A Photon Collider Experiment based on SLC

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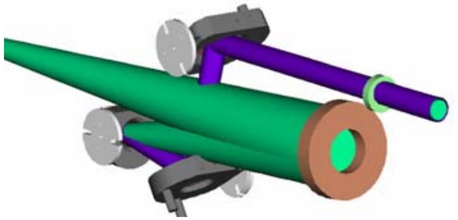
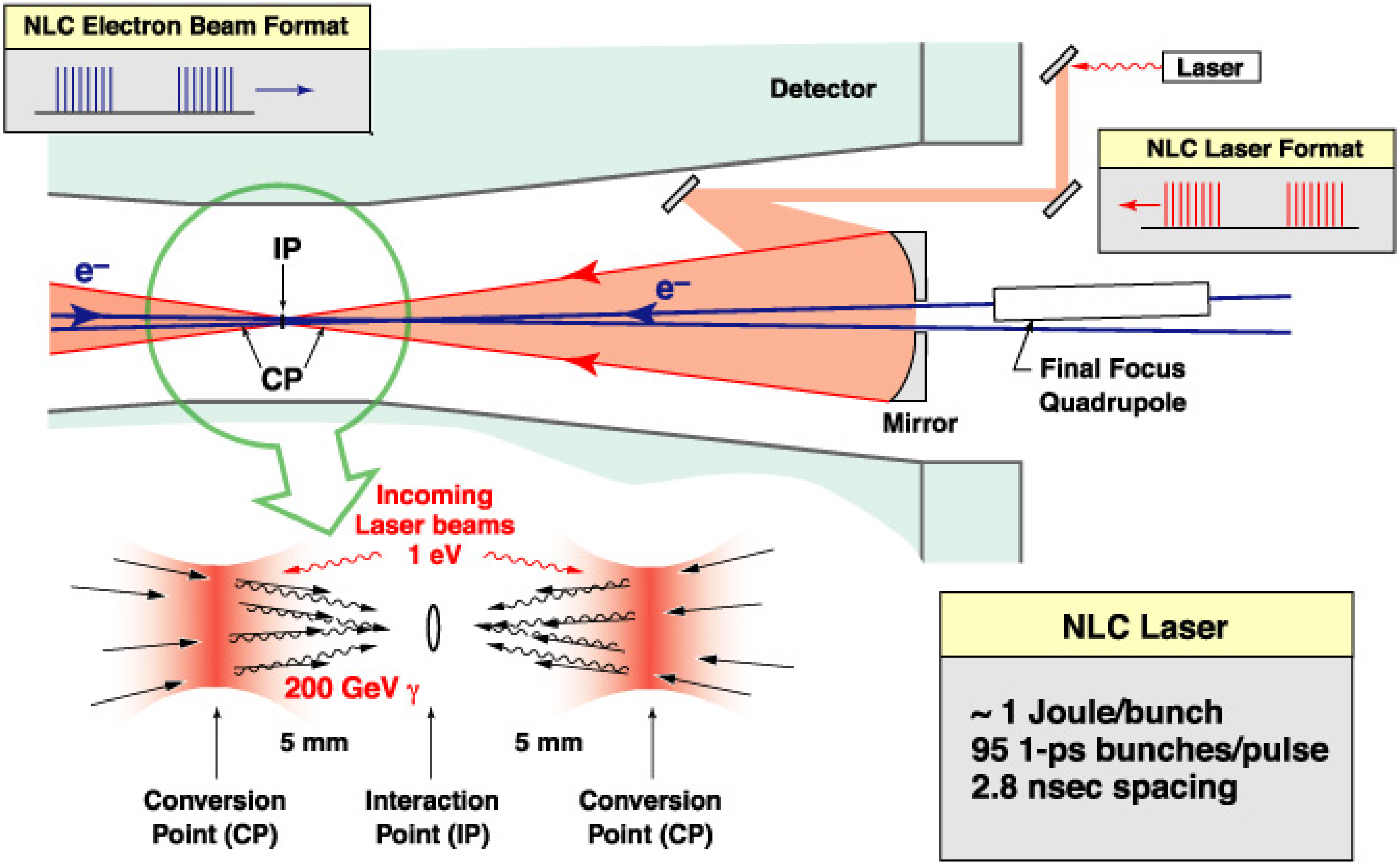
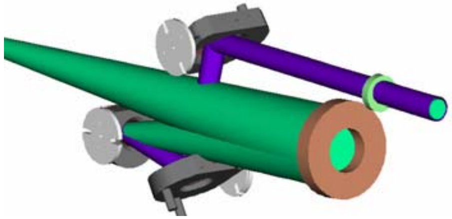
This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.



A Photon Collider interaction region is being developed for the future TeV Linear Collider

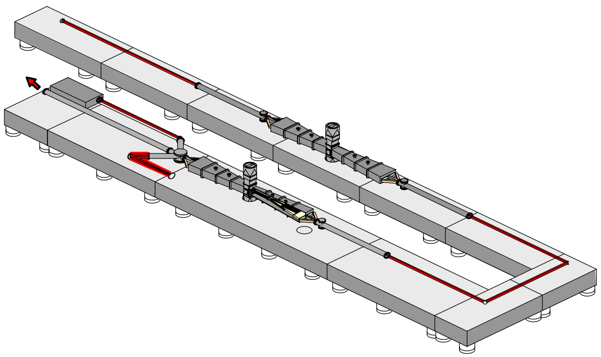


First proposed 1981; Ginzburg, Kotkin, Serbo, Telnov



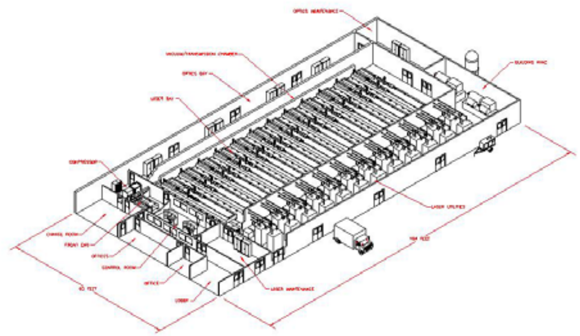
Technology for the warm machine has been under development

MERCURY Laser



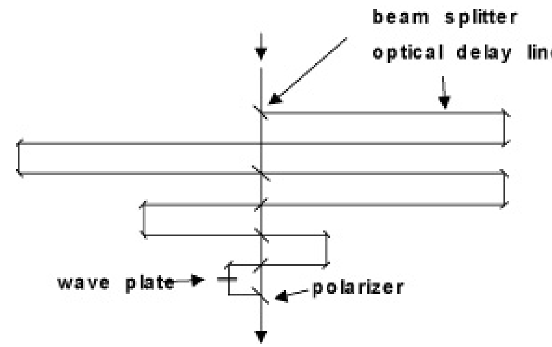
1 pulse = 100 Joules = 1 train

Laser Plant



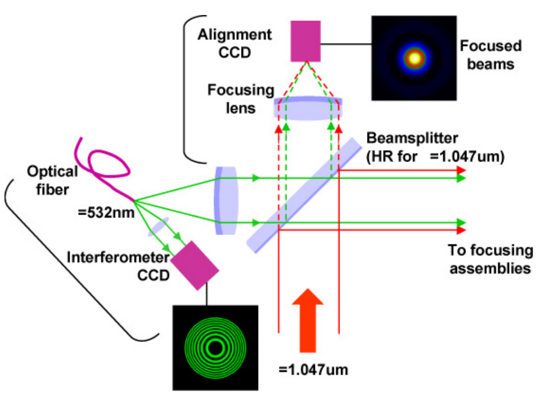
12 Lasers x 10Hz = 120Hz

Beam Splitter

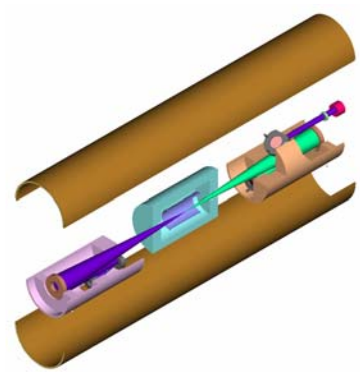


1, 100 Joule pulse -> 100, 1 Joule pulses

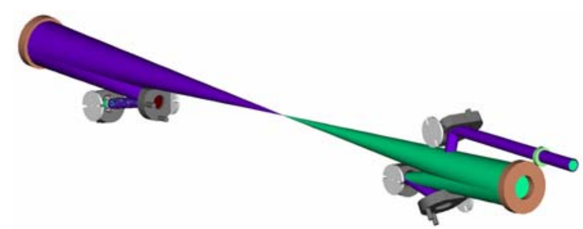
Interferometric Alignment System

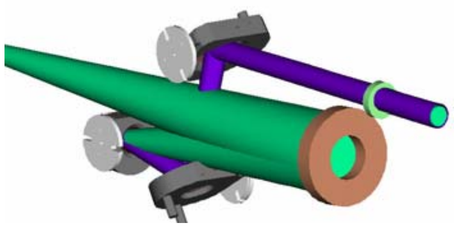


Beam Pipe



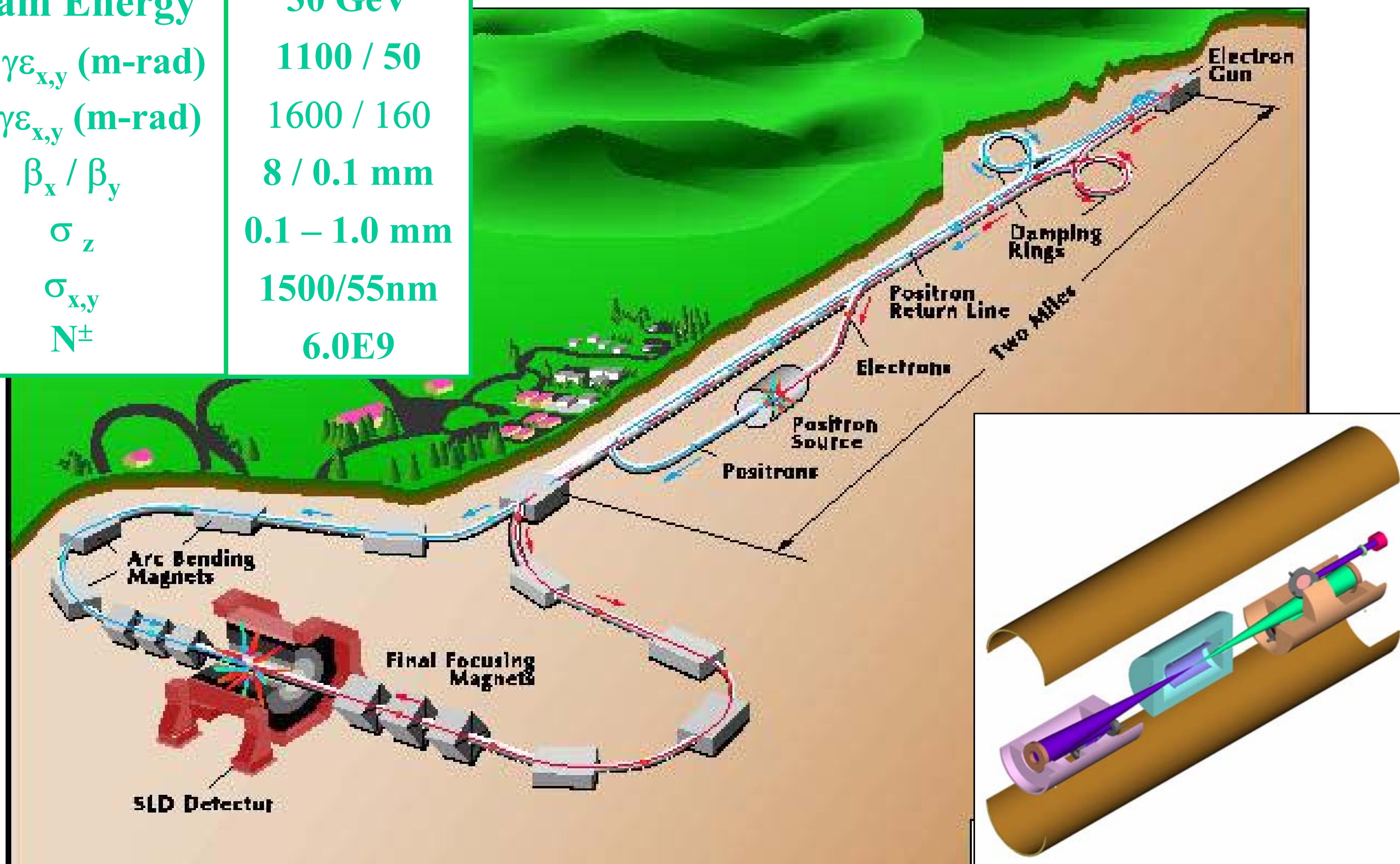
Optics Assembly

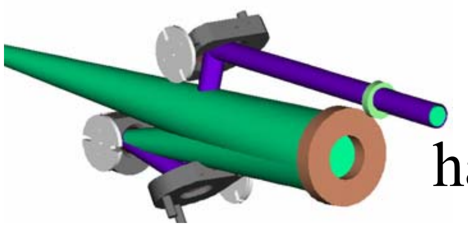




The SLC provides an opportunity to move to actual tests of the photon collider technology

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**

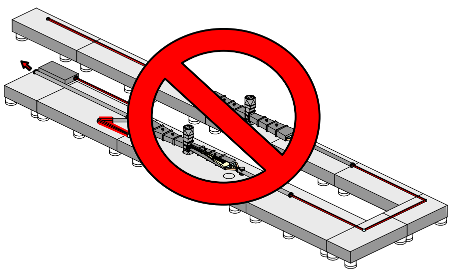




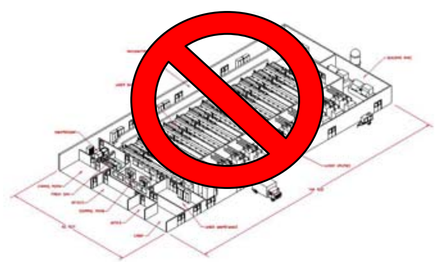
An SLC Photon Collider testbed can test the IR hardware and operations without requiring a large laser

Pulses at 30 Hz at SLC, 11,000 Hz at NLC
The laser is easy for a SLC testbed

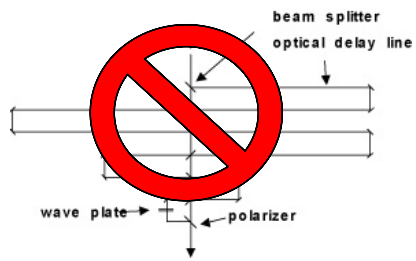
MERCURY Laser



Laser Plant

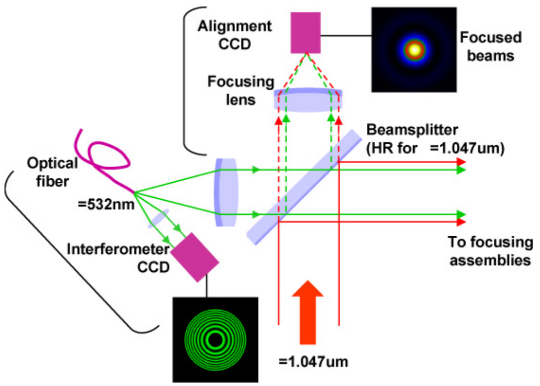


Beam Splitter

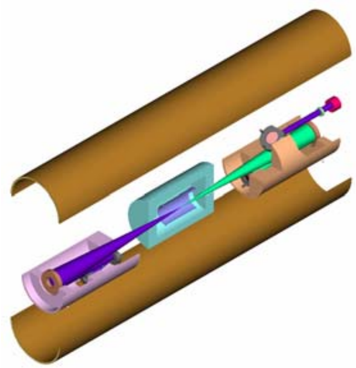


A small laser,
0.1J x 2 x 30Hz,
6W average power
laser is sufficient
for this experiment

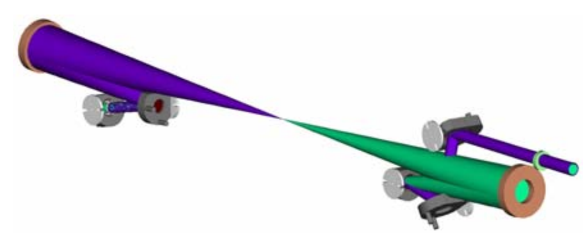
Interferometric Alignment System



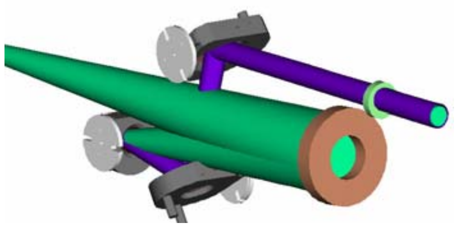
Beam Pipe



Optics Assembly

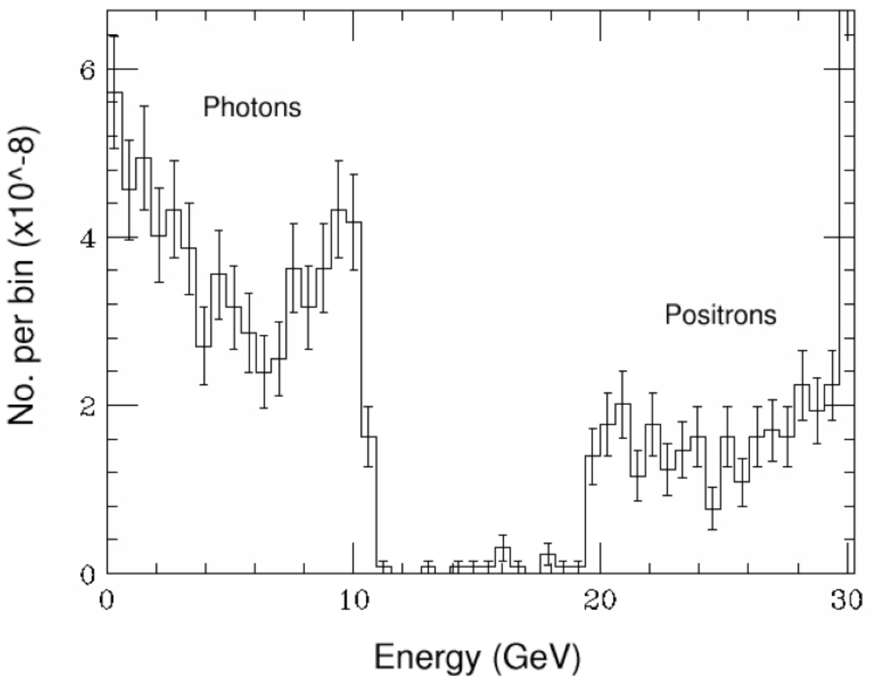


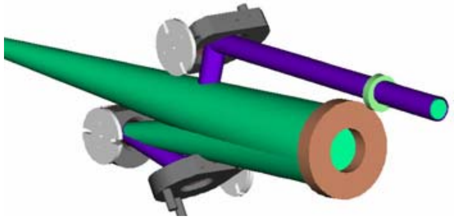
½ size to fit in SLC



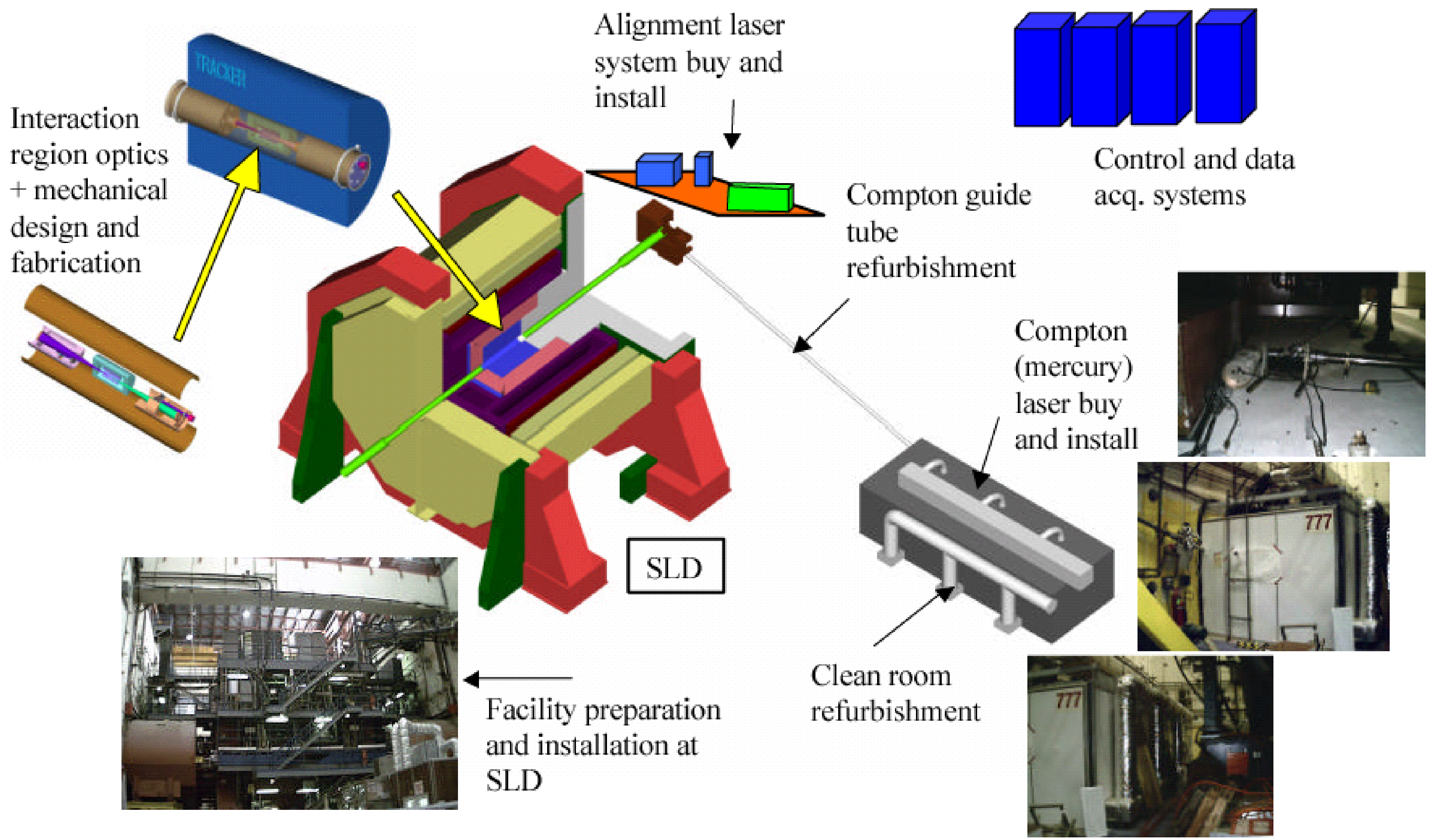
Luminosity spectrum can be seen in two hit events in the SLD calorimeter

- The kinematics of Compton backscattering causes the photons and spent electrons to occupy different energy regions
  - Photons 0 – 10 GeV/c
  - Electrons 20 – 30 GeV/c
  - At 0.1 J flash energy 0.25 photons / electron
- Events from γγ, eγ, ee are separable by their C.M. energy and z boost.

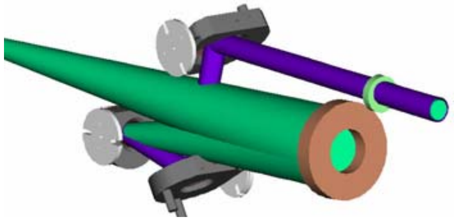




A proposal is under development for this test facility

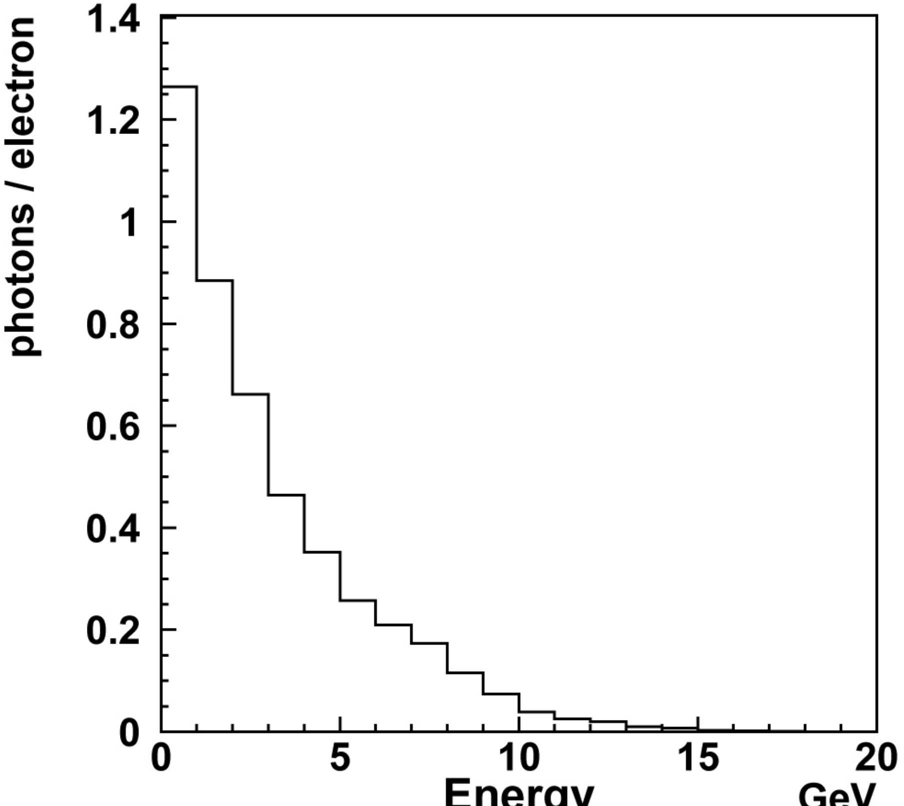


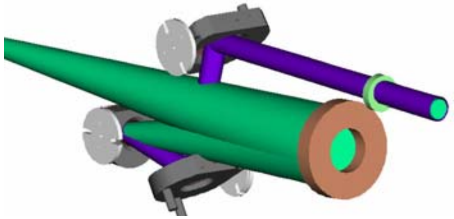
- Rough estimate ~$10M total project cost (incl manpower)



Can we produce enough luminosity to do interesting physics?

- For luminosity we can:
  - Increase laser energy to get multiple photons per incoming electron
  - Luminosity $\propto N_{photon}^2$
- At SLC a 2J laser pulse produces 4 photons / incoming electron
  - Each subsequent scatter produces photons of lower energy
  - Distribution peaked toward lower energy

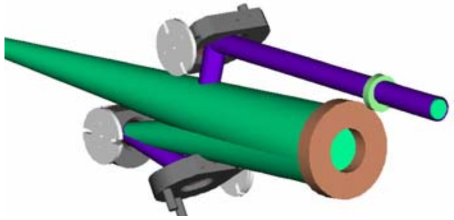




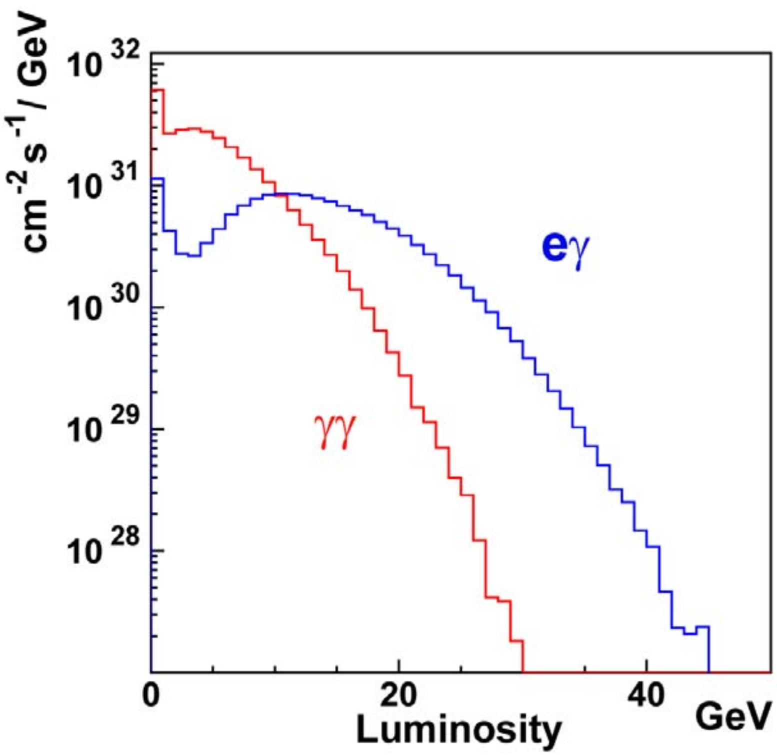
Photon-photon luminosity is proportional to the geometric e+e- luminosity

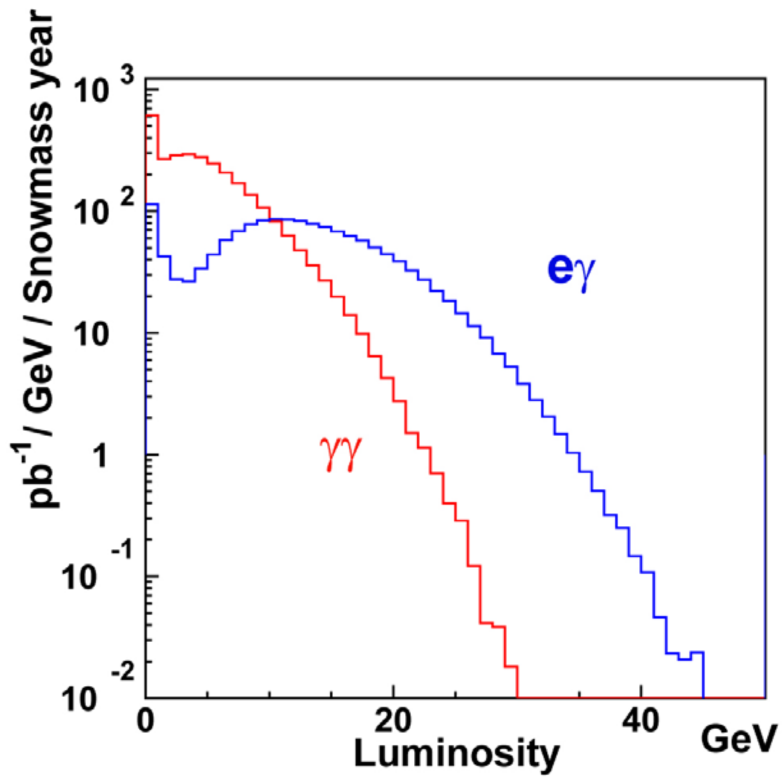
- Bunch charge
  - 0.6E10 → 4.0E10
- Repetition rate
  - 30 Hz → 120 Hz
  - More laser energy required
- New final focus magnets with LINX design

- $L = 3 \times 10^{31}\ cm^{-2}\ s^{-1}$
- Previously achieved:
  - $3 \times 10^{30}\ cm^{-2}\ s^{-1}$
- $L_{\gamma\gamma} = 16 \times L_{geom}$
- $L_{e\gamma} = 8 \times L_{geom}$

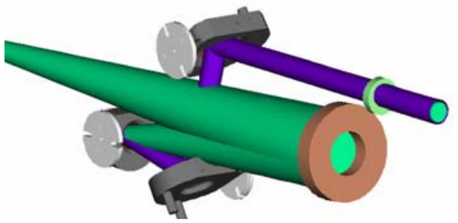


Total luminosity is higher but spread over a large energy range

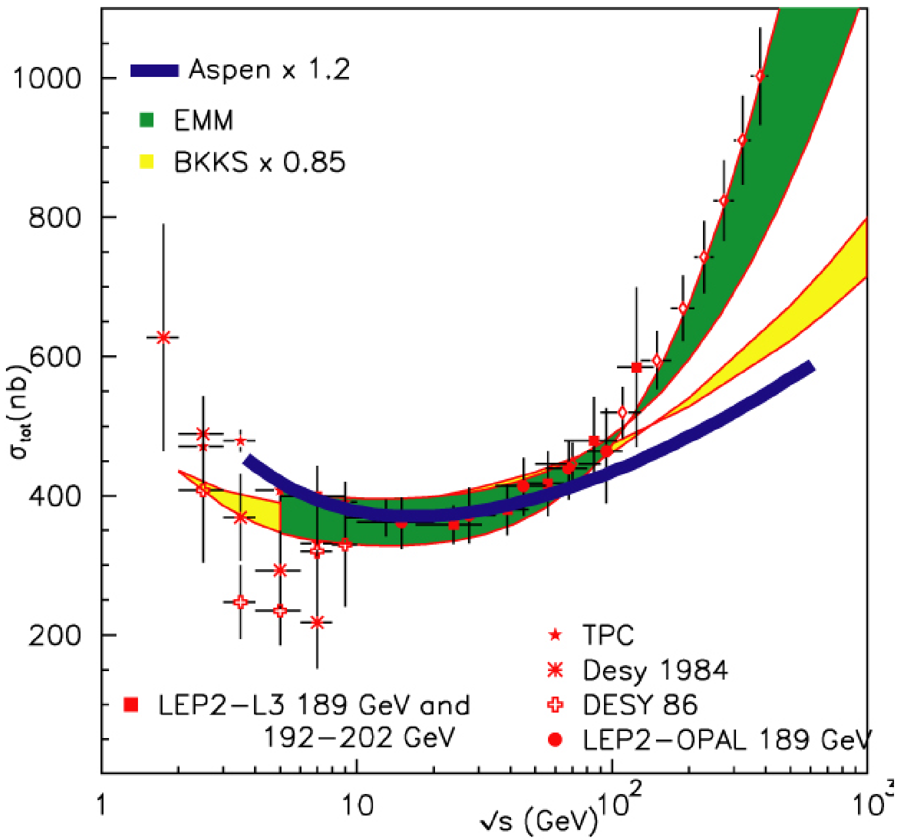




- Full simulation with the CAIN program
- Additional low energy luminosity comes from beamstrahlung photons

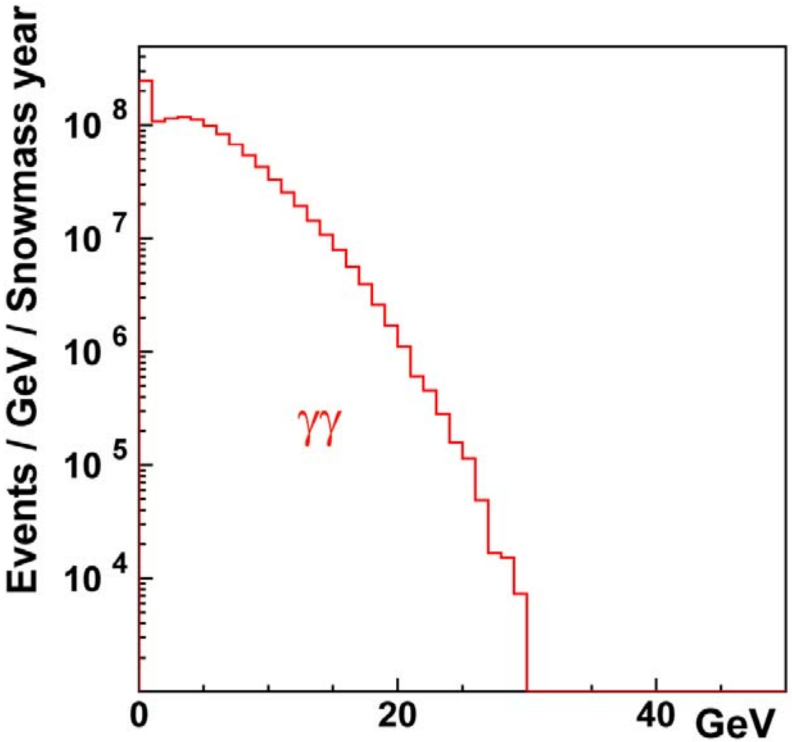


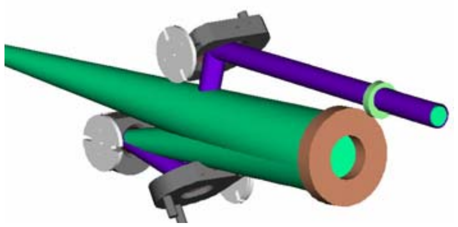
Photon-photon events become the dominant source of events



From hep-ph/0303018
Godbole, Grau, Pancheri, de Roeck

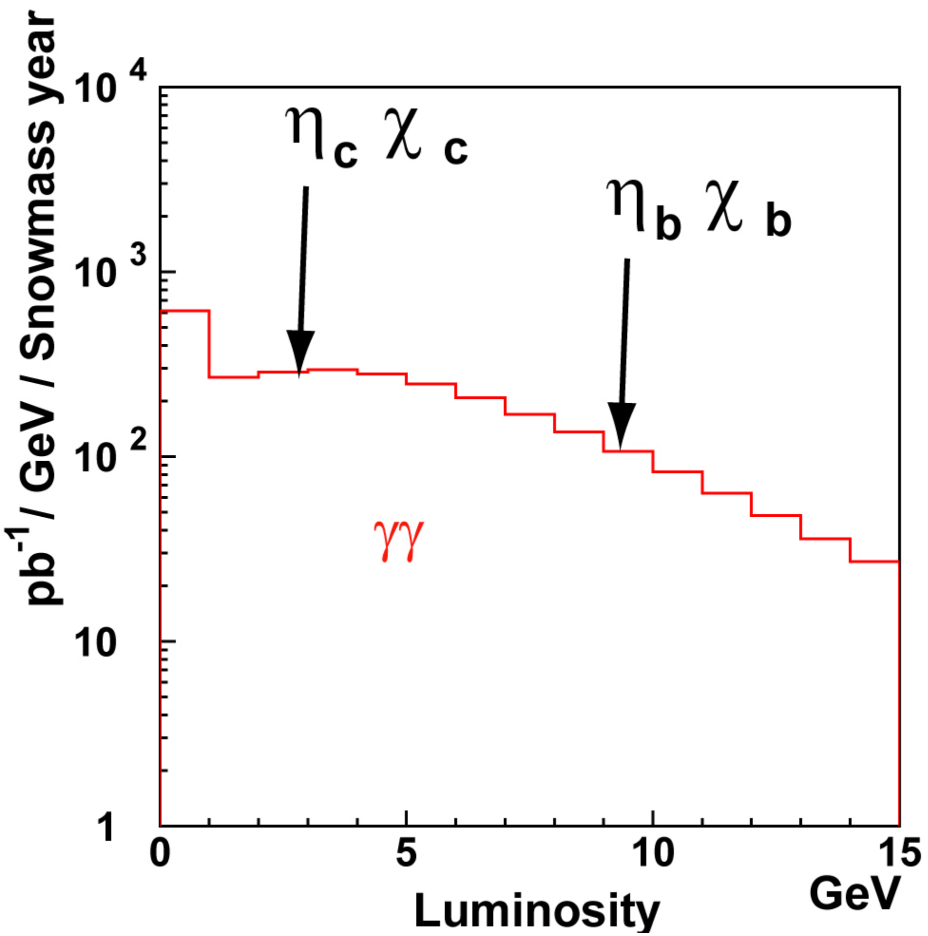
Assume σ_{tot} = 400 nb

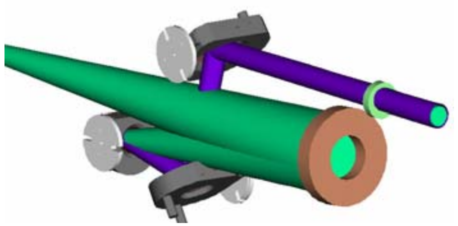




Spin 0 and spin 2 resonances can be directly produced

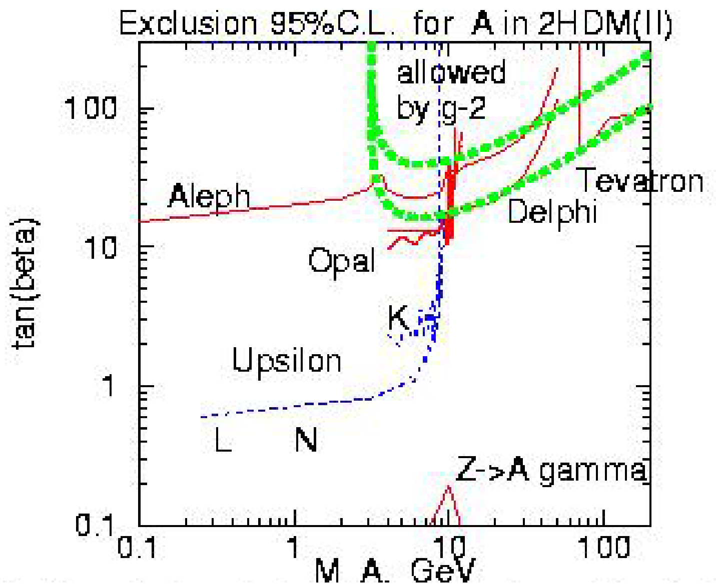
- Assuming luminosity is equally spin-0 and spin-2
- $\eta_c = 6 \times 10^6$
- $\chi_c = 3 \times 10^6$
- $\eta_b = 3 \times 10^3$
  - events per Snowmass Year per quantum number



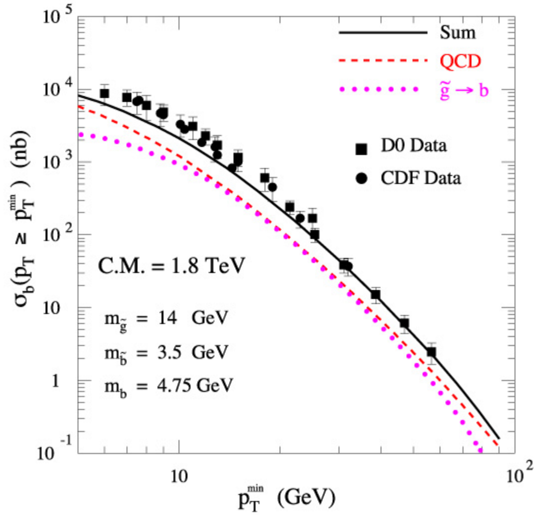


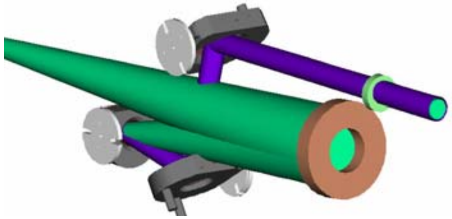
Is there even the possibility of a beyond Standard Model physics program?

- Beyond Standard Model
  - Low Mass SUSY H^0 and A^0
    - Unexcluded in a general 2HD model
      - Maria Krawczyk
      - Hep-ph/0208076
    - Large production at low mass and high tan(beta)
      - 100's of events



  - Low Mass SUSY squarks
    - Invoked to explain excess of b events at the Tevatron
      - Berger et al.
      - Hep-ph/0012001
    - $\gamma\gamma \rightarrow b^+b^-$ squarks
    - Spin 0 charged particles should be copiously produced at photon collider

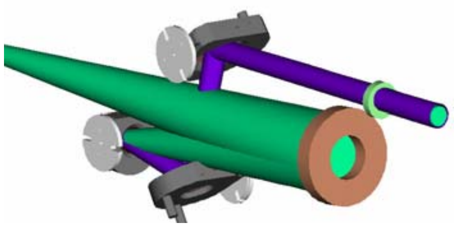




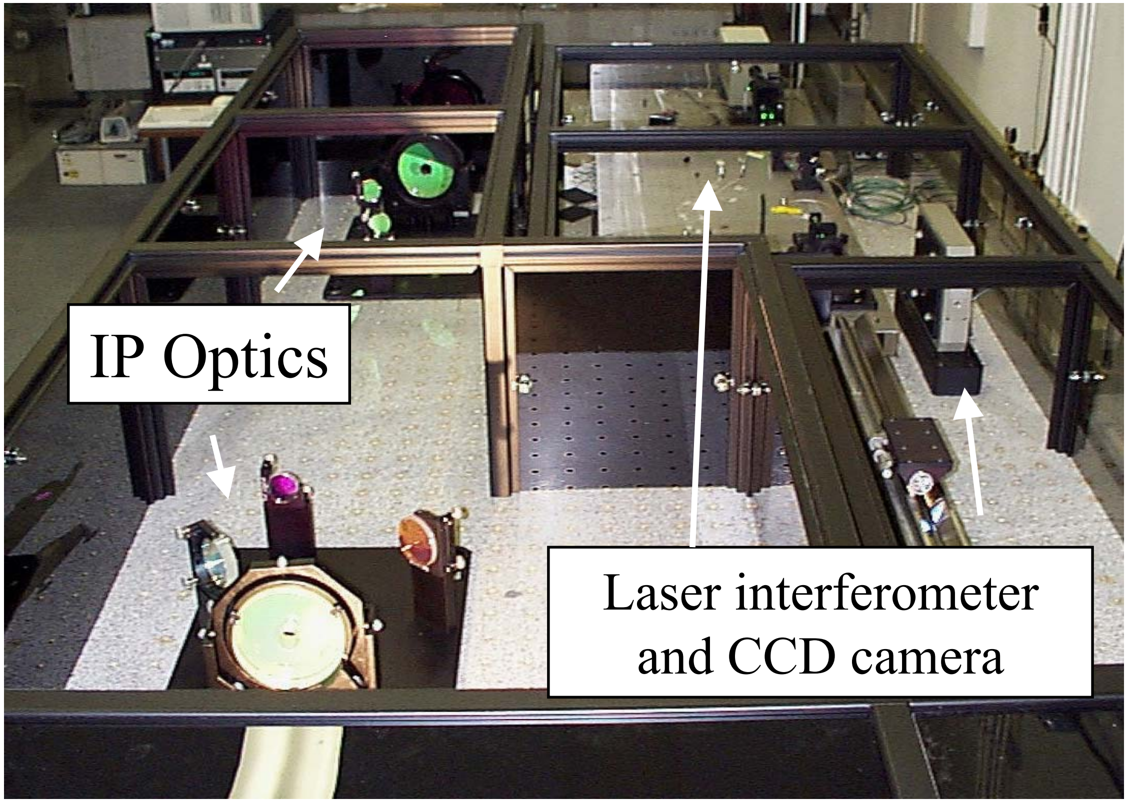
The experiment has a number of analysis advantages

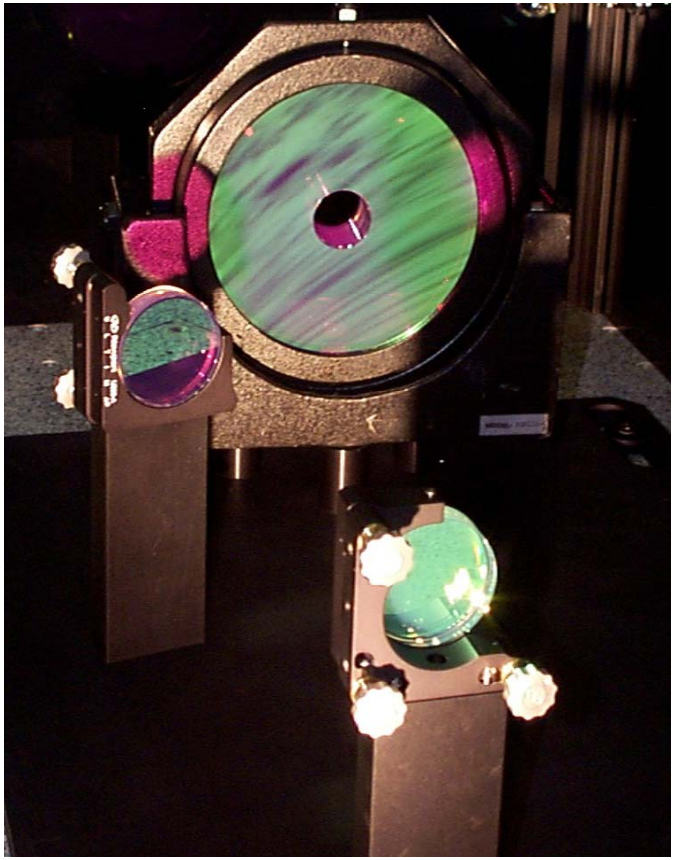
- No trigger
  - 120Hz of data can be written to tape
- Photon-photon events are dominant
- Electron-photon events can be separated by their boost

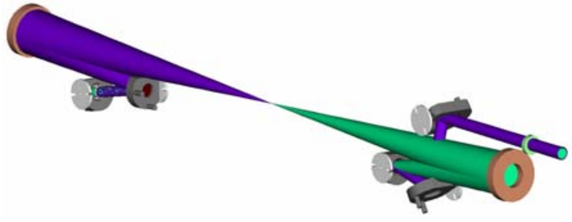
- Unclear until MC studies are done
  - what kind of detector is required
  - What is really the physics reach



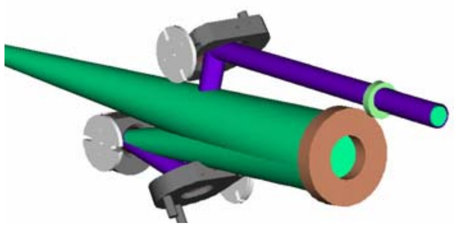
Is the technology ready for a photon collider?



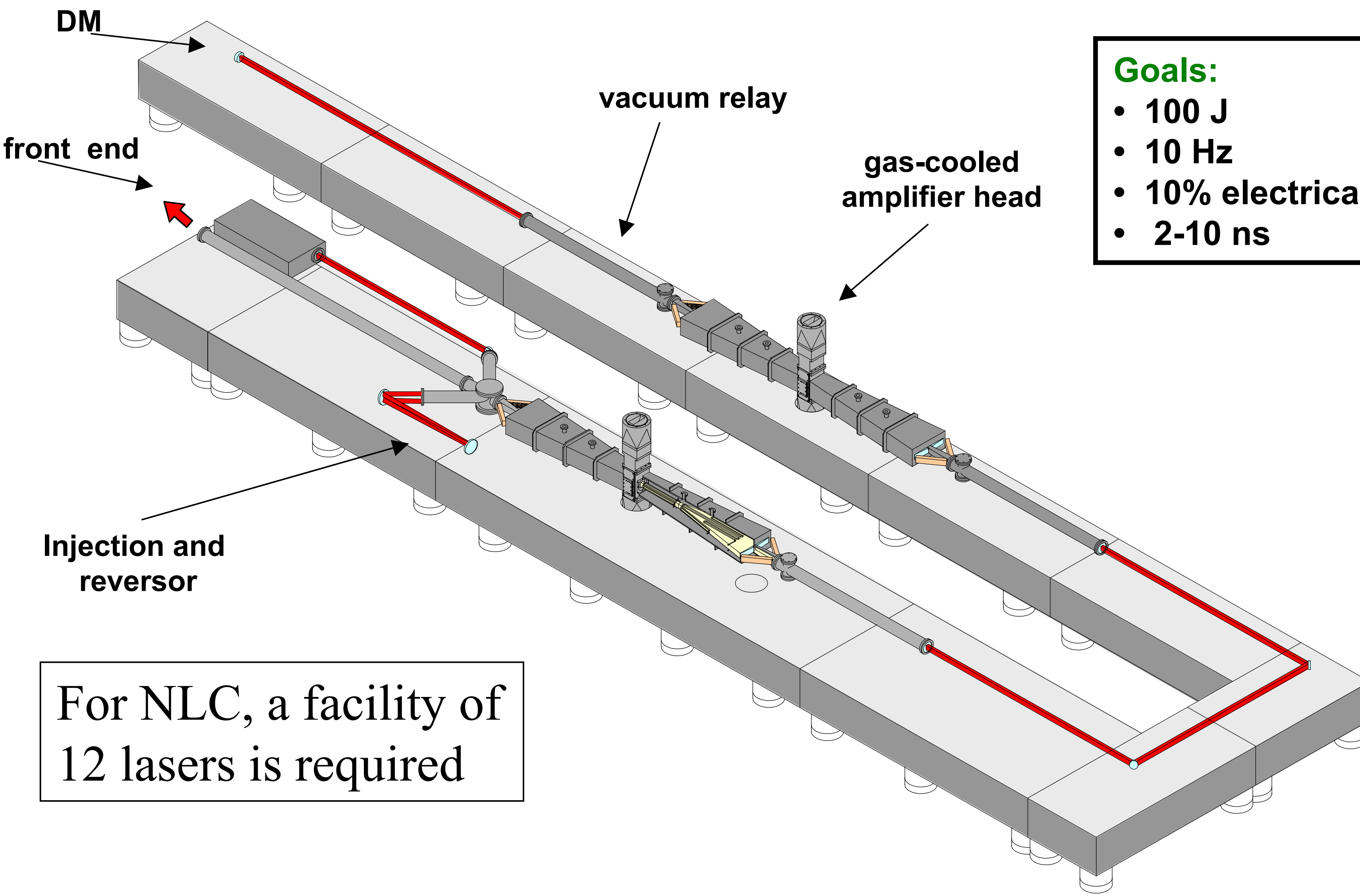




The layout of the interaction region optics has been designed, simulated and prototyped

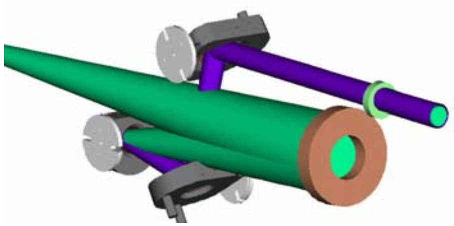


Mercury is designed to produce 100J pulses, the low energy experiment will require only 5J pulses

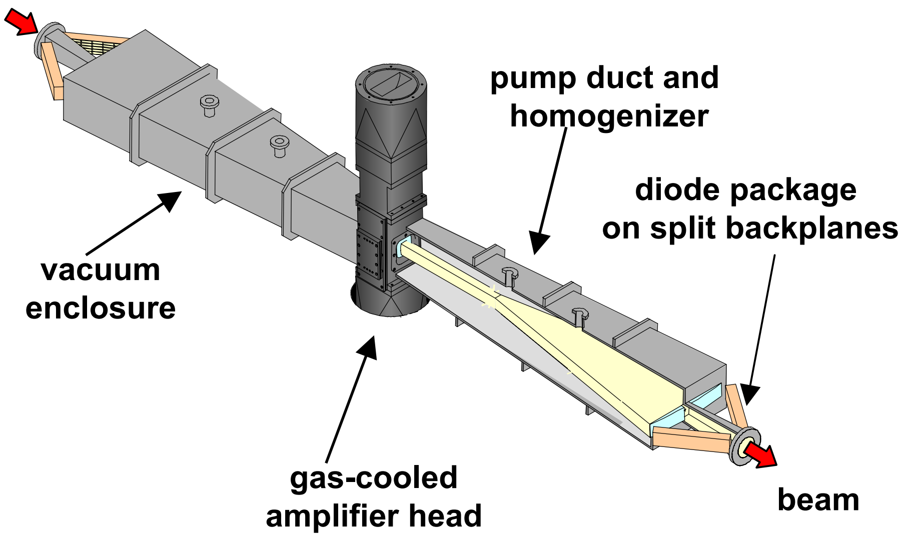


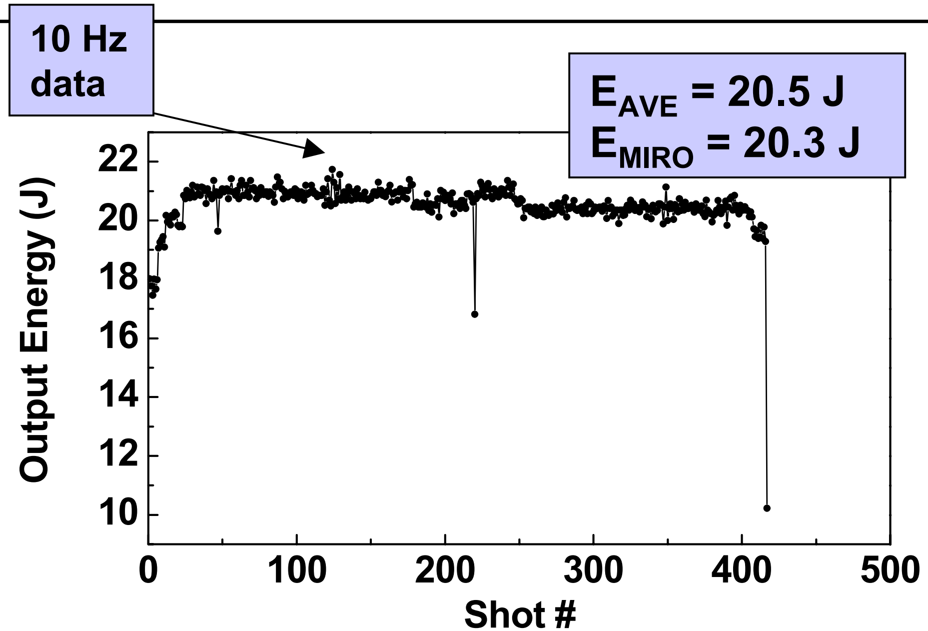
Goals:
- 100 J
- 10 Hz
- 10% electrical
- 2-10 ns

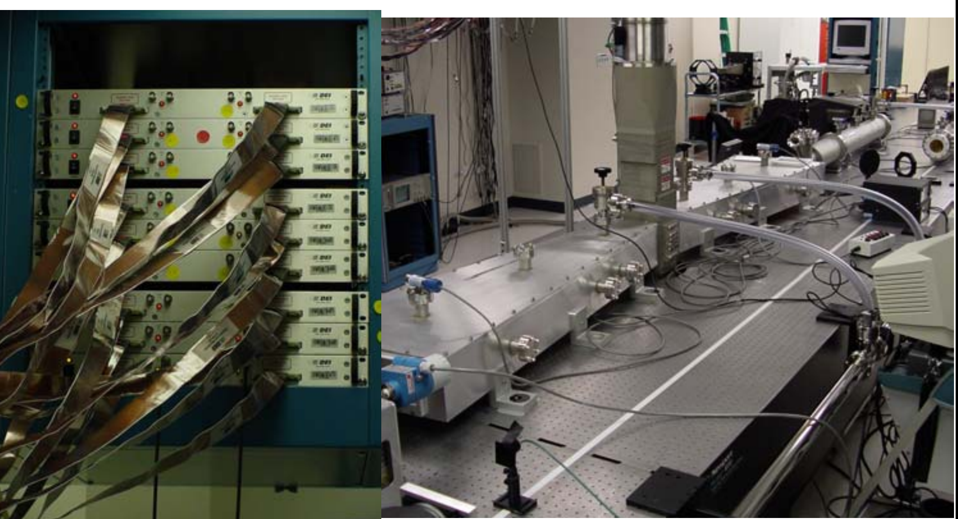
For NLC, a facility of 12 lasers is required



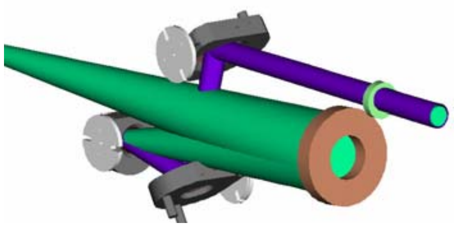
MERCURY prototype can already drive a photon collider experiment at SLC





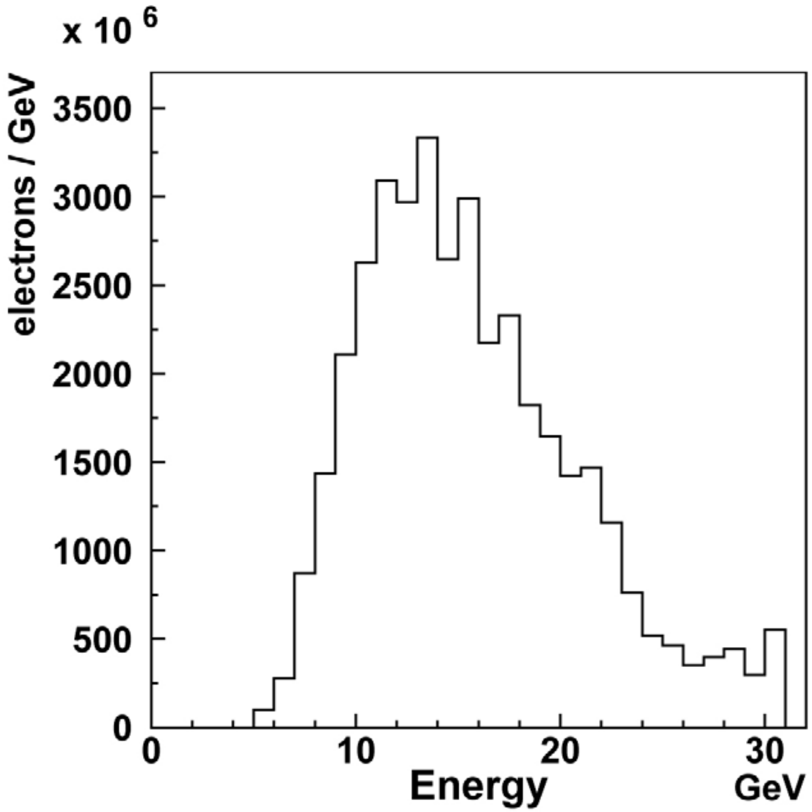


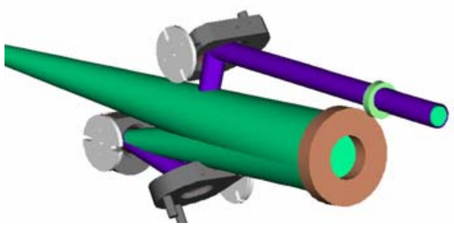
- Single head MERCURY produces 20J x 10Hz
  - Equivalent to 5J x 40Hz
- 3 Single head MERCURYs can produce 120Hz
- Cost $30M (?)



Some modifications required for the SLC extraction line

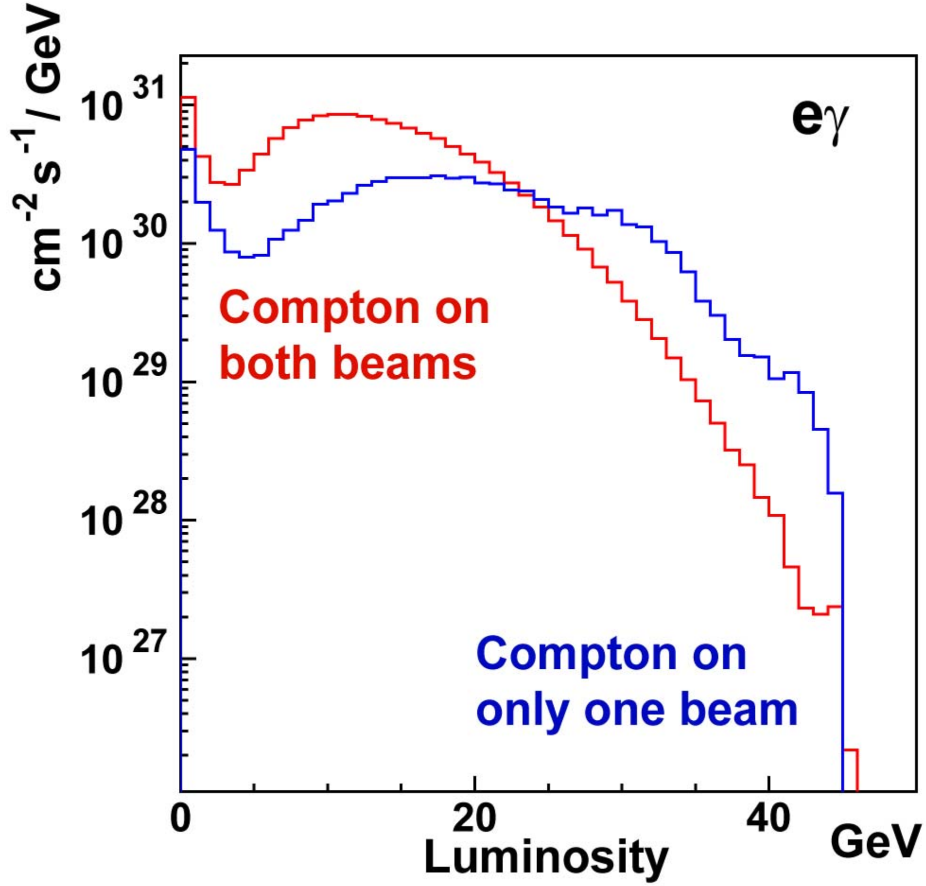
- Electron beam after Compton scattering
  - Mean 15 GeV
  - Spread 4 GeV
- Current extraction line cannot work
  - Photon beam with ½ the beam energy hits beamline components
  - Off-energy electrons are lost in the SC quads and cause a quench
    - Not to mention radiation and backgrounds
- NLC extraction line solution would have to be implemented
  - Crossing angle to separate incoming and outgoing beamlines
  - Field free extraction line
  - Straight line path to a beam dump

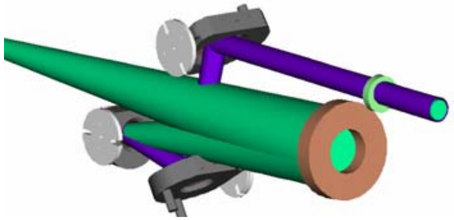




One side of the laser could be turned off to enhance the eγ events

- Total eγ luminosity goes down since there are fewer photons
- But,
  - More luminosity at higher center of mass
  - Well defined initial electron state





Conclusions

- A photon collider experiment at low energy is technically feasible
- Can the achievable luminosity and experimental conditions justify a physics program?