SUMMARY : LCWS WG-D2

Machine Detector Interface

plus contributions on

$\gamma\gamma$, e-e-, and Fixed Target options

Tom Markiewicz/ SLAC

LCWS-2000

27 October 2000

This Talk

- Summarize and ensure excellent forward progress is reported to wider audience
- Try to answer Komimiya-san's charge:
  - Develop case for 500 GeV collider
  - Bring together and build cooperation in the world community
  - Review priorities
- Try to be PROVACATIVE
  - Stress SIMILARITIES, not small differences

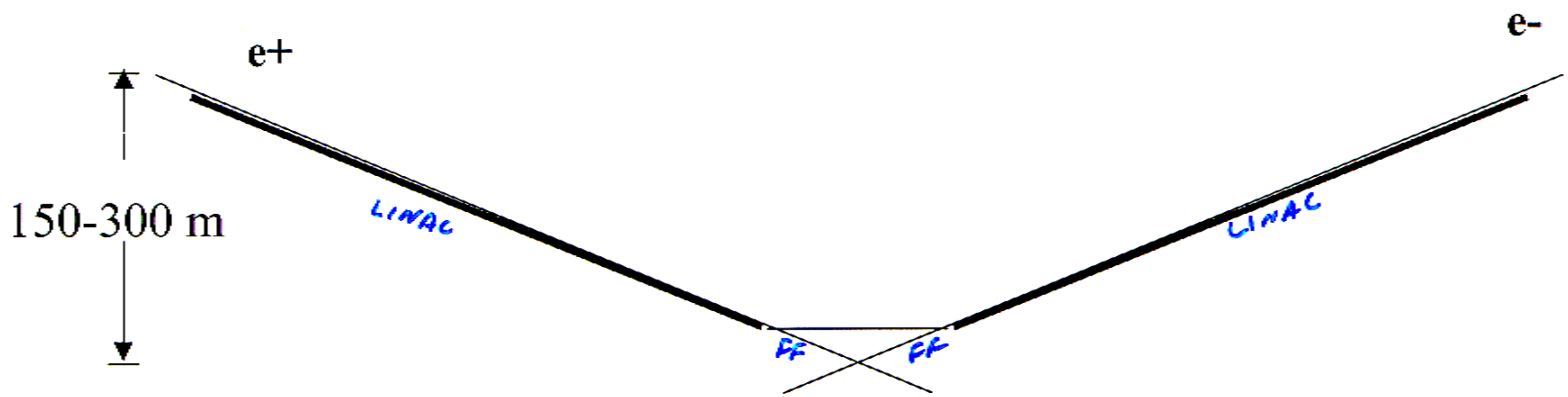
Site Layouts & Accelerator Physics Solutions

- Olivier Napoly/DESY
  - TESLA IR Layout, collimation and extraction
- Tor Raubenheimer/SLAC
  - NLC IR Layout Options
- Andrei Seryi/SLAC
  - The new NLC FF: tunability and tolerances
  - Final Focus Tests in the SLC

Layout & Accel. Physics Summary

- Layout Discussion
  - Crossing linacs at an angle makes site machine independent
  - Minimizing bends to one IR allows us to move past questions of starting energy and energy reach
- New NLC FF
  - Local chromaticity correction scheme is magic
  - Relative freedom of FF length from Energy and L* with
    - BETTER bandwidth (and backgrounds)
    - Same or better tunability or tolerances
    - Shorter with fewer optical elemenets
  - Final Focus Tests in the SLC
    - A good rallying point for collaboration

Two ~10-20km tunnels with a crossing angle is a generic LC site Decide which one later!

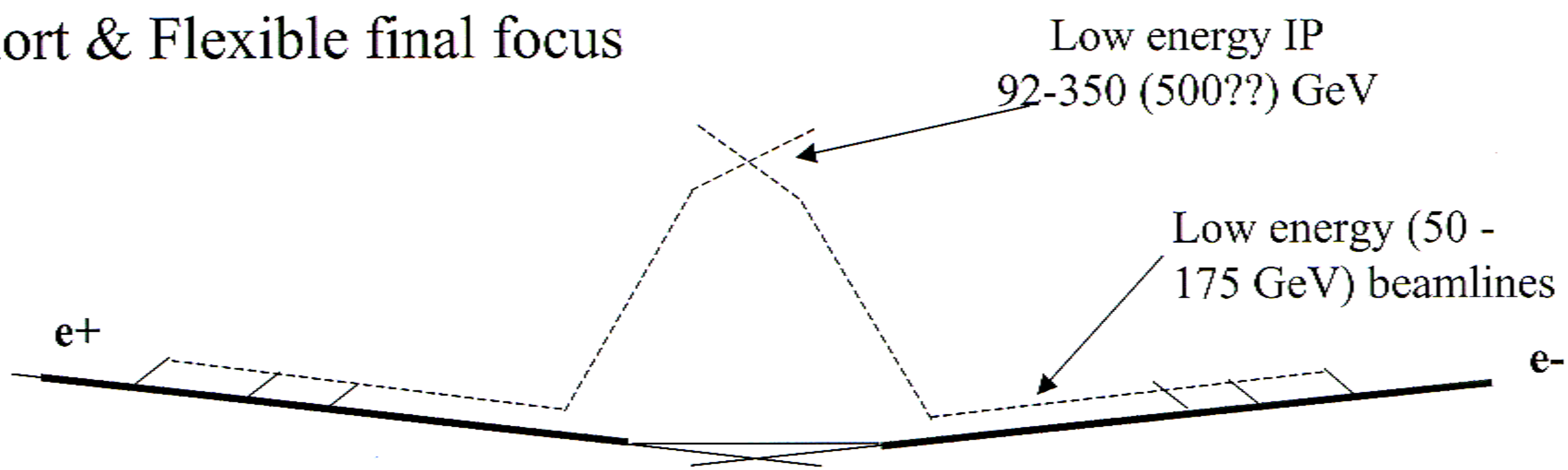


- Compatible with long bunch or short bunch spacing
- Last part of tunnel can provide zero crossing angle, if desired
  - Not a big deal given a relatively short FF and a reasonable tunnel diameter
- Make sure tunnel dimensions can accommodate cryo support OR DLDS pulse compression OR two beam systems

Hi/Lo IR

Defuse issues of starting energy, near-term energy reach & long-term energy

- Transport to one IR with no large bends to beat E^6 emittance scaling
  - Degree of "straightness" required "to be determined"
- Short & Flexible final focus



Tactical (as opposed to strategic) choices

- How two IRs are implemented and what detectors and beams go where
- Technology used to achieve starting energy

Luminosity Scaling with Energy

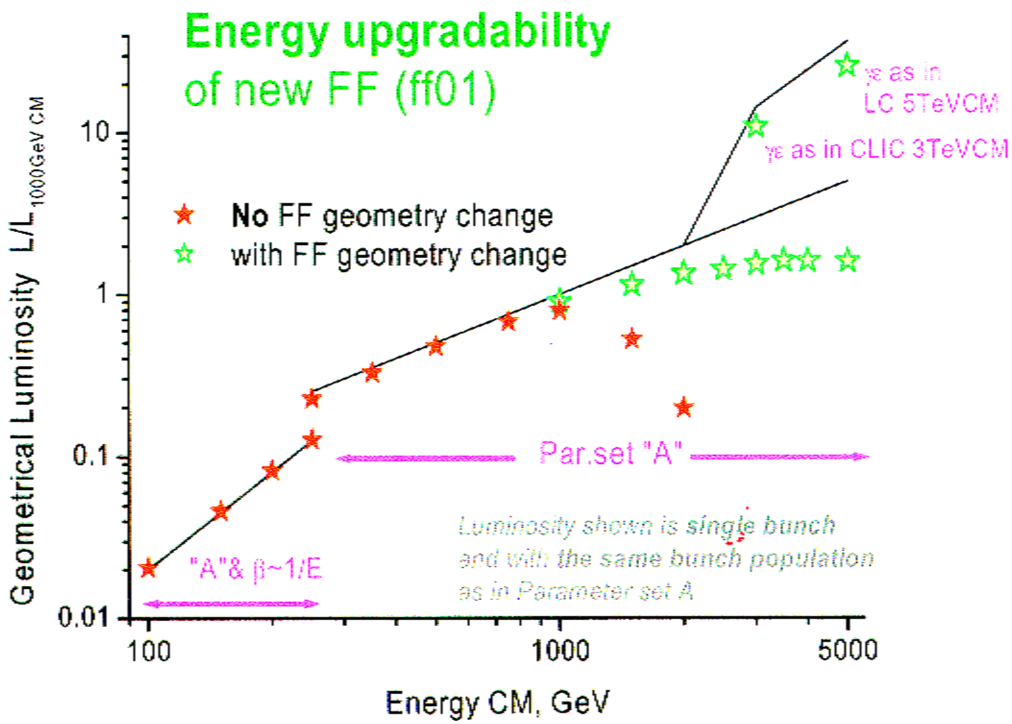
Raubenheimer

- Assuming same injector, the luminosity scales as:

$$\text{Low Energy}: \quad L \propto \gamma^2 \qquad \text{(aperture limited)}$$

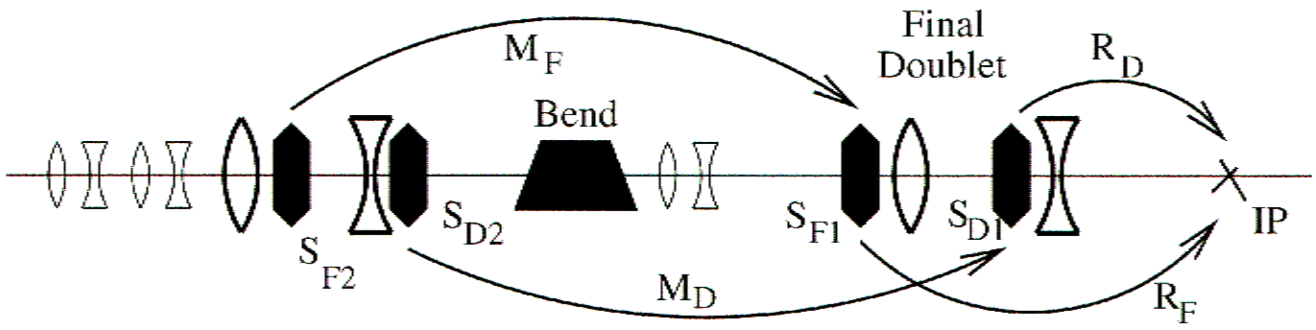
$$\text{Mid Energy}: \quad L \propto \gamma \qquad \text{(bunch length limited)}$$

$$\text{High Energy}: \quad L \propto \gamma^{-2.5} \qquad \text{(SR limited)}$$



- Luminosity in high energy FF scales linearly with energy between 250 and 1 TeV
- Low energy FF scales similarly but at lower energy!

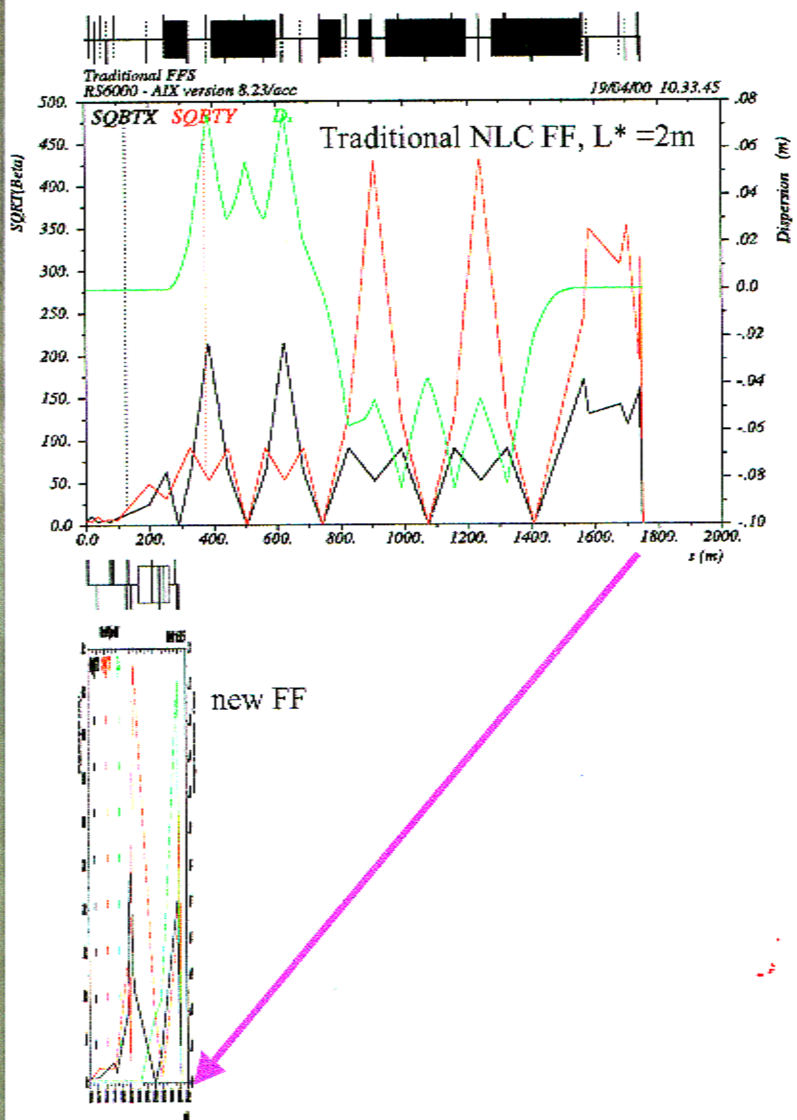
Principles of the "ideal" FF



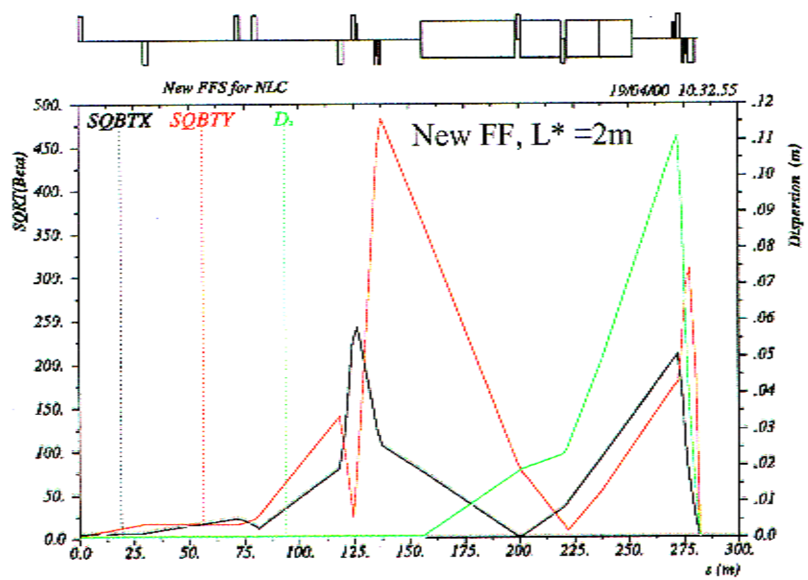
- A Final Doublet is required to provide the necessary demagnification.
- The chromaticity is cancelled locally by two sextupoles interleaved with the FD together with a bend upstream to generate dispersion across them.
- Geometric aberrations of the FD sextupoles are cancelled by two more sextupoles placed in phase with them and upstream of the bend.
- Four more quadrupoles are needed for β-matching

P.Raimondi, A.Seryi

Traditional and new FF



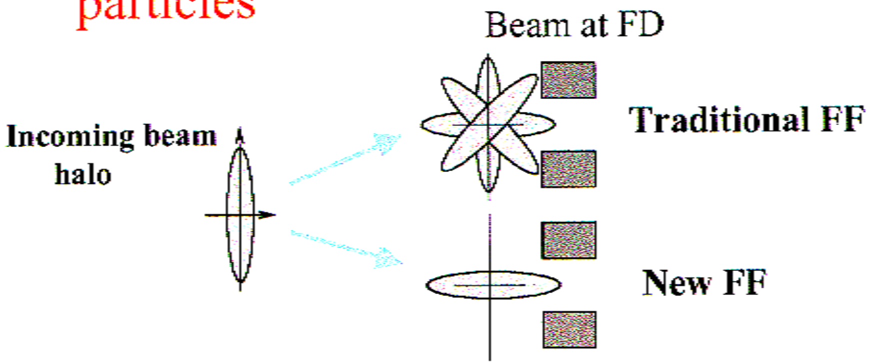
A new FF with the same performance as NLC FF can be ~300m long, i.e. 6 times shorter

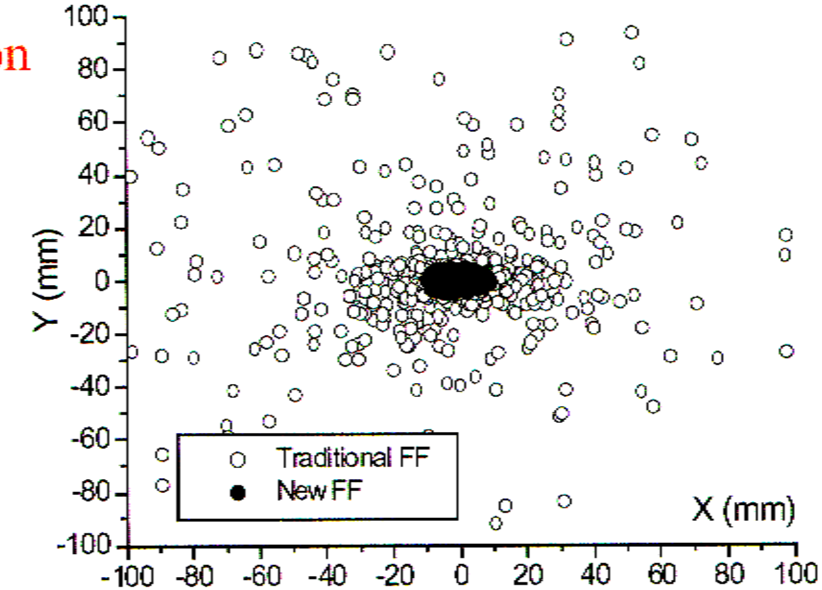


P.Raimondi, A.Seryi

Collimation and background

- Traditional FF **does not preserve** betatron phase of halo particles
- New FF **dos not mix** IP and FD phase particles





Halo beam at the FD entrance.
Incoming beam has 100 times larger coordinates in IP phase than in FD phase.

Particles of incoming beam are placed on a surface of an ellipsoid with dimensions N_σ (x,x',y,y',E) = (800,8,4000,40,20) times larger than nominal beam parameters.

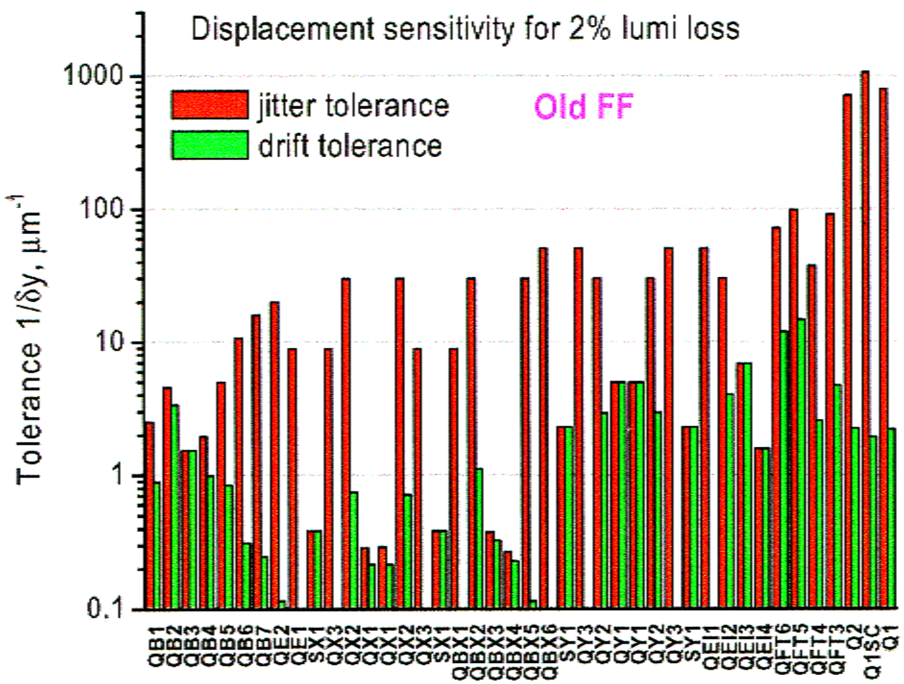
=> **Both IP and FD** phase collimation **required** for traditional FF

=> **Collimation design** may **benefit** from the phase conservation feature of the **new FF**

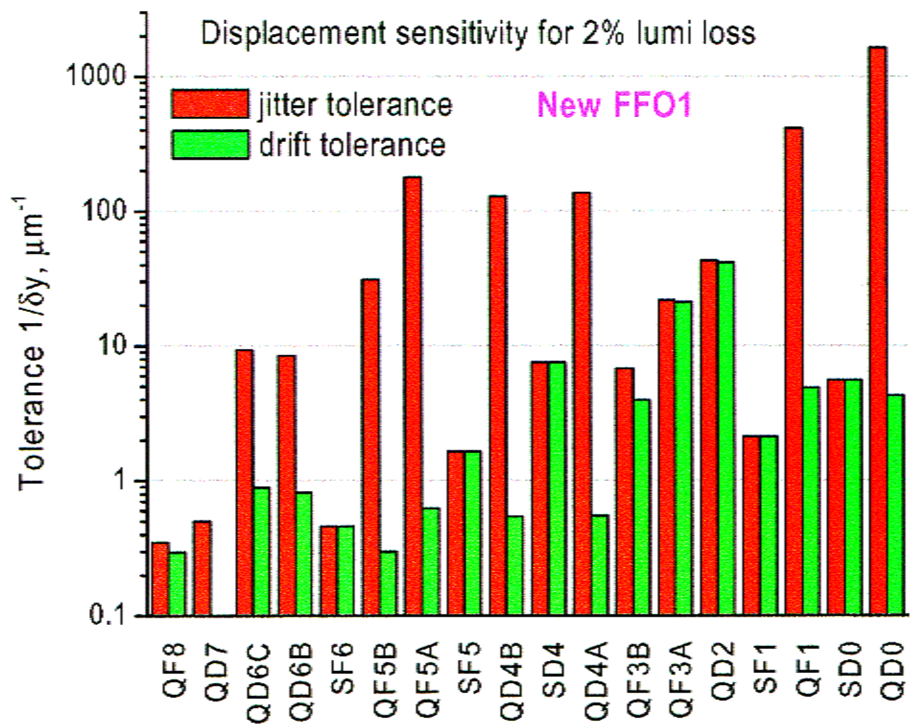
P.Raimondi, A.Seryi

Tolerance to vertical motion of magnets

Old FF, L^*=2m



New FF, L^* = 4.3m



Tolerance 1/δy for 2% luminosity loss:

jitter - no correction

drift - IP offset and angle are corrected

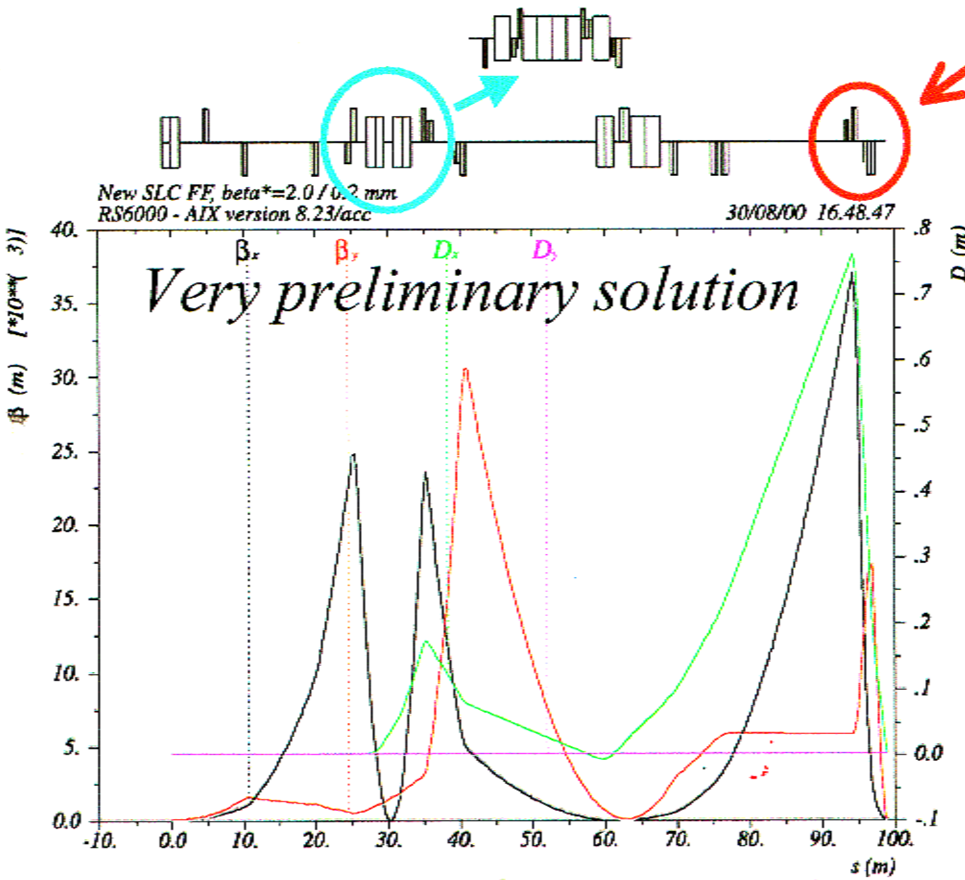
Calculated with FFADA

Beam energy, GeV	500
$\gamma\varepsilon_x$ / $\gamma\varepsilon_x$ (10^{-8} m)	400 / 6
σ_x^* / σ_y^* at IP (nm)	197 / 2.7
Energy spread σ_E (10^{-3})	3

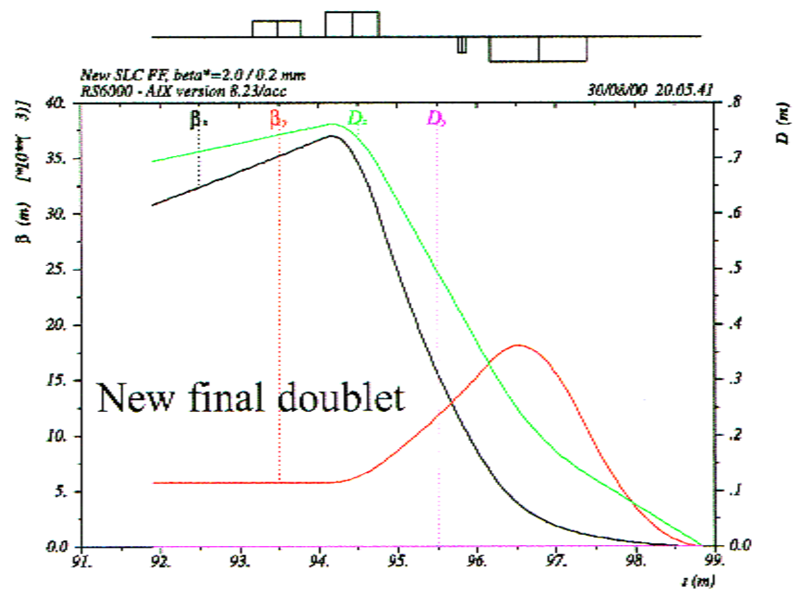
P.Raimondi, A.Seryi

LCTF Final Focus optics

- Use existing SLC FF
- Make MIN modifications



LCTF final focus with $\beta_{x,y}$=2/0.2mm, L^*=1.5m



- Required modifications:
  - final doublet
  - make bend B2 longer (to reduce sync.rad. effect in horiz. beam size)

P.Raimondi, A.Seryi

LCTF parameters

- Based on conservative extension of the achieved SLC parameters
- Work at 30GeV@10Hz to reduce synch.rad in arcs, FF, and to reduce electricity bill (e.g. for arcs: ~ 1MW @45.6GeV per arc)
- Work with lower current to improve beam stability

Emittances routinely achieved at SLC @45.6GeV and $N^{\pm}$= 1.5e10 :

- Damping ring: $\gamma\varepsilon_{x,y}$=2.9/0.15E-5m
- Final focus: $\gamma\varepsilon_{x,y}$=4.0/0.30E-5m (synch.rad. Arc contribution: $\Delta\gamma\varepsilon_{x,y}$=1.1/0.15E-5m)

LCTF parameters

Beam Energy:	30 GeV
DR emittances:	$\gamma\varepsilon_{x,y}$=1.0/0.05E-5m
FF emittances:	$\gamma\varepsilon_{x,y}$=1.6/0.16E-5m
IP Betas:	β_x=2mm β_y=0.2mm
Bunch length:	σ_z=0.8 - 0.2mm
IP spot sizes:	$\sigma_{x,y}$=750/75nm
Beam currents:	$N^{\pm}$= 1.0e10

P.Raimondi, A.Seryi

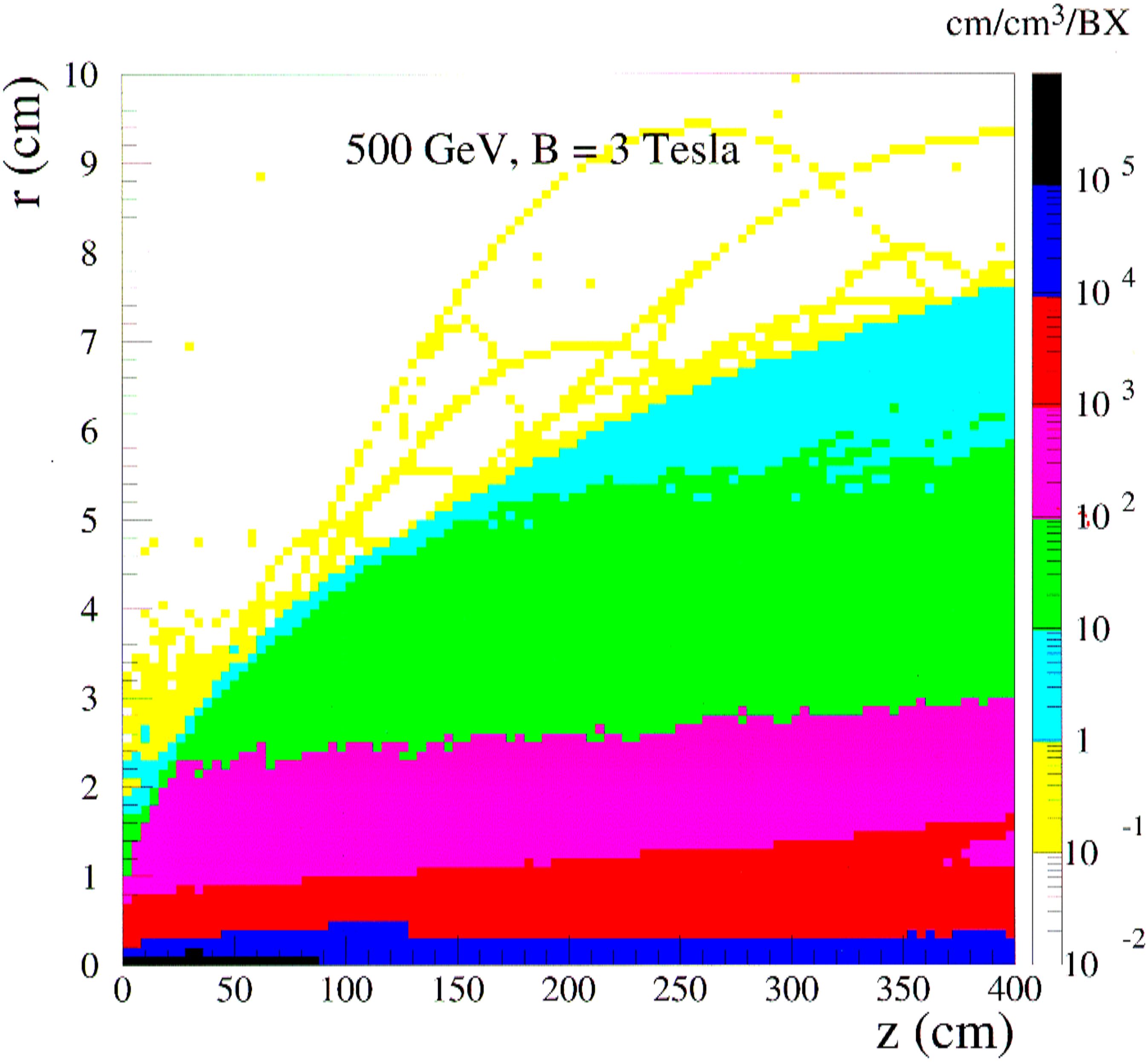
IR Layouts & Backgrounds

- Karsten Buesser / DESY
  - Mask design and background studies for TESLA
- Yasuhiro Sugimoto / KEK
  - New JLC Mask System at B=3 Tesla
- Jeff Gronberg / LLNL
  - NLC Layout, Masks, & Backgrounds
- Daniel Schulte / CERN
  - Backgrounds at CLIC

IR Layout Summary

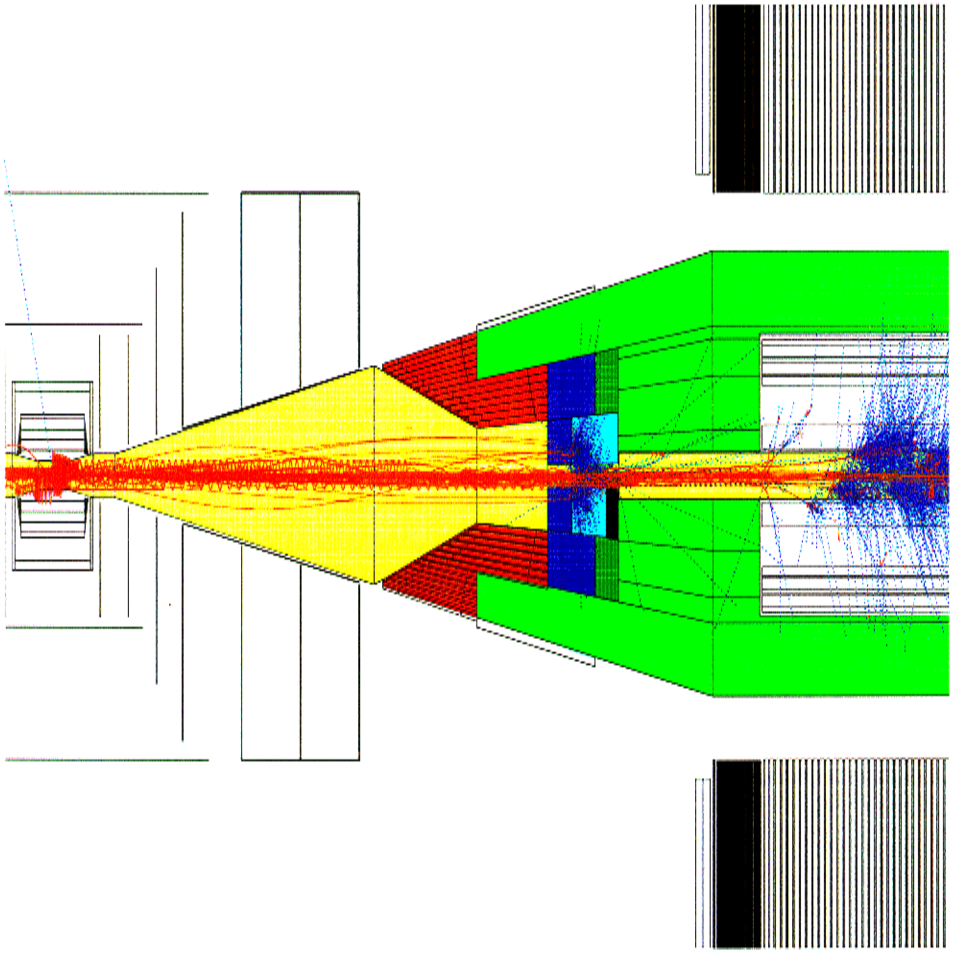
- All IR Layouts similar
  - Instrumented masking for $r > r_{max}$ of pair bknd at L*
  - Separate Lum/Position Monitor for $r_{QD0} < r < r_{max}$
  - Low Z absorber for backscattered neutrons and soft debris
- All L*, Crossing Angles, Final Doublet Magnet Technologies different
  - TESLA at 0^0 as bunch structure allows it
  - JLC and NLC @ 8^0 and 20^0, resp. for last 6 years
    - Arbitrary choices within allowed range
  - CLIC: new detailed study of requirements
    - COHERENT pairs SEEN by incoming beam!!

Pair background track density



Background: Pairs in the Mask

$\approx 0.1\%$ of one bunchcrossing @ 500 GeV , 3T

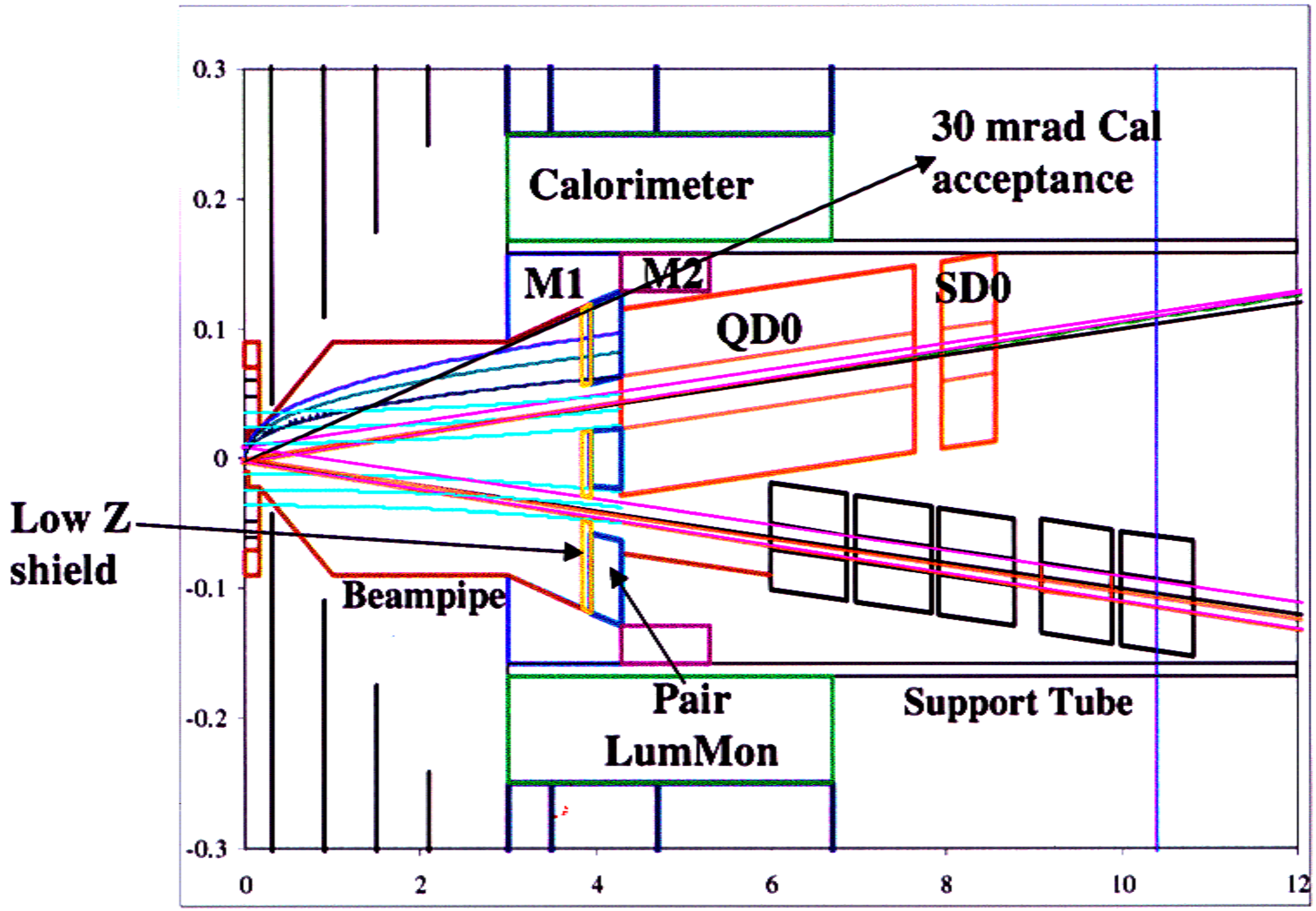


Pairs on one side $(z \geq 0)$ for one full BX

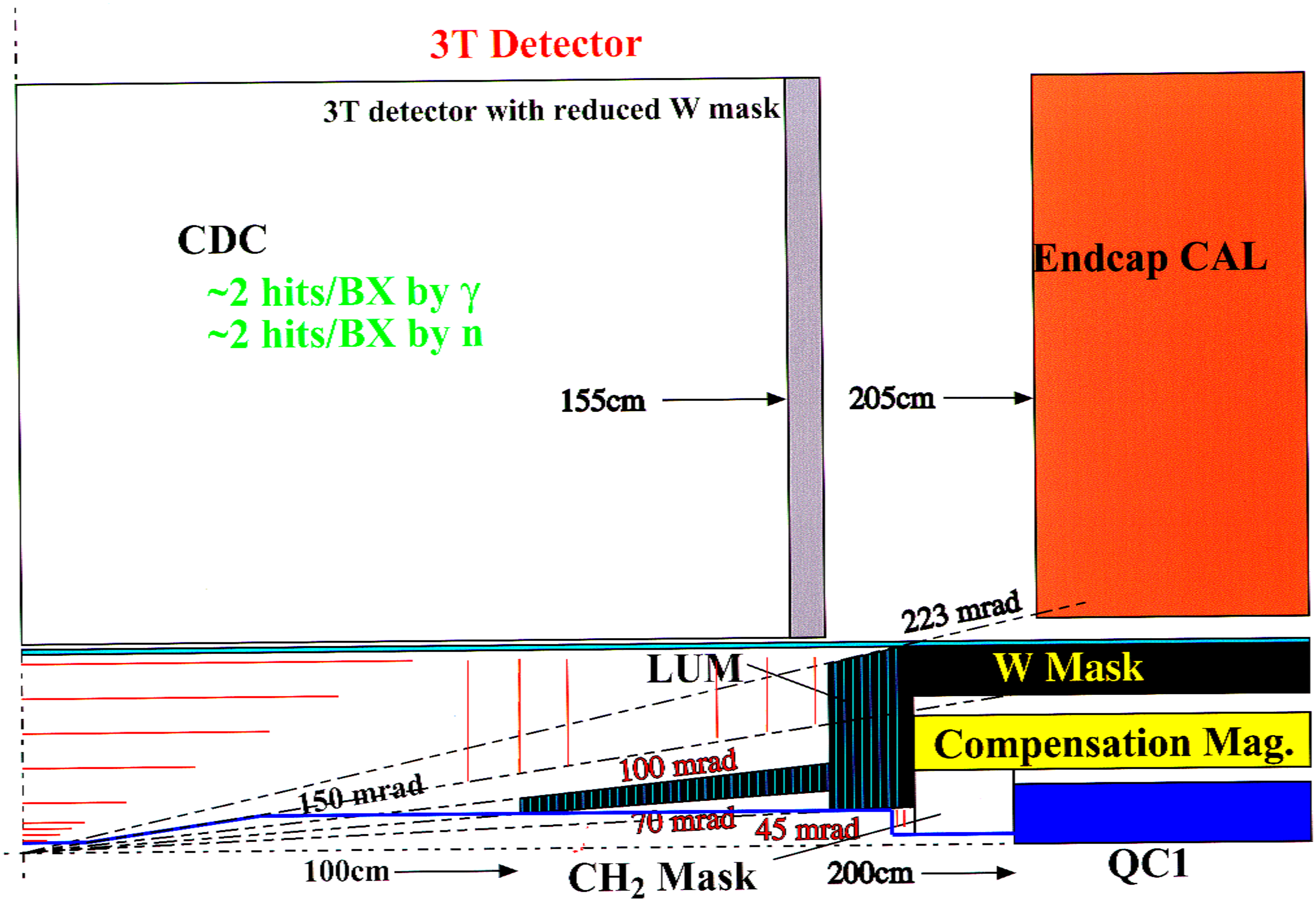
Energy	# produced	Total E	# on LCAL	E on LCAL
500	60000	150 TeV	110000	21 TeV
800	90000	490 TeV	170000	35.5 TeV

Every channel of LCAL fires !!

LCD-L2 (3T) with 4.3m L* Optics



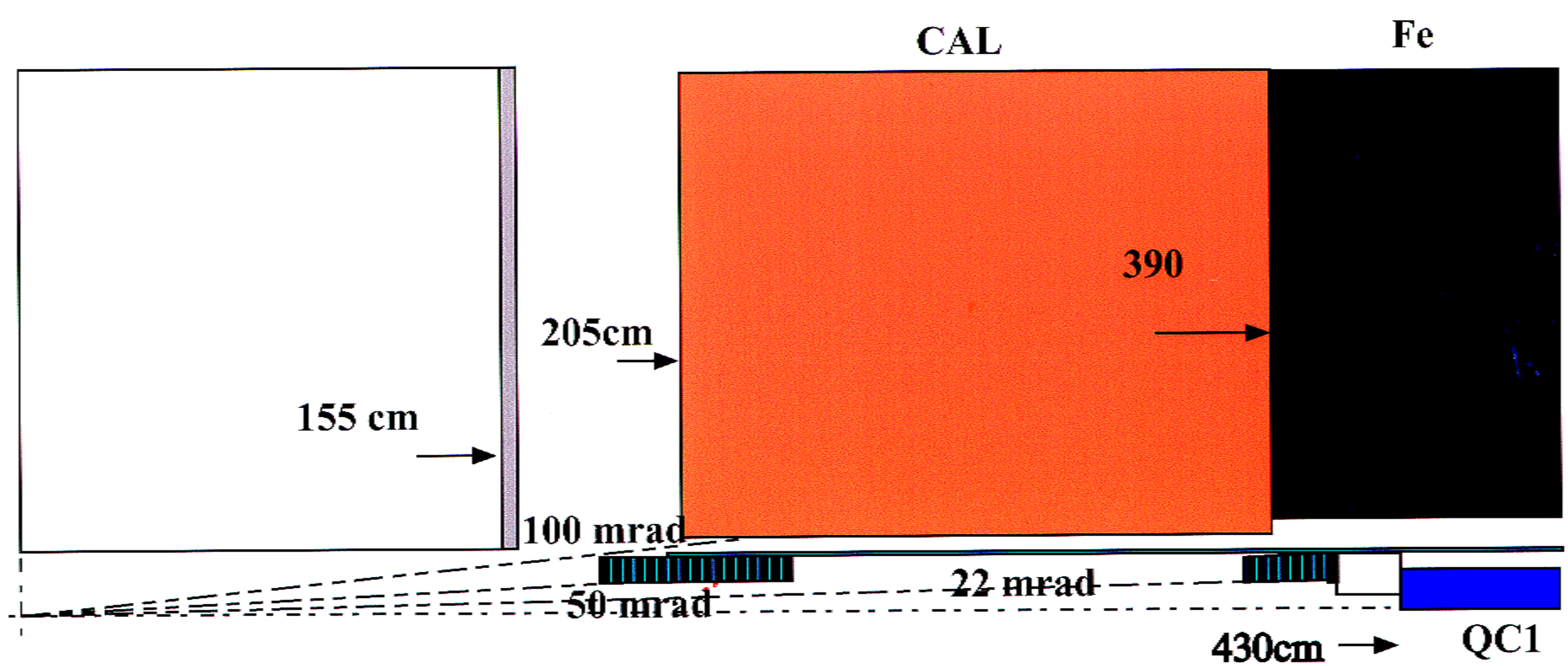
3T Detector



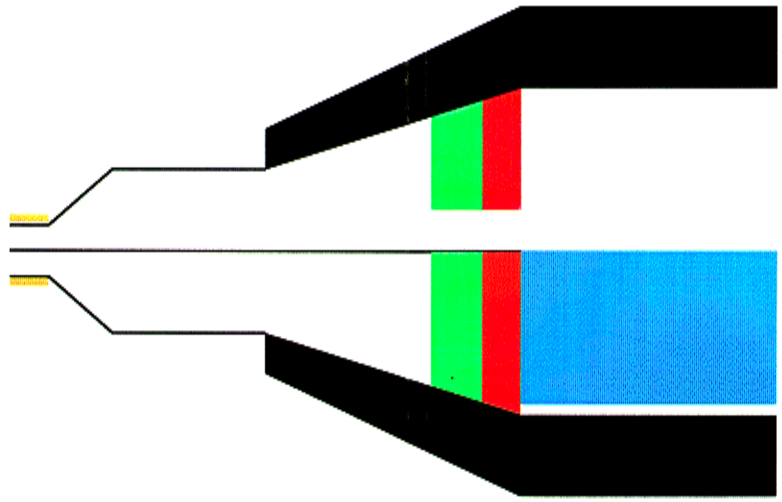
3T detector with reduced W mask
CDC
~2 hits/BX by γ
~2 hits/BX by n
155cm
205cm
Endcap CAL
223 mrad
W Mask
LUM
Compensation Mag.
100 mrad
150 mrad
70 mrad
45 mrad
100cm
CH2 Mask
200cm
QC1

Impact of the new optics (l^*=4.3m) on the detector

- -Huge W-mask NOT needed
- -Background hit much smaller (CDC, CAL)
- -No need for Support tube (?)
- -No need for Compensation magnet (?)
  if the B field @4.3m is weak enough
- -Smaller R_{min} of CDC and CAL possible



Mask Design



no final design

preliminary design to have first idea of background

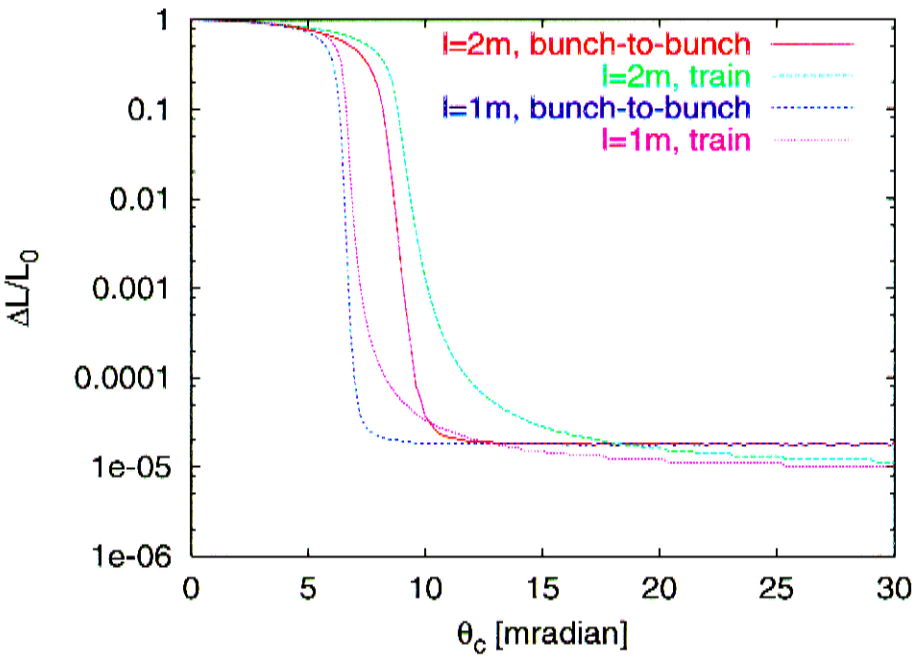
outer mask to prevent backscattering of photons

inner mask to prevent backscattering of charged particles

inner mask should instrumented for the machine

instrumentation for low angle tagging will be included later

Multi-Bunch Kink Instability



Two main contributions to kick

beam

coherent pairs

kick is approximated

bunches are separated after $l = 2\,\mathrm{m}$ ($1\,\mathrm{m}$)

⇒ at $\theta_c = 20\,\mathrm{mradian}$ luminosity loss is increased by $\approx 60\,\%$ for coherent offset

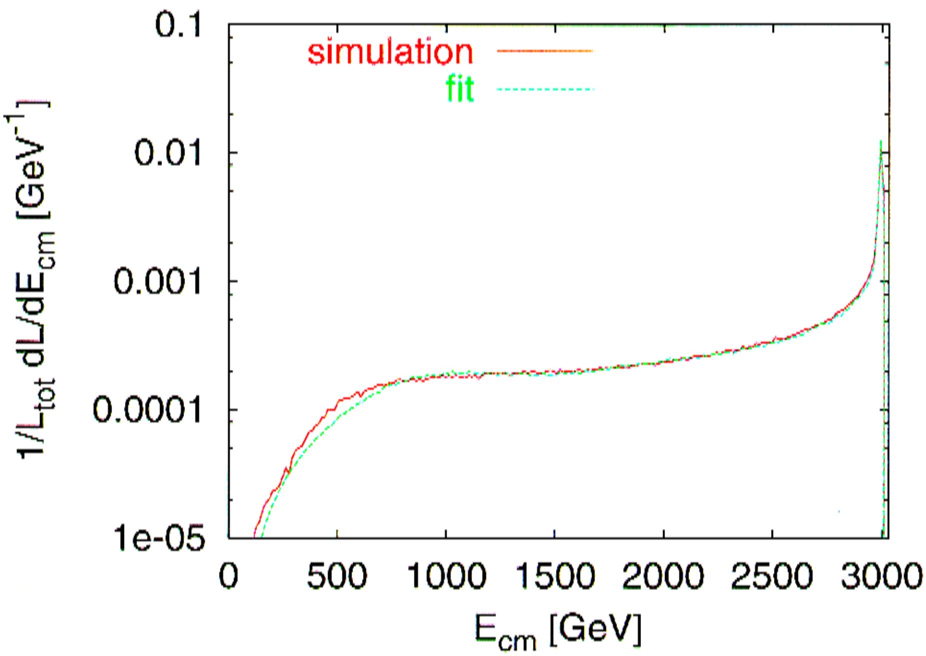
⇒ only $\approx 13\,\%$ for $l = 1\,\mathrm{m}$

⇒ more precise model needed

Pair Backgrounds Summary

- Excellent simulation packages for beam-beam bknds
  - CAIN, Guinea Pig beam-beam generators
  - GEANT3, FLUKA8
- VXD & Tracker hits look OK for $B_s > 3$ T
- First look at performance of monitor in the pair region
  - TESLA Diamond/Tungsten sampling calorimeter
  - JLC Active Pixel Sensor R&D Program (Gianluca Alimonti)
- Neutron radiation damage to VXD controlled by apertures, distance to source, and shielding: looks OK

Preliminary Parametrisation



Consider four cases

$$E_1 > \check{E}_0,\ E_2 > \check{E}_0$$

$$E_1 > \check{E}_0,\ E_2 < \check{E}_0$$

$$E_1 < \check{E}_0,\ E_2 > \check{E}_0$$

$$E_1 < \check{E}_0,\ E_2 < \check{E}_0$$

replace $E_i < \check{E}_0$ with $f(E_1/E_0)$

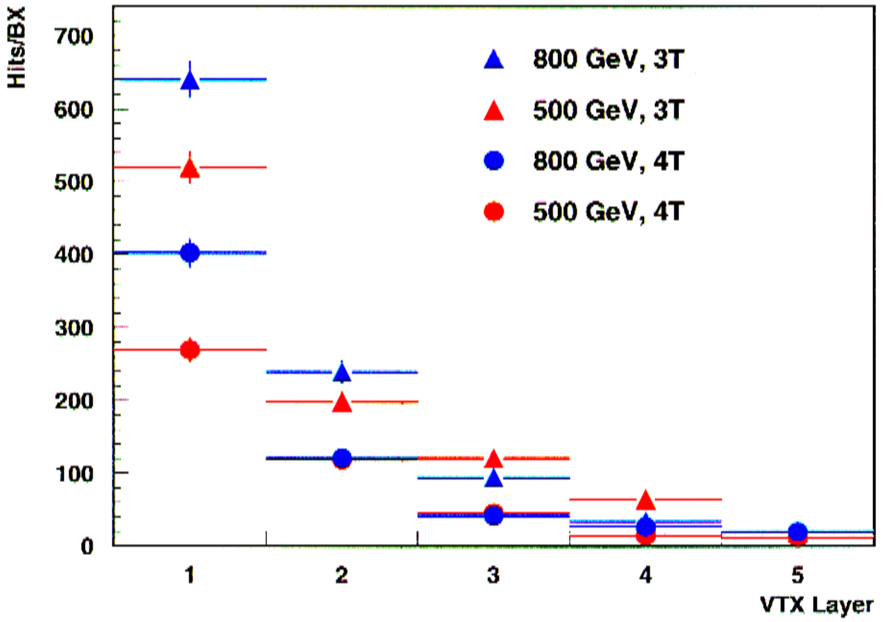
replace $E_i > \check{E}_0$ with constant (to be improved)

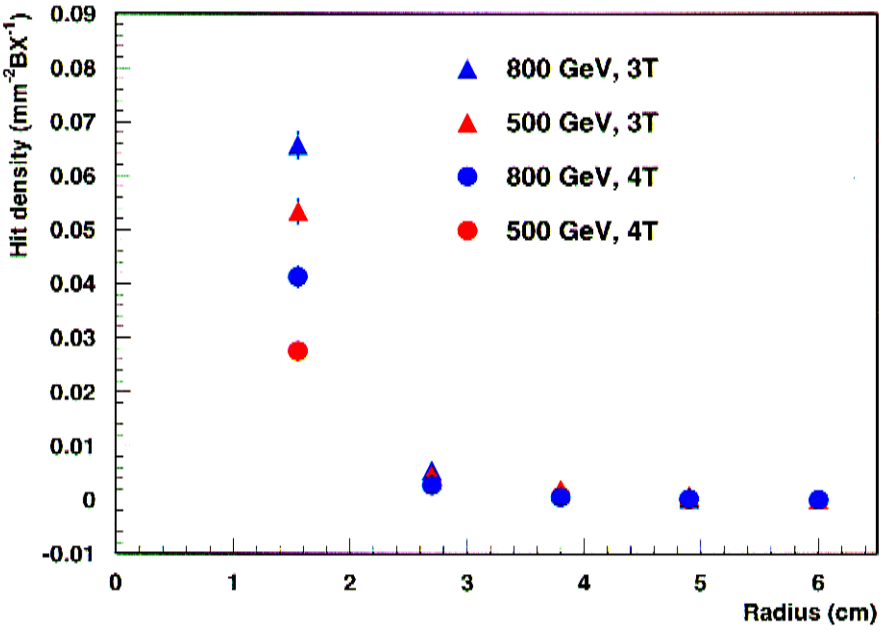
use proper weights for the four cases

$\Rightarrow$ approximation seems good for the tail

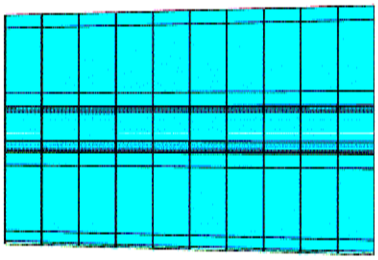
Hits from Pairstrahlung in the Vertex Detector

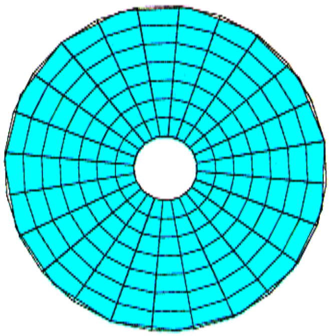
Hits in the vertex detector (CCD option)





Instrumentation of the LCAL





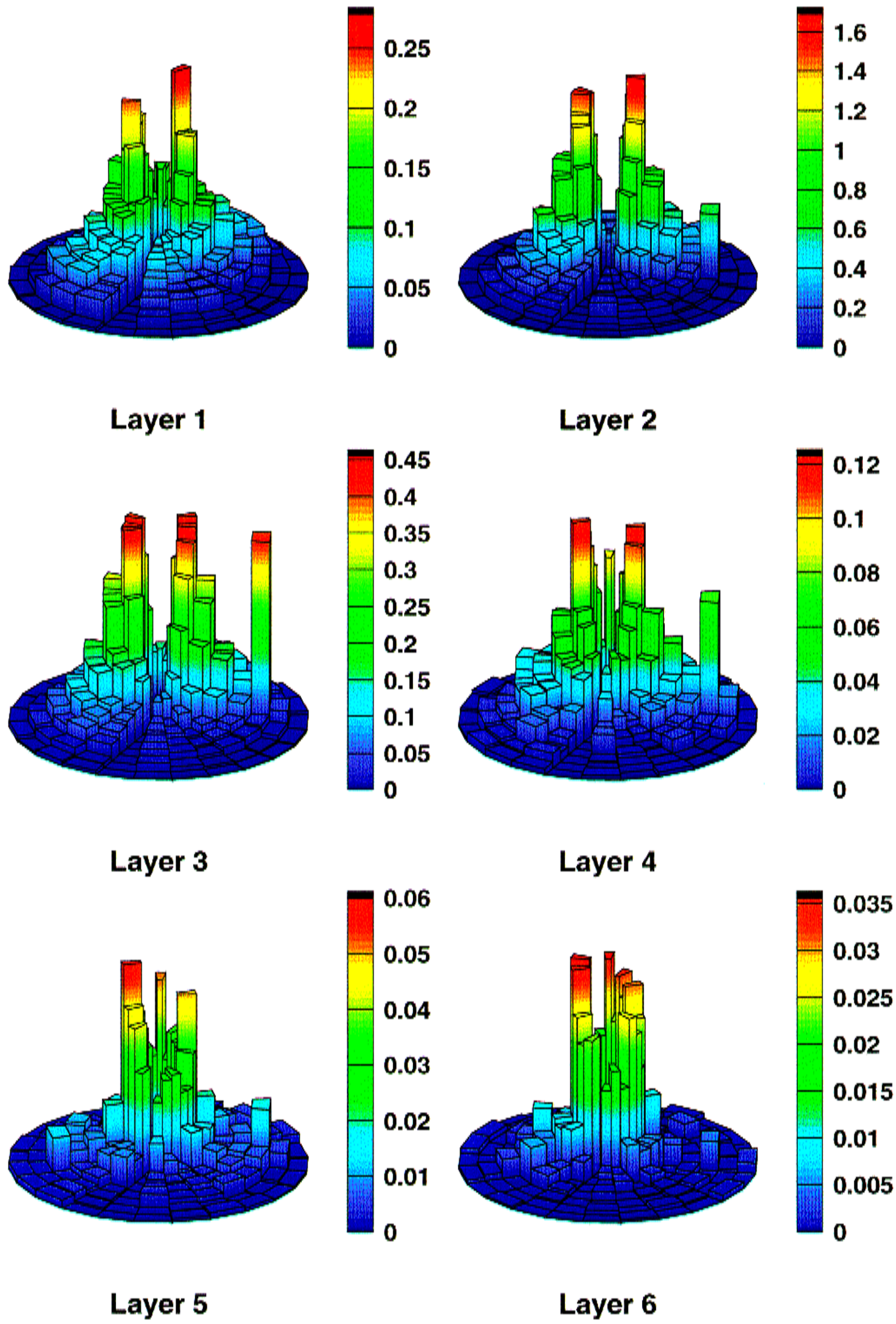
- Diamond/tungsten sampling calorimeter
- first layer is diamond (pair monitor)
- $\Delta\theta \approx 3.3$ mrad
- $\Delta\phi = 15$ deg
- Segmentation in z is under investigation right now

LCAL signal will be included in the fast feedback system
$\Rightarrow$ readout has to be done in ≤ 40 ns

LCAL: Pair Background and Electron Signal

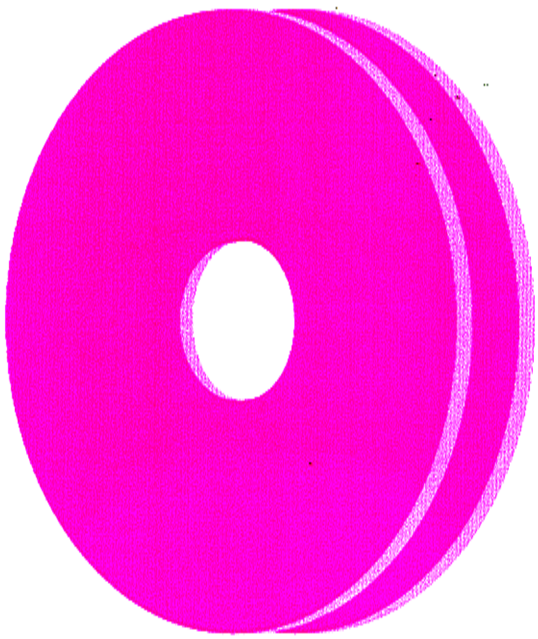
250 GeV electron at $\theta = 20$ mrad

$+$ pair background for 1 BX @ $\sqrt{s} = 500$ GeV



Pair Monitor

as a beam profile monitor



single Active Pixel Sensor

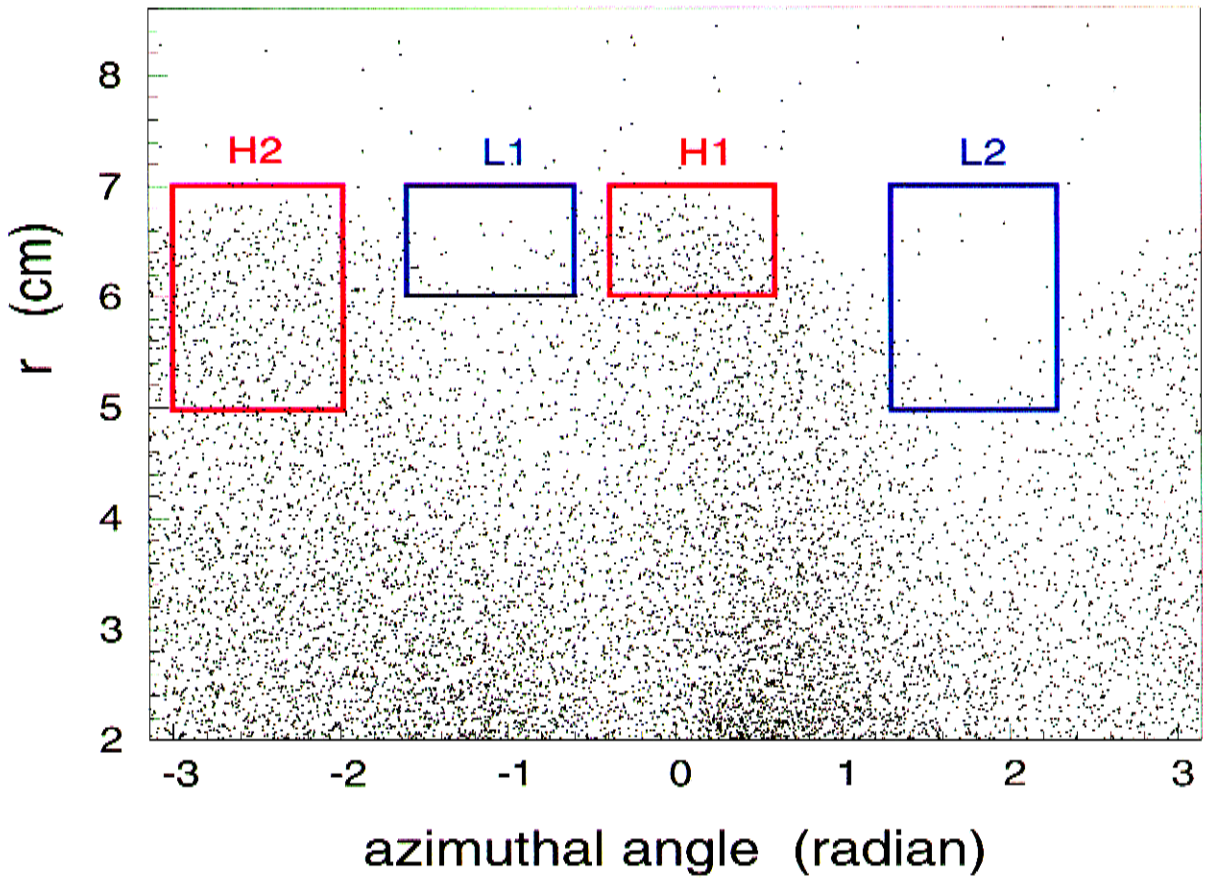
~~double~~ layer of silicon disks

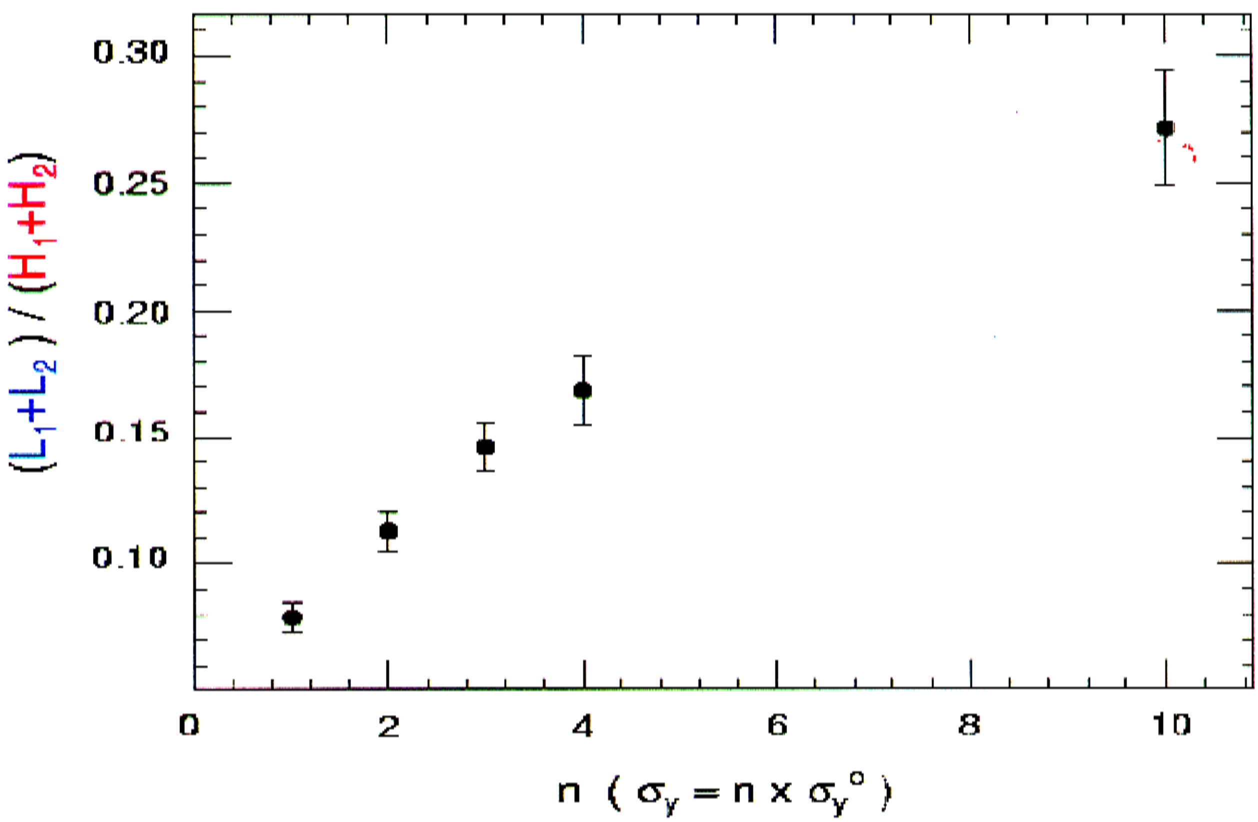
pixel size	100 x 100 μm^2
thickness	300 μm
inner radius	2 cm
outer radius	8.5 cm
location (z)	176 and ~~177~~ cm from IP

Measurement:

position and energy deposit

Pair Monitor

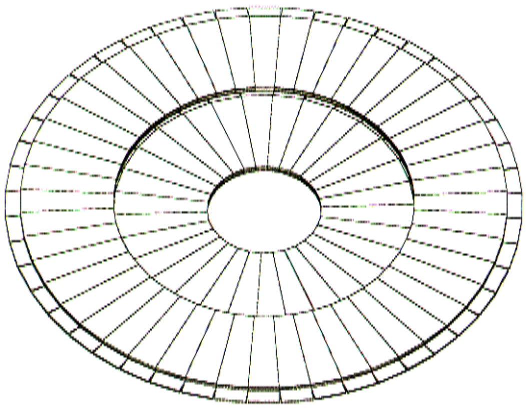




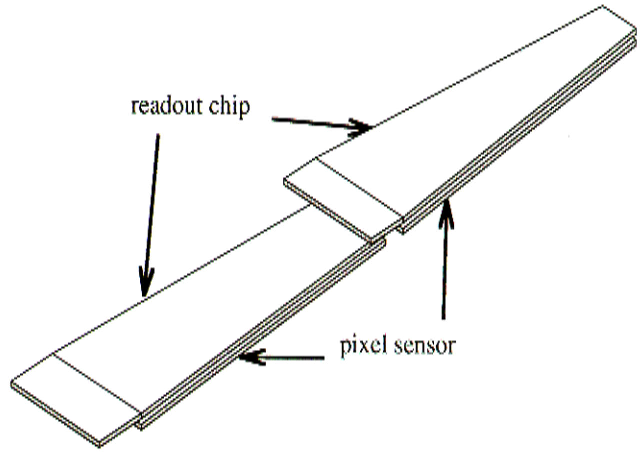
Pair Monitor Prototype

A set of 3D sensors currently in fabrication @SNF.

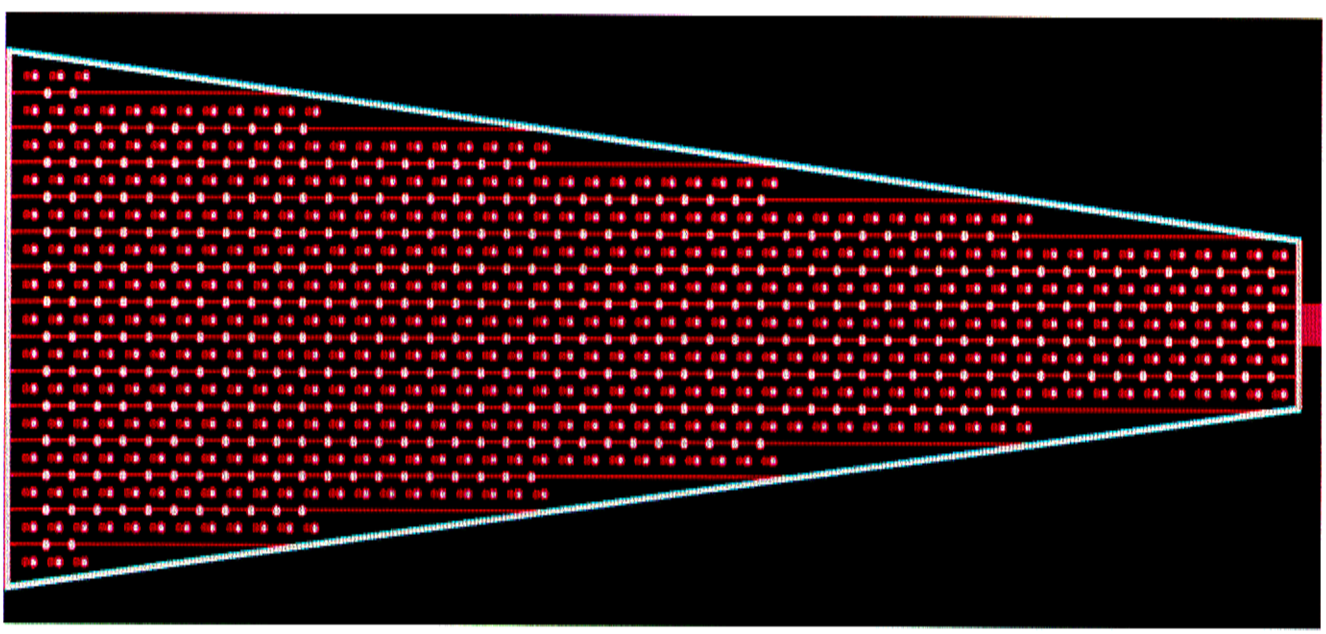
If all goes well, sensors available by the end of the year.



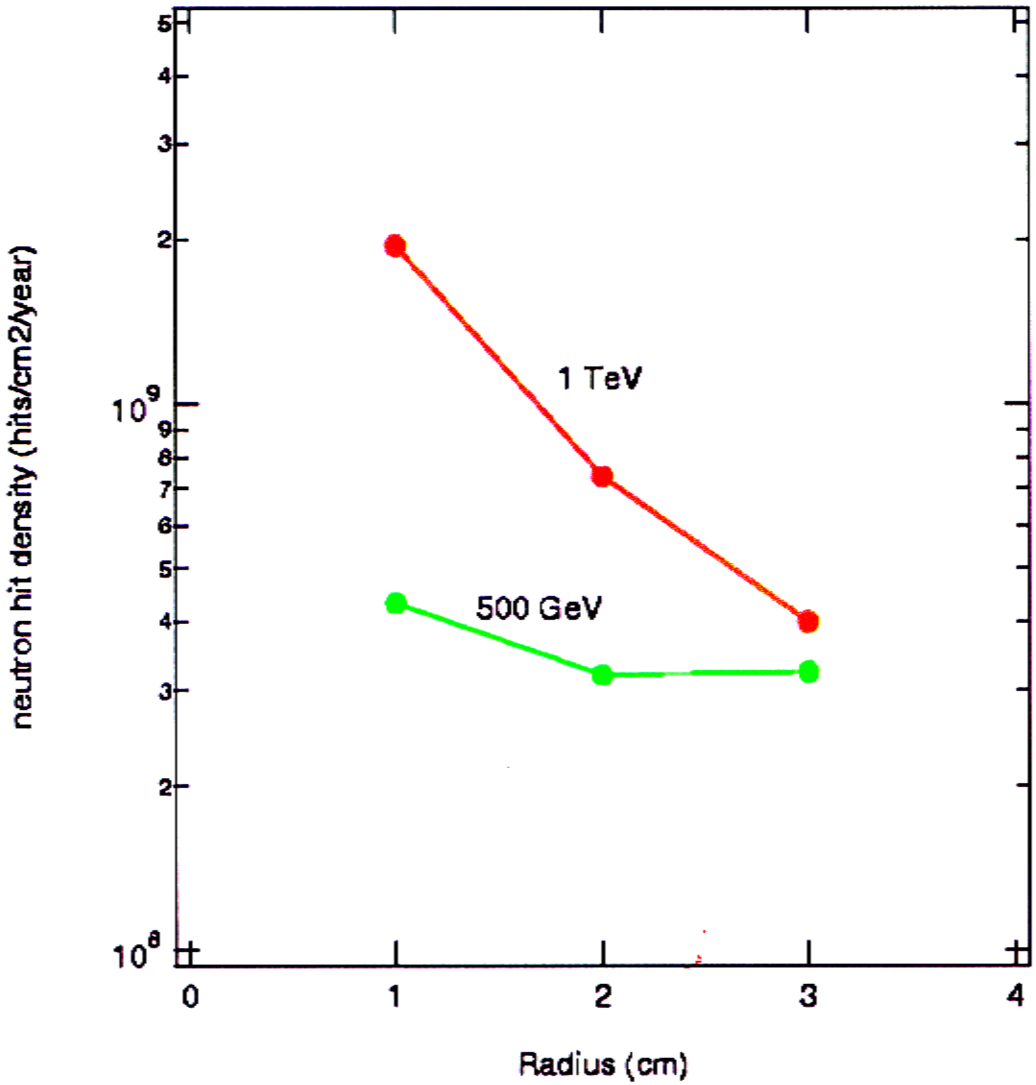
One disk showing the detector arrangement: top side facing the IP



One trapezoidal component of the disk: sensor facing the IP



Neutron Hit Density vs. Extraction Line Aperture



Particles showering close to the IR are bad for neutrons.

Increasing extraction line aperture transports them farther away.

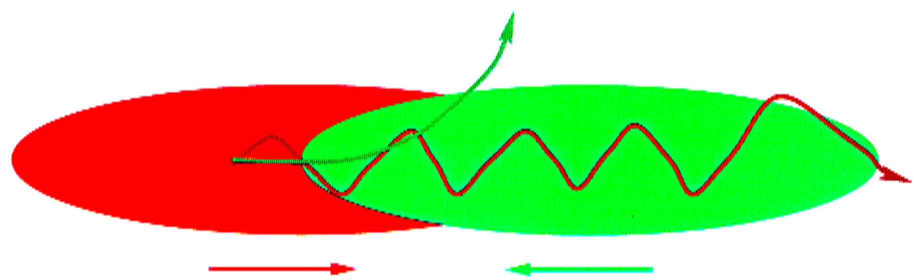
Coherent Pairs, Muons, Hadrons, & SR

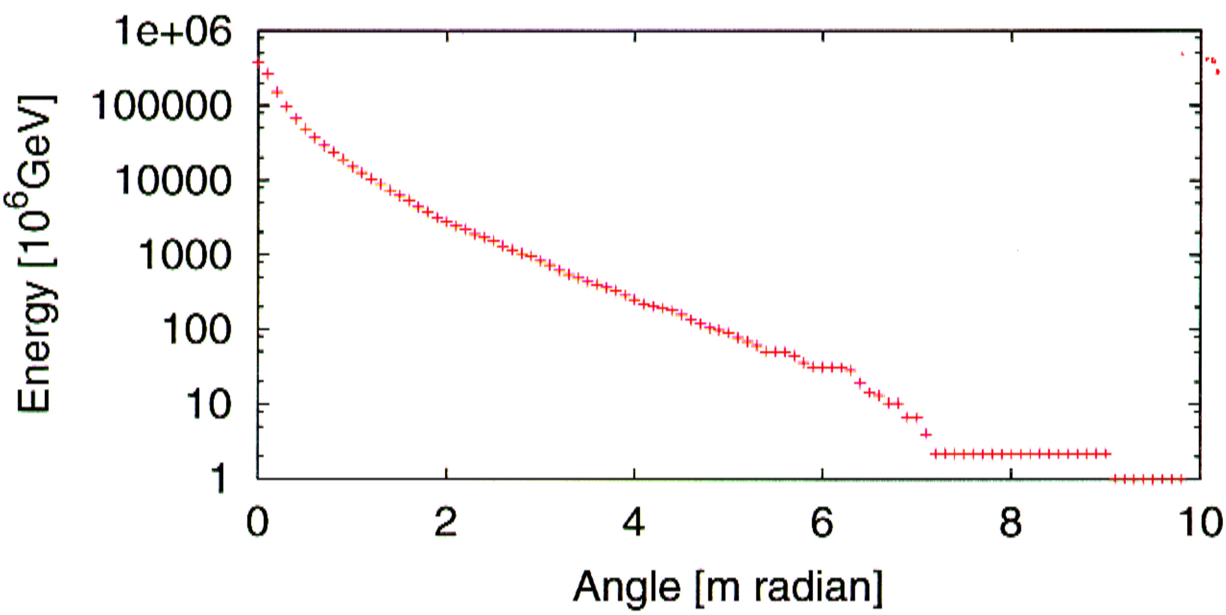
- Coherent Pairs (Upsilon)
  - First quantitative simulations of their effect (Schulte)
- Muon Backgrounds
  - If halo assumed low (10^{-6}), not a problem for ANYONE
  - Helped further in TESLA by bunch structure; in NLC/JLC by detector time resolution
  - Could be removed by deflecting magnet system (muon spoilers)
- Hadrons
  - Acceptable track/energy deposition per BX in TESLA
  - Short train machines probably need time and spatial resolution
    - Certainly need more effort here in NLC
- Synchrotron Radiation
  - Collimation and detector apertures sized so this is not a problem

Coherent Pairs

E_{CM} [TeV]	no of pairs	$E_{coh}[10^9\,\mathrm{GeV}]$
0.5	700	10^{-4}
1	$3 \cdot 10^6$	0.8
3	$6.7 \cdot 10^8$	440
5	$1.8 \cdot 10^9$	1630

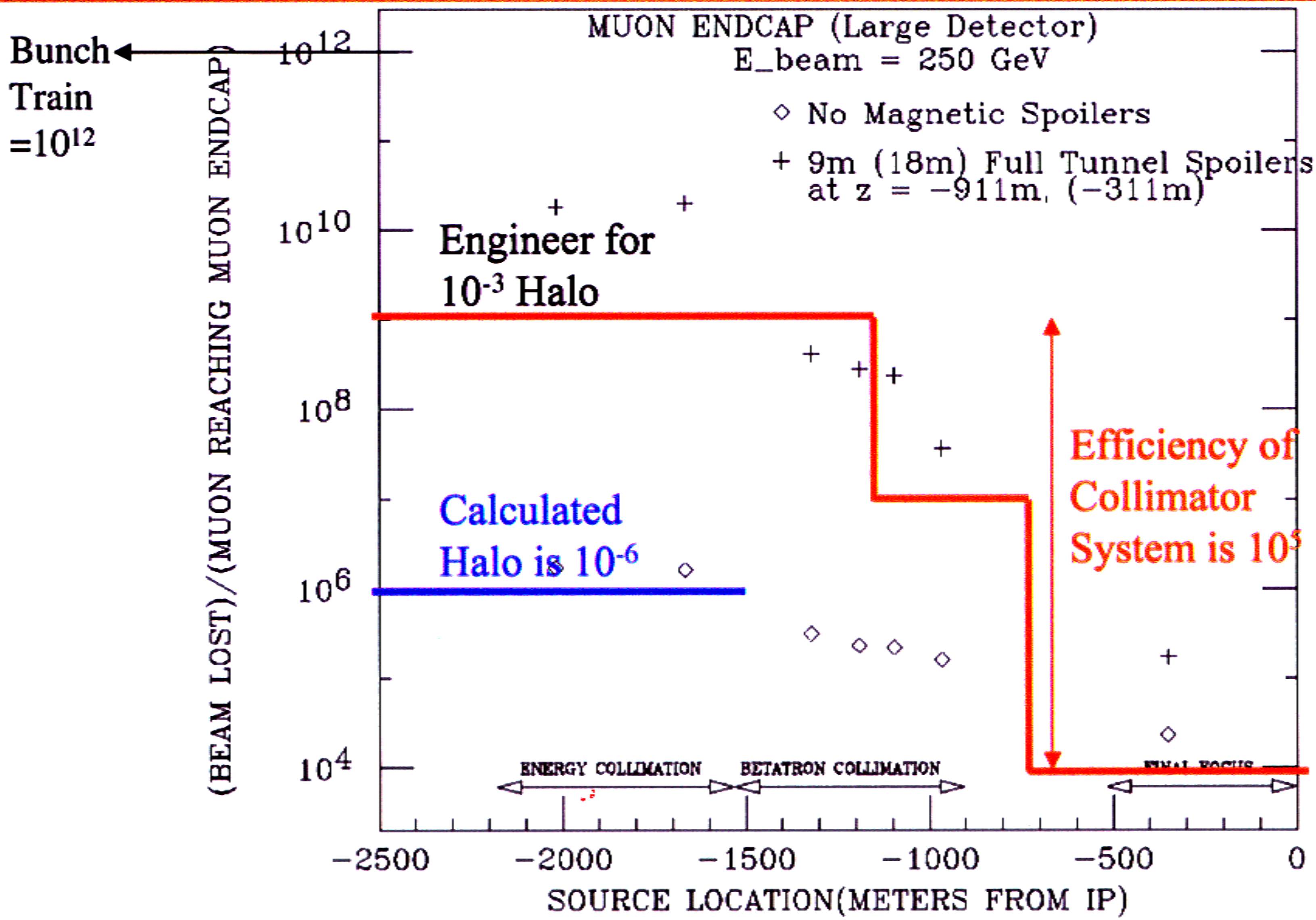
$\Rightarrow$ significant fraction of bunch charge $(4 \cdot 10^9)$





$\Rightarrow$ exit angle larger than $10\,\mathrm{mradian}$

250 GeV/beam Muon Endcap Background



Hadronic Background

Hadronic background: $e^+e^- \to e^+e^-\gamma\gamma \to$ hadrons

(see LC-DET-2000-001 by C. Hensel)

Simulated using GUINEA-PIG (photons) and HERWIG 5.9 with mulitparton interaction on for the $\gamma\gamma$ interaction.

TESLA 500 GeV, $L = 3.14 \cdot 10^{34}$ cm^{-2} s^{-1}

type	events/BX (10^{-2})	mult.	charg. mult.	E_{tot}/BX (GeV)
direct	0.53	15.2	8.5	0.25
single res.	0.40	30.5	15.7	0.32
double res.	1.12	44.7	22.2	1.50
all	2.05	34.3	17.4	2.07

Charged hits in vertex detector

Total number of charged hits/BX on inner layer:

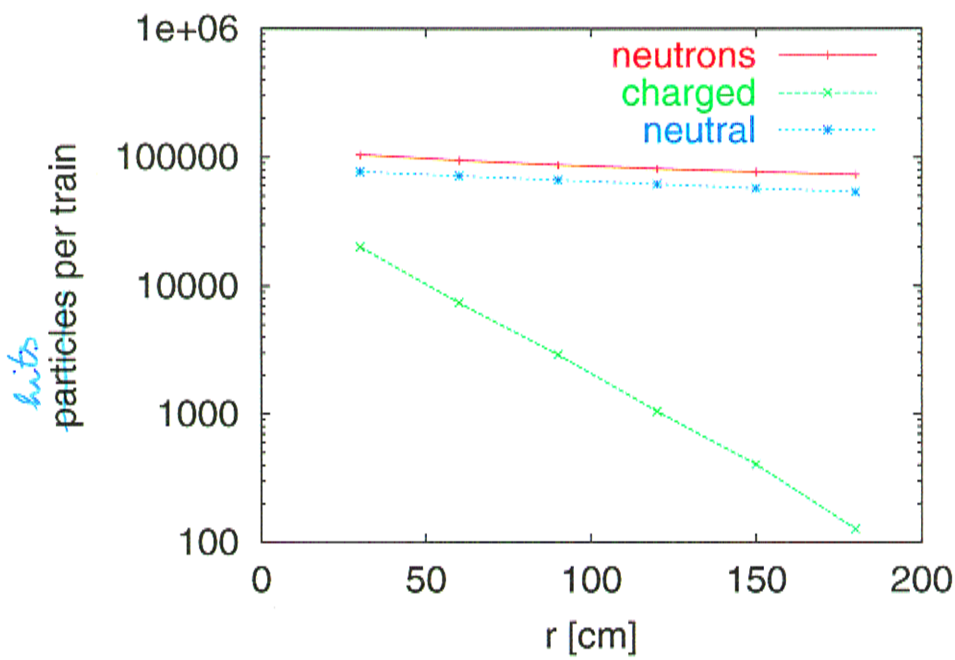
$\leq 3400 \cdot 10^{-8} \cdot mm^{-2}$

Charged tracks in TPC

Total number of charged tracks/BX in TPC:

$\leq 0.7 \to \approx 105$ in 150 BX

Hadronic Background in the Central Tracker



Full GEANT simulation

events from HADES with PYTHIA

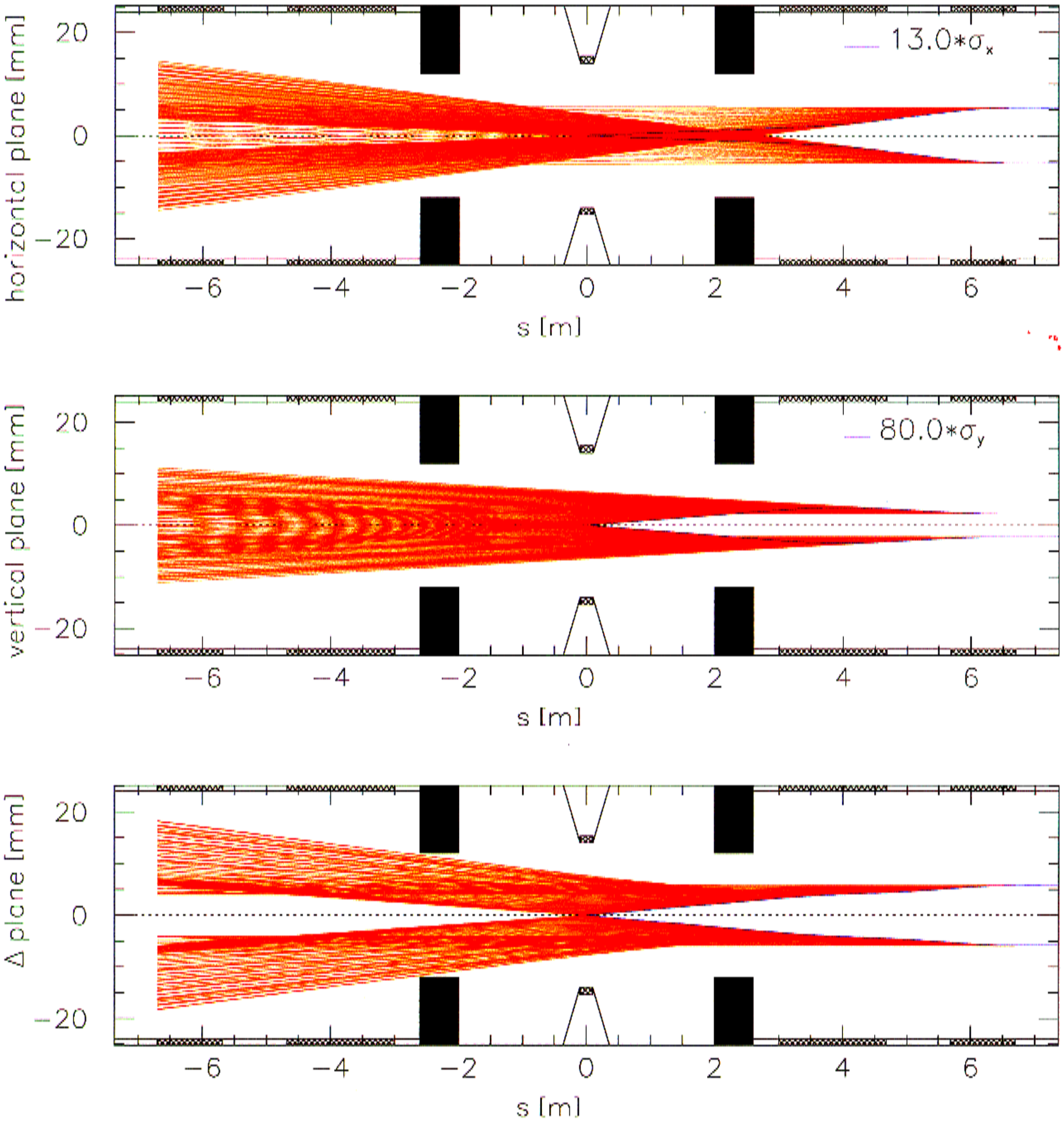
no cavity effect included

2000 bunch crossing simulated

⇒ density of charged particles drops quickly with radius

SYNCHROTRON RADIATION from FINAL DOUBLET QUADRUPOLES

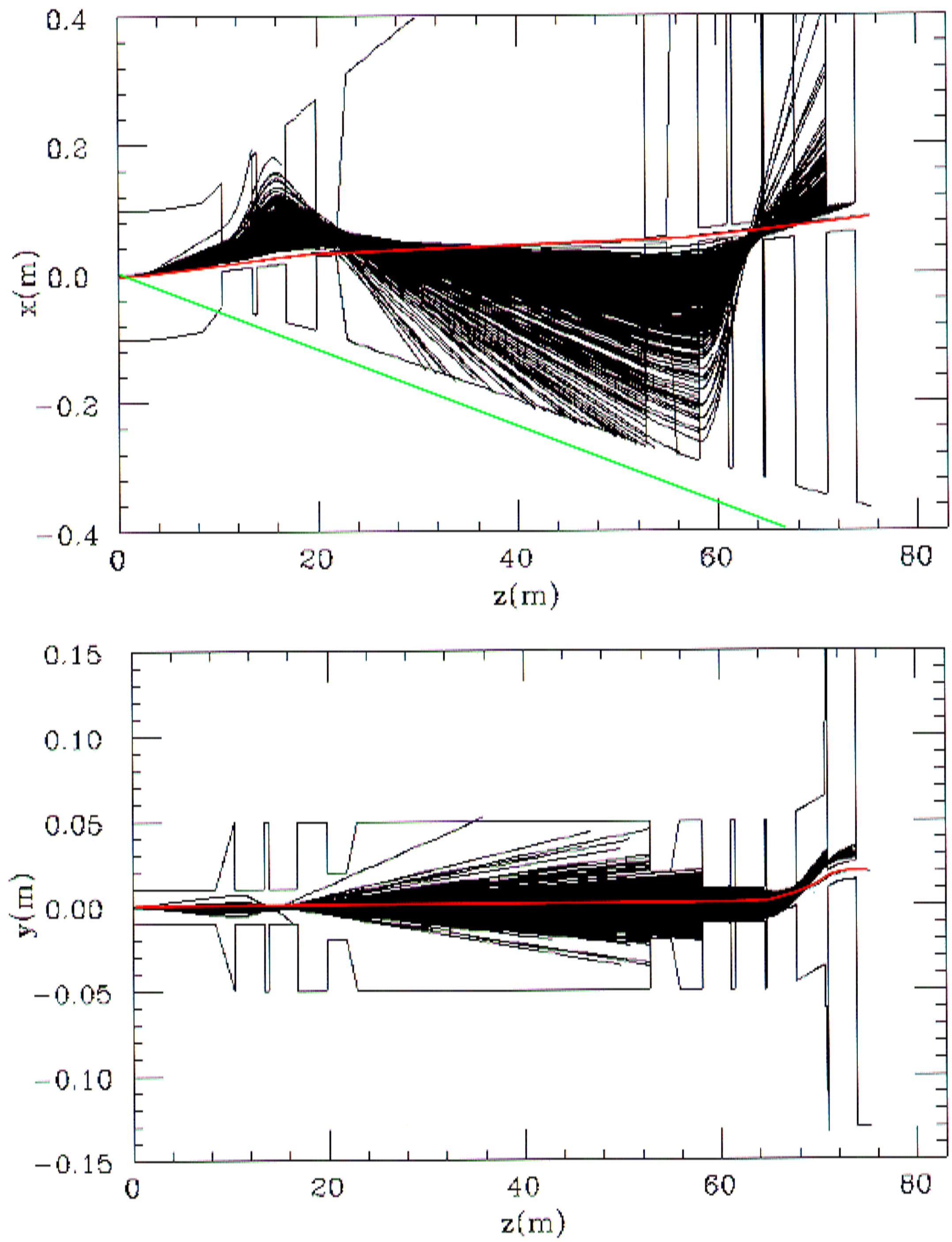
TESLA_iL 500 GeV (3 doublets)



Extraction Line Backgrounds

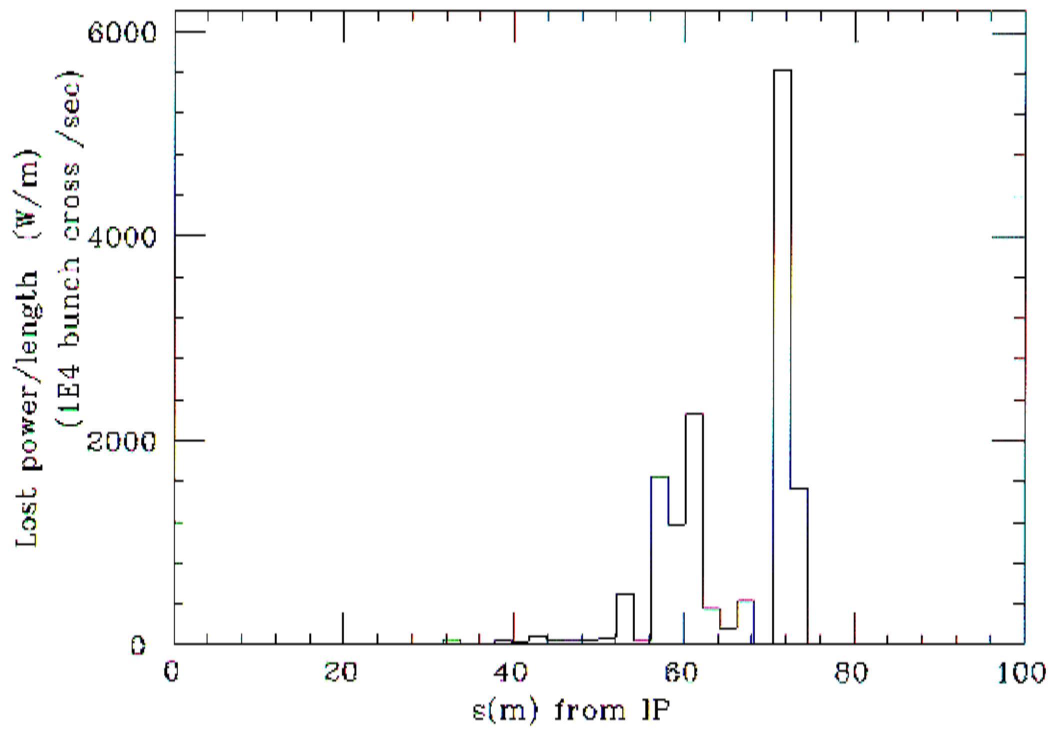
- Everyone is struggling to understand how to best cleanly extract a highly disrupted beam
  - Vertical bending (JLC & TESLA); Horizontal (NLC)
- Neutron-Backshine from the dump onto the VXD looks OK for the typical 1mrad apertures in e+e-
  - May be SIGNIFICANT issue in e-e- and gg (more on this later)

Trajectories of the lost electrons

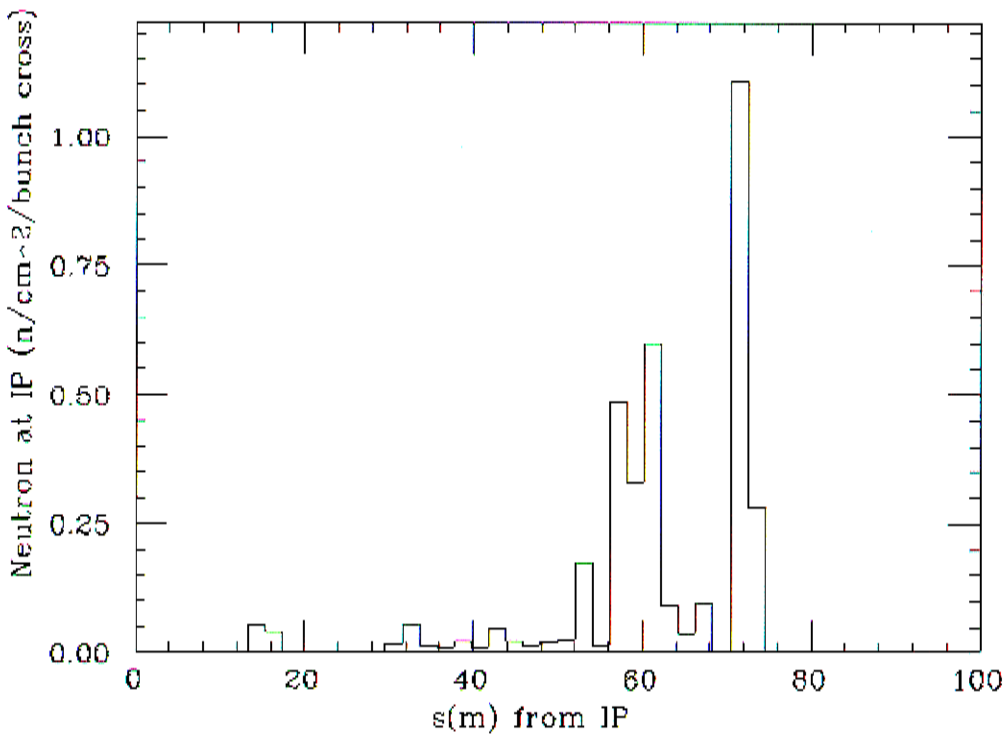


Beam loss along the extraction line

Power (W/m)



Neutron at IP (/cm^2/bunch crossing)



0.1 n/ GeV is assumed (self shielding effect NOT included)

Total = 4×10^{11}/cm^2/y at IP -> 1/100 attenuation is enough

gg, e-e-, and extracted beams

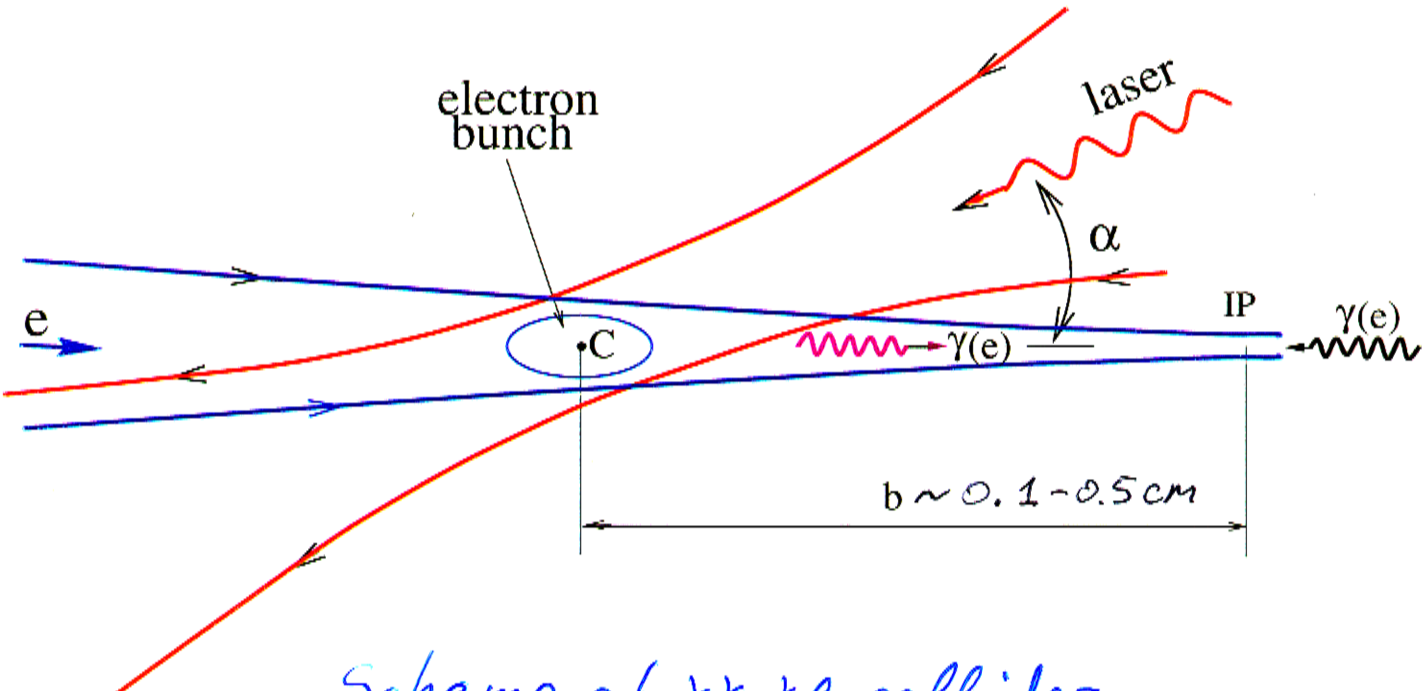
- Valery Telnov / DESY & Budker INP
  - Photon colliders at TESLA: parameters & IR issues
- Jeff Gronberg / LLNL

  IR and background modelling
- Jim Early / LLNL
  - Status of laser technology
- Rainer Pitthan / SLAC
  - Fixed target physics and beamline design at the NLC
- Siggi Schreiber / DESY
  - e-e- collisions at TESLA

Gamma-Gamma at TESLA

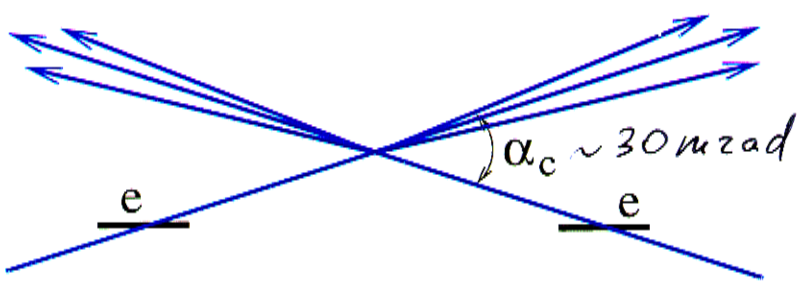
- Can the beam parameters be adjusted to increase L:
  - Laser cooling in DR could improve horizontal emittance x4
  - Reduced E_x at IP from 5 to 1.5mm
- Laser Development
  - Optical storage ring to pump laser power for TESLA

Photon colliders



Scheme of γγ, γe collider

a)



b)

crab crossing

Laser cooling of electron beam for LC

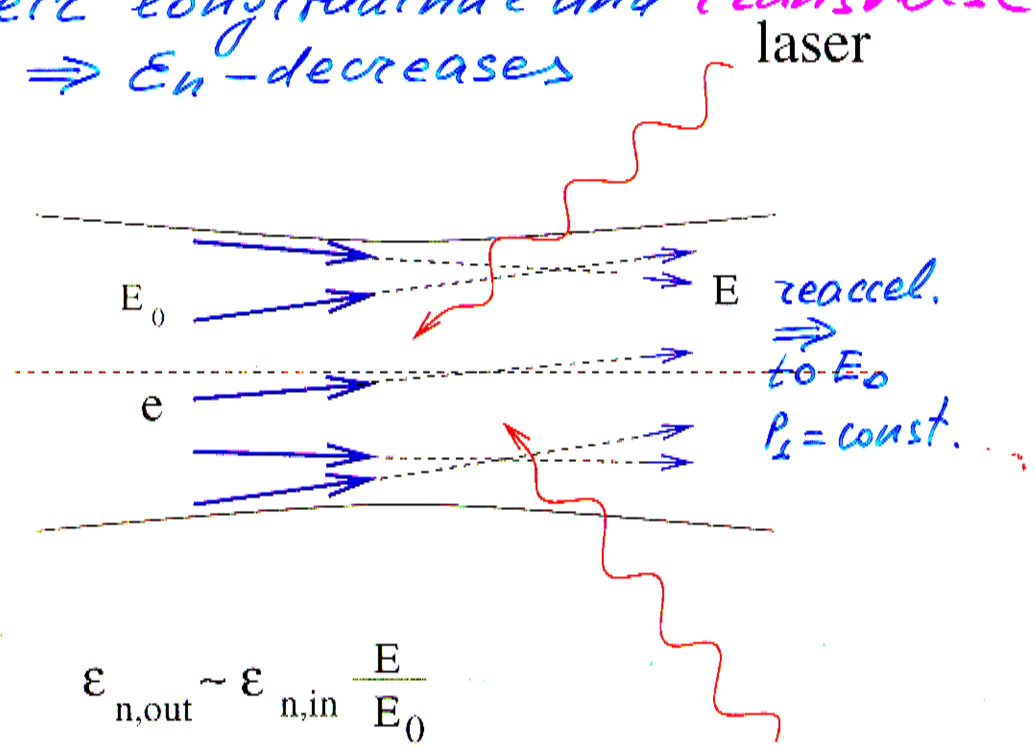
V. Telnov

V. Telnov
PRL 78(1997)4757
80(1998)2747(er)

$\varepsilon_i = \sigma_i \cdot \theta_i \qquad \varepsilon_{n,i} = \varepsilon \gamma$

$\sigma_{IP} \sim \sqrt{\dfrac{\varepsilon_n \sigma_z}{\gamma}}$ $\qquad \varepsilon_n$ – normalized emittance.

Principle: electrons with the energy ~5 GeV are collided with powerful laser pulse and lose their longitudinal and transverse momenta $\Rightarrow \varepsilon_n$ – decreases



$$\varepsilon_{n,out} \sim \varepsilon_{n,in} \frac{E}{E_0}$$

$$\sim \left(\frac{1}{10} \div \frac{1}{5}\right) \varepsilon_{n,in}$$

Problems, issues

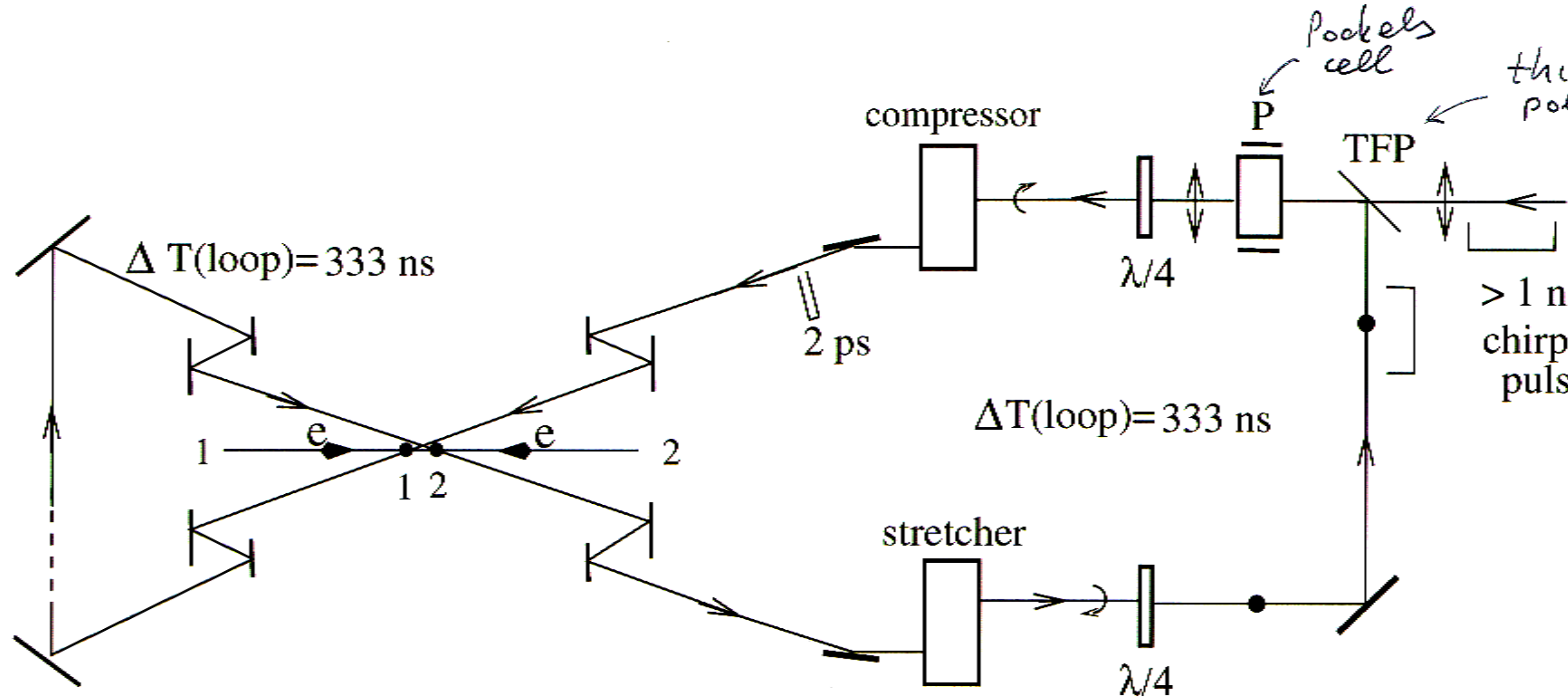
1. Flash energy
2. Energy spread
3. Ultimate emittance
4. Depolarization
5. Ponderomotive forces
6. Radiation damage of optics.

Optical scheme for photon collider at TESLA

optical „storage ring"
optical trap

hep-ex/0010033
V. Telnov

o)



Each 5 J, 2ps laser bunch makes ~ 10 round trips in the "optical storage ring" and 2×10 times collide with electron beams

$\bar{P}_{laser} \sim 7$ kW (~8 lasers)
diode pumped

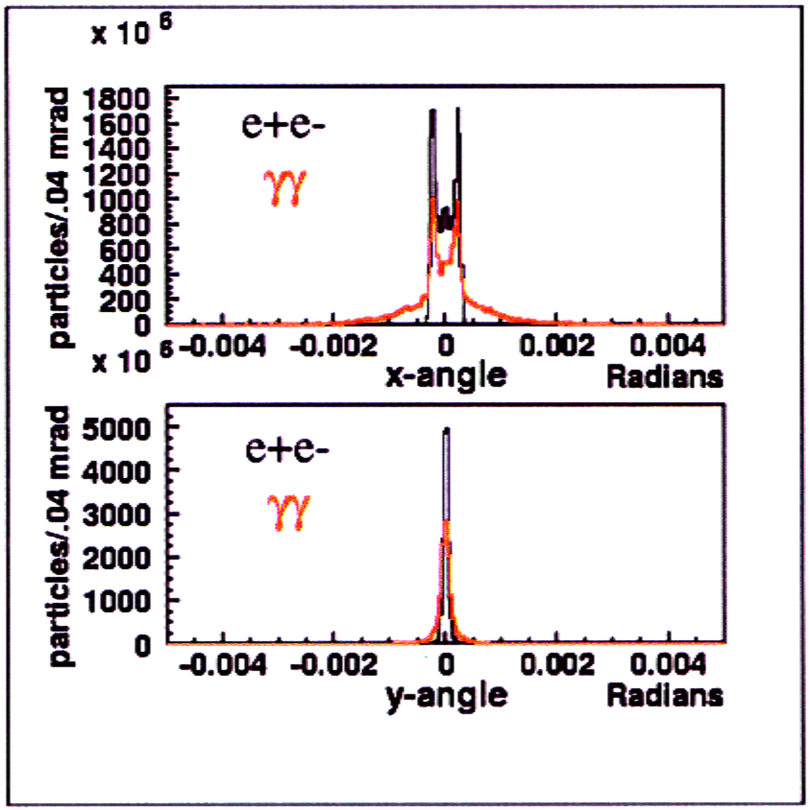
P_{peak}(diodes) = 3 MW
× 5 $/W
15 M$

Cost of diodes
5 $/W – now
1 $/W – planing exper.
0.07 $/W – fusion

Gamma-Gamma @ NLC/JLC

- Examination of gg IR issues at has LLNL begun
  - 1 EP, 1 AP, 1 Laser Phys., 2 students, 1 boss at LLNL
- Begin with official e+e- parameter set and IR design
  - Extraction line aperture > 5mrad
    - Larger if go to more aggressive beam parameters
    - Exposes SVX to backshine from dump
      - Energy density in μrad photon beam may be problem for dump window
    - Reminded that will want gg produced from e-e-
      - So both g can be highly pol.
      - Suppress unwanted states arising from e+e-
  - Central mirror going to be a challenge
- Laser R&D
  - Architecture driven by bunch structure
  - Adapt LLNL MERCURY project laser system
    - Power, heat management, temporal & spectral pulse shaping & amplification

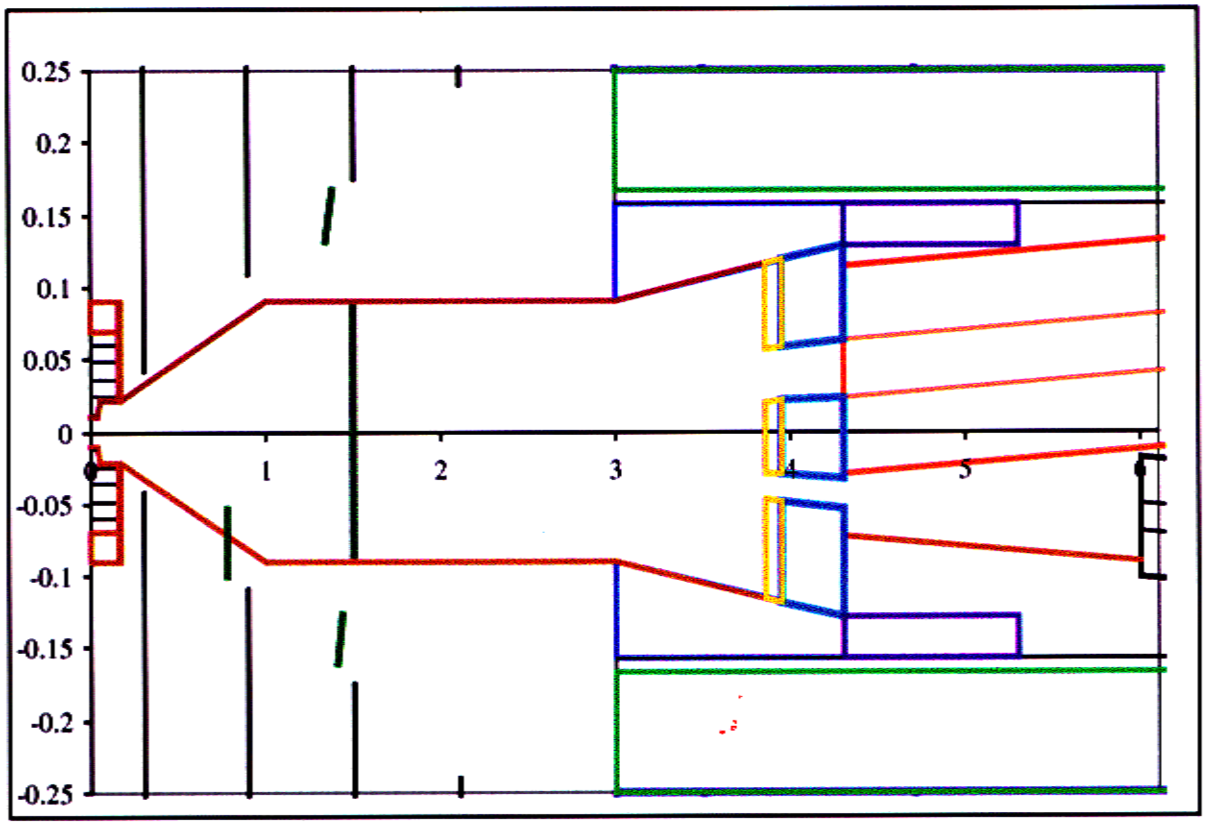
Disrupted Beam



- The first priority is to ensure that the disrupted beam can be transported away from the IR.
  - Easy for e+e-, minimal angular disruption.
  - Difficult for gamma-gamma
  - Energy spread in incoming pulse leads to larger angles.
- Requires extraction line aperture +/- 5 milliradians
- Zero field extraction line, no optics.
- Physics impact of no diagnostics?

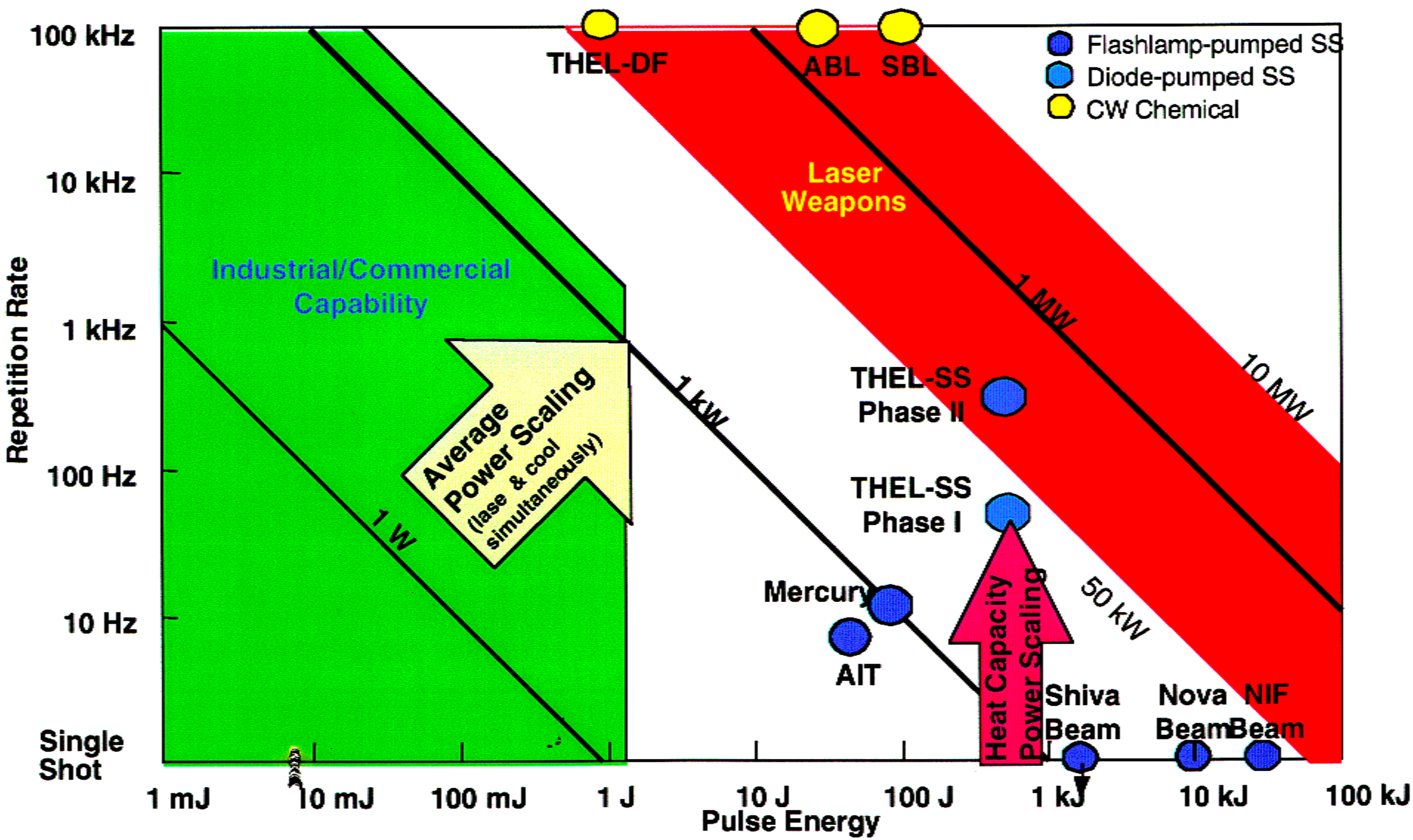
Focusing mirrors - tight fit

LCD - Large with ZDR mirrors



- Current IR beam pipe doesn't accommodate but there is room for the mirrors with modification.
- Only the final mirror is in the path of the pairs.
- Standard mirror design 4.3 cm thick.
  - Reduce material in the path of the pairs to 1cm thick.

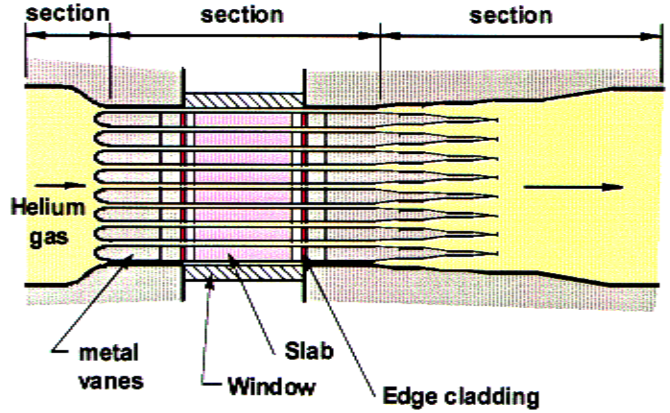
HCL Solid-State Lasers are approaching the average power necessary for laser weapons



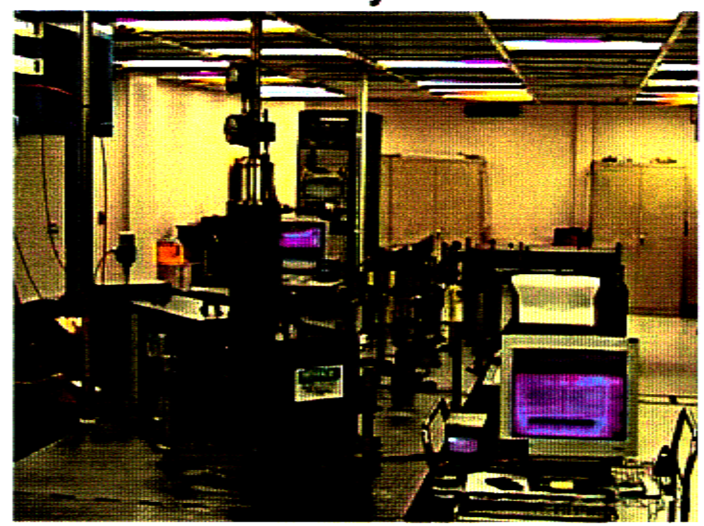
HELERP
19 Nov 99

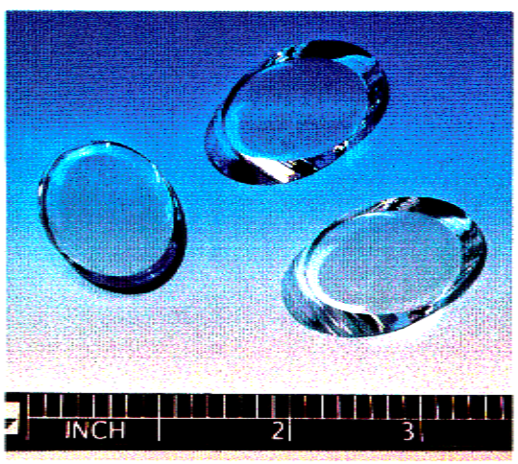
We are developing diode-pump solid state lasers as the next-generation fusion driver - Mercury will deliver 100 J at 10 Hz with 10% efficiency

Gas flow concept

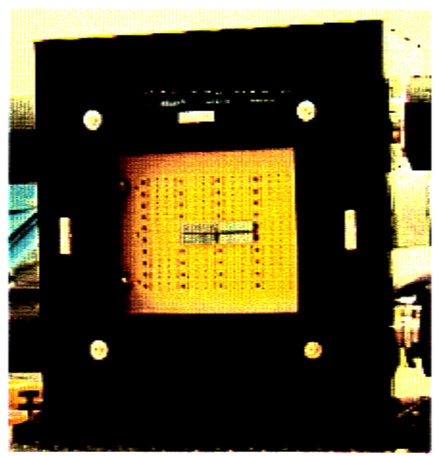


Mercury Lab



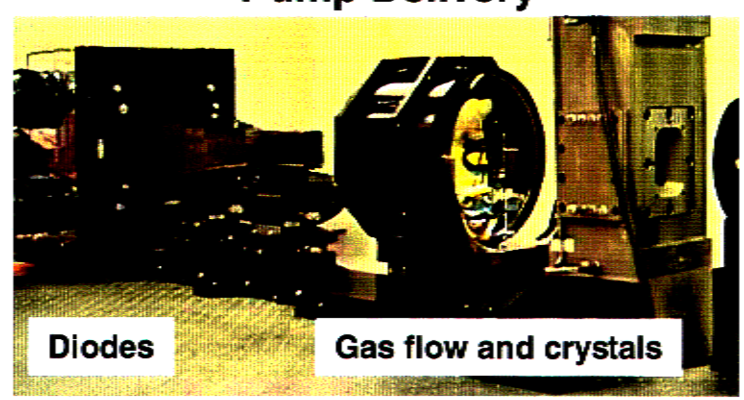


Yb:S-FAP crystals

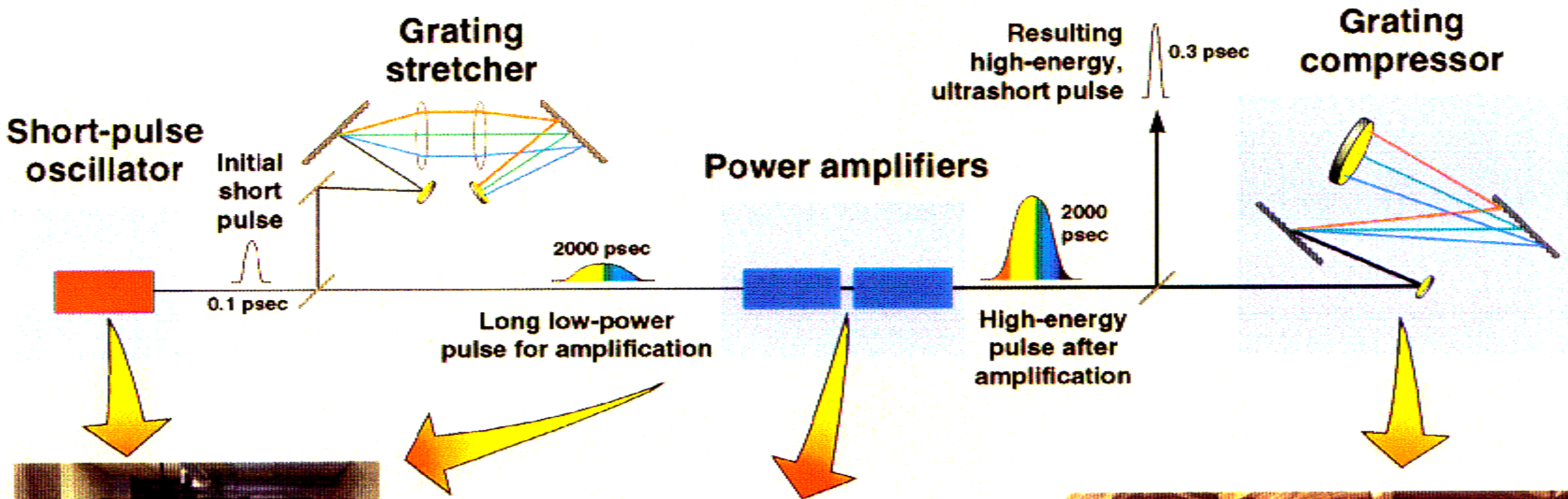


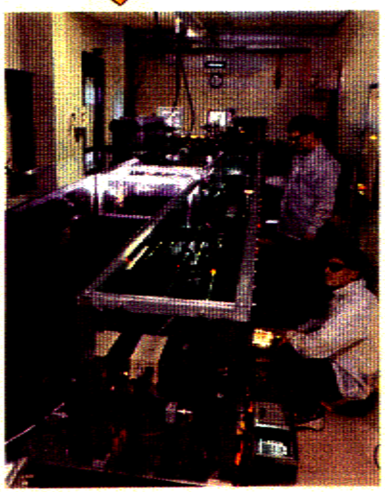
Diode array capable of 160 kW

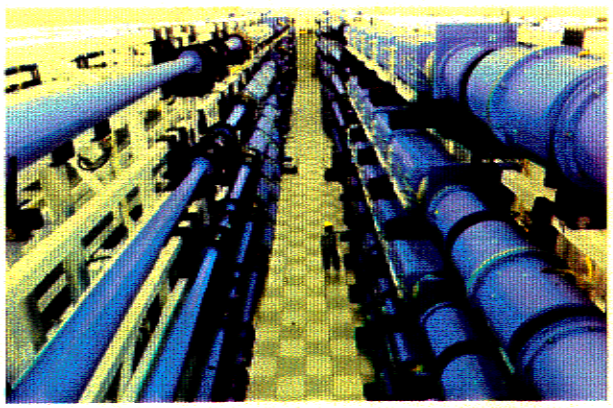
Pump Delivery

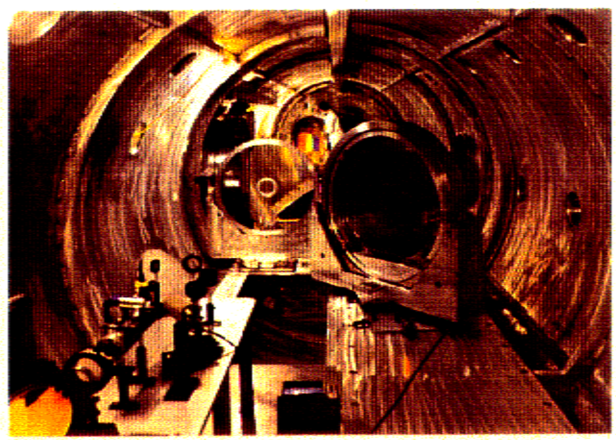


New technology enables production of Terawatt to Petawatt (1000 TW) pulses









70-60-0895-1899B

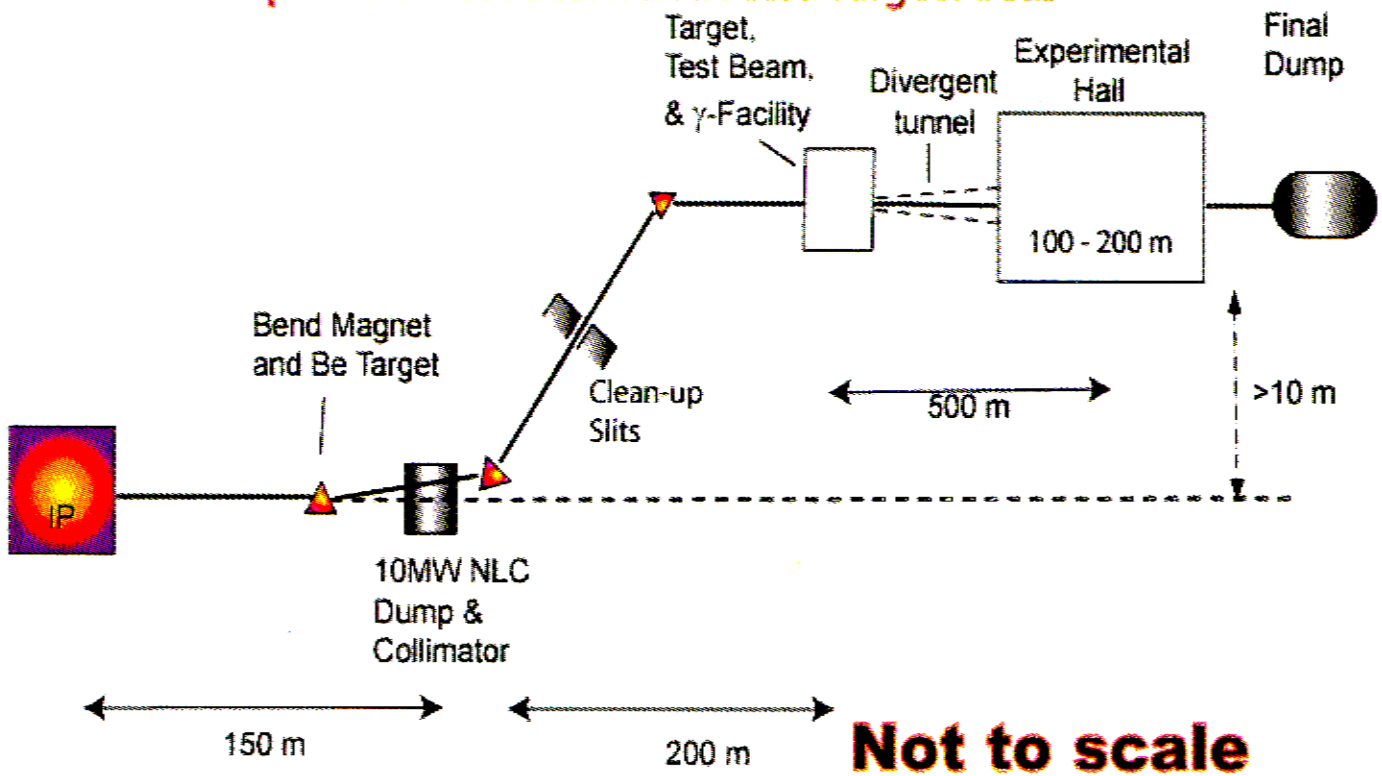
8 May 1999

Fixed Target and e-e- Summary

- Extraction of full energy primary or test beams
  - Test beams are "easy" if users demand them
    - Based on scheme currently in use at SLAC
    - Too late for 1st generation detectors
  - FT Physics opportunities exist
    - Will need to use disrupted beam as expts. too long for devoted runs
      - Cleaned by high power energy slits
    - Non-trivial, but seems possible
- e-e-
  - Reduced Lum relative to e+e- leads one to want to play with beam parameters sig_z and sig_x
  - Anti-pinch makes intra-train feedback more important, but should not be a problem for system designed
  - Increases disruption means larger but still feasible losses in extraction line

Schematic

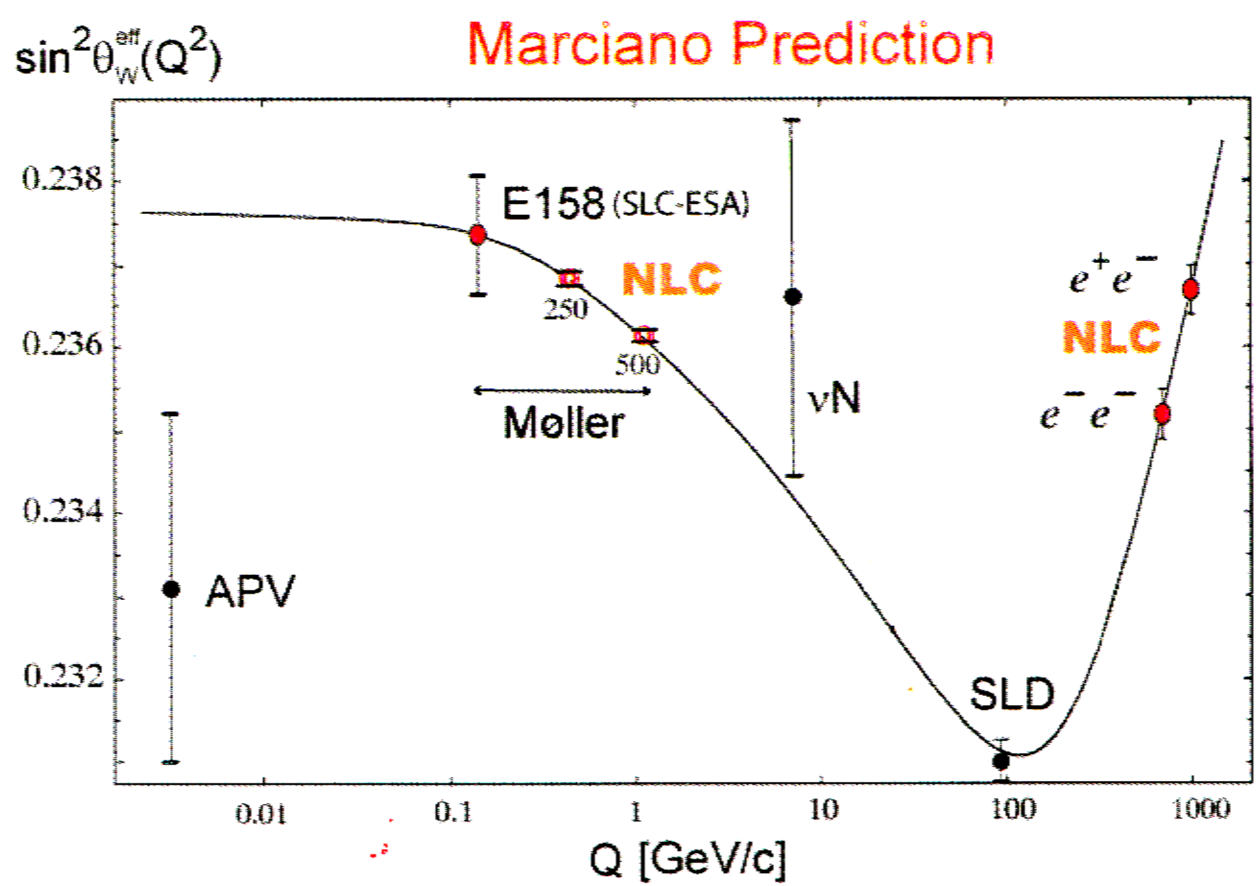
Topview of Test Beam and Fixed Target Areas



Not to scale

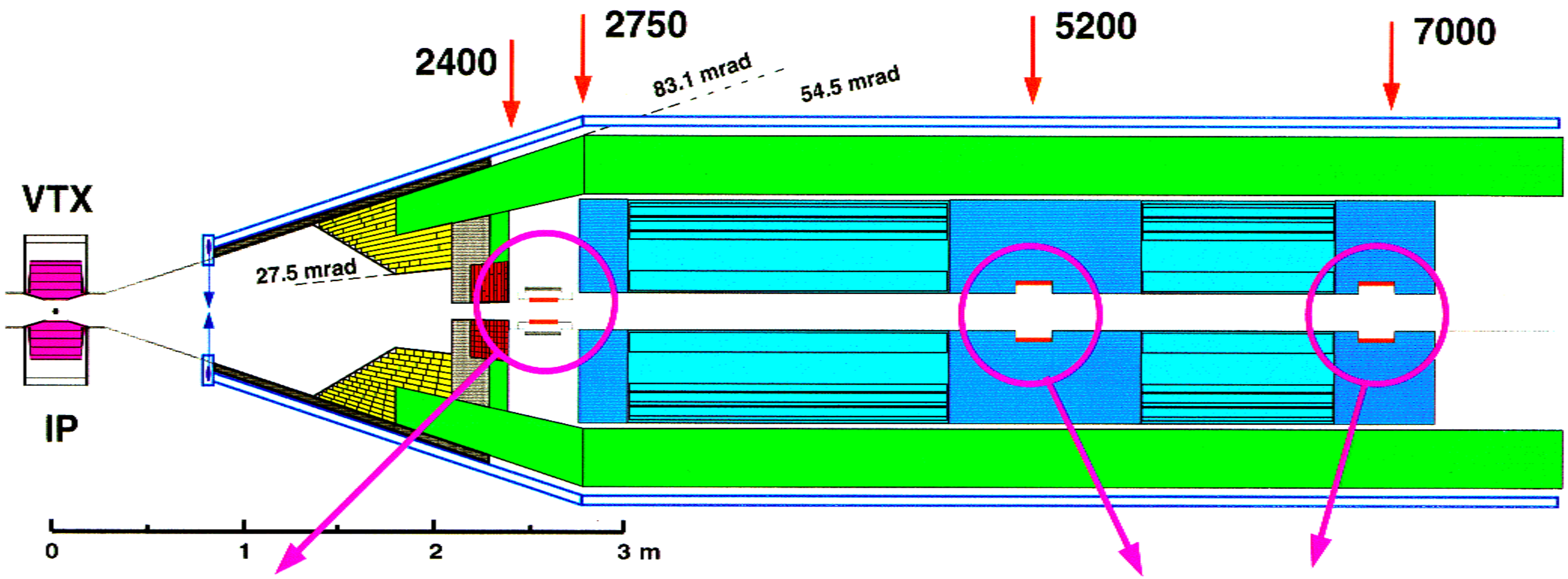
Rainer Pitthan

The Running of $\sin^2\Theta_W$ and Polarized Møller Scattering



Rainer Pitthan

Beam Position Monitors at the mask for feedback



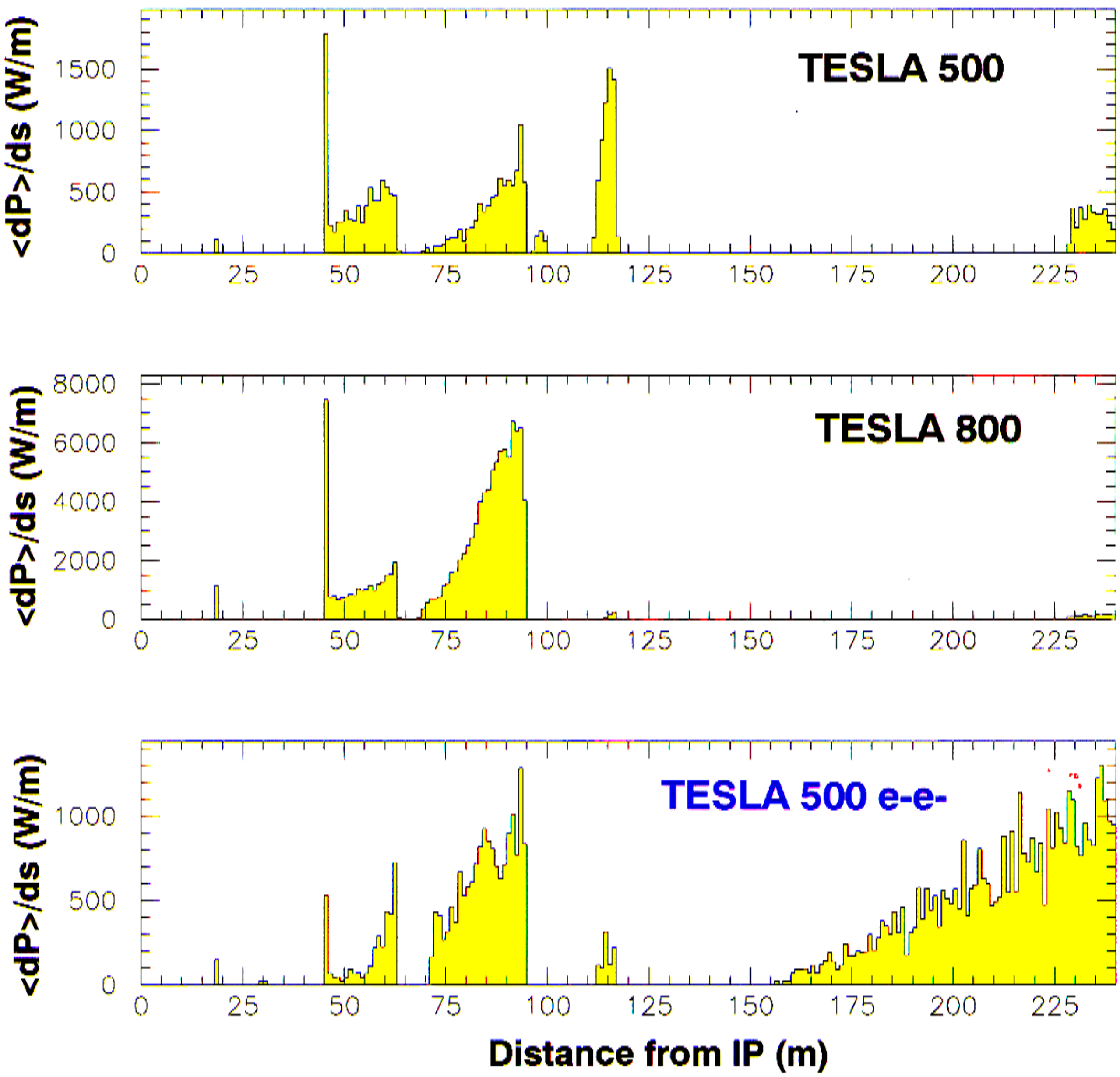
- **need:** BPM resolution: < 5 um
  must resolve e+/e- bunches -> response < 20 ns
- **best solution:** stripline monitors
  advantage: strip lines are directive
  but: difficult to put them into the kryostat

- 2 additional BPMs useful
  to determine the beam orbit
- reentrant cavity BPMs
  in the kryostat
- resolution < 5 um
- difficult to resolve e+/e-
  response < 30/50 ns

Tungsten Shield | Kryostat | Quadrupoles

Spent beam losses during extraction

(O. Napoly)



Spent beam losses in the e-e- case not much worse than e+e- (800 GeV)

Diagnostics & Instrumentation

- Beam Energy Measurement and Calibration
  - Stan Hertzbach / U. Mass
    - SLD E Spectrometer Approach
  - Mike Hildreth / Notre Dame
    - LEP E measurement approach
- Peter Schuler / DESY
  - Polarimeter studies for TESLA
- Gianluca Alimonti / U. Hawaii & U. of Milan
  - Recent Progress of the Pair Profile Monitor

Diagnostics Summary

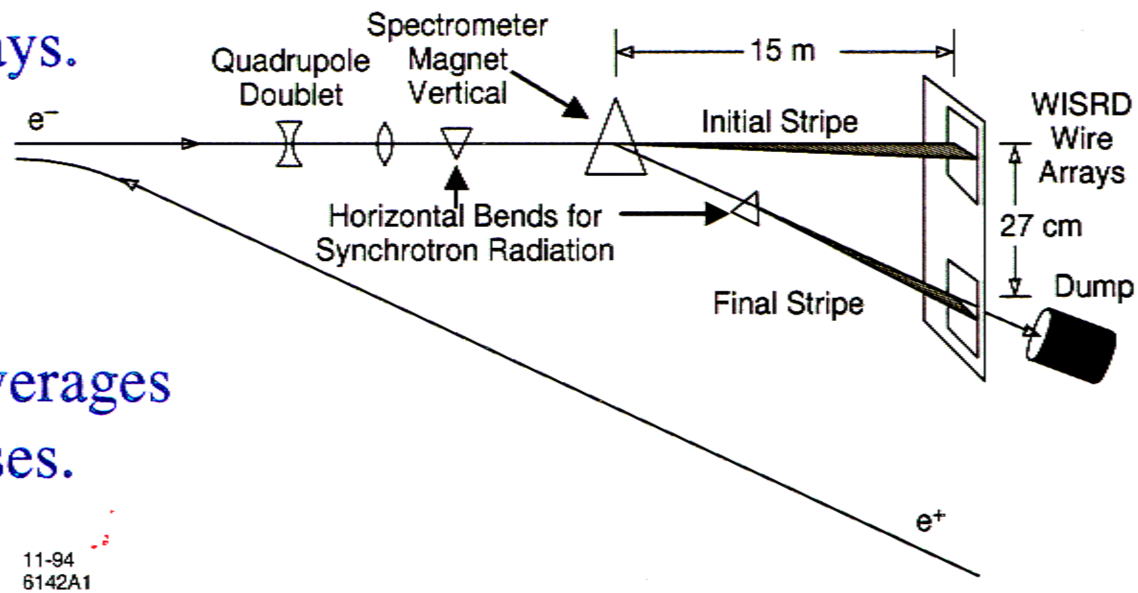
- Extraction Line Spectrometer
  - Could back up colinearity measurements of disrupted beam energy
  - Will be a challenge
- LEP style Energy spectrometer
  - Design into the project to maximize stability of all components
  - Plan scheme (calibrated movers?) to turn relative measurement into absolute measurement
- Compton Polarimeter
  - Location 630m before IP designated
    - Straight section parallel to IP
    - Electron spectrometer after downbeam bend
    - Study of trajectories of degraded electrons has just begun

SLC/SLD Energy Spectrometer

(ca 1986-1990 technology)

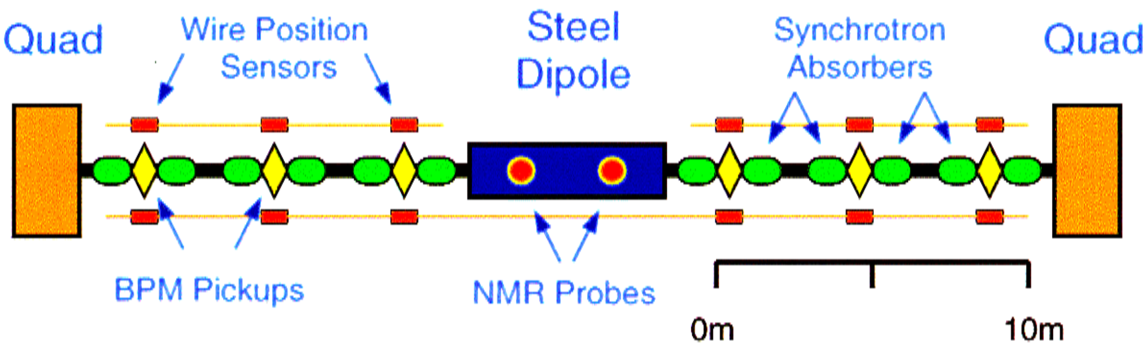
- Energy spectrometer in extraction line, just before beam dump.
- Horizontal bends create synchrotron radiation stripes.
- Vertical spectrometer magnet separates stripes.
- Measure separation of stripes on wire arrays.
- Measurements at 120 Hz beam rate.
- Large single-pulse electronic noise, averages out over many pulses.

THE EXTRACTION LINE SPECTROMETER
BEAM OPTICAL ELEMENTS
(Electron ELS Shown)



The LEP Spectrometer

Near LEP IP3, We installed (in 1999)



Available space dictated $\theta = 4.8$ mrad, Lever arm $\sim$ 10 m:

BPM Resolution in bending plane $\Rightarrow \delta x_{\rm BPM} \sim 1\mu{\rm m}$

Stability required for a few hours only

BUT must be stable as machine energy doubles

Beam Pickups

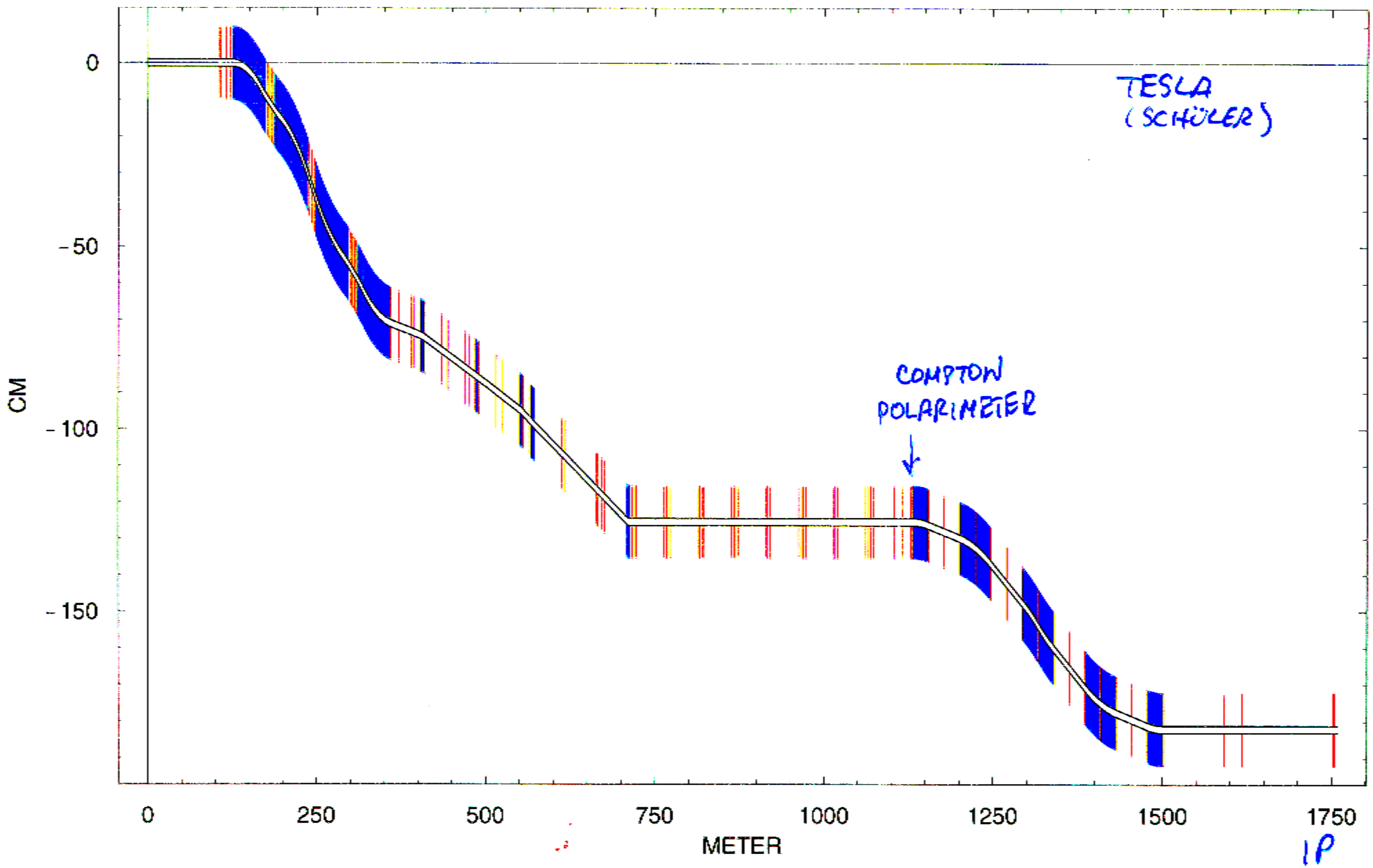
- Mechanical and Thermal stability
- Precise and Stable Electronics

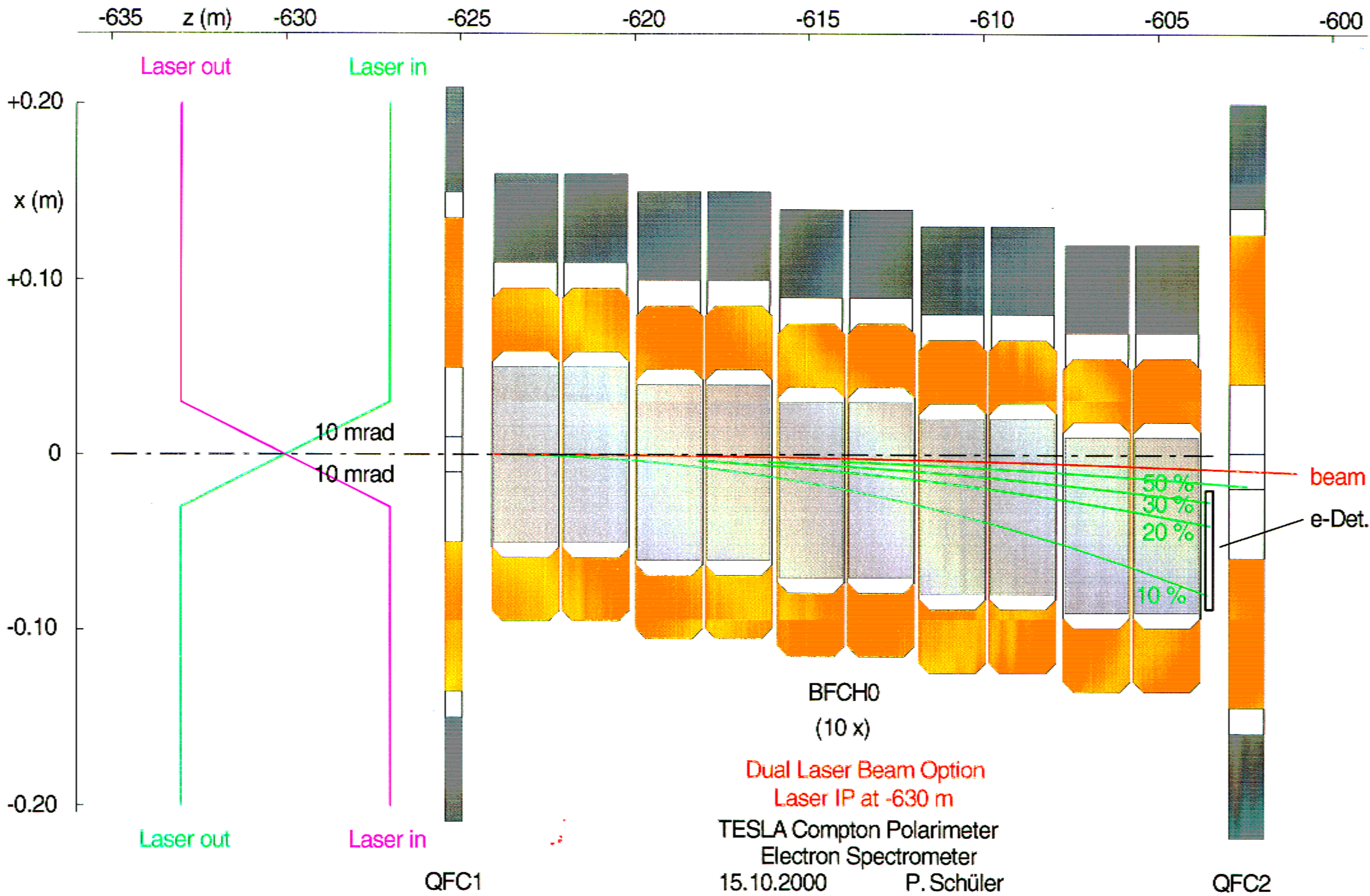
Capacitive Wire Position Monitors

- Independent Position Monitoring
- Limit Rotations of Triplet Arms

Magnet System

- Well-Behaved Steel Dipole
- NMR Instrumentation
- Precision Field Map


TESLA
(SCHÜLER)
COMPTON
POLARIMETER
IP
CM
METER
0
-50
-100
-150
0
250
500
750
1000
1250
1500
1750



-635
z (m)
-630
-625
-620
-615
-610
-605
-600
Laser out
Laser in
+0.20
x (m)
+0.10
0
-0.10
-0.20
10 mrad
10 mrad
50 %
30 %
20 %
10 %
beam
e-Det.
BFCH0
(10 x)
Laser out
Laser in
QFC1
QFC2
Dual Laser Beam Option
Laser IP at -630 m
TESLA Compton Polarimeter
Electron Spectrometer
15.10.2000
P. Schüler

Conclusions

- Diversity of effort has produced solutions for many technical challenges at expense of duplication of effort
- All groups "shamelessly" use each other's ideas
  - Design similarities are seen in many areas
    - Mimics "parameter table convergence" that began in 1992
  - Design differences in the IR area reflect mainly taste, feeling, & previous experience
    - And, admittedly, bunch structure
- Priority is to stop merely turning the crank and generating incremental improvements on each design and to globalize our efforts
  - Site layout, IR layout, detector studies, & physics studies could be joined while individual lab R&D efforts continue on the optimal way to achieve gradient