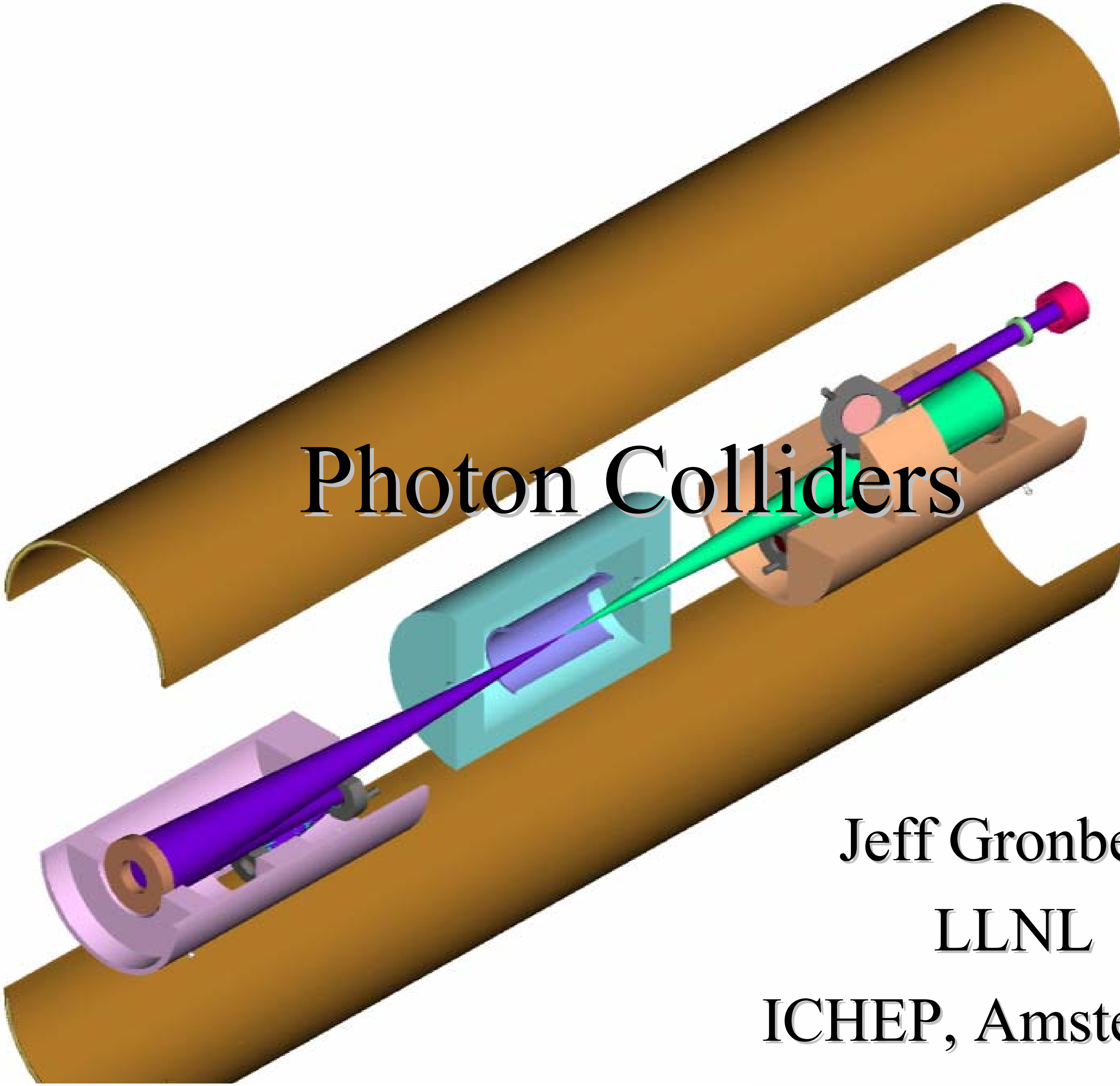
Photon Colliders



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ICHEP, Amsterdam

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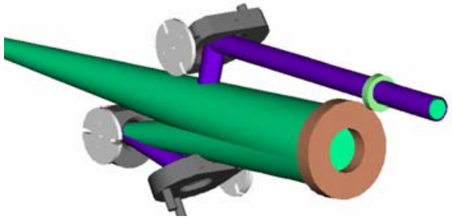
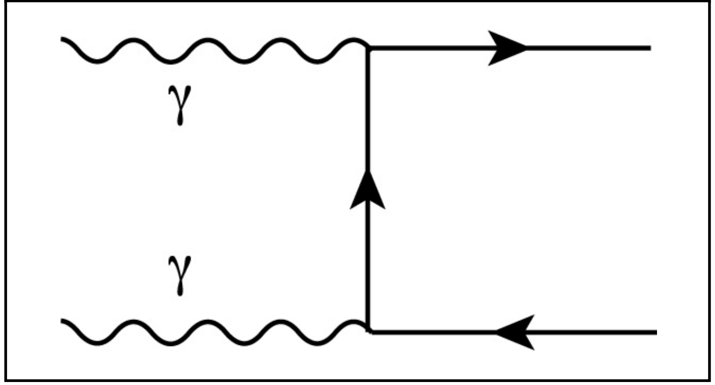


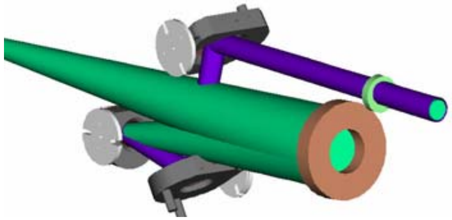
γγ collisions – Casting new light on Particle Interactions

- **The workhorses of particle physics at the energy frontier have been e^+e^- and pp collisions**
  - **Stable, charged particles can be accelerated and focused**
  - **But other particle interaction can have unique physics reach**
- **Virtual γγ collisions have been studied at e^+e^- machines**
- **Technique for producing real photon collisions through Compton Compton backscattering proposed by Ginzburg *et al*. in 80's**
  - **The technology is becoming mature to produce collisions of real photons at high energy**

Photon collisions produce anything that has electric charge

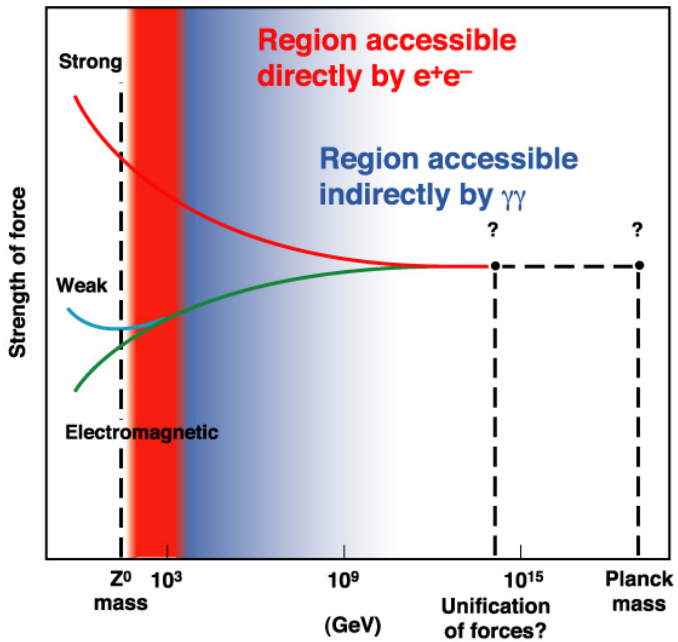


- Production is model independent, electromagnetic coupling only
- Control of photon polarization allows couplings to be probed
- See talk of S. Soldner-Rembold for complete discussion of γγ physics reach



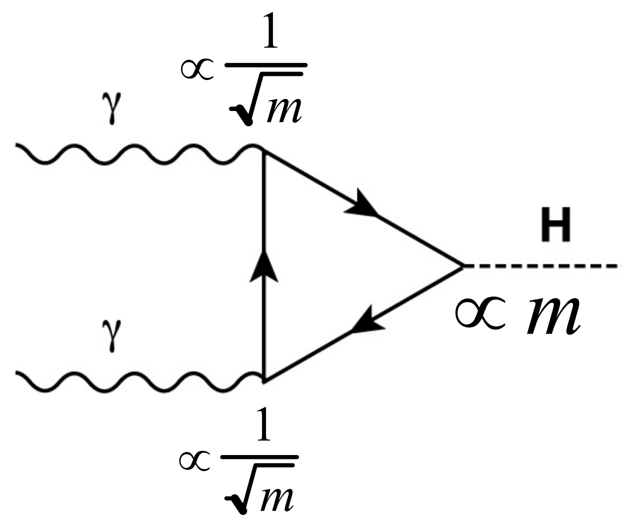
Photon collisions provide a unique probe of physics at high energies

No future accelerator will ever directly probe the unification scale



The largest machine ever proposed would only go to 100 TeV

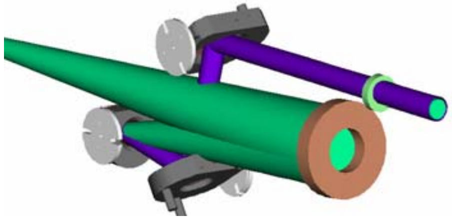
But $\gamma\gamma$ can indirectly probe arbitrarily high mass scales

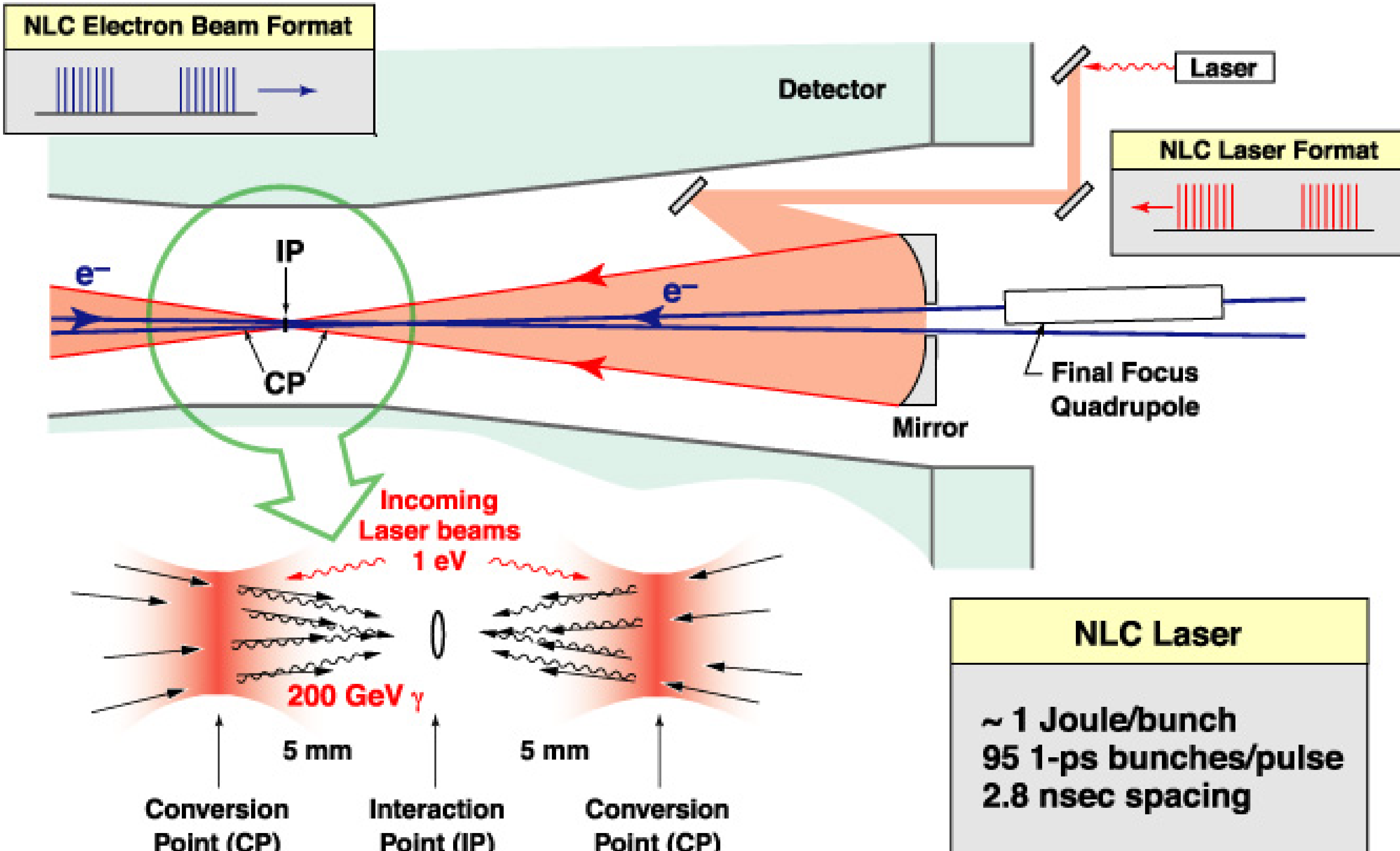


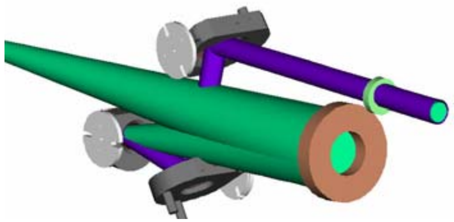
Because the Higgs couples to ***mass***, all charged particles contribute, independent of their mass

The existence of new generations of quarks and leptons can thus be detected in regions not directly accessible

Photon Colliders – The marriage of lasers and electron linear colliders

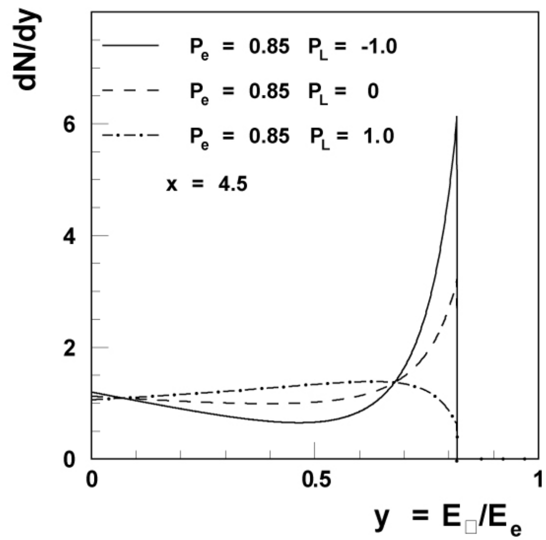


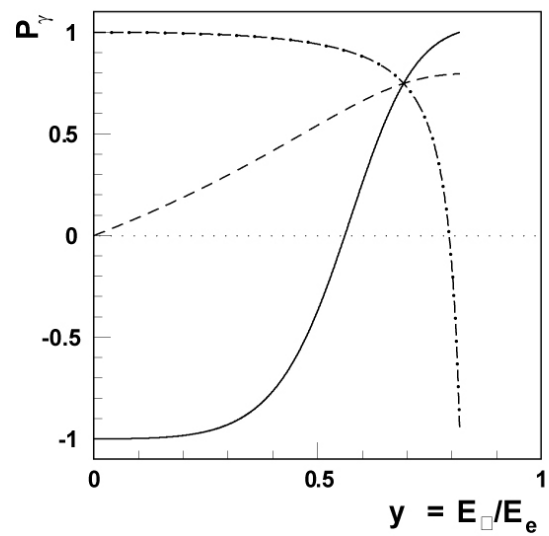


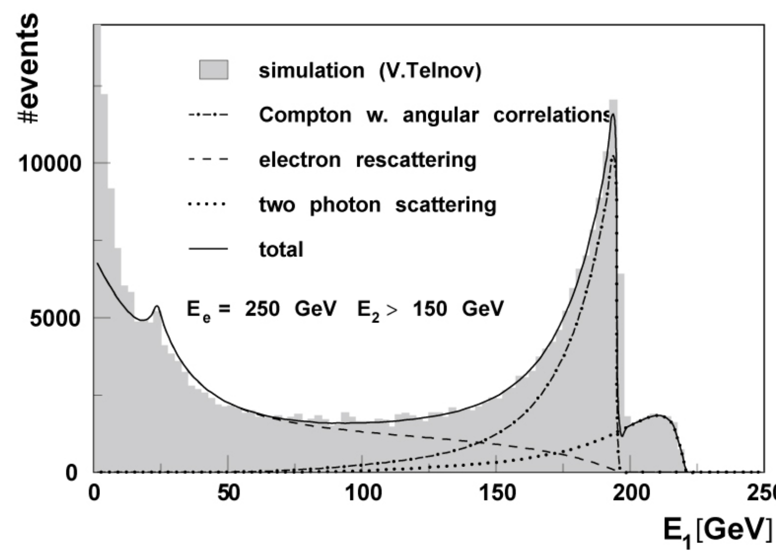


Simulations and parameterizations describe the luminosity

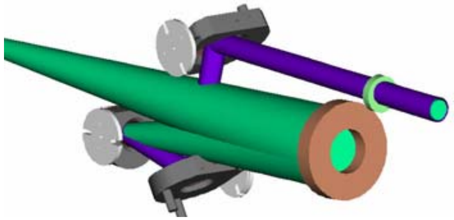
- Compton backscattering is complicated
  - Polarization dependent
  - Energy dependent
  - Laser Intensity dependent
  - Energy / Angle correlation
- Full simulations exist
  - Code from V. Telnov
  - CAIN simulation from P. Chen *et al.*
- Luminosities have been parameterized
  - CompAZ from A. Zarnecki
  - CIRCE from T. Ohl





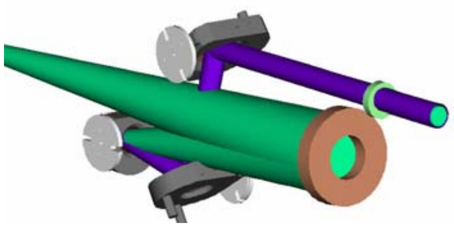


From hep-ex/0207021 A. Zarnecki

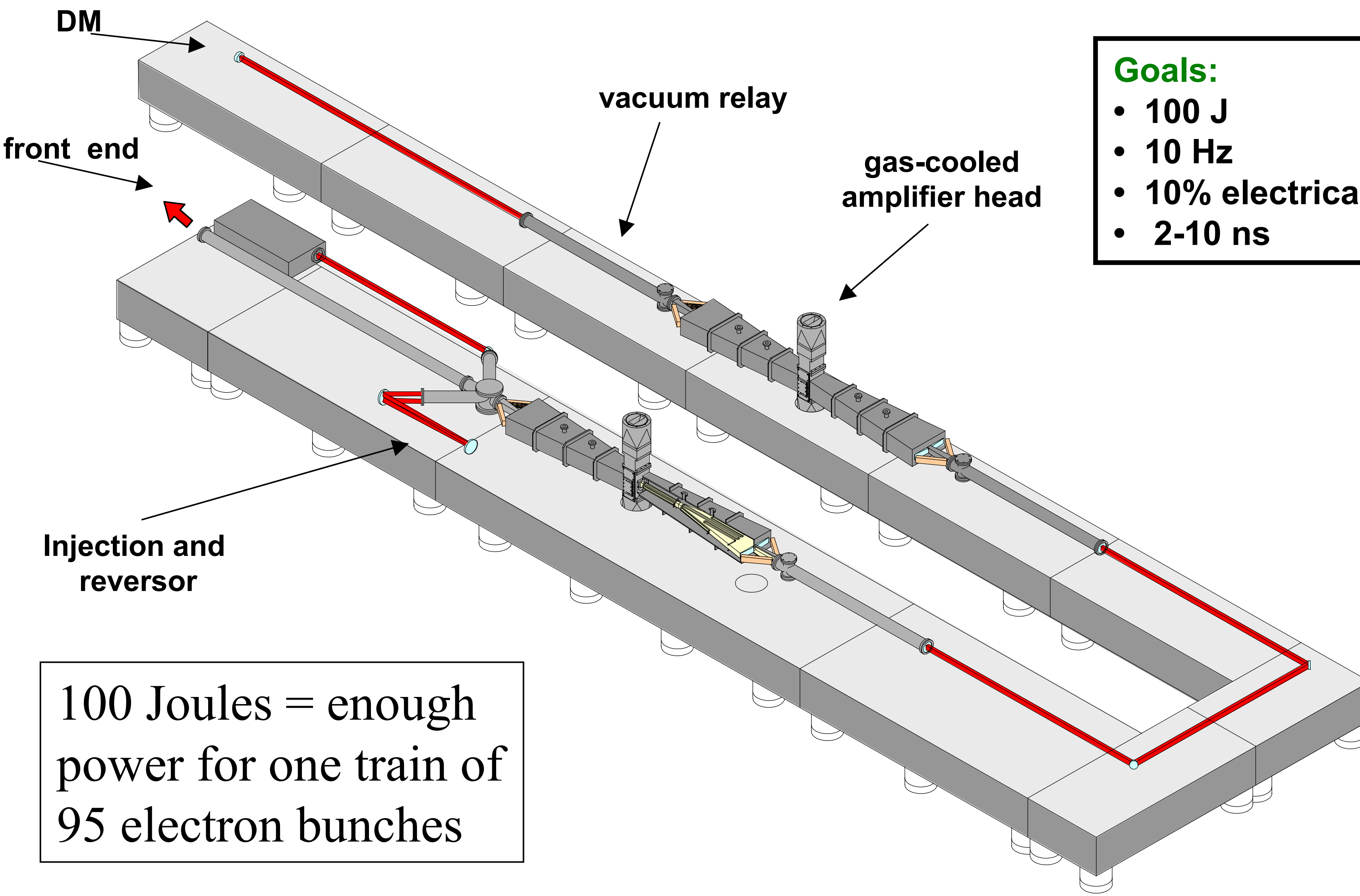


Required laser technology pushes the state of the art

- High Average Power, Short-Pulse Lasers
  - Terawatt peak power - 1 Joule in 1 ps
  - 20 kilowatts average power
  - Near diffraction limit
  - Time structure matched to the electron beam
- Laser focusing optics
  - Co-located in the beam pipe vacuum
  - Cannot interfere with:
    - The accelerator
    - The detector

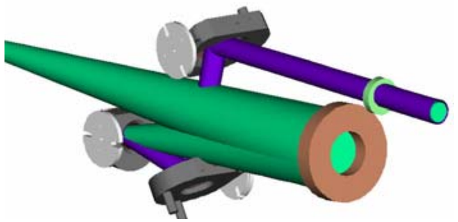


The Mercury laser will utilize three key technologies: gas cooling, diodes, and Yb:S-FAP crystals



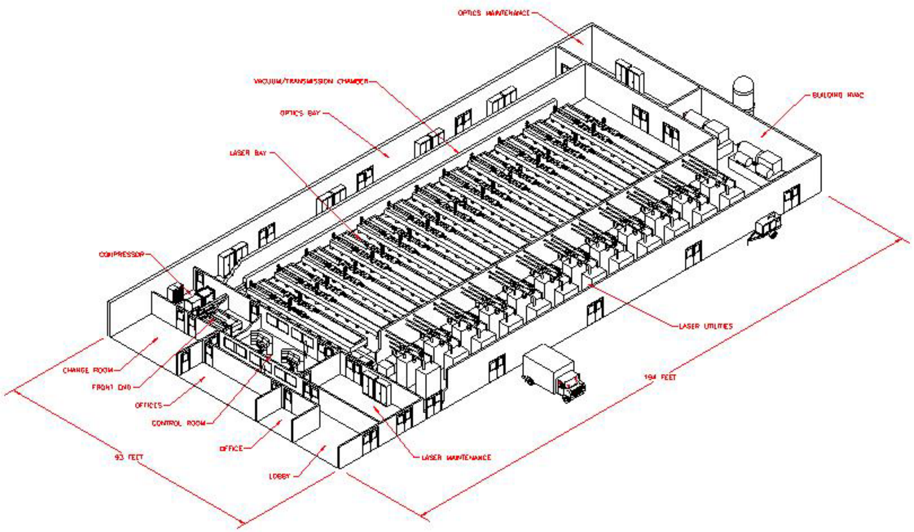
Goals:
- 100 J
- 10 Hz
- 10% electrical
- 2-10 ns

100 Joules = enough power for one train of 95 electron bunches



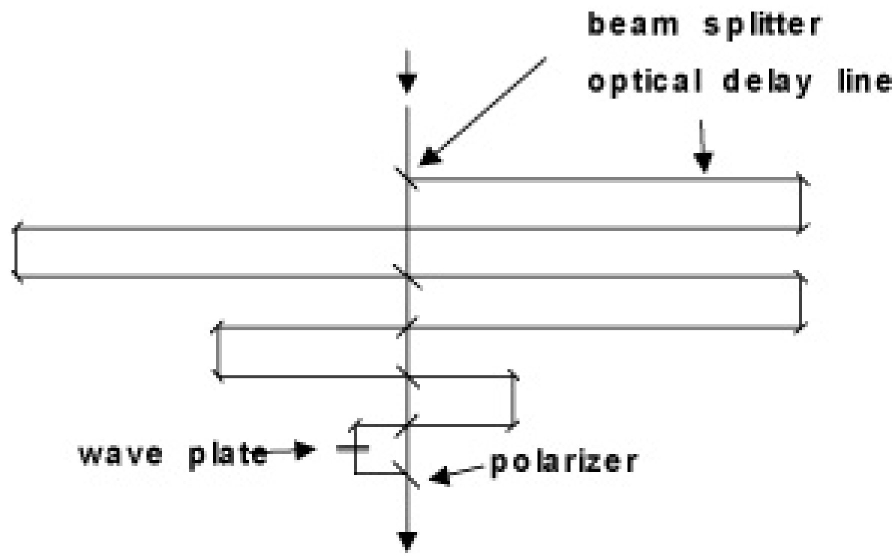
MERCURY output must be time structured to match the electron bunches

Laser Plant



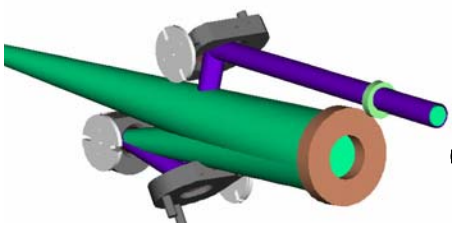
12 Lasers x 10Hz = 120Hz

Beam Splitter

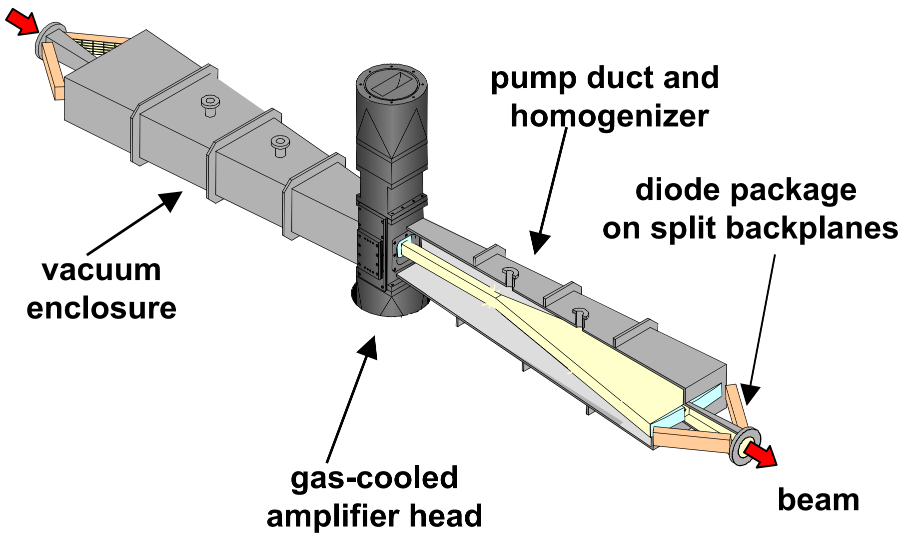


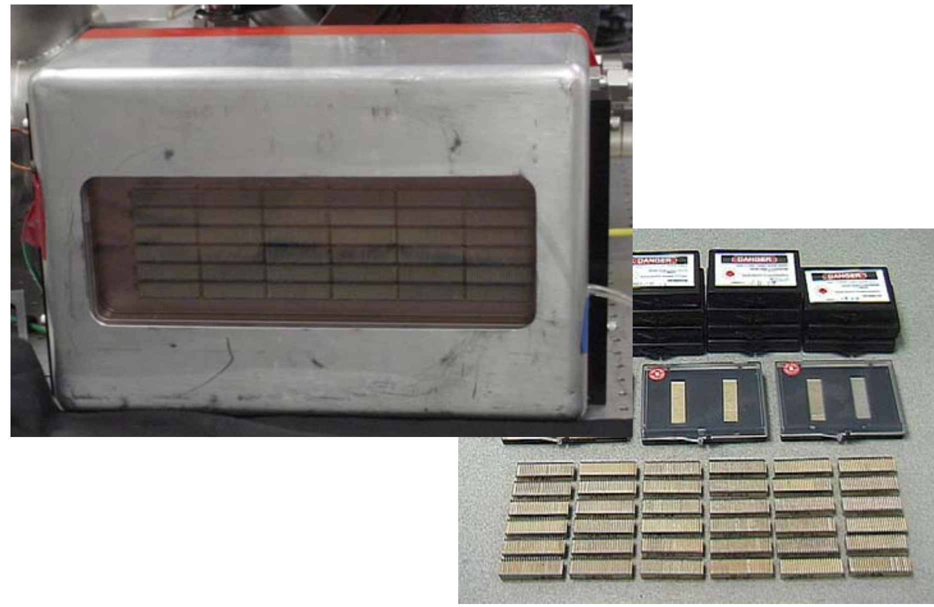
1, 100 Joule pulse -> 100, 1 Joule pulses

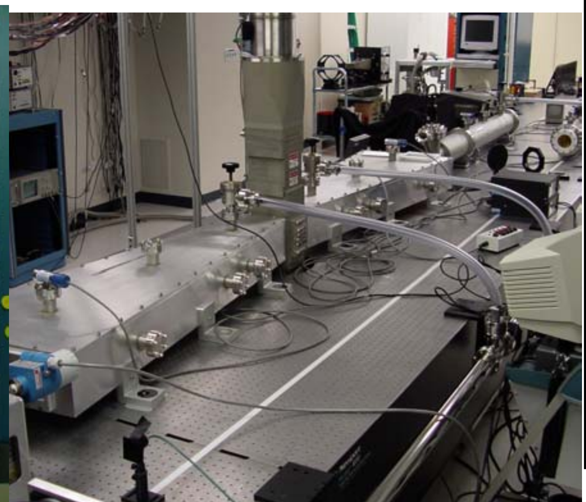
- Laser plant for NLC / JLC < $200M



MERCURY commissioning has begun
One amplifier head with 4 of 7 crystals installed

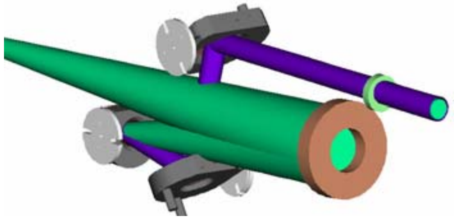




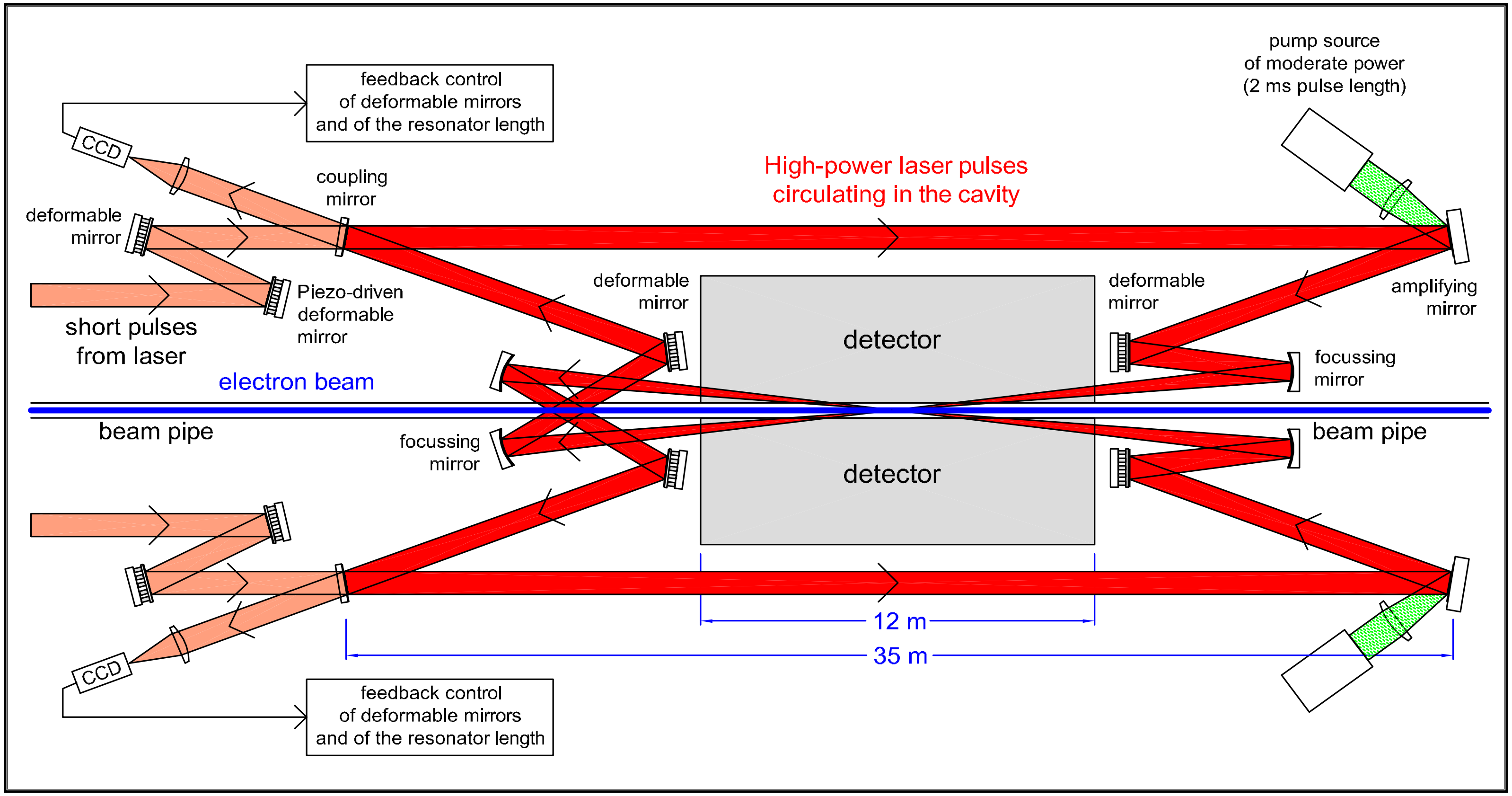


Status

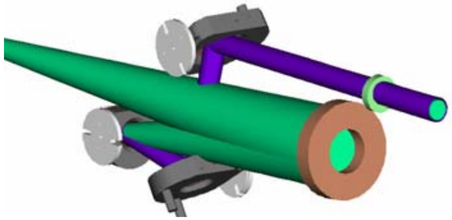
- Producing 10 Joule pulses at 0.1 Hz
  - Theoretical max 14 Joules w/ 4 crystals
- Operation of two heads with 14 crystals within the next year
- Installation of new front end for 10Hz operation



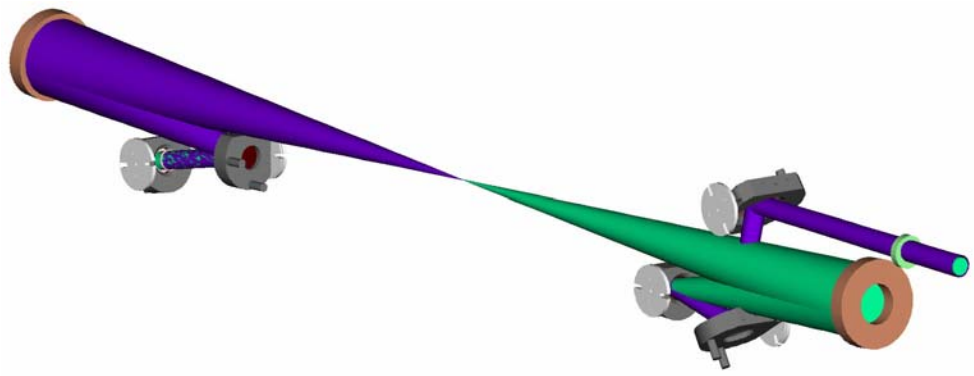
NLC solution might be adapted to TESLA, but TESLA bunch spacing opens new options

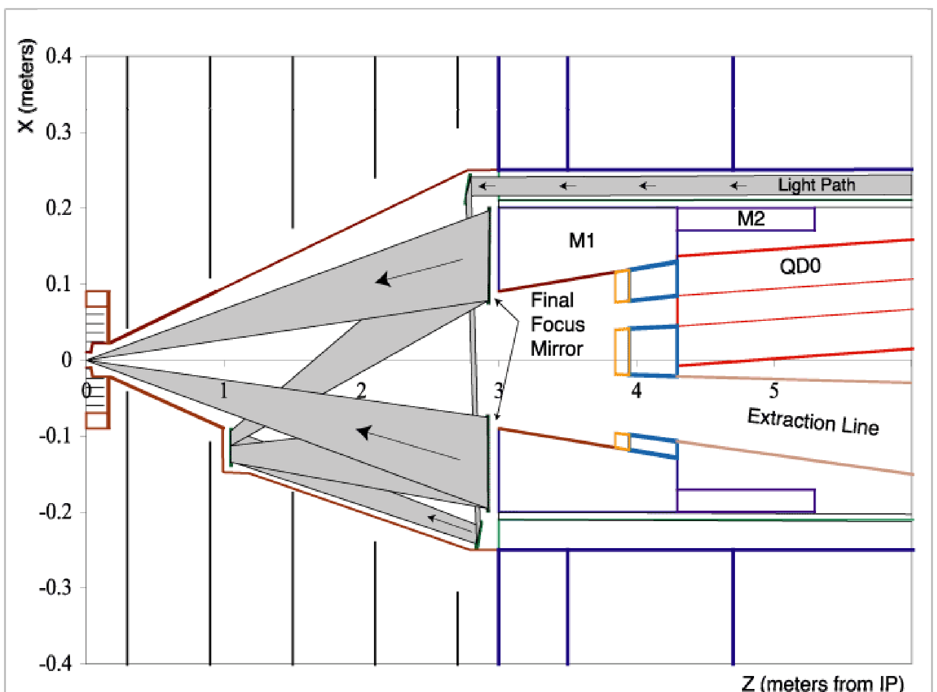


- A single light pulse can travel around the ring and hit every bunch in the TESLA train
  - DESY and Max Born Institute will prototype a scale model
    - Tolerances are tight, but enormous savings in laser power

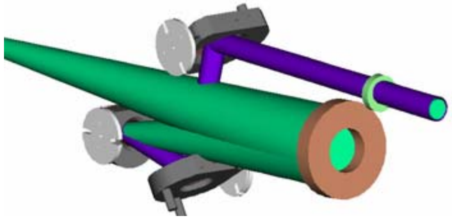


System Integration – Optics/Beampipe



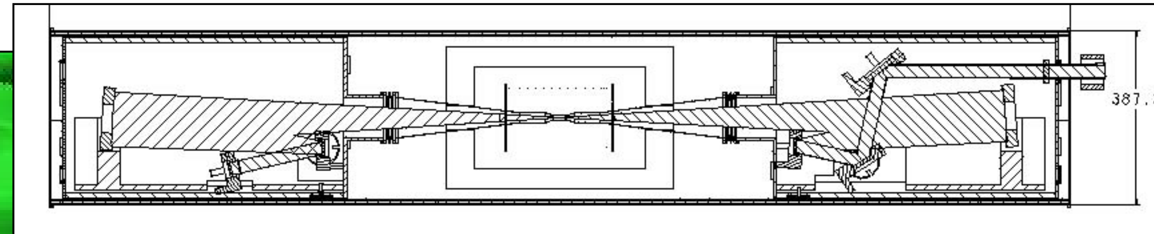


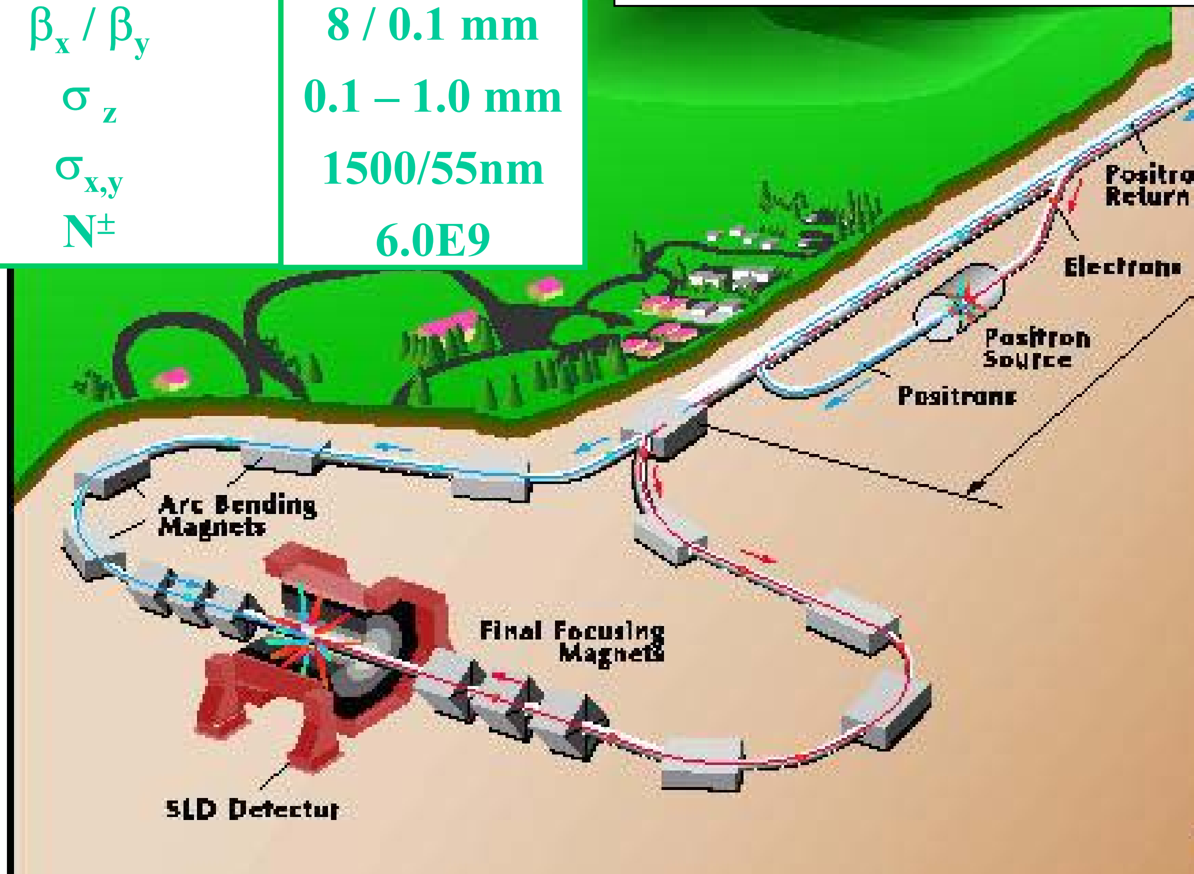
- Essentially identical to the e^+e^- IR
- All masking preserved
- 30 mRad x-angle
- Extraction line ± 10 mRadian
- New mirror design 6 cm thick, with central hole 7 cm radius.
  - Remove all material from the flight path of the backgrounds

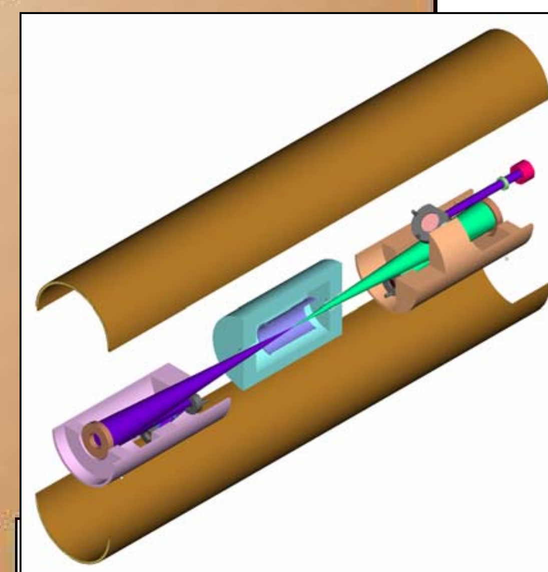


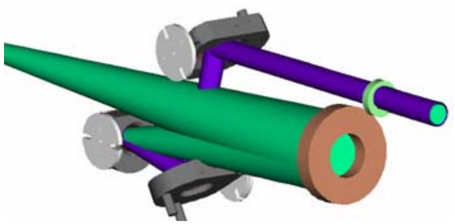
γγ Engineering Test Facility at SLC
Revive SLC and install beampipe with optics

Beam Energy	**30 GeV**
DR $\gamma\varepsilon_{x,y}$ (m-rad)	**1100 / 50**
FF $\gamma\varepsilon_{x,y}$ (m-rad)	1600 / 160
β_x / β_y	**8 / 0.1 mm**
σ_z	**0.1 – 1.0 mm**
$\sigma_{x,y}$	**1500/55nm**
$N^{\pm}$	**6.0E9**









Conclusions

- Photon collisions provide new physics reach
- Laser technology is maturing, driven by other applications
  - Core laser technology will be prototyped and demonstrated within the year
- A basic design for the integration of the optics with the detector/accelerator exists
  - Ready for prototyping and demonstration at a low energy linear e^+e^- collider