2005 International Linear Collider Physics and Detector Workshop
and Second ILC Accelerator Workshop
Snowmass, Colorado, August 14-27, 2005

ILC FIXED TARGET INITIATIVE

"Overview, Challenges, Tasks, Ginzburg Proposals, τ Decay"

Global Group 6 Presentation

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Fixed Target Session

Snowmass 2005

OVERVIEW

- DETERMINE GOALS
- IDENTIFY IMPORTANT EXPERIMENTS
- SEEK COLLABORATORS
- CHALLENGES AND TASKS
- GINZBURG PROPOSALS
- THEORY OF τ DECAY

SUGGESTED GOALS

- Ascertain the level of interest within both the high energy and medium energy physics communities in operating fixed target experiments at the ILC.

- Provided that the interest is high, work to establish fixed target experimental halls at the end of the spent electron and positron beamlines, or a special electron beamline as proposed by TESLA-N.

- Provide high energy test beams for such uses as detector development and optimization of Compton backscattering for the ILC Gamma-Gamma Collider Option.

SUGGESTED GOALS
(cont'd)

- Determine and minimize the construction and operating costs associated with a fixed target program.
- Involve colleagues from developing countries in both sharing the costs of and playing leadership roles in fixed target experiments.
- Run successful fixed target experiments at the ILC that will test the Standard Model to unprecedented levels of precision.

IDENTIFY IMPORTANT EXPERIMENTS

- **High Precision Møller scattering**
  $e^- e^- \rightarrow e^- e^-$ — Y. Kolomensky
- Lepton Flavor Violation in
  $e^- N \rightarrow \tau^- + X$ — S. Kanemura
- Photoproduction of Charm & Bottom
  $\gamma p \rightarrow c \bar{c} (b \bar{b}) + X$ — **W. Johns, J. Cumulat**
- Precision Studies of Polarized τ Decay
  $\gamma p \rightarrow \tau^+ \tau^- + X$ — S. Mtingwa, M. Strikman

IDENTIFY IMPORTANT EXPERIMENTS (cont'd)

- Neutrino Factory I. Ginzburg
- Accelerator-Driven Subcritical Fission Reactor
  I. Ginzburg
- Gluon Contribution to Nucleon Spin Structure
- γ p -> to 3 jets

  Probes in a clean way the three quark component of the proton wavefunction.
  L. Frankfurt and M. Strikman
  Phys.Rev.D67:017502,2003

SEEK COLLABORATORS FROM THE FOLLOWING:

- Proposed experiments like TESLA-N
  Polarized e^- on polarized targets

- Current experiments, e.g..
  - COMPASS @ CERN (muon and hadron beams)
    - Transverse spin structure of nucleons
    - Run will resume in 2006
  - HERMES @ DESY (polarized e^- on polarized target)
    - Transverse Spin structure of nucleons
    - Run2 2001-2007

- Former highly successful experiments, e.g..
  - Møller scattering, SLAC E158
  - FOCUS experiment at Fermilab

SEEK COLLABORATORS FROM THE FOLLOWING: (cont'd)

- Excellent unfunded experiments like
  - BTeV – High sensitivity studies of B decays
  - CKM – Study of rare decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$
  - Similarly in other geographic regions
- Those who don't want to join huge ILC collaborations
- Medium energy physics community

CHALLENGES AND TASKS

- Organization of Fixed Target Initiative
- Accelerator/Beamline specifications
- Laser specifications
- Detector designs for first experiments
- Accelerator/Laser/Detector interfaces

ORGANIZATION

- (Initial) Co-Chairs: Yury Kolomensky and Sekazi Mtingwa

- Experimental Coordinator: Yury Kolomensky
  - Liaison to Global Group 6 (Telnov, Parker *et al.*)
  - Identify Assistants from all geographic regions: Rainer Pitthan, etc.
  - Critique accelerator and laser specifications of proposed experiments (Ask right questions)

- Theory and Phenomenology Coordinator: Shinya Kanemura
  - Mark Strikman
  - Ilya Ginzburg
  - Sekazi Mtingwa
  - Identify others

ORGANIZATION (cont'd)

- Laser Coordinator: Jeff Gronberg
  Identify others from all geographic regions

- Photoproduction Coordinators
  - Will Johns
  - John Cumulat
  - Identify others from all geographic regions

ORGANIZATION (cont'd)

- TESLA-N Coordinator(s)
- τ Physics Coordinator
- Beamline Design
  - Rob Appleby, Daresbury Laboratory
  - Yuri Nosochkov, SLAC
- Cost Optimization – SLAC

ORGANIZATION
(cont'd)

- Overall Communication and Logistics
  Sekazi Mtingwa
- Web Master
- Regional Coordinators
  - North America: Yury Kolomensky, USA
  - South America: Joao dos Anjos, Brazil (not confirmed but interested)
  - Asia:
  - Europe:
  - Africa: Zeblon Vilakazi, South Africa
  - Central America/Caribbean: Hector Mendez, Puerto Rico

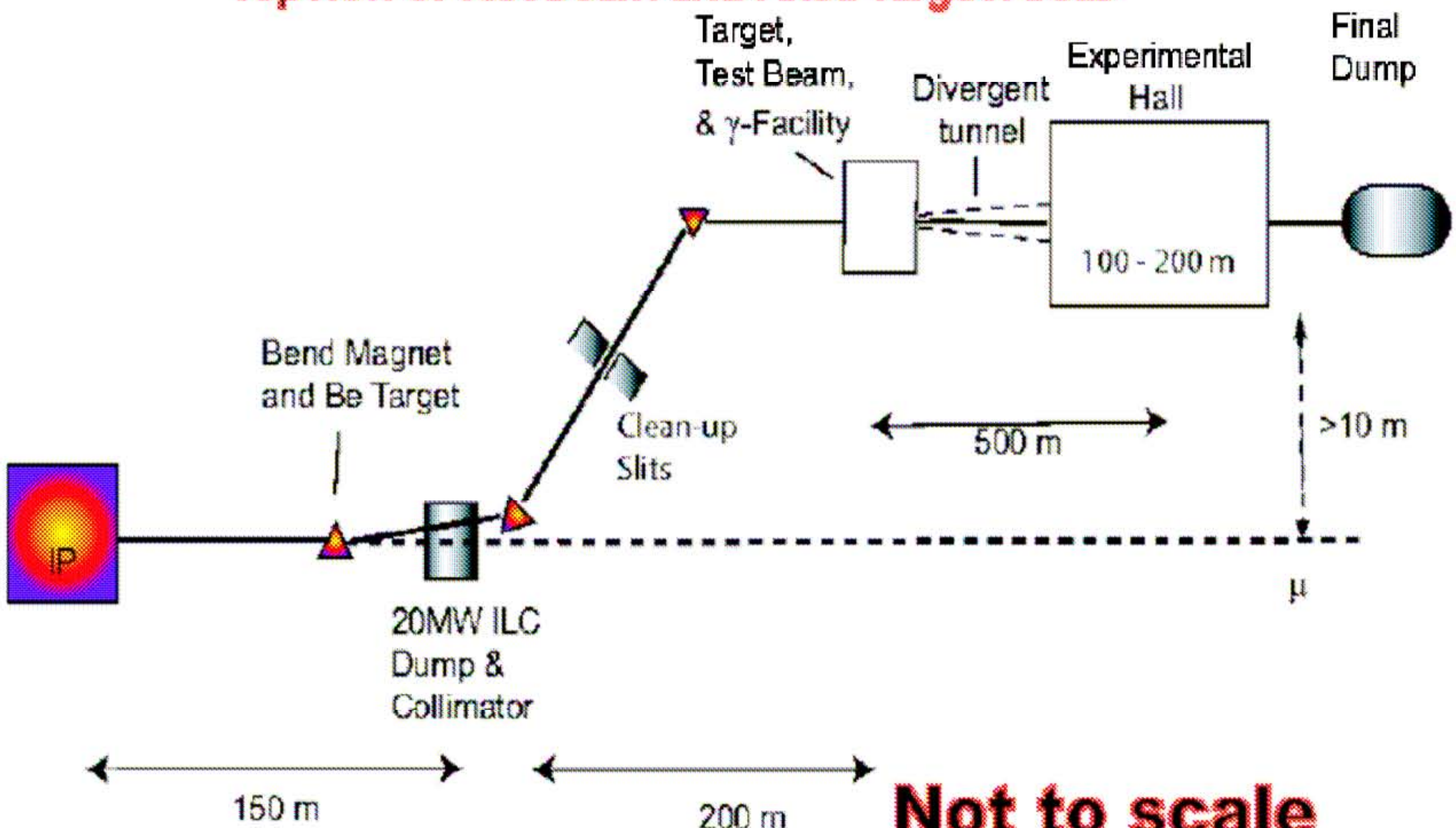
BEAMLINES

- Design beamlines after polarimeter, including beam dumps.
- Reduce momentum spread of disrupted beam to a usable value.
- Refocus disrupted electron beam to a suitable spot for both Compton backscattering and direct e^- on target.

SLAC Style

SLAC-PUB-8570; arXiv:physics/0101070

Topview of Test Beam and Fixed Target Areas



Not to scale

Beyond the Disrupted Beam?

Since it only needs one beam, Møller Scattering is also considered to be a good start-up/tune-up dedicated experiment. But does Fixed Target Physics at the NLC in general work with a disrupted beam?

For 250 GeV 57% of disrupted beam is within $\Delta E/E = 1\%$.

Assume 45% efficiency* ⇒ 120 Coulomb in 9 month

Summary:

Use of disrupted beams is possible - if energy collimation can be solved and de-polarization is small....

*SLC experience!

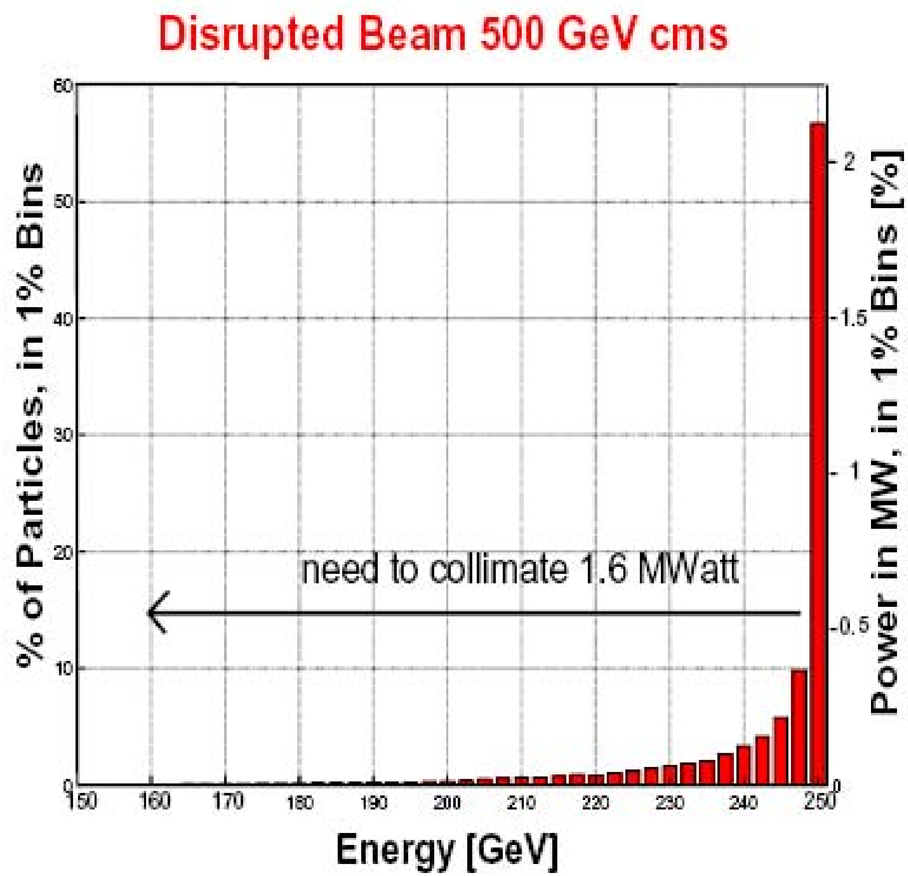
Disrupted Beam: Can You Fix the Energy Spread?

Energy Collimation: Possible, but needs design effort

Long energy tails of particles.

At 250 GeV per beam, 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 even more severe.



CHALLENGES & TASKS
(cont'd)

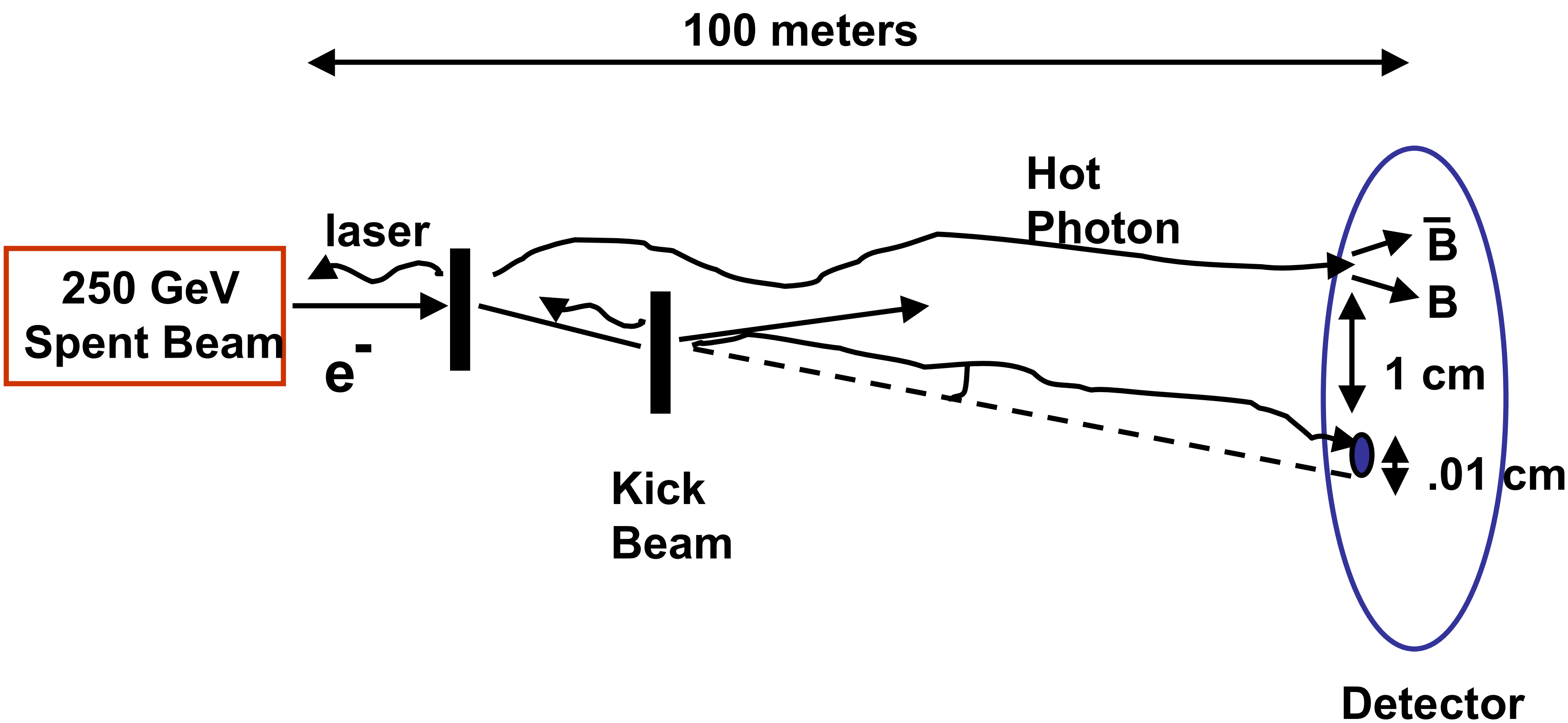
- Specify laser system, although not as challenging as for gamma-gamma collider.
  J. Gronberg is laser expert.

- Avoid data pile-up on target by rastering the electron beam, where necessary.

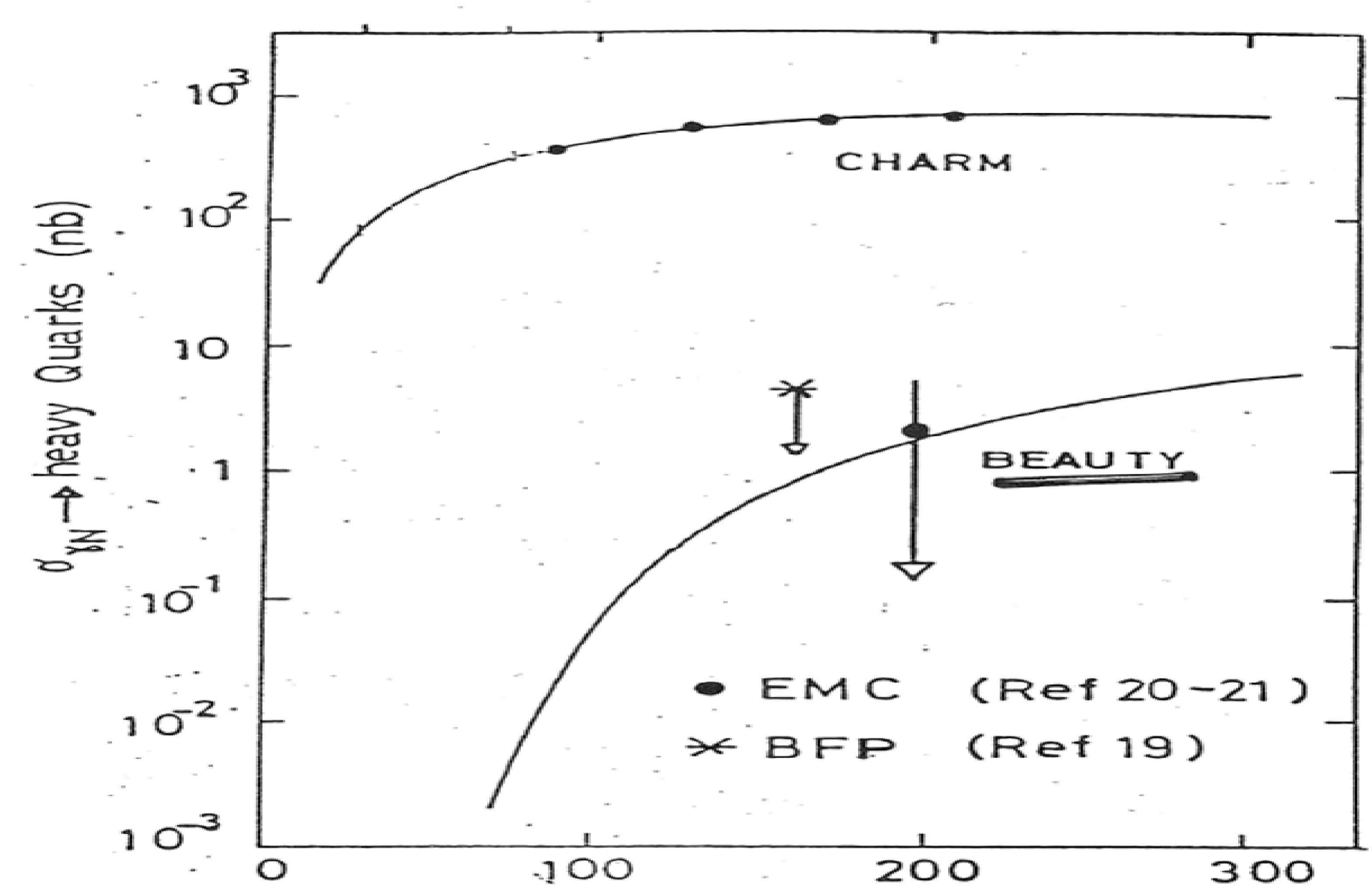
- Determine how many of the 10^6 photons per Compton backscattering can be used at 10kHz rep rate of the electron bunches.

BACKGAMMON

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

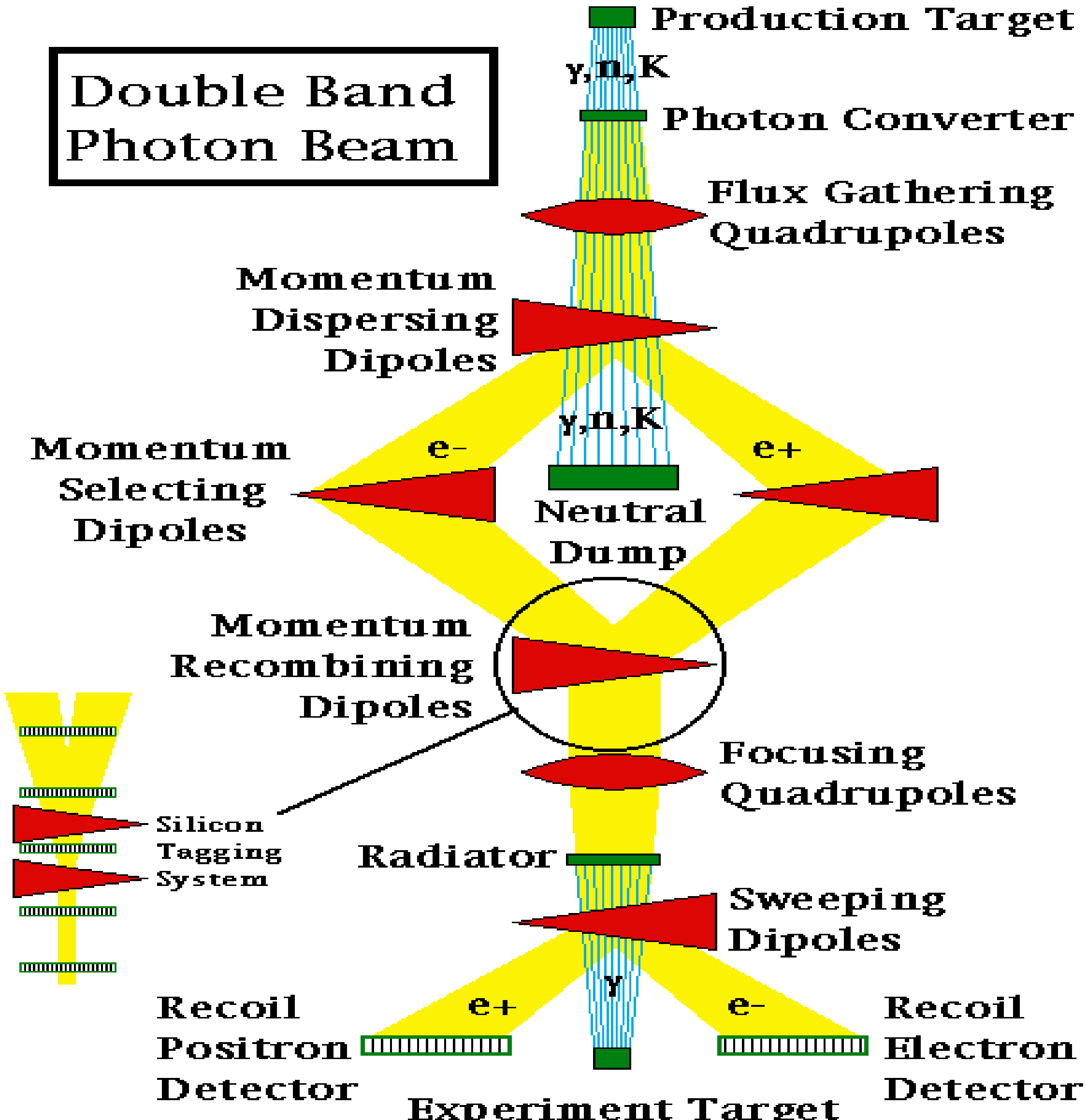


HEAVY QUARK CROSS SECTIONS



Photon Energy (GeV)

FOCUS @ FNAL



Double Band
Photon Beam
Production Target
γ,n,K
Photon Converter
Flux Gathering
Quadrupoles
Momentum
Dispersing
Dipoles
γ,n,K
e-
e+
Momentum
Selecting
Dipoles
Neutral
Dump
Momentum
Recombining
Dipoles
Focusing
Quadrupoles
Silicon
Tagging
System
Radiator
Sweeping
Dipoles
γ
e+
e-
Recoil
Positron
Detector
Recoil
Electron
Detector
Experiment Target

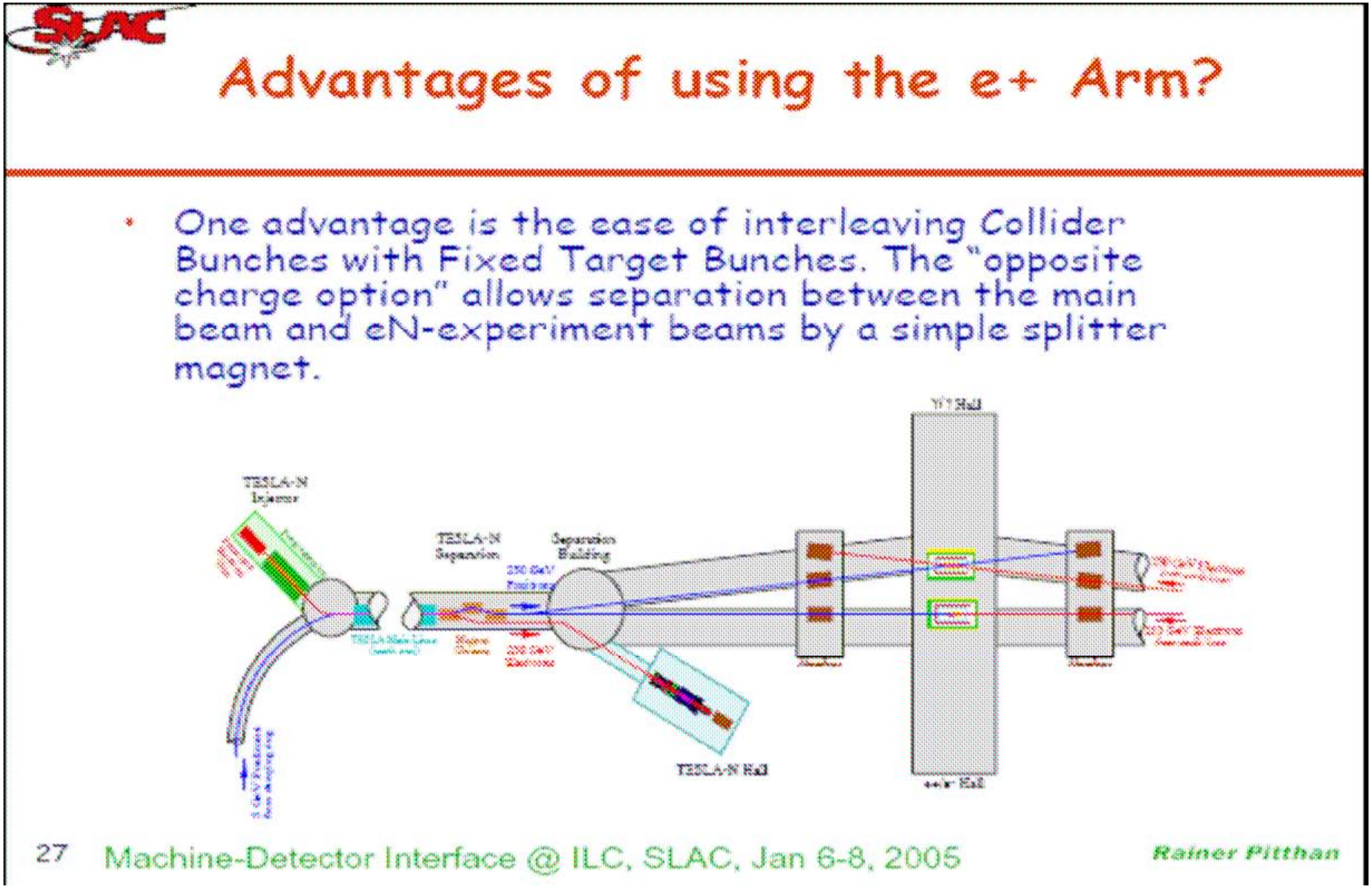
COMPARISON OF BACKGAMMON AND FOCUS

	FOCUS	BACKGAMMON
Rep Rate	1/60 sec	10 kHz
Hot γ's/bunch	4×10^{7}	10^{6}
Seconds/yr	3×10^{7}	3×10^{7}
Target int. length	10%	10%
Hadronic int/e^+e^-	10^{-3}	10^{-3}
Branch. Ratio to $b\bar{b}$	2×10^{-4}	2×10^{-4}
$b\bar{b}$ / year	4×10^{5}	6×10^{9}

CHALLENGES & TASKS (cont'd)

- Examine utility of using empty buckets between positron trains à la TESLA-N.

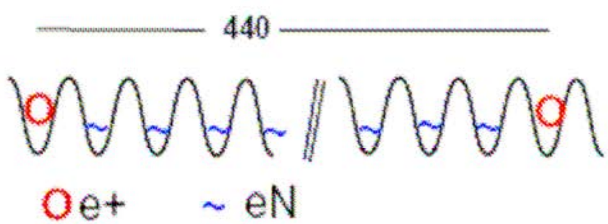
TESLA-N


Advantages of using the e+ Arm?
One advantage is the ease of interleaving Collider Bunches with Fixed Target Bunches. The "opposite charge option" allows separation between the main beam and eN-experiment beams by a simple splitter magnet.
TESLA-N Injector
TESLA-N Separation
Separation Building
TESLA-N Hall
27
Machine-Detector Interface @ ILC, SLAC, Jan 6-8, 2005
Rainer Pitthan

TESLA-N
(cont'd)

Filling the Empty Buckets

- Duty cycle advantage: by filling the empty 440 buckets between the 2830 e+e- bunches with a very low charge (~2 10^4 e^- are proposed), a 0.5 % duty cycle beam for coincidence experiments is being created. This increases the beam loading by only 0.04%.
- The physics proposed is an extension of the HERMES physics, and, therefore, is geared toward needing a good duty cycle.



CHALLENGES & TASKS (Cont’d)

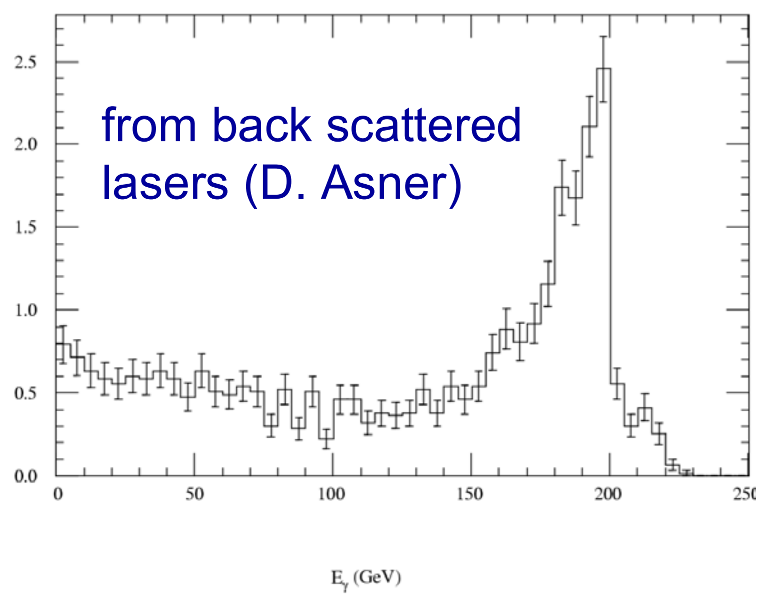
- Determine whether spent gamma-gamma beams can be used for high quality experiments.
- Compare coherent Bremstrahlung with Compton backscattering for producing hot polarized gammas.

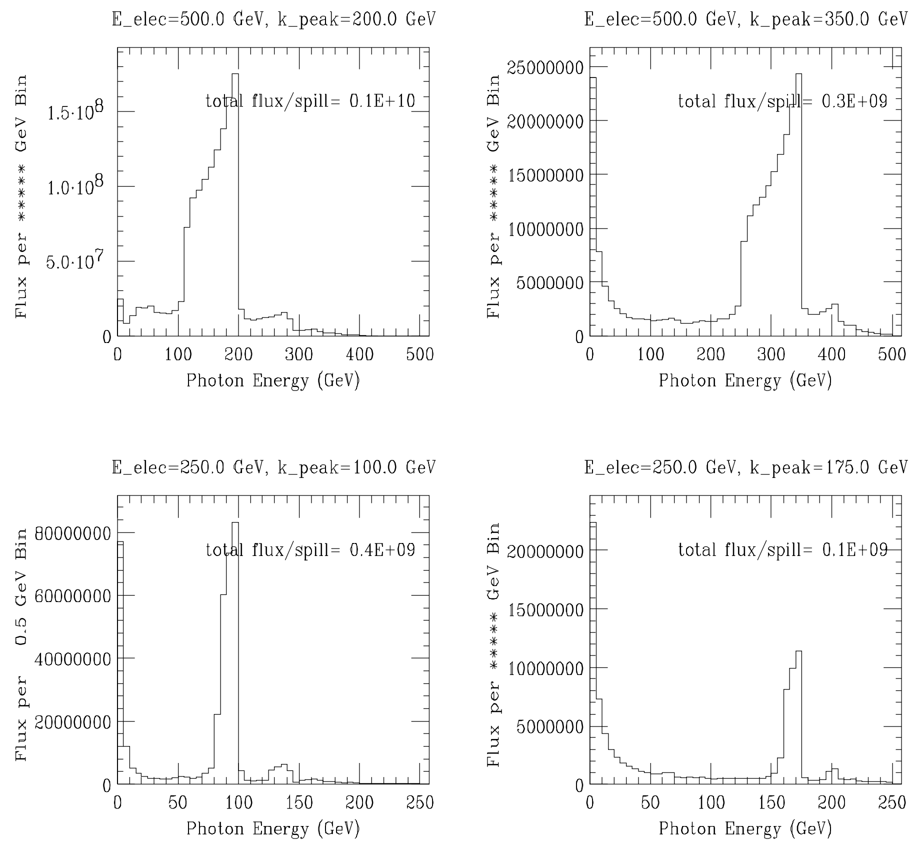
Polarized physics with real photons

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

Proposals on Beam–Dump Utilization for Linear Collider

Ilya F. Ginzburg
Sobolev Inst. of Mathematics, SB RAS,
Novosibirsk

OUTLINE

How to work with beam dump?

Standard approach: *destruction.*

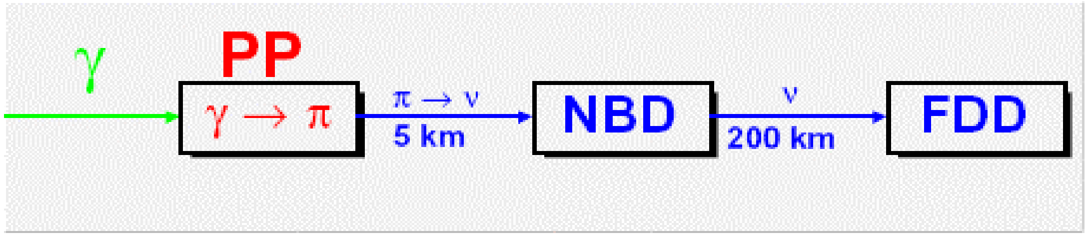
Proposal: $\Longrightarrow$ *utilization for technics and physics.*

I. Initiation of an accelerator–driven sub–critical reactor

The idea to work with sub–critical nuclear reactor, initiated by proton or electron beam, for foolproof production of energy and (or) cleaning of nuclear pollution is well known (Rubbia). Here proton or electron beam with particle energy of about 1 GeV is suggested to produce neutrons in the cascades within body of reactor. The problem here is in obtaining necessary beam power of about 5 MW or larger.

For definiteness, in TESLA project we expect mean used beam power about 11 MW with electrons or (and) photons having energies of about hundreds GeV. In the suitable target this particle energy can be transmitted to low energy particles to initiate fission process in reactor.

II. Neutrino factory



A. Pion producer (PP) – water cylinder of length about 20 cm (*radiation length*). Here electrons produce photons via bremsstrahlung, and than these photons (or direct photons) produce pions via $\gamma N \longrightarrow \pi\pi\pi ... N$

B. Neutrino transformer (NT) – low vacuum pipe of length 1–5 km and radius about 2m for $\pi \longrightarrow \mu\nu$ decay with $0.6 \cdot 10^{11}$ ν/s and angular spread $2 \div 0.4$ mrad. $1 \div 2$ events $\nu_\mu N \longrightarrow \mu X$

C. Nearby detector (NBD) at 1.1-10km after NT – for estimates: water of length 100m with radius 2-10 m. – $1 \div 100$ events $\nu_\mu \longrightarrow \mu X$ /sec

D. Far distance detector (FDD) at the distance $L = 100 \div 200$ km: water of length 1 km with radius about 40 m with $\sim 100 \div 1000$ events $\nu_\tau N \longrightarrow \tau X$ /year from $\nu_\mu \longrightarrow \nu_\tau$ oscillations (twice larger than background).

THEORY OF τ DECAY

A. Pich, Workshop on τ/c Factory

AIP Conf Proc, 349, p. 45 (1996)

Let us consider the leptonic decays $l^- \to \nu_l l'^- \bar{\nu}_{l'}$, where the lepton pair (l, l') may be (μ, e), (τ, e), or (τ, μ). The most general, local, derivative-free, lepton number conserving, four-lepton interaction Hamiltonian, consistent with locality and Lorentz invariance

$$\mathcal{H} = 4 \frac{G_{l'l}}{\sqrt{2}} \sum_{\epsilon,\omega=R,L}^{n=S,V,T} g^n_{l'_\epsilon l_\omega} \left[\overline{l'_\epsilon} \Gamma^n (\nu_{l'})_\sigma \right] \left[\overline{(\nu_l)_\lambda} \Gamma_n l_\omega \right] ,$$

$$\frac{d^2\Gamma}{dx\, d\cos\theta} = \frac{m_l \omega^4}{2\pi^3} G^2_{l'l} \sqrt{x^2 - x_0^2} \left\{ x(1-x) + \frac{2}{9}\rho \left(4x^2 - 3x - x_0^2\right) + \eta\, x_0 (1-x) \right.$$
$$\left. - \frac{1}{3} \mathcal{P}_l\, \xi \sqrt{x^2 - x_0^2} \cos\theta \left[1 - x + \frac{2}{3}\delta \left(4x - 4 + \sqrt{1 - x_0^2} \right) \right] \right\} ,$$

where θ is the angle between the l^- spin and the final charged-lepton momentum, $\omega \equiv (m_l^2 + m_{l'}^2)/2m_l$ is the maximum l'^- energy for massless neutrinos, $x \equiv E_{l'^-}/\omega$ is the reduced energy and $x_0 \equiv m_{l'}/\omega$. For unpolarized l's, the distribution is characterized by the so-called Michel [17] parameter ρ and the low-energy parameter η. Two more parameters, ξ and δ can be determined when the initial lepton polarization is known. If the polarization of the final charged lepton is also measured, 5 additional independent parameters [3] (ξ', ξ'', η'', α', β') appear.

PRECISION STUDIES OF MICHEL PARAMETERS

$$\rho - \frac{3}{4} = -\frac{3}{4}\left[\left|g^V_{LR}\right|^2 + \left|g^V_{RL}\right|^2 + 2\left|g^T_{LR}\right|^2 + 2\left|g^T_{RL}\right|^2 + \mathrm{Re}(g^S_{LR}g^{T*}_{LR} + g^S_{RL}g^{T*}_{RL})\right]$$

$$\eta = \frac{1}{2}\mathrm{Re}\left[g^V_{LL}g^{S*}_{RR} + g^V_{RR}g^{S*}_{LL} + g^V_{LR}\left(g^{S*}_{RL} + 6g^{T*}_{RL}\right) + g^V_{RL}\left(g^{S*}_{LR} + 6g^{T*}_{LR}\right)\right]$$

$$\xi - 1 = -\frac{1}{2}\left[\left|g^S_{LR}\right|^2 + \left|g^S_{RR}\right|^2 + 4(-\left|g^V_{LR}\right|^2 + 2\left|g^V_{RL}\right|^2 + \left|g^V_{RR}\right|^2)\right.$$

$$\left. -4\left|g^T_{LR}\right|^2 + 16\left|g^T_{RL}\right|^2 - 8Re(g^S_{LR}g^{T*}_{LR} - g^S_{RL}g^{T*}_{RL})\right] ,$$

$$(\xi\delta) - \frac{3}{4} = -\frac{3}{4}\left[\frac{1}{2}(\left|g^S_{LR}\right|^2 + \left|g^S_{RR}\right|^2) + (\left|g^V_{LR}\right|^2 + \left|g^V_{RL}\right|^2 + 2\left|g^V_{RR}\right|^2)\right.$$

$$\left. +2(2\left|g^T_{LR}\right|^2 + \left|g^T_{RL}\right|^2) - \mathrm{Re}(g^S_{LR}g^{T*}_{LR} - g^S_{RL}g^{T*}_{RL})\right] .$$

In the SM, $\rho = \delta = 3/4$, $\eta = \eta'' = \alpha' = \beta' = 0$ and $\xi = \xi' = \xi'' = 1$.

BIG THANKS!

- MARK OREGLIA
- ED BERGER

THEY HAVE GIVEN US ENCOURAGEMENT TO PURSUE THIS INITIATIVE AND SEE IF WE COULD DEVISE A HIGH QUALITY PROGRAM OF FIXED TARGET EXPERIMENTS.

We want to become a real ILC Working Group!