Fixed Target Physics
with Polarized Electrons at ILC

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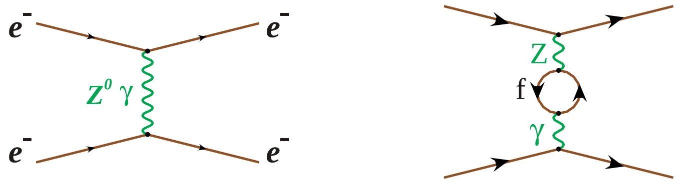
- ✓ Selected physics opportunities
  - -Weak mixing angle at "low" Q^2
  - - Spin structure functions
- ✓ Technical Details

Opportunities for FT Facility

- Electroweak Physics
  - Polarized Møller scattering ($\sin^2\theta_W$)
  - Mixing, CPV in charm sector (S.Mtingwa,W.Johns)
  - Tau physics, LPF (S.Kanemura)
- Nucleon spin structure
  - evolution and low *x* physics
  - sea and gluon polarization
  - Open charm production (gluon polarization)
- Test beams… or new ideas (S.Mtingwa) ?
- The key is to think about it as a facility
  - ➔ *If you build it, they will come*

Polarized Møller Scattering

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



Benchmark:

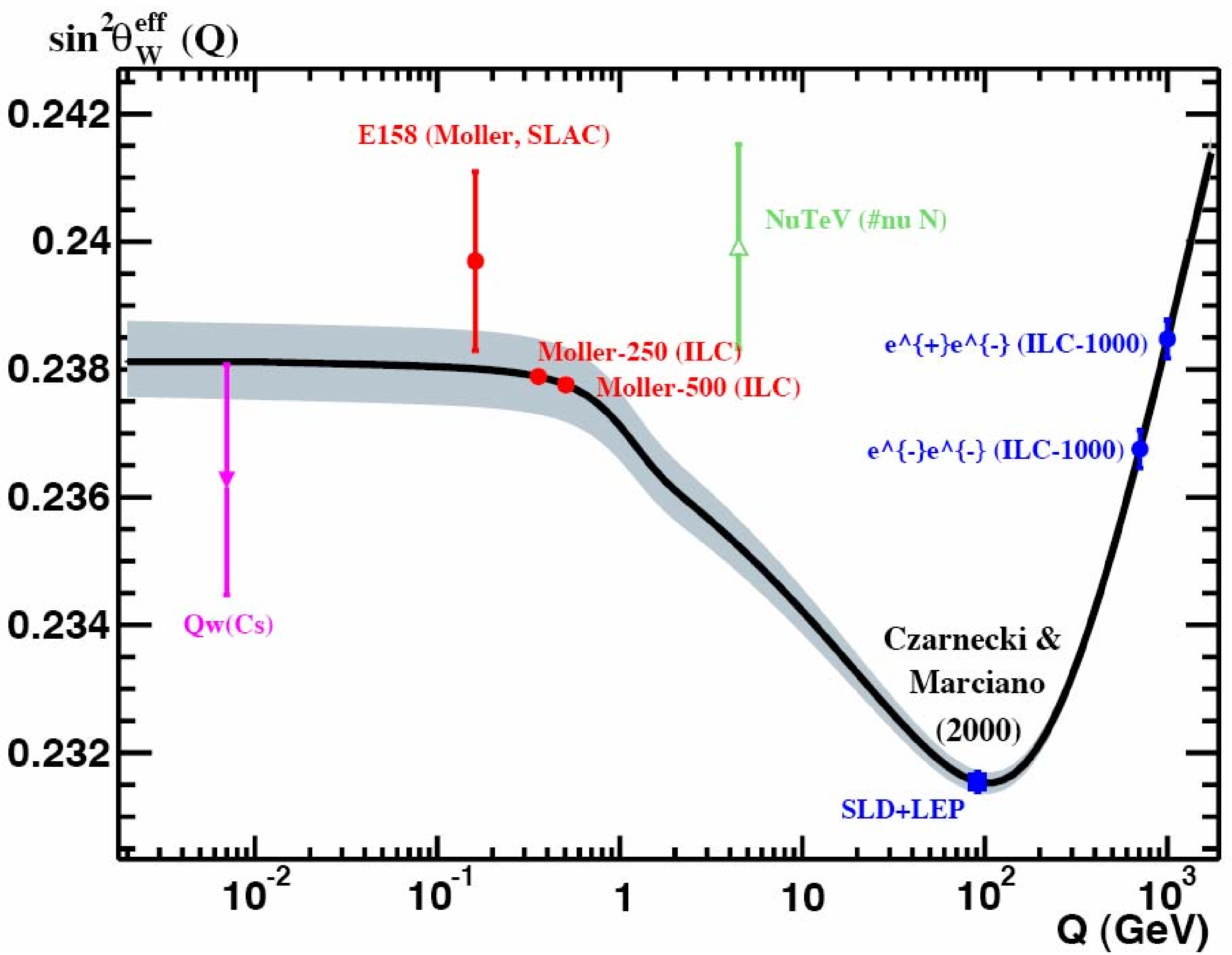
- $\sigma(\sin^2\theta_W)=0.0003$ from Z pole

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



Prototype: E158 at SLAC

- Scattering of polarized 50 GeV electrons off unpolarized atomic electrons
- Measure $A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = -A_{LR}$
- Small tree-level asymmetry

$$A_{PV} = -mE\frac{G_F}{\sqrt{2\pi\alpha}}\frac{16\sin^2\Theta}{(3+\cos^2\Theta)^2}\left(\frac{1}{4} - \sin^2\theta_W\right)$$

- At tree level, $A_{PV} \approx$ 280 parts per billion
- Raw asymmetry about 140 ppb
  - Measure it with precision of ~10%
  - Most precise to date low energy measurement of $\sin\theta_W$ with $\sigma(\sin^2\theta_W)=0.0013$

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%

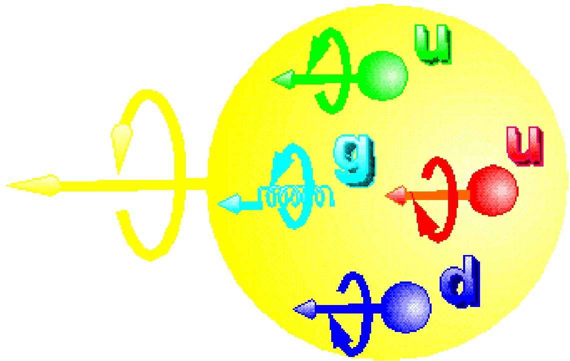
$$\sigma(\sin^2\theta_W) \text{ @ 250 GeV} = 0.000092$$
$$\sigma(\sin^2\theta_W) \text{ @ 500 GeV} = 0.000082$$

Limits on Compositeness Scale: 60 TeV

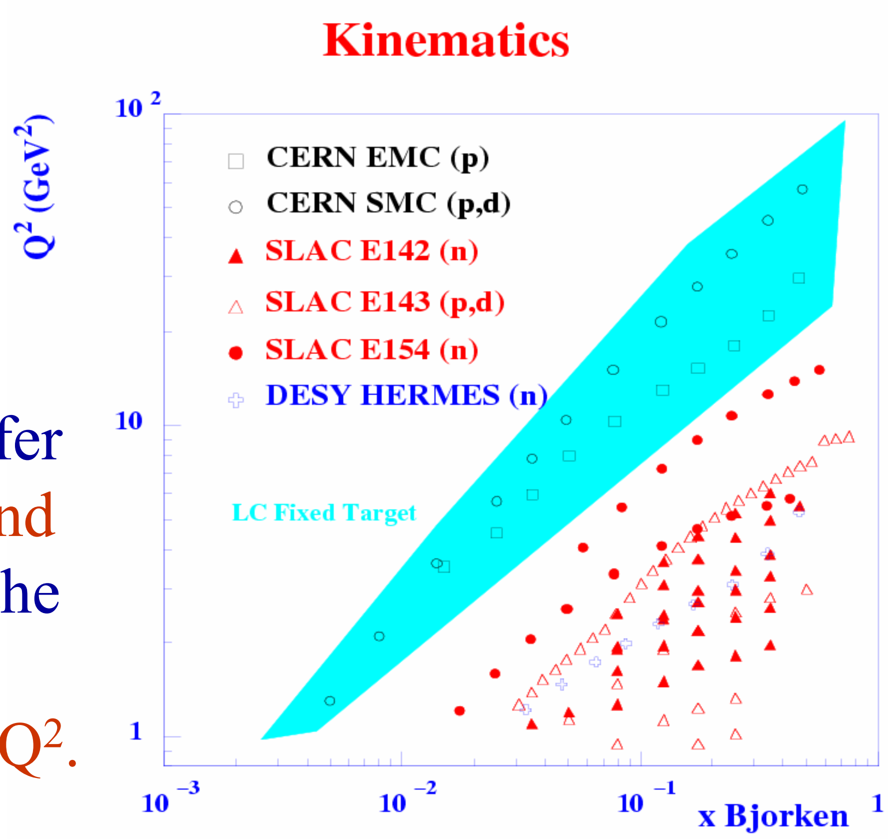
Limits on Z': 3 TeV

Perfect tuneup experiment for the ILC

Nucleon Spin Structure

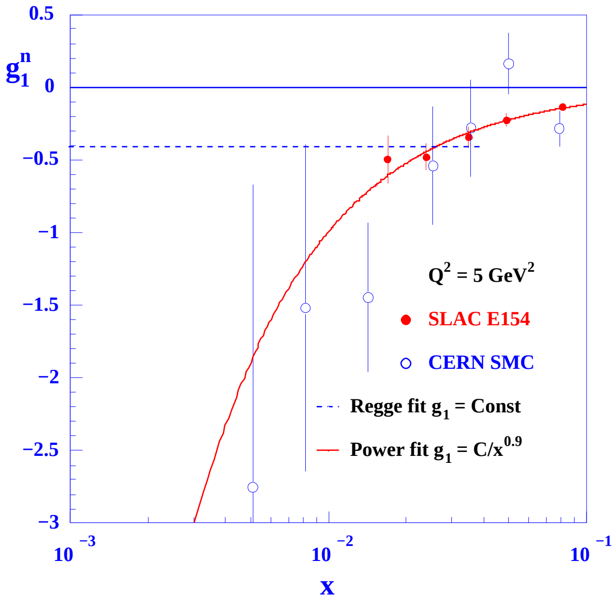


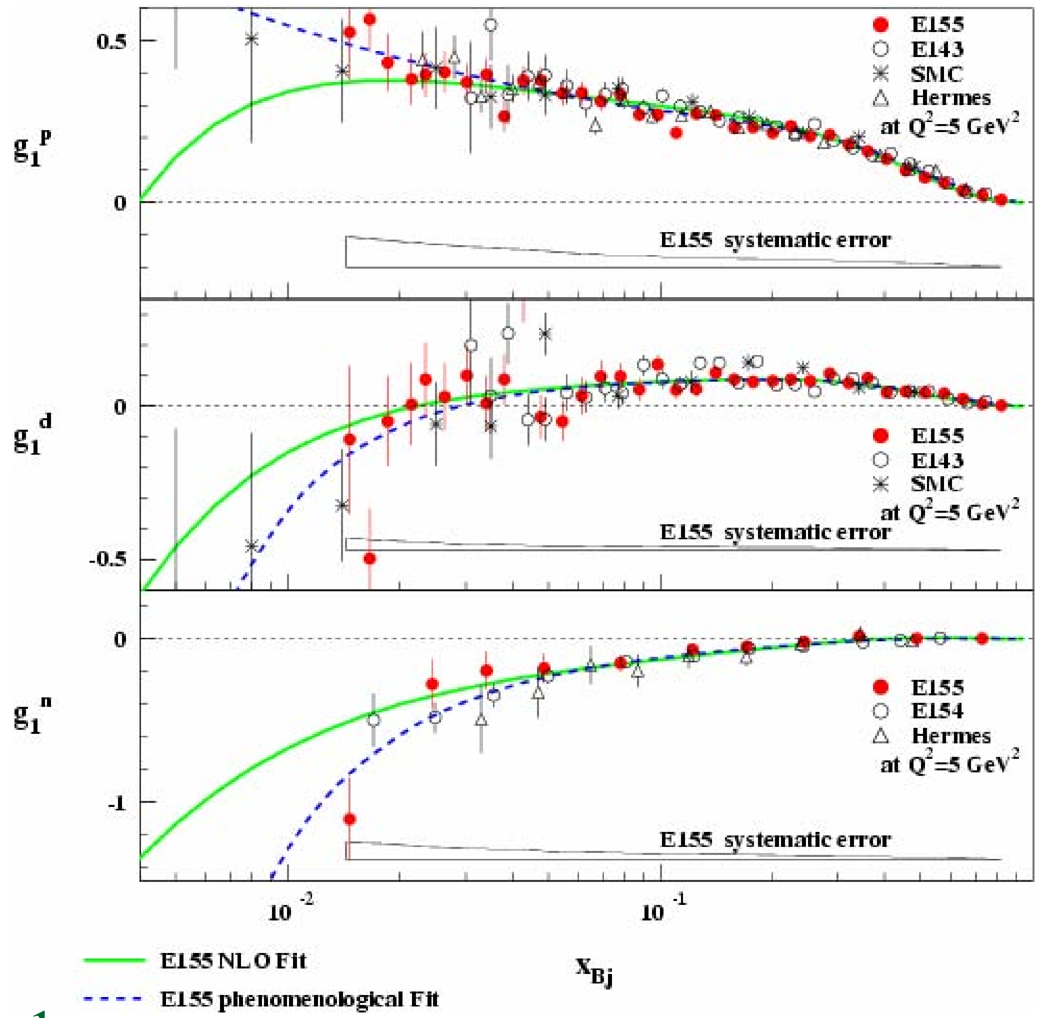
Lepton based Linear Colliders offer unique opportunities for virtual and real photon experiments to push the limits with good statistics by one order in magnitude both in *x* and Q^2.



Inclusive Spin Structure Functions

Low x fits





Qualitative understanding of pQCD in spin sector

Valence distributions well-constrained

Next: focus on sea and gluons

Current state of the art: $\sigma(\Delta G)\sim 1$

Typical Experiments at Polarized Lepton Facilities

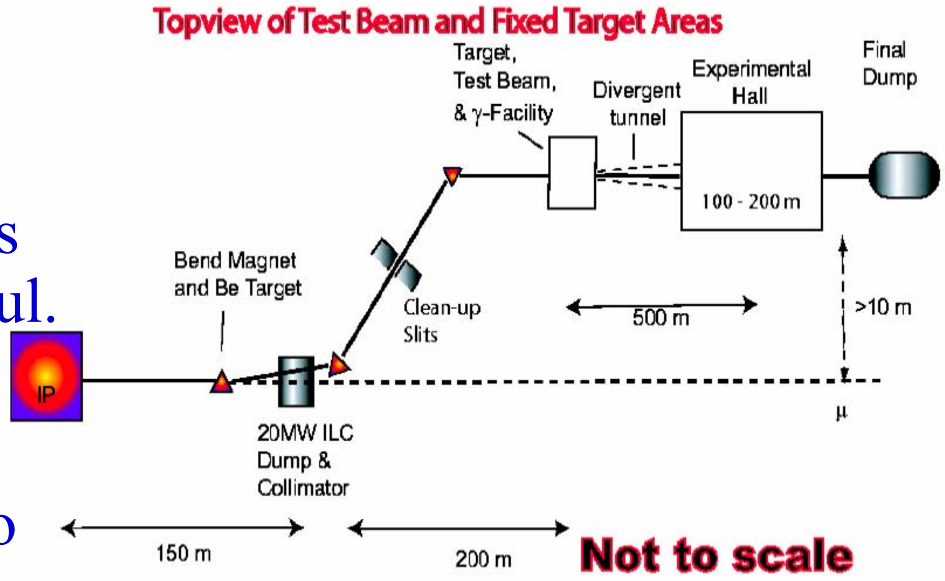
Facility/Experiment	E_{CM}[GeV]	L [cm^{-2} sec^{-1}]
SLAC	5-10	$<5*10^{38}$
HERMES	7	$2*10^{31}$
COMPASS	20	$5*10^{32}$
ELFE@CERN	7	$5*10^{35}$
TESLA-N	22	$8*10^{34}$
ILC-FT	22 – 31	$\sim5*10^{38}$

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

Extraction Line, Test Beams, Fixed Target Beams….

….all 3 must be designed together

- Test Beams and Fixed Target beams must eliminate the tail to be useful.
- The extraction (dump) line must neutralize the tail, i.e., not allow background to be created close to the IP.



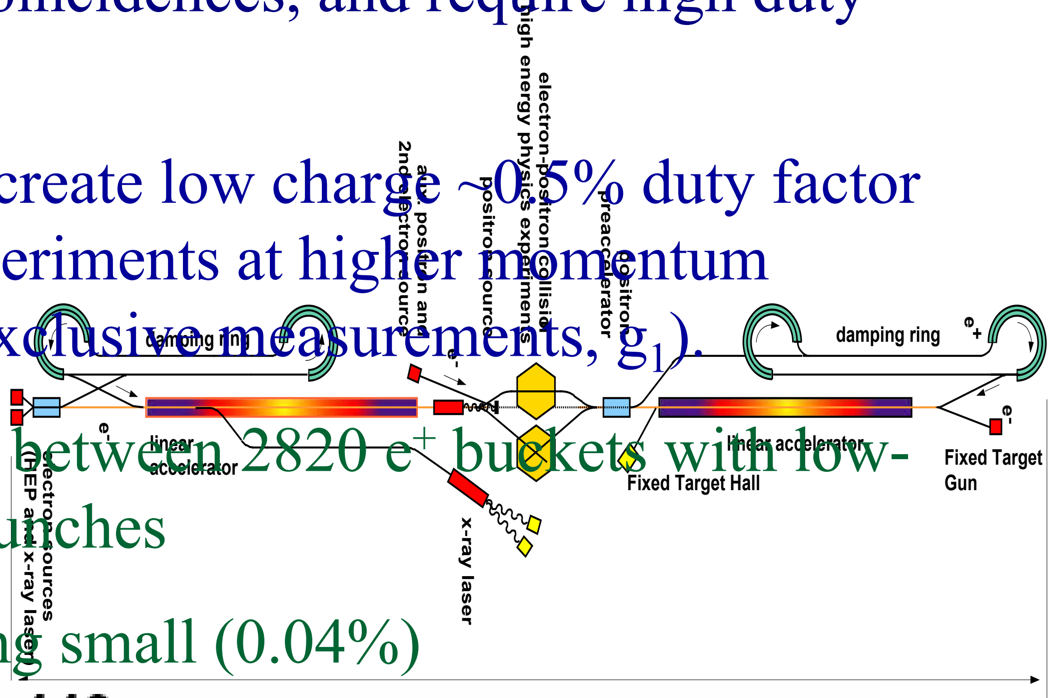
From arXiv:physics/0101070

- Zero net bend to avoid g-2 precession
  - 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

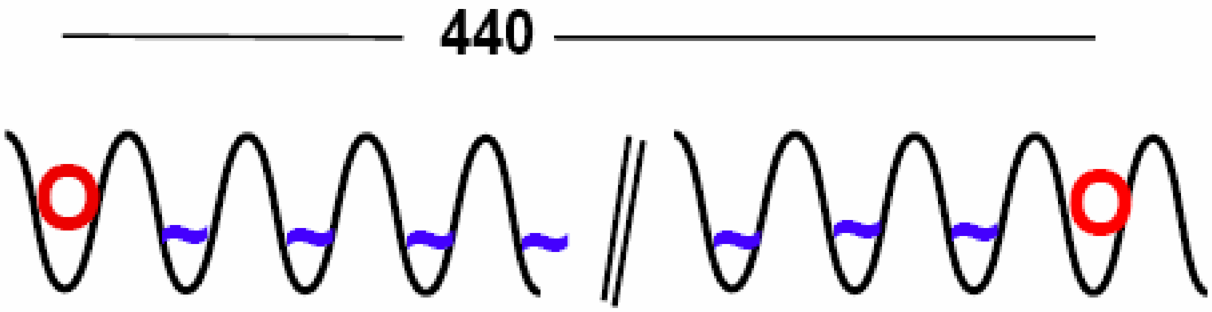
Different Approach: TESLA-N

Some experiments look for coincidences, and require high duty cycle

Idea: use the positron arm to create low charge ~0.5% duty factor beam for HERMES-style experiments at higher momentum transfer (transversely, semi-exclusive measurements, g_1).



- ✓ Fill empty 440 buckets between 2820 e^+ buckets with low-charge ($2*10^4$) electron bunches
- ✓ Additional beam loading small (0.04%)

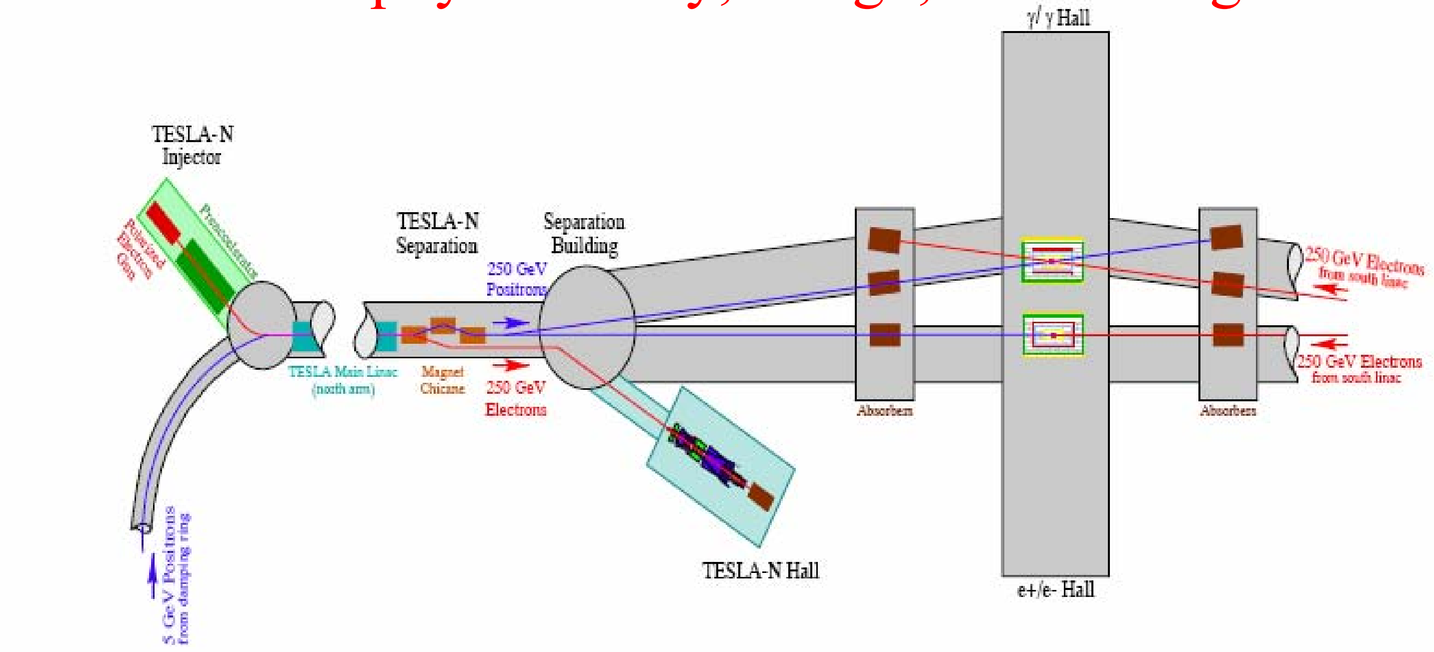


O e+ ~ eN

arXiv:hep-ph/0011299

TESLA-N

- Advantages: high duty cycle, high quality beam
  - Good for coincidence DIS, charm photoproduction experiments
  - Simpler beamline (splitter magnet to separate e+ from e-, smaller beam losses)
  - But can't do high-rate experiments this way
  - ➔ Detailed beam physics study, design, and costing needed



Conclusions

- A wide range of physics opportunities
  - Electroweak measurements complementary to collider program
  - QCD
  - Rare decays, symmetry violations
  - Test beams
- A range of options
  - High rate, moderate beam quality (spent beams): good for statistics-limited experiments. No technical show-stoppers
  - Low-rate, high beam quality (TESLA-N proposal): good for coincidence measurements
- Community largely orthogonal to e+e-
  - Nuclear, flavor physics. They will be looking for things to do (post JLab, RHIC, BTeV). Good for ILC to build support in this community
  - Should consider this as an inexpensive facility
  - Panofsky principle