Fixed Target Option at the ILC

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BDS KOM, October 12, 2007

With contributions from R.Appleby, S.Mtingwa, H.White

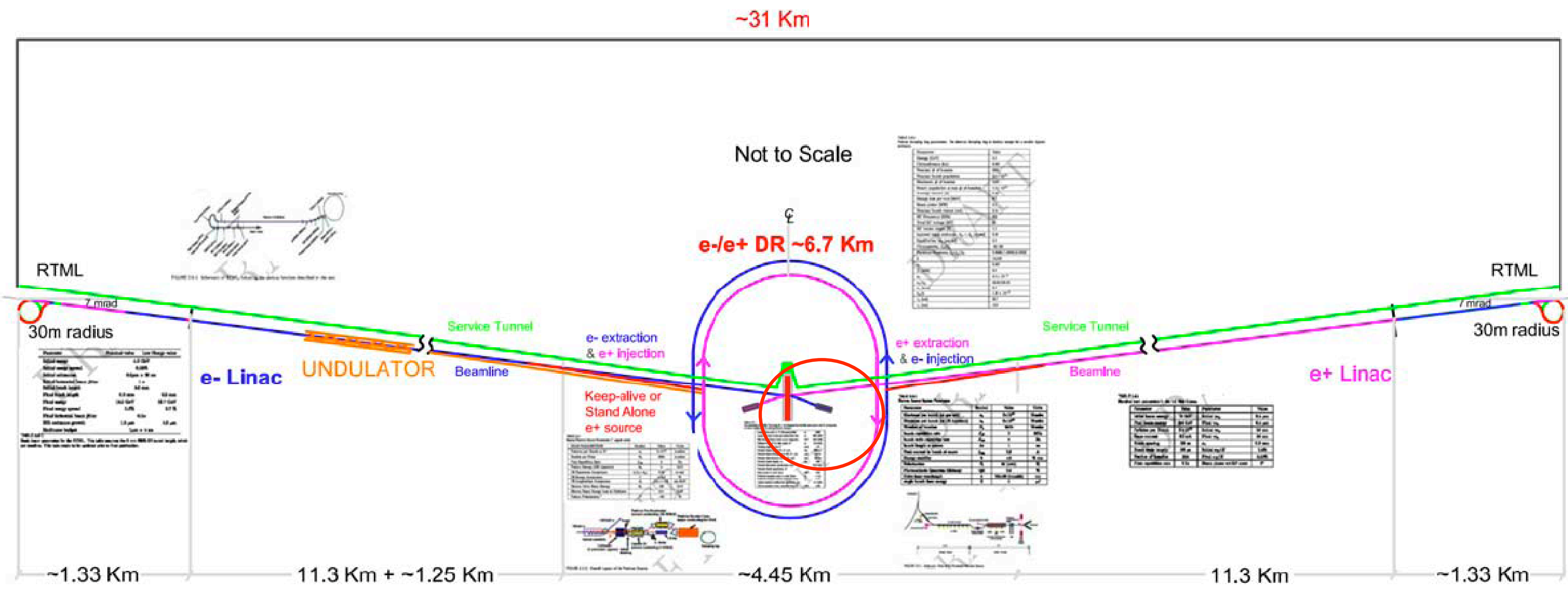
- ✓ Selected physics opportunities
- ✓ Facilities and hardware needs

ILC Centered Around Colliding Beams…..

But after collision, 11 MW of spent beams must be extracted to a beam dump, reasonably far away (~200 m), without too much loss, which creates background.

Those spent beams can also be used for:

- A Fixed Target Facility
- Test Beam Facility (Detector development)



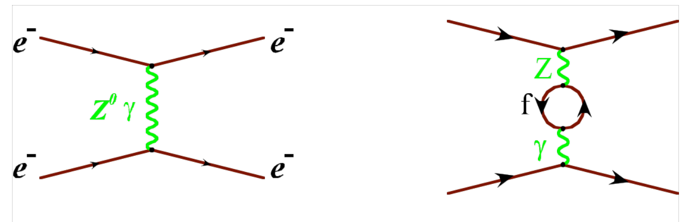
Schematic Layout - Plan View of the 500 GeV Machine

Opportunities for FT Facility

- Electroweak Physics
  - Polarized Møller scattering ($\sin^2\theta_W$)
  - Mixing, CPV in charm sector
  - Precision tau physics, lepton-flavor violation
- Nucleon spin structure
  - evolution and low *x* physics
  - sea and gluon polarization
  - Open charm production (gluon polarization)
- Test beams… or new ideas
- The key is to think about it as a facility
  - Broader physics community, complementary physics and R&D opportunities

Polarized Møller Scattering

Precise handle on new physics through running of $\sin^2\theta_W$



Benchmark:

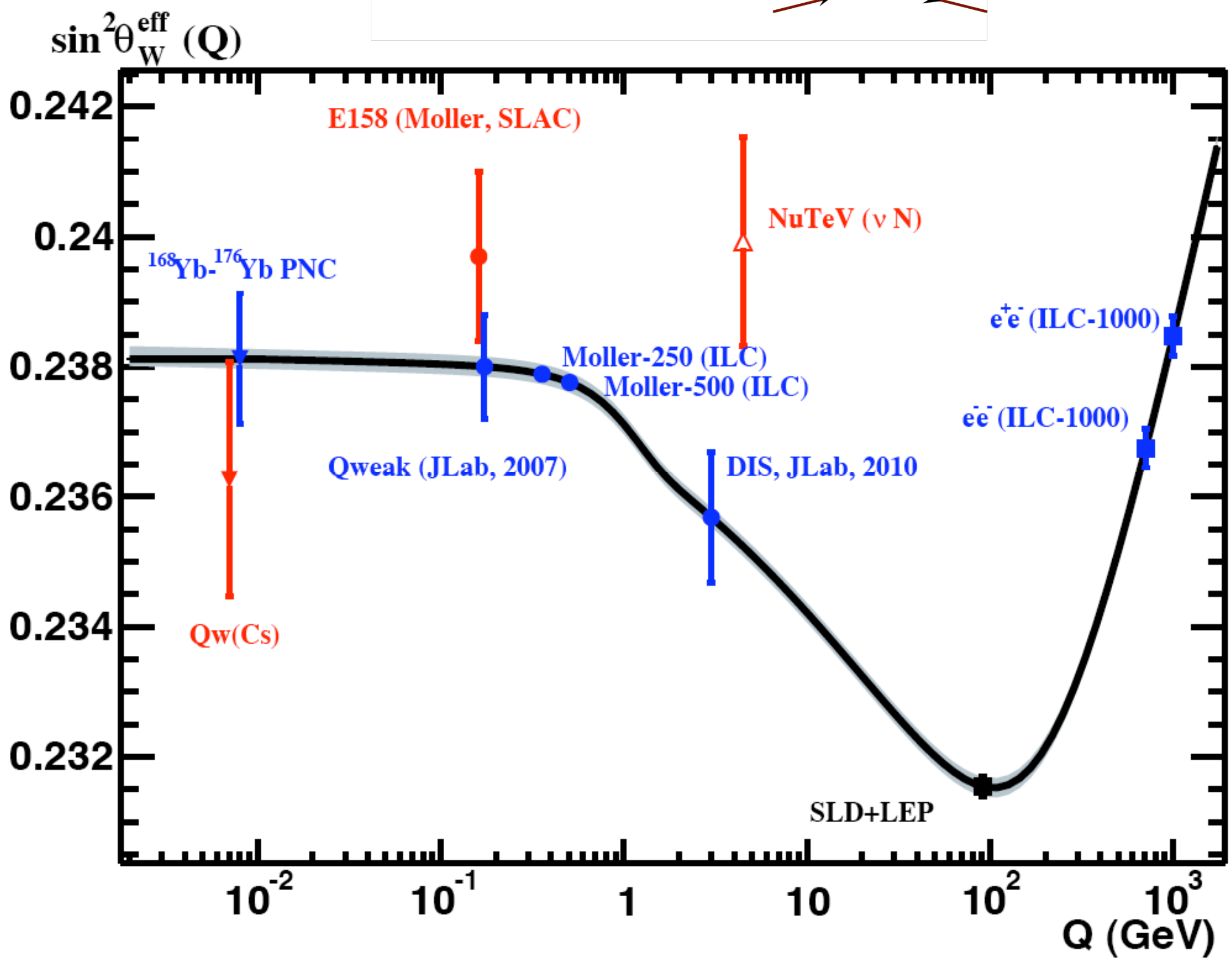
- $\sigma(\sin^2\theta_W)=0.0003$ from Z pole

E158:

$\sigma(\sin^2\theta_W)=0.00013$

Potential at ILC:

- $\sigma(\sin^2\theta_W)=0.00006$ from GigaZ
- $\sigma(\sin^2\theta_W)=0.00015$ from collider e^+e^- and e^-e^-
- $\sigma(\sin^2\theta_W)<0.0001$ at each energy from LC Møller



Møller Scattering at a LC

- Unique kinematics of Møller scattering
  - $\sigma \sim 1/E$ (vs. $1/E^2$ for inelastic electron scattering in general), $A_{LR} \sim E$, but figure of merit is: $A^2\sigma \sim E$.
- Consequence: The statistical error decreases with increasing beam energy!
- With 100% Polarization assumed:

Experiment	E158	LC500	LC1000
E (GeV)	48	250	500
A_{LR} (10^{-7})	3.2	16.1	32.2
Stat. error advantage	1	5.4	10.8

Achievable Precision

- SLD Data: δP=0.5% (T. Abe, Osaka 2000):

$$\sin^2\theta_W(M^2_Z) = 0.23098 \pm 0.00026$$

- E-158 with >80% polarization, (4-6)·10^{11} e^-/pulse train @ 60-120 Hz, 6 month, 90% efficiency, δP=4%

$$\sigma(\sin^2\theta_W) \text{ @ average 46.4 GeV} = 0.0013$$

- ILC-Møller Projection: 90% polarization, 1.4*10^{14} e^-/sec (50% of linac current) 1 Snowmass Year, 32% eff, δP=0.3%

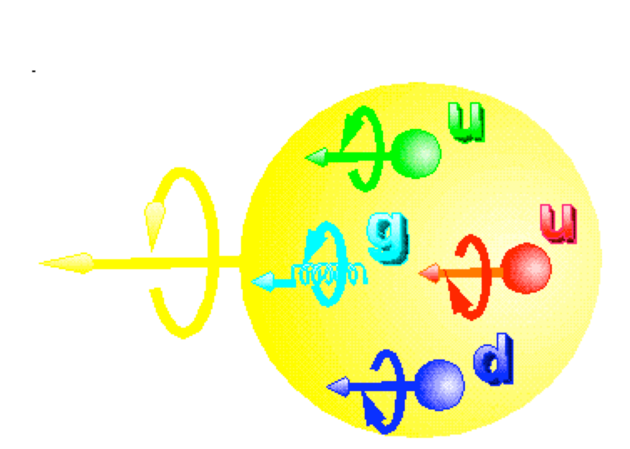
$$\sigma(\sin^2\theta_W) \text{ @ 250 GeV} = 0.000092$$
$$\sigma(\sin^2\theta_W) \text{ @ 500 GeV} = 0.000082$$

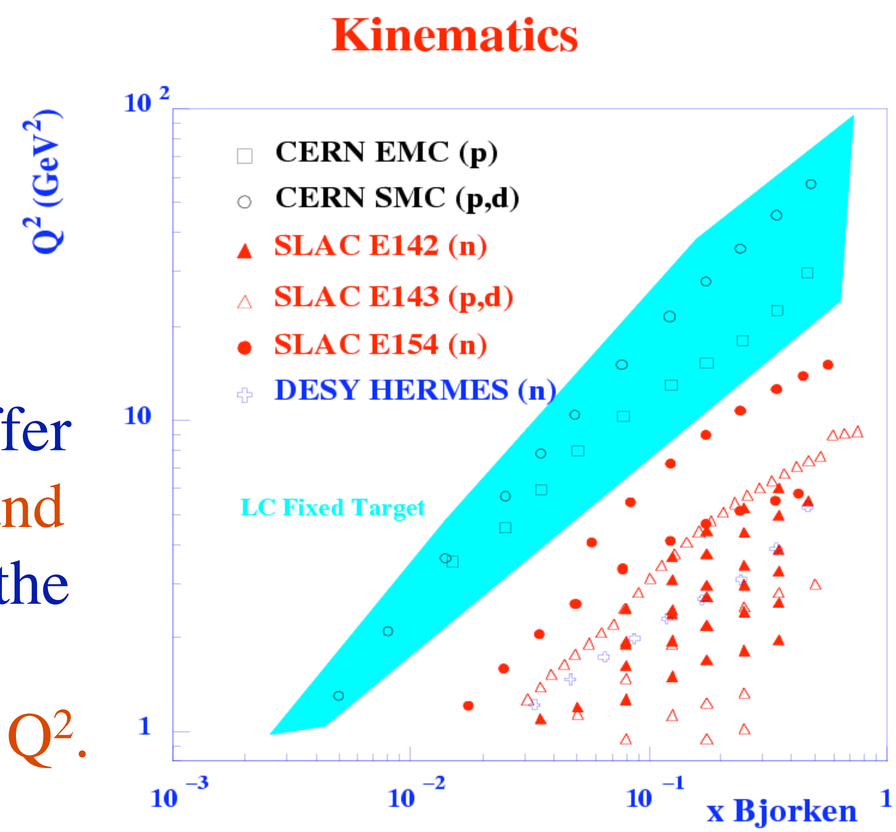
Compositeness Scale sensitivity: 60 TeV

Z' sensitivity: 3 TeV

Perfect tuneup experiment for the ILC

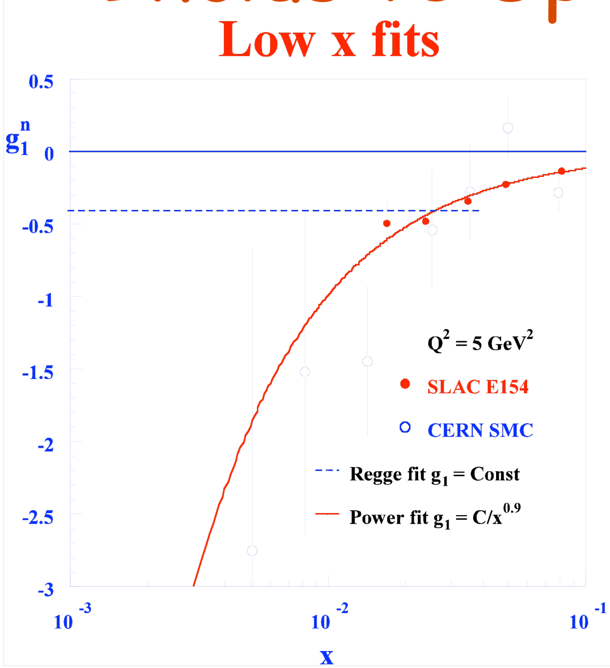
Nucleon Spin Structure

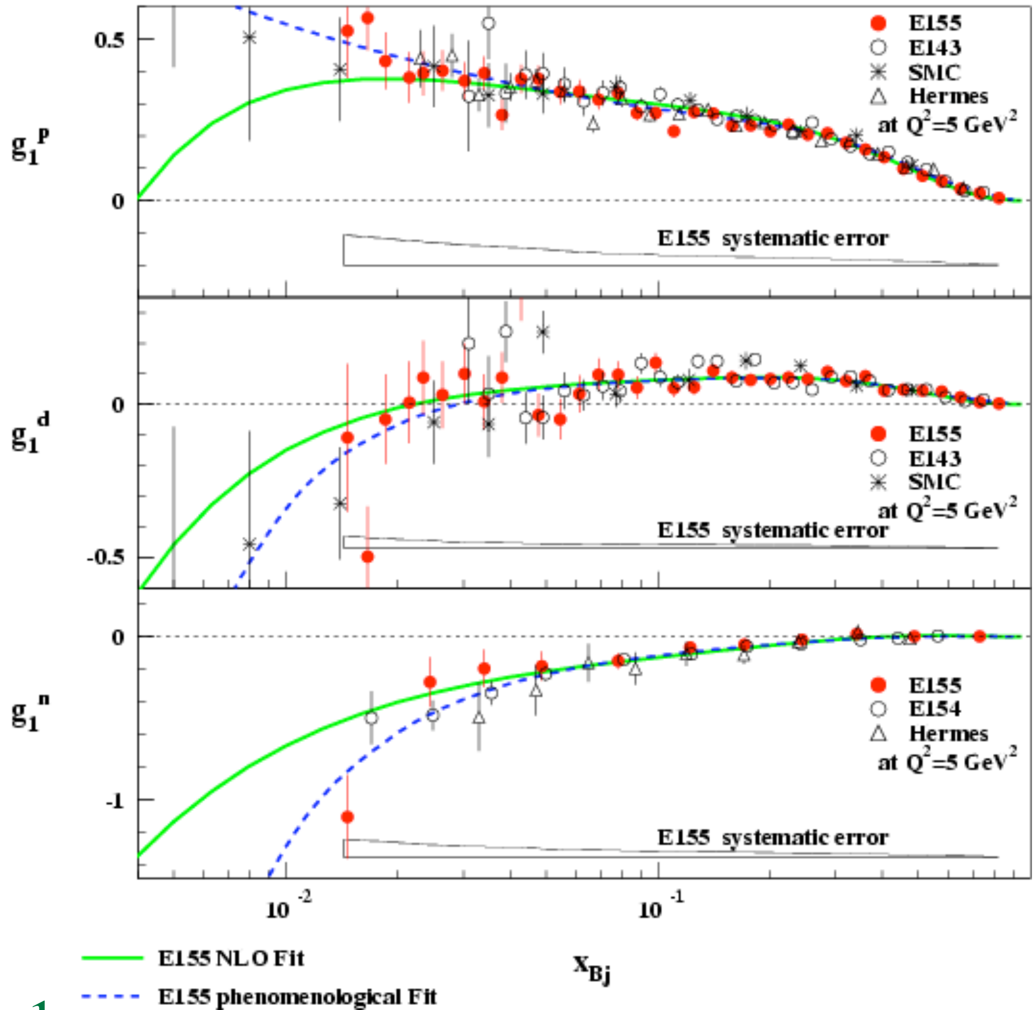




Lepton based Linear Colliders offer unique opportunities for virtual and real photon experiments to push the limits with good statistics by one order in magnitude both in *x* and Q^2.

Inclusive Spin Structure Functions





Qualitative understanding of pQCD in spin sector

Valence distributions well-constrained

Next: focus on sea and gluons

Current state of the art: σ(ΔG)~1

Typical Experiments at Polarized Lepton Facilities

Facility/Experiment	E_{CM}[GeV]	L [cm^{-2} sec^{-1}]
SLAC	5-10	$<5*10^{38}$
HERMES	7	$2*10^{31}$
COMPASS	20	$5*10^{32}$
ELFE@CERN	7	$5*10^{35}$
TESLA-N	22	$8*10^{34}$
ILC-FT	22 – 31	$\sim5*10^{38}$

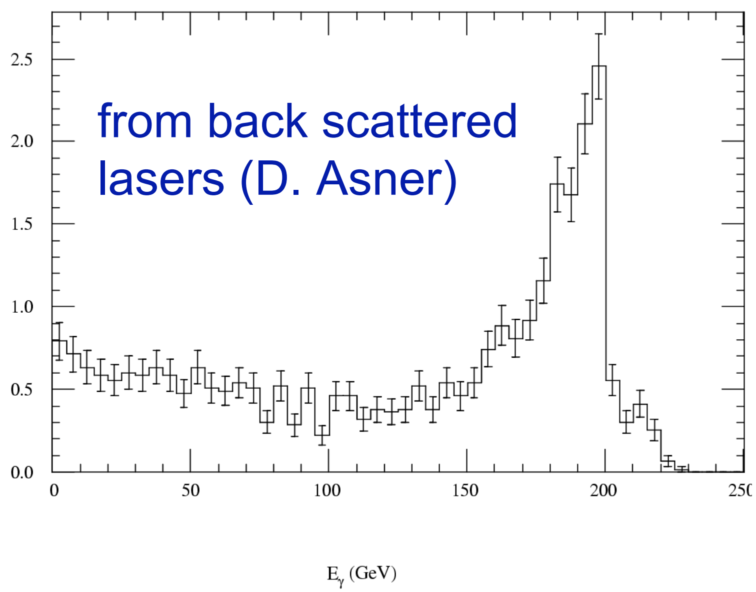
➔ Can measure ΔG inclusively to ~0.1 in 1 Snowmass year

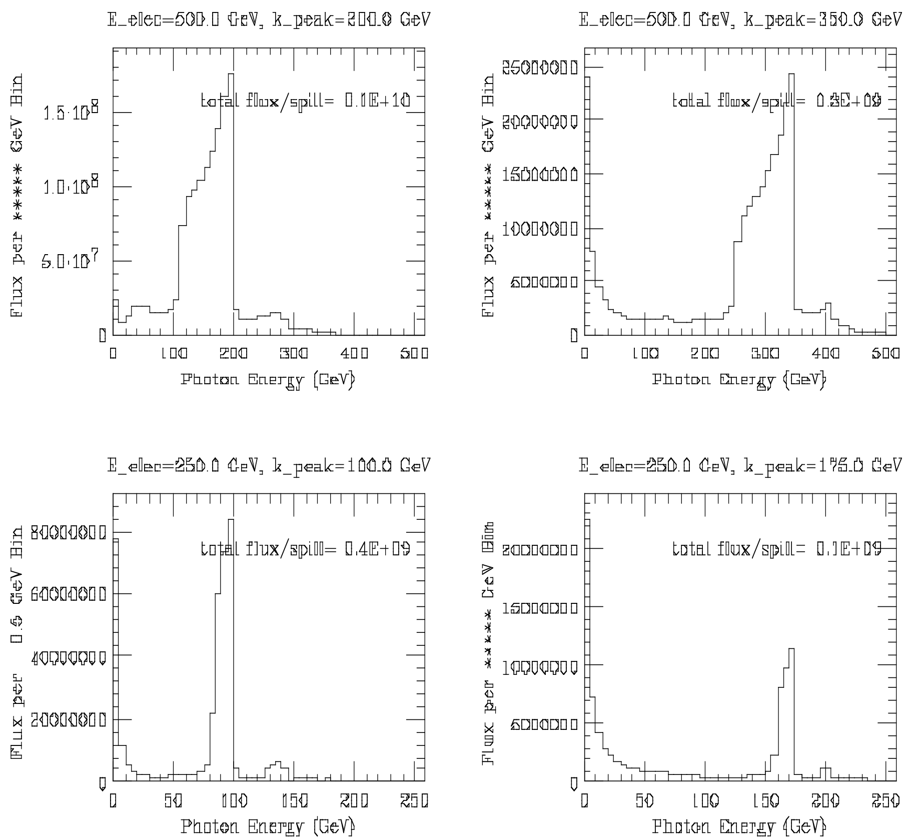
Polarized physics with real photons

Measure ΔG through open charm photoproduction (e.g. SLAC E161)

- back scattered lasers
- or coherent Bremsstrahlung

Yet to be optimized.

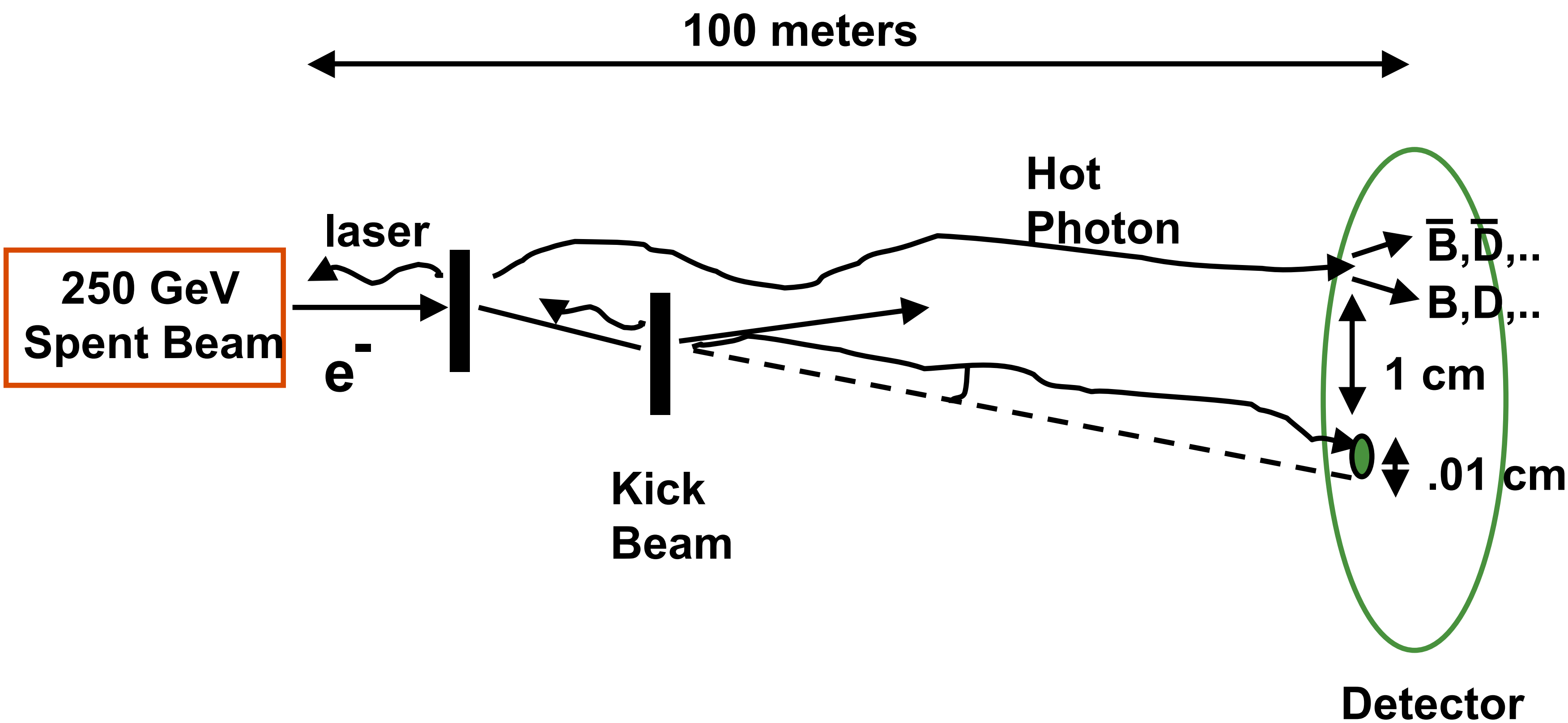




Coherent Bremsstrahlung Production from crystal (diamond) scattering, with 4 10^{+10} electrons incident, from a 0.0004 radiation length diamond. Calculations by P. Bosted

BACKGAMMON

Phys Rev Lett. 64, 1522 (1990) Mtingwa and Strikman



More Opportunities

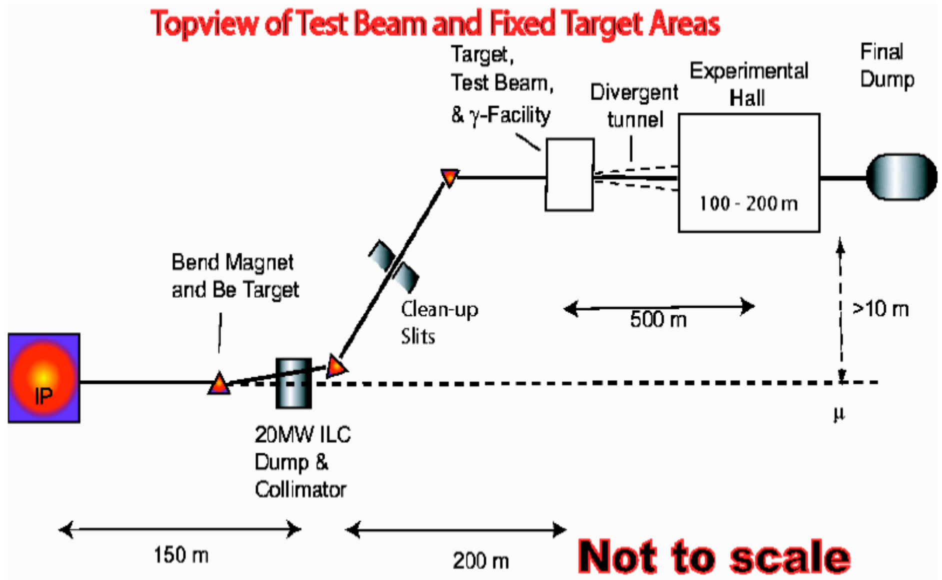
- Charm physics
  - Polarized (ΔG) and unpolarized (spectroscopy, CPV, rare decays: c.f. FOCUS)
- Tau physics
  - Michel parameters, LFV
- Secondary beams
  - E.g. as a test facility or for physics

Fixed Target Beams and BDS

For FT option to be feasible, FT beamline needs to be integrated into BDS

Test Beams and Fixed Target beams must eliminate the tail to be useful.

Zero net bend to avoid g-2 precession



From arXiv:physics/0101070

Possible to keep ~50% of beam charge within ΔE/E<1%

Depolarization less than 1%

Use same beamline for test beams (e.g. low-rate hadron production)

Need help with detailed beamline design and simulations, costs

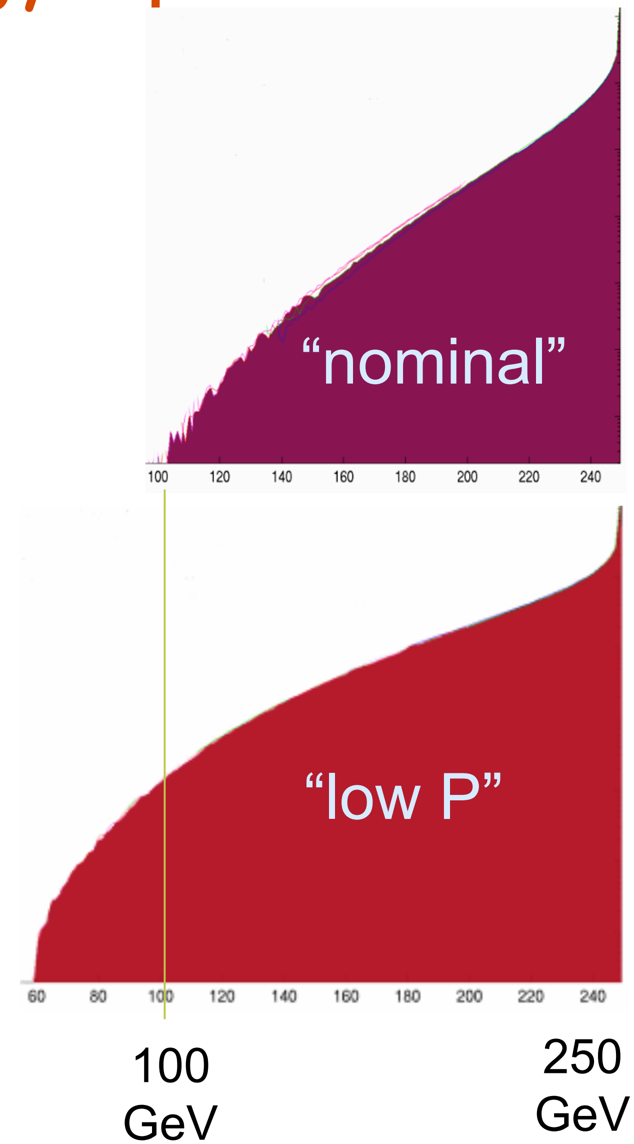
Disrupted Beam: Energy Spread

Energy Collimation:

Possible, needs design effort.

- Long tails of particles.
- For $\Delta E/E$ =1%, 1.6 MW have to be collimated.

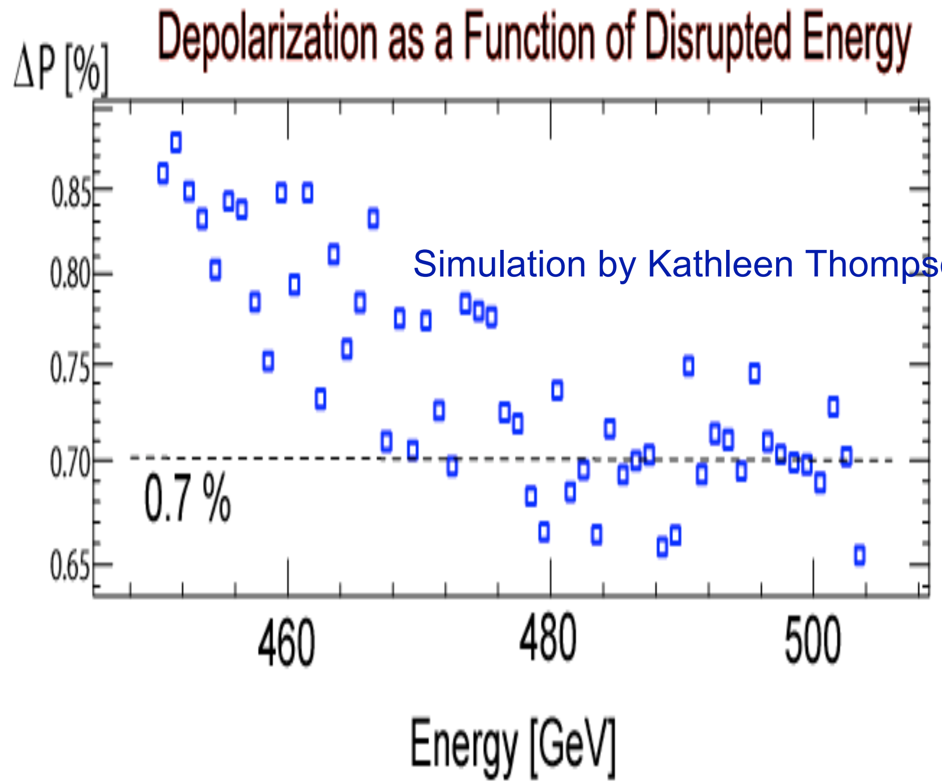
At higher energy, the beams at collision get smaller, and the beamstrahlung and coherent pair production effects get more severe.



Disrupted Beam: De-Polarization?

<u>Depolarization</u>

E_0/GeV	ΔP/%
500	0.3
1000	0.7
1500	0.9

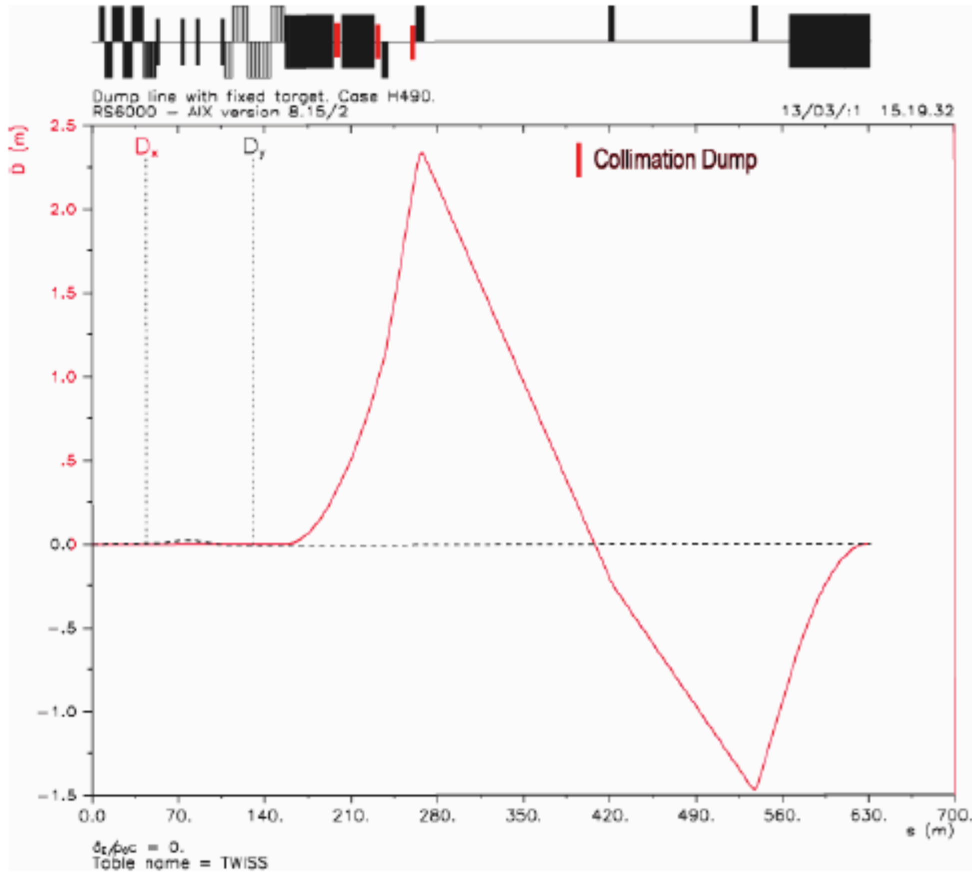


Simulation by Kathleen Thompson

No problem for the physics, but P must be measured near the target.

Yuri Nosochkov's Design

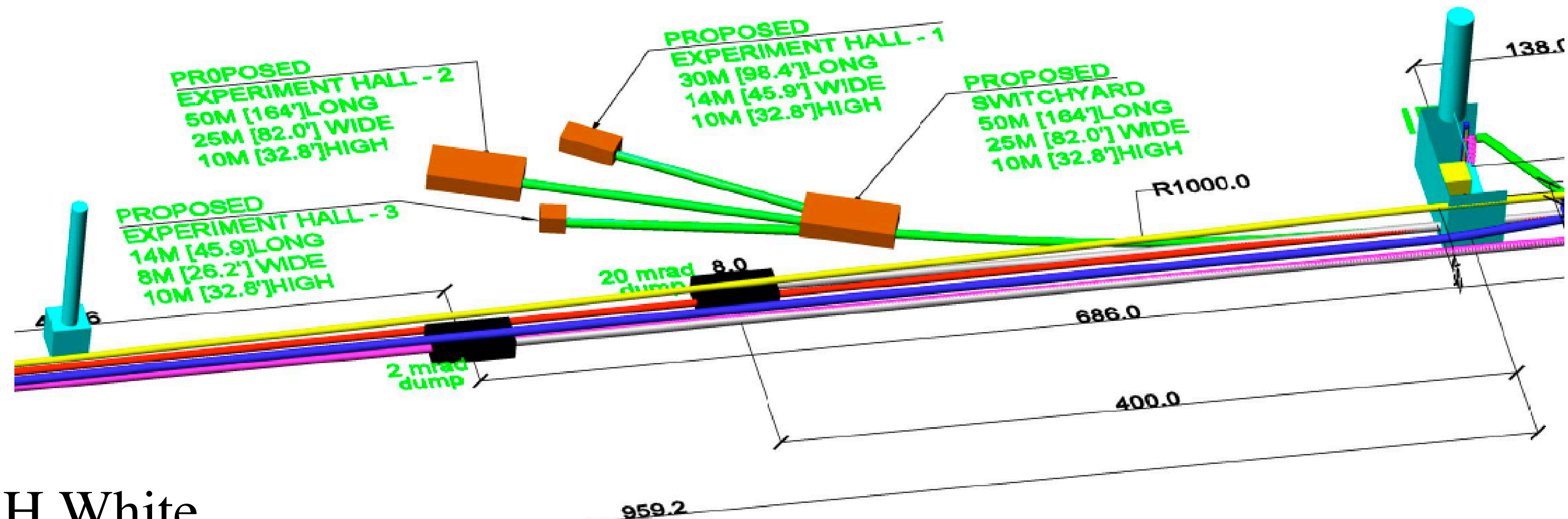
- Design has three separate beam dumps (red lines in plot) at progressively higher dispersion. The first dump is the conventional dump needed in any case.
- Each beam dump has a through-pipe which collimates the fixed target beam in energy.
- The final energy definition **is ±0.5%** (HWHM).



Need more detailed work and integration with BDS

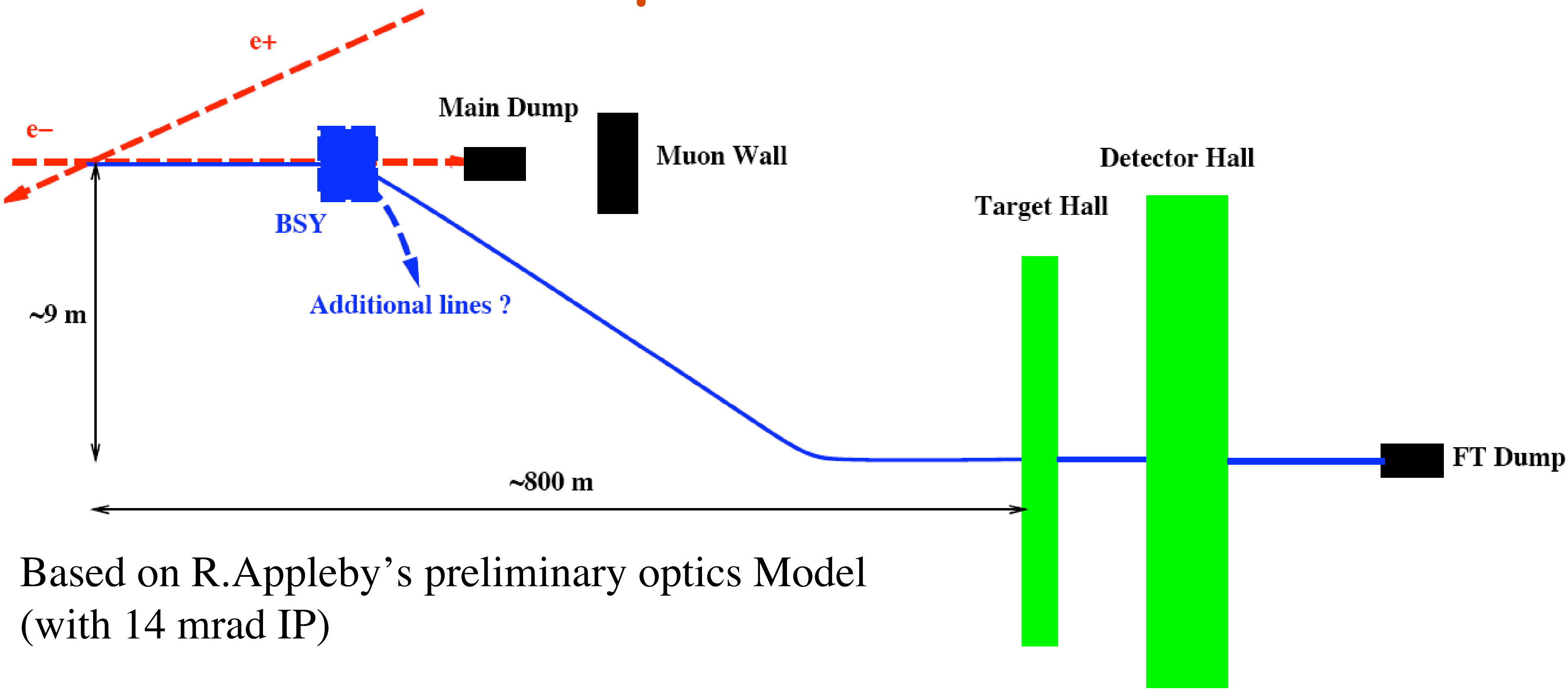
R.Appleby (in progress)

Conceptual View



H.White
(based on pre-RDR BDS)

Conceptual View II



Based on R.Appleby's preliminary optics Model (with 14 mrad IP)

- Target Hall: ~50x10x10 m^3, accommodate targets, Compton IP, energy spectrometer
- Tunnel (large enough to accommodate IP magnets)
- Detector Hall: 100x25x10 m^3, spectrometers and detectors
- Possible additional lines (upgrade ?)

Hardware, CF Needs

- Tunnel and beamline (~1 km)
  - Successive collimation (2-3 stations)
  - Zero net angle, dispersion free at target
  - Beam instrumentation: cavity BPMs, energy spectrometer, laserwire, Compton polarimeter
- Target hall
  - Sized to accommodate cryogenic targets, polarimetry
- Detector Hall
  - Can be separated from target hall (forward scattering)
  - Sized to accommodate spectrometers from ~1 mrad to 2-3^{o} angles
- Infrastructure
  - LHe, vacuum, water, HVAC, reference RF, DAQ/timing systems, cranes, access shafts/tunnels

Conclusions

- A wide range of physics opportunities
  - Electroweak measurements complementary to collider program
  - QCD
  - Rare decays, symmetry violations
  - Test beams
- Community largely complementary to e+e-
  - Nuclear, flavor physics. They will be looking for things to do (post JLab, RHIC). Good for ILC to build support in this community
  - Should consider this as an inexpensive (?) facility
- Design in very early stages
  - Need help