Laser Acceleration In Vacuum at ATF

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Outline

- What we need
- Where we are
  - Electron beam parameters and focusing
  - CO_2 laser beam
  - Spectrometer
- ICA experiment as VA test
- Acceleration Theorems
- Conclusion

Practical Requirements for Vacuum Acceleration

- High power laser beam

  (we need power and not energy
  to avoid optical damage
  yet achieve reasonable accelerating gradients)

- We need to limit interaction length preserving ways for laser alignment

- We need bright electron beam to transmit enough electrons through limiting apertures and preserve energy spread.

CO_2 Laser status

Currently CO2 provide: 200 ps; ~2 J (10GW)

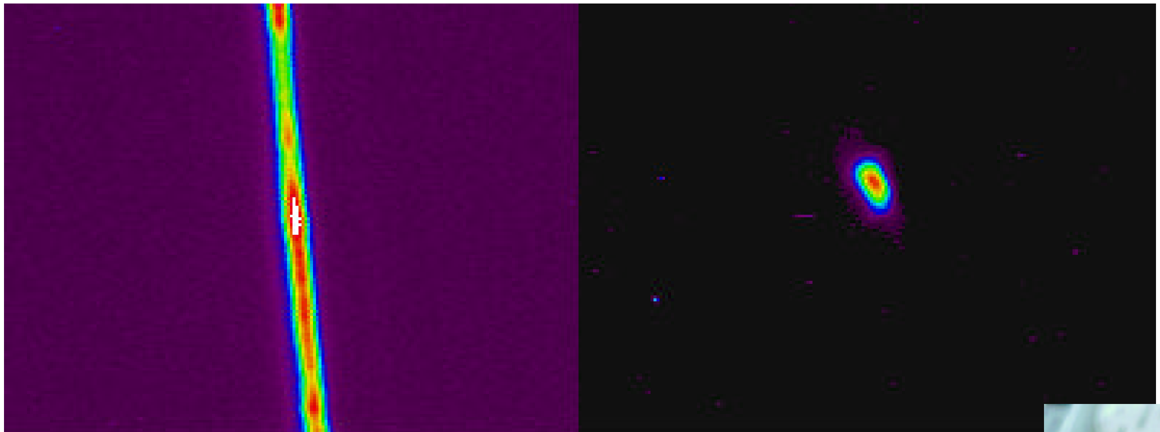
We plan to have in one year 1-10ps, ~5J (~1TW)

- new 10 atm. preamplifier
- seed pulse generation upgrade

We are not going to have intermediate step ~30ps

Small electron beam focusing

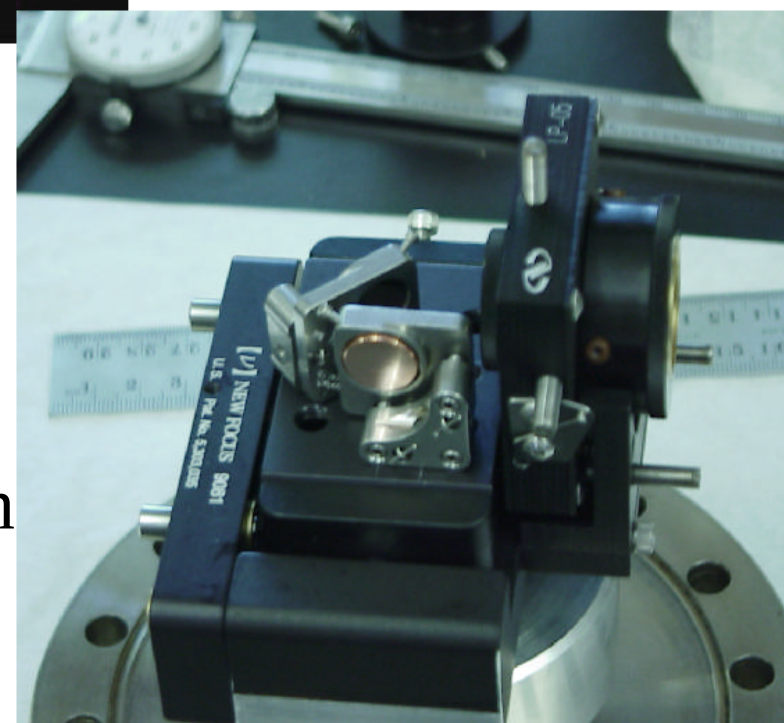
We use in-vacuum permanent magnet quads to achieve β~1 cm



$\sigma_{RMS} \sim 10\ \mu m$
@ 0.5 nC

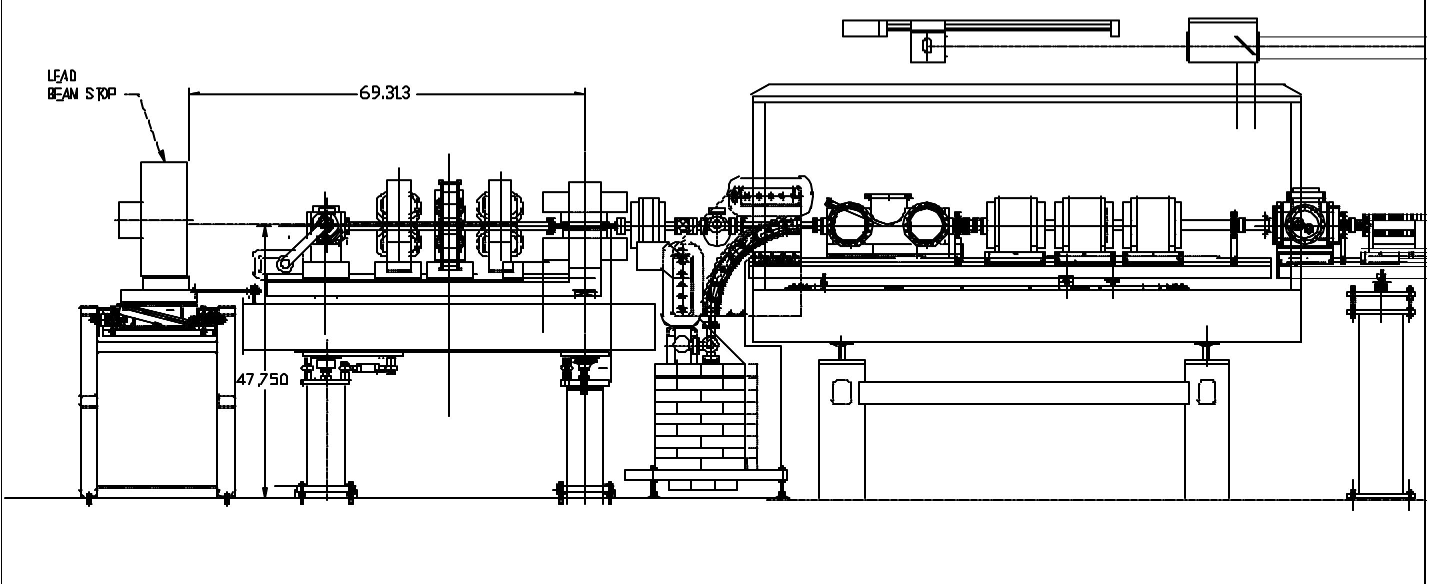
•Image of the 30 μm wire taken with same optical magnification as e-beam on the right

•We measured up to 70% of the electron beam transmission through two 100 μm apertures spaced by 1 cm

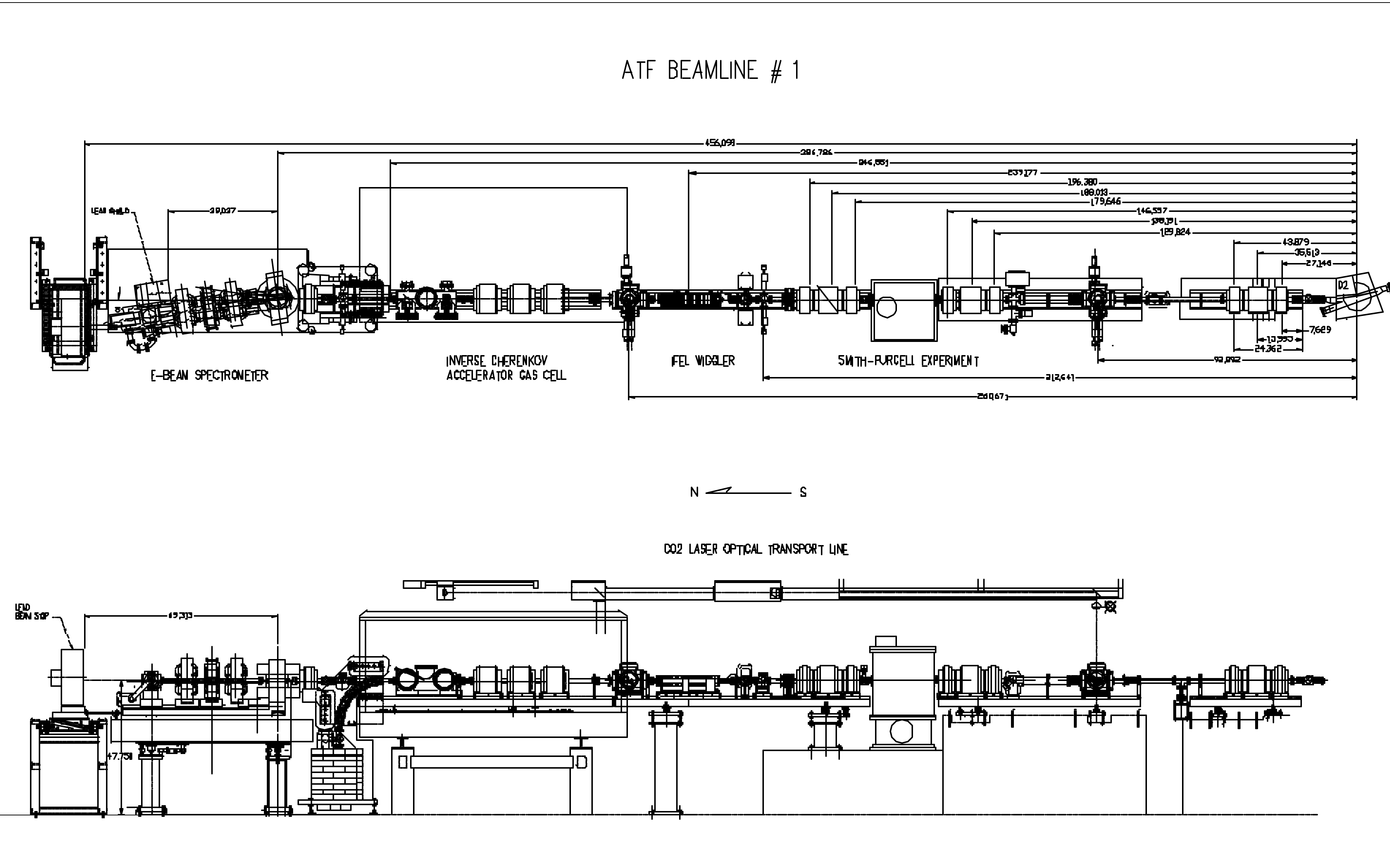


Spectrometer

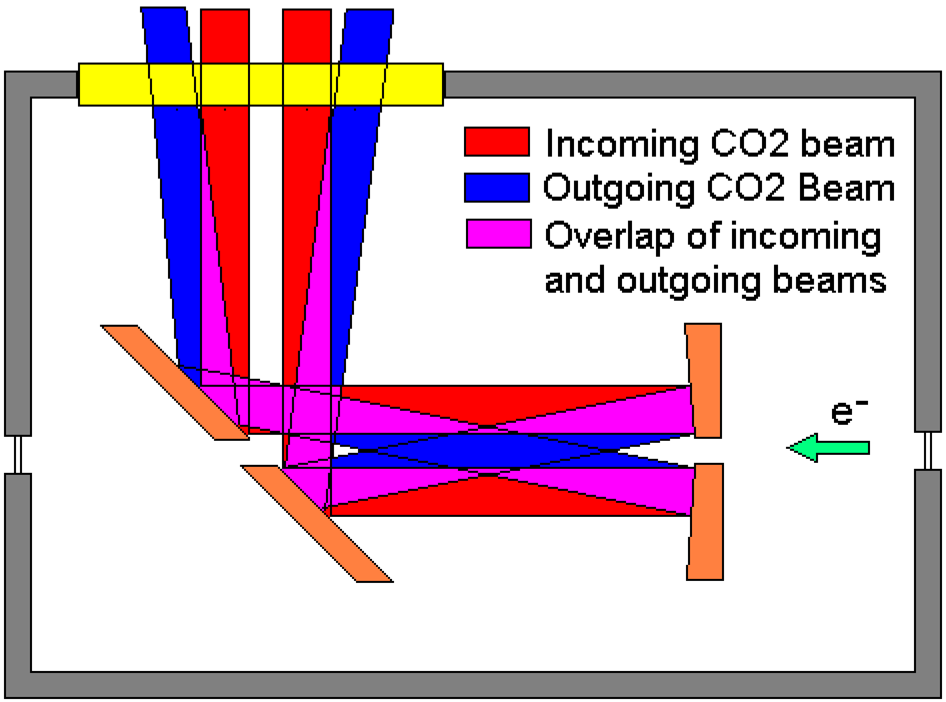
- We will install high resolution spectrometer.
- New spectrometer has classical $^{\pi}/_{2}$ or 90 degrees design.
- It provides tight focus and large dispersion.
- The energy resolution is going to be of the order of 10^{-4} and will be limited by energy spread in the beam.



Beam Line 1 Layout



ICA experiment



ICA parameter set (as of 1995):

- Laser Pulse length 220 ps
- Peak power at IR 0.6 GW
- (Limited by input window)
- Cherenkov angle 20 mrad
- Hydrogen pressure 2 atm.
- Measured acceler. 3.5 MeV

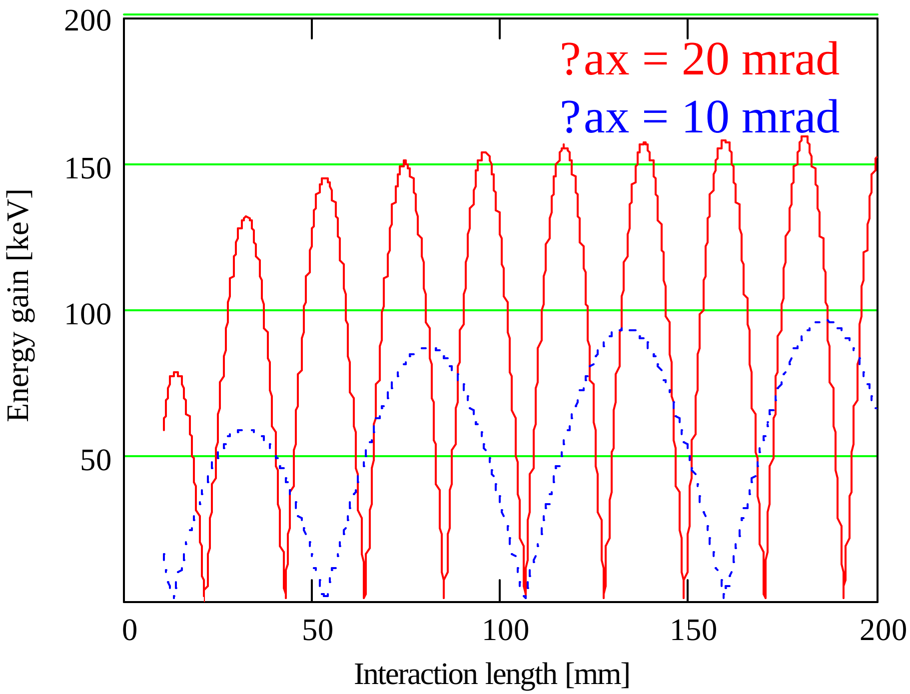
$$\Delta j = \left(\frac{1}{b\ n} - \cos q \right) kl$$

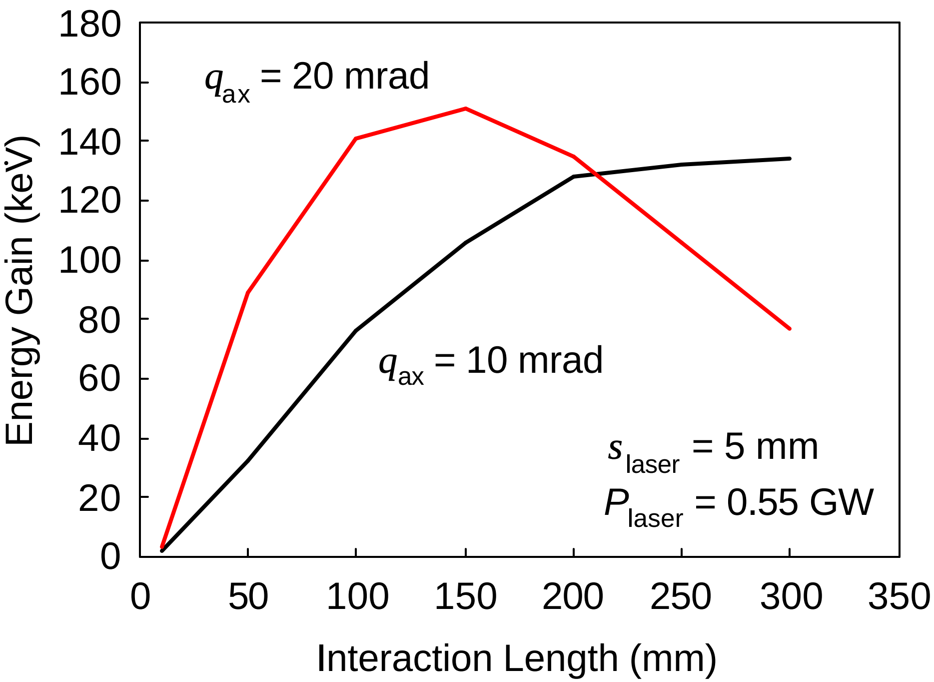
ICA experiment as VA test

$$\Delta j = \left(\frac{1}{b\ n} - \cos q \right) kl$$

No gas ⇒ n=1 ⇒ Δϕ ? 0

Decrease in acceleration can be estimated by including phase slippage in ICA



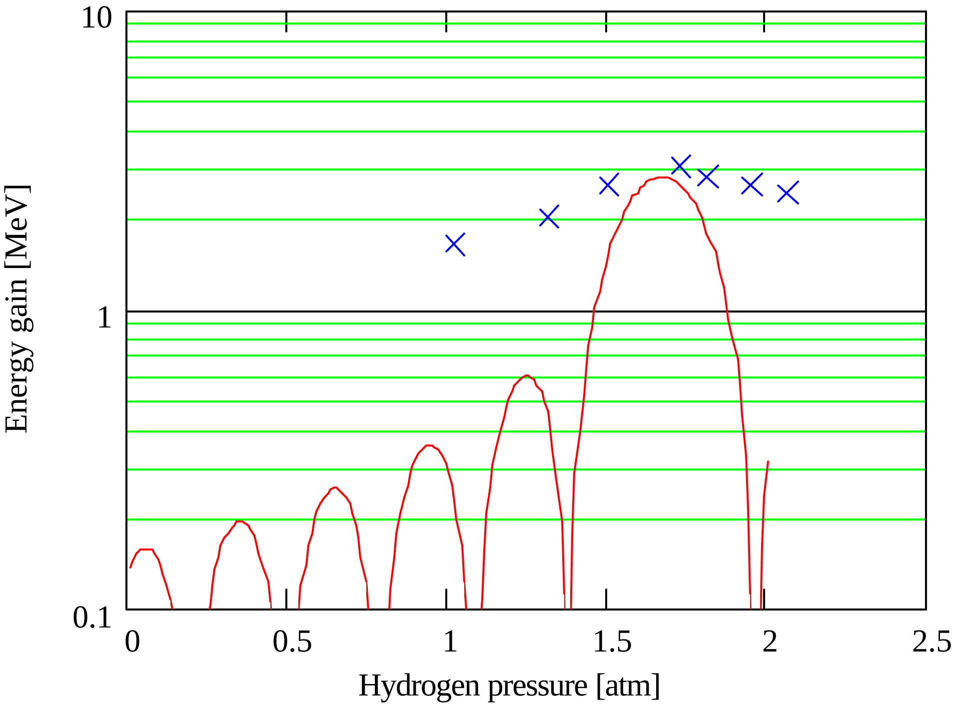


Wayne Kimura simul. of VA and ICA geometry

Plan of ICA experiment as VA test

- Reestablish ICA with 12 cm interaction region and 20 mrad axicon. This would confirm laser alignment and correct timing.
- Measure acceleration for different pressure point until we reach vacuum
- Test if acceleration can be improved by installing spherical lens and pinhole.

Simulation, Experimental data



Predictions and ICA experimental measurements of Energy gain VS. pressure

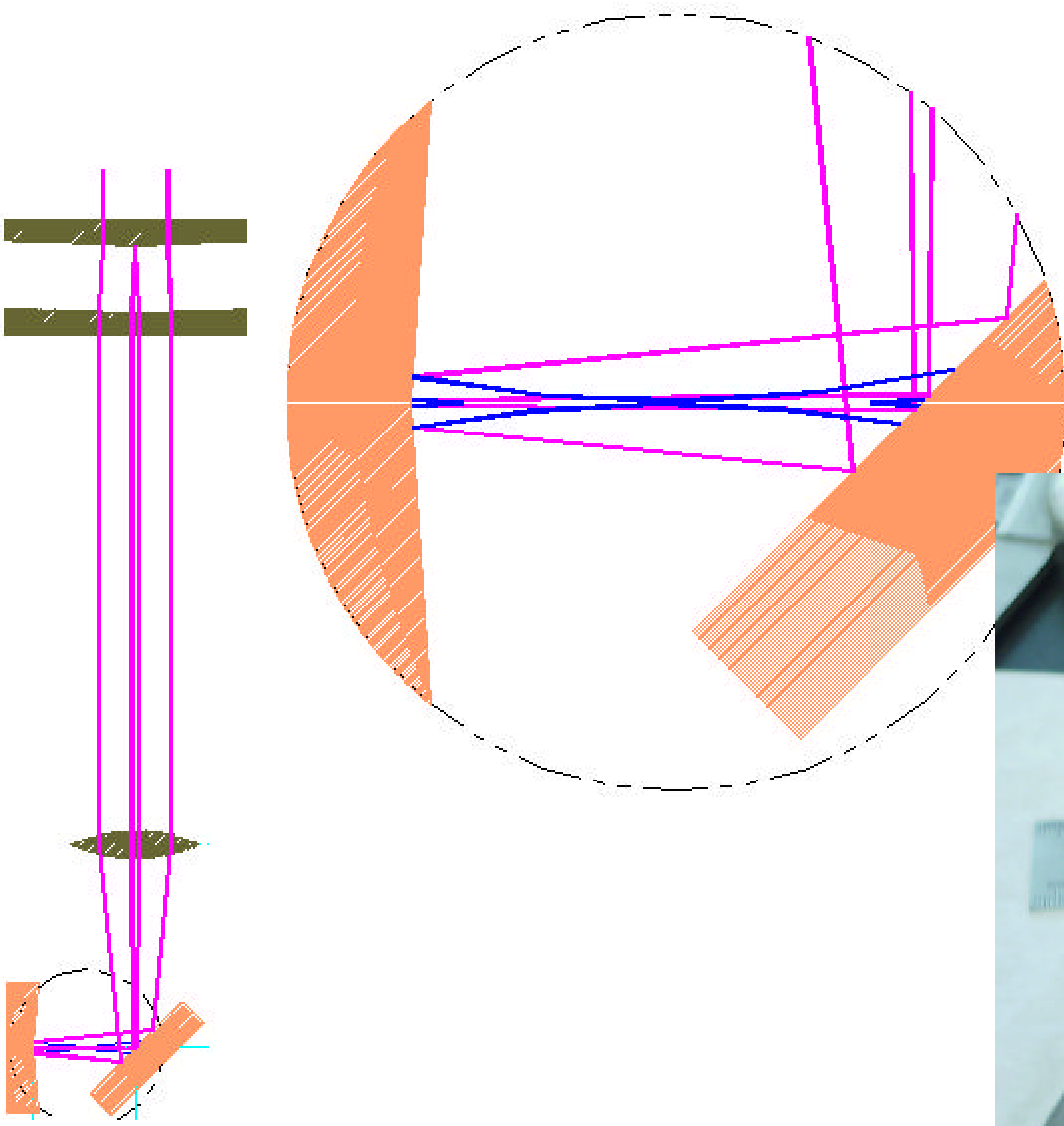
Acceleration Theorems

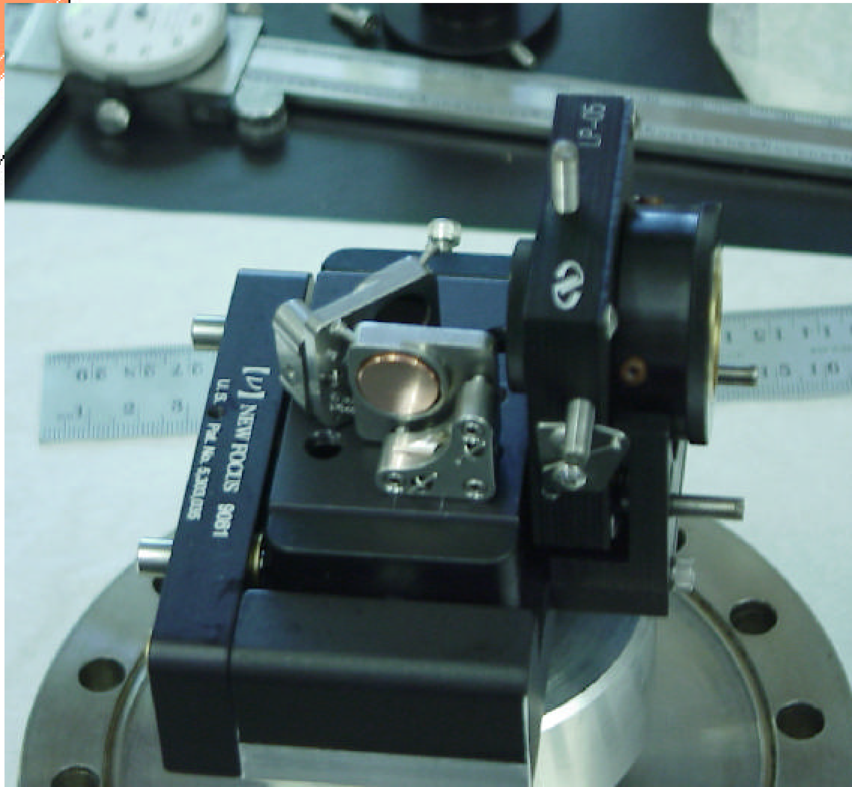
R.B.Palmer, AAC 1994

No combination of far fields in an otherwise field free vacuum, can produce first order net acceleration.

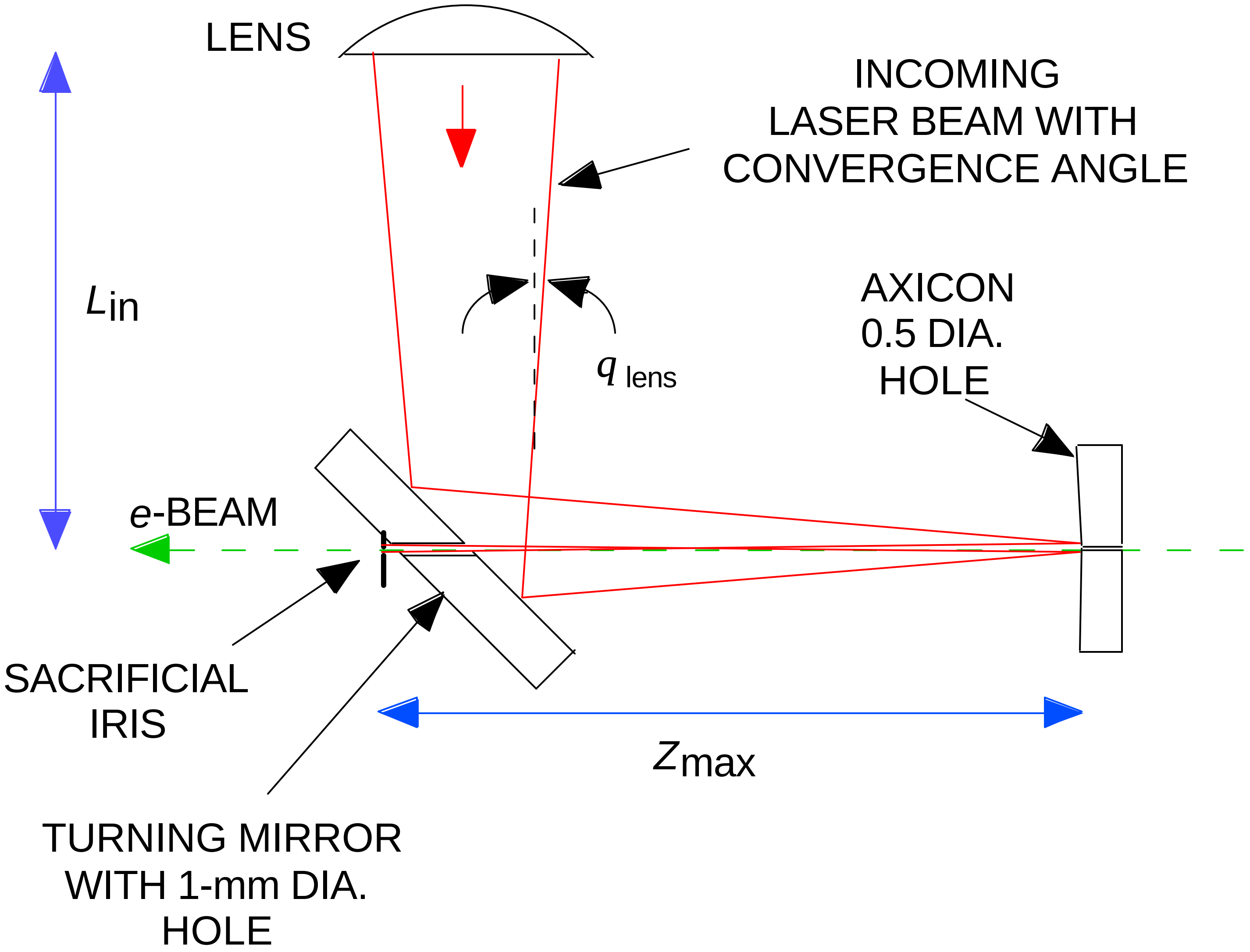
- “near field” (intensity cannot increase with distance)
- “far field” (can be focused to increase intensity)
- “otherwise field free” (IFEL, ISR)
- “in a vacuum” (plasma, collective, ICA)
- “first order” (second order Compton)
- “net acceleration” (local acceleration)

Basic Layout #1

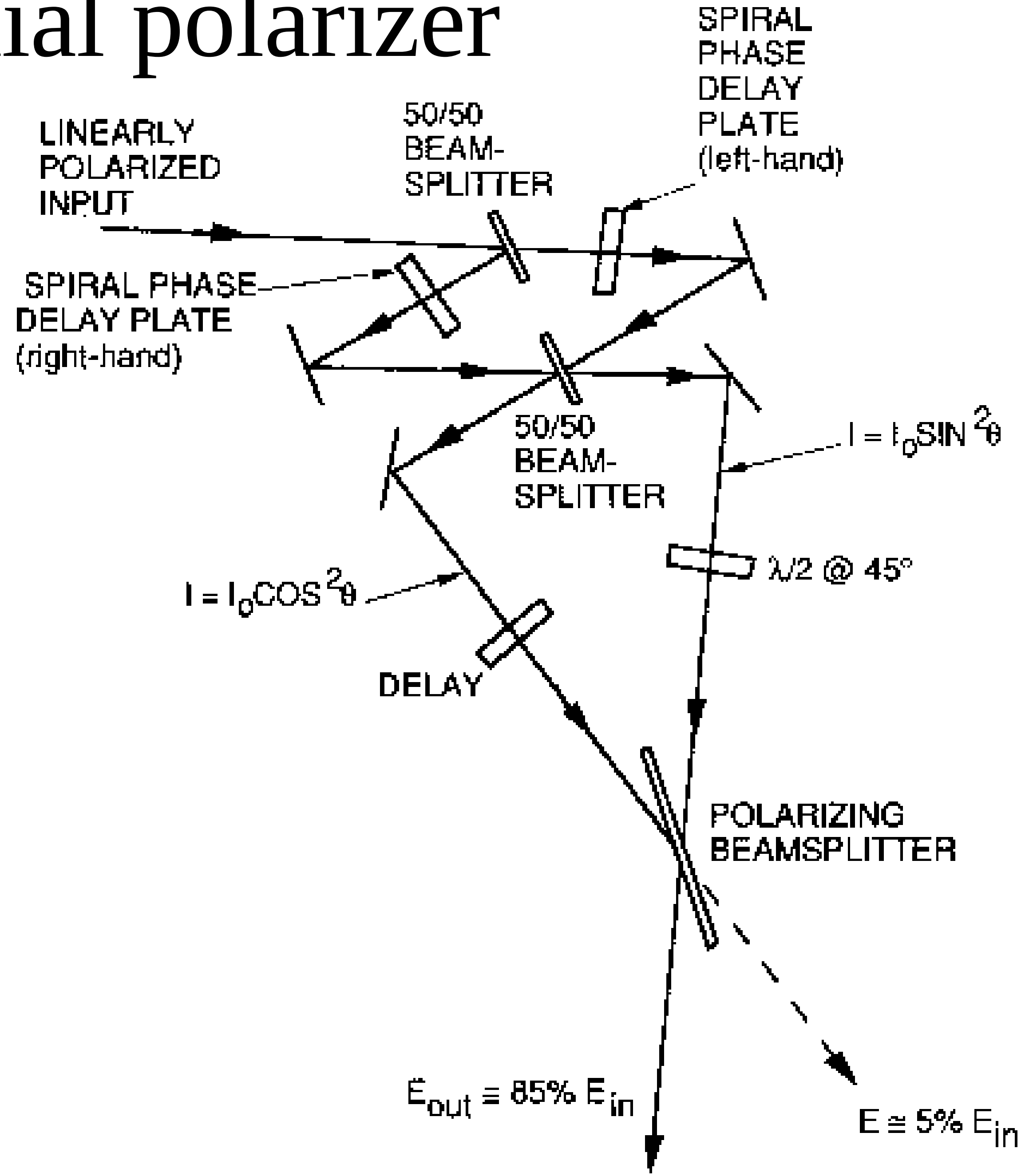




Basic Layout #2



Radial polarizer



Conclusion

- We achieved good transmission of electron beam through accelerating structure with 100 μm limiting apertures (we need to improve laser alignment procedure and picoseconds CO2 laser to continue in this direction)
- High precision spectrometer is ready for experiment.
- We plan to reestablish ICA experimental setup and measure acceleration dependence from hydrogen pressure down to vacuum


THANK YOU!