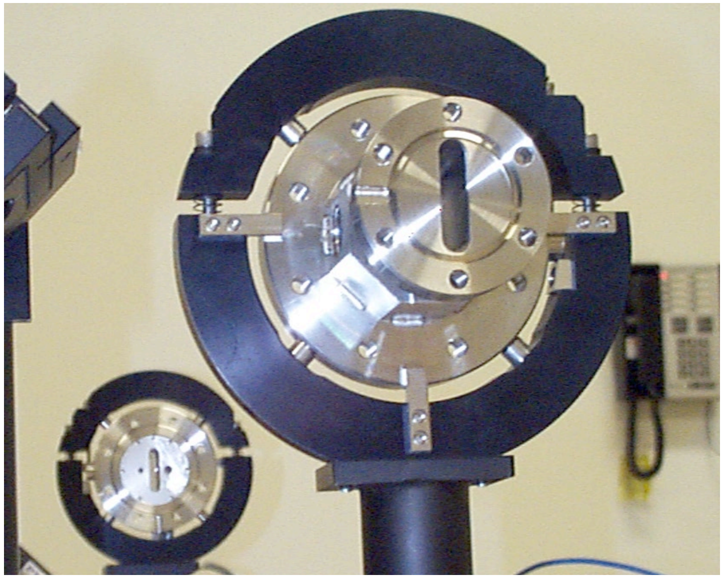
High power FP cavities require very low-loss (<50 ppm) dielectric mirrors

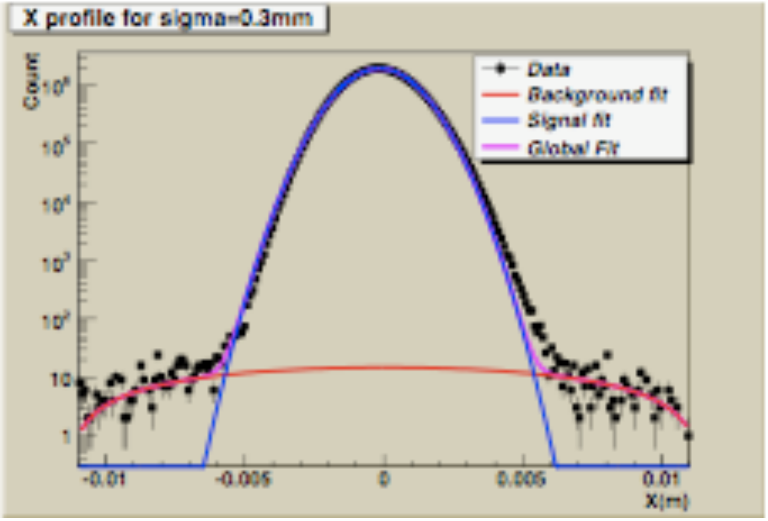
→Experience in Hall A has taught us these mirrors CAN survive in "high" current electron beamline for years at a time
→ BUT, you must take care ….



Beam Halo and Backgrounds

Halls A and C use CW, Fabry-Perot cavities
→Both systems have mirrors ~5 mm from
→ Small apertures protect mirrors from beam excursions, really bad beam properties





Yves Roblin and Arne Freyberger
JLAB-TN-06-048

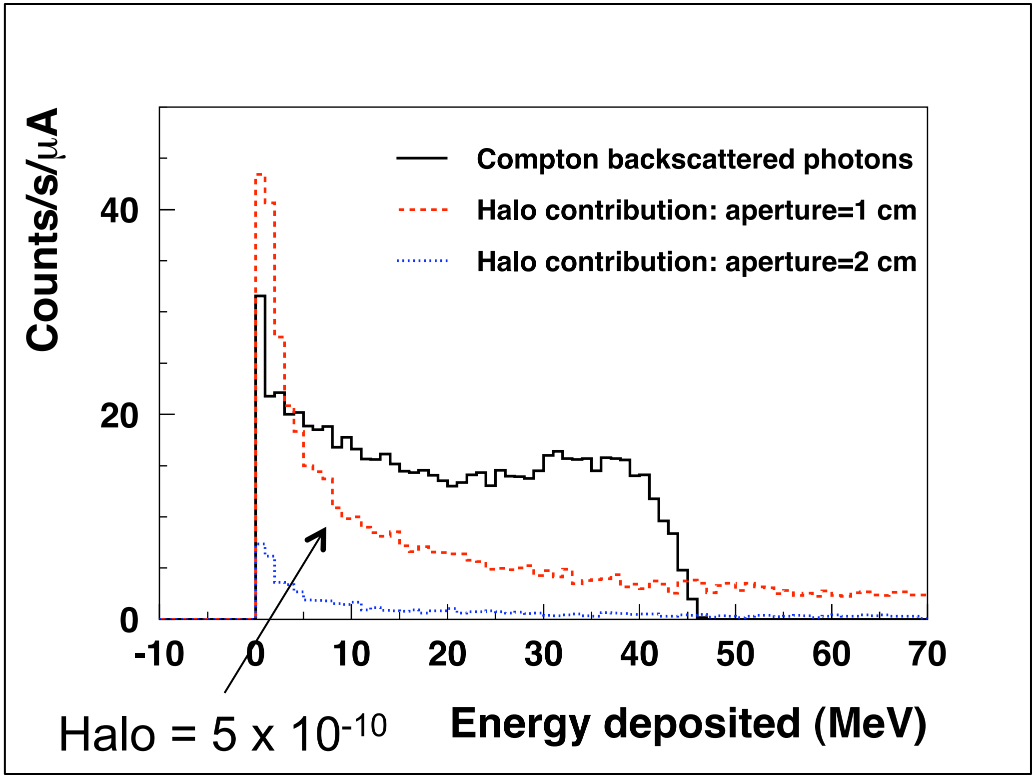
Same protective apertures can lead to backgrounds due to interactions with beam halo
→ Backgrounds already problematic – results in significant lost time
→ At 12 GeV, beam halo will be worse

Beam Halo – Compton Simulation

GEANT Simulation of Hall C Compton → 1.16 GeV beam on 1 kW, 532 nm laser

Background from Bremsstrahlung ~ 3 Hz/uA for 10^{-8} vacuum

Model uses halo of form similar to Yves' form in TN
→ Halo forced to zero at edge of (1 inch) beam pipe
→ Eliminating (increasing) horizontal aperture helps



Interaction region should be modified to mitigate apertures → laser system should be compatible with larger crossing angle

RF pulsed FP Cavity

JLab 12 GeV:

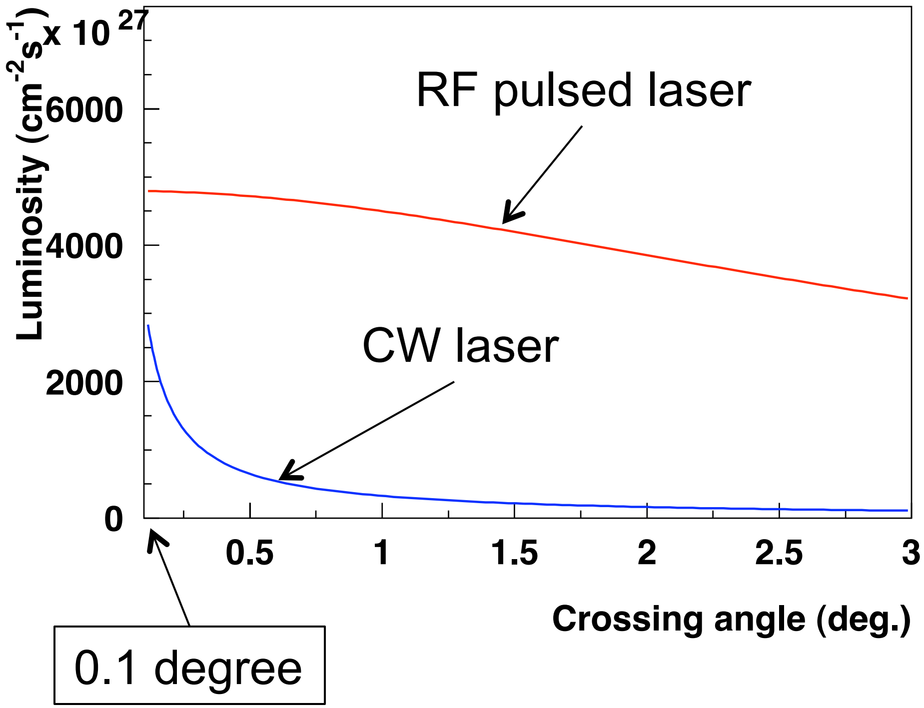
Control of beam halo, spot size likely worse

→ Would like to double crossing angle between laser and electron beam without undo loss of luminosity

→This could be accomplished by switching from CW cavity, to RF pulsed cavity

→At non-zero crossing angle, luminosity larger, drops more slowly with crossing angle

JLab beam → 499 MHz, Δτ~0.5 ps

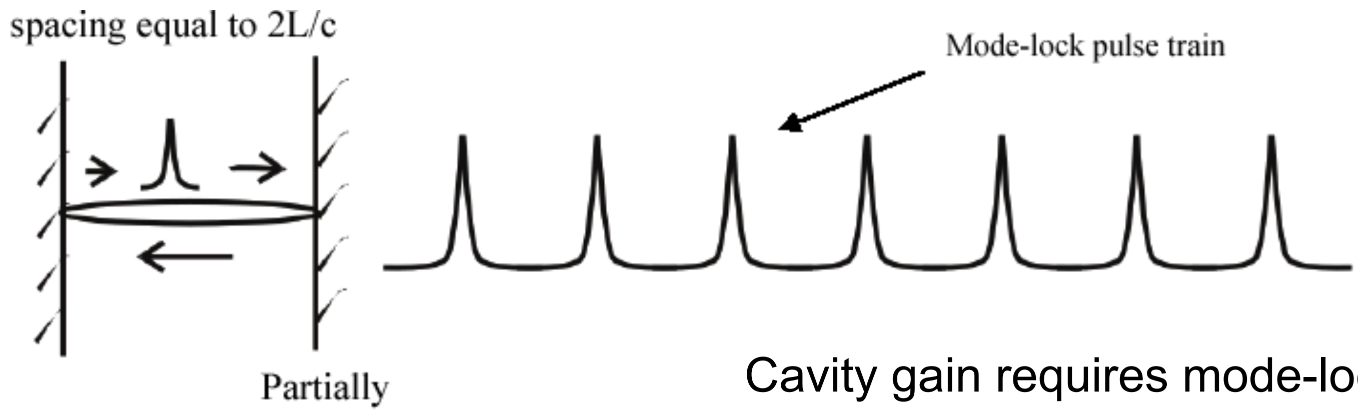


RF pulsed cavities have been built – this is a technology under development for ILC among other applications

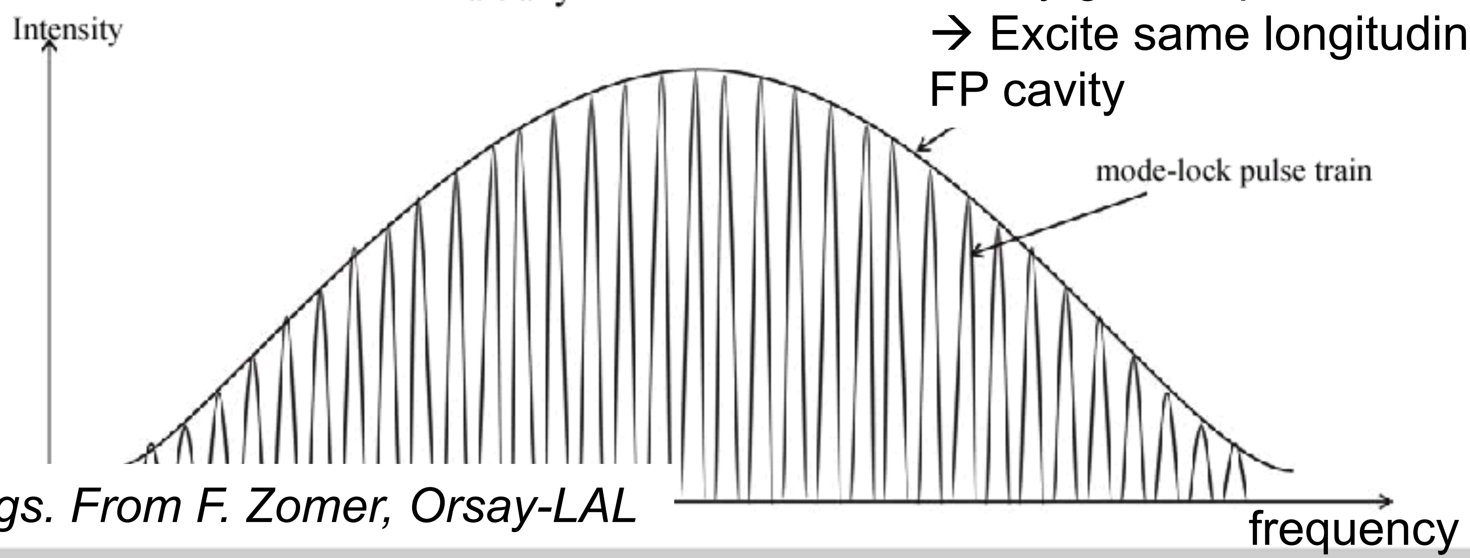
Pulsed vs. CW FP Cavity

CW cavity resonance condition: $2L_{cavity} = n\,\lambda$

Additional condition for pulsed laser: $2L_{cavity} = n\,c/f_{RF}$



Cavity gain requires mode-locked laser!
→ Excite same longitudinal modes in FP cavity



Figs. From F. Zomer, Orsay-LAL

Laser Options: Rates and FOM

Options for 11 GeV Compton laser system
→I assume a fixed collision angle of 2.8 degrees and fixed electron beam size (100 μm)
→50 uA → backgrounds 5-25 kHz if not improved
→Note that 1 kW for FP cavities conservative – 2-3 kW should be readily achievable

Laser	<P> (W)	λ (nm)	$A_{endpoint}$	<EA>	$\Delta x_{endpoint}$	Rate	t(1%)
CW	1000	532	32.0%	13.1%	7 cm	16.9 kHz	300 s
cavity		1064	17.7%	8.0%	3.5 cm	32.2 kHz	359 s
RF	1000	532	32.0%	13.1%	7 cm	719 kHz	7 s
cavity		1064	17.7%	8.0%	3.5 cm	1158 kHz	10 s
RF	8	532	32.0%	13.1%	7 cm	5.8 kHz	888 s
1 pass	32	1064	17.7%	8.0%	3.5 cm	37.1 kHz	312 s

Counting – not integrating

Discussion

- Single pass options attractive for ability to measure transfer function cleanly
  - Rates for 1 pass RF system at 1064 not too bad
  - Off-the-shelf systems exist
- RF pulsed cavity guaranteed to give sufficient rate
  - IR simpler, no need to frequency double
  - Green is easier to see – larger asy. (required?)
  - Challenging technology, but low gain sufficient
- CW cavities tenable → higher stored power than 1 kW preferred
  - No new technology required, but need high finesse consistently

Minimum Pain Solution

- Increasing horizontal aperture on laser table is important
  - 20 mm would be great, even 15 mm would help
  - This alone would require a fair amount of effort
- Existing CW cavity would likely give sufficient rate
  - 3 kW stored green power should be doable
  - If accelerator has better than expected control of beam size at interaction point, can take advantage of small spot sizes
- Alternate "easy" solution → one-shot RF laser
  - Probably need to use IR to get sufficient rate
  - Better control of laser polarization
  - Still need to synch to beam RF
  - Expensive → likely $200K

Ambitious Solution

- RF-pulsed, mode locked laser, FP cavity
- This would require total re-design of interaction region → cavity length now constrained by RF of electron beam (can no longer be 85 cm → must be 75 cm or 1.5 m)
- Feedback gets complicated, may need to actuate FP cavity mirror in vacuum
- Payoff = no question about suppressing backgrounds → rates potentially through the roof
- I've put in "Early Career" Proposal to build such a system → should hear sometime in March