FUTURE LINEAR e^+e^- COLLIDER

DAVID MILLER
IOP@ BRUM
30/6/99

ALL ABOUT CHOICES

- MACHINE OPTIONS
  X-BAND OR TESLA?
  (+ MANY MORE DETAILS)
- DETECTOR OPTIONS
  LARGE OR SMALL
  (+ MANY TECHNOLOGIES)
- ORGANISATION

MUST BE PHYSICS-DRIVEN
(SEE GRAHAM)
∴ NEEDS PHYSICISTS
NOW!

ALREADY A GOOD UK
CONTINGENT.

PARTS OF THE MACHINE

LOTS OF PROGRESS MADE IN LAST 7 YEARS

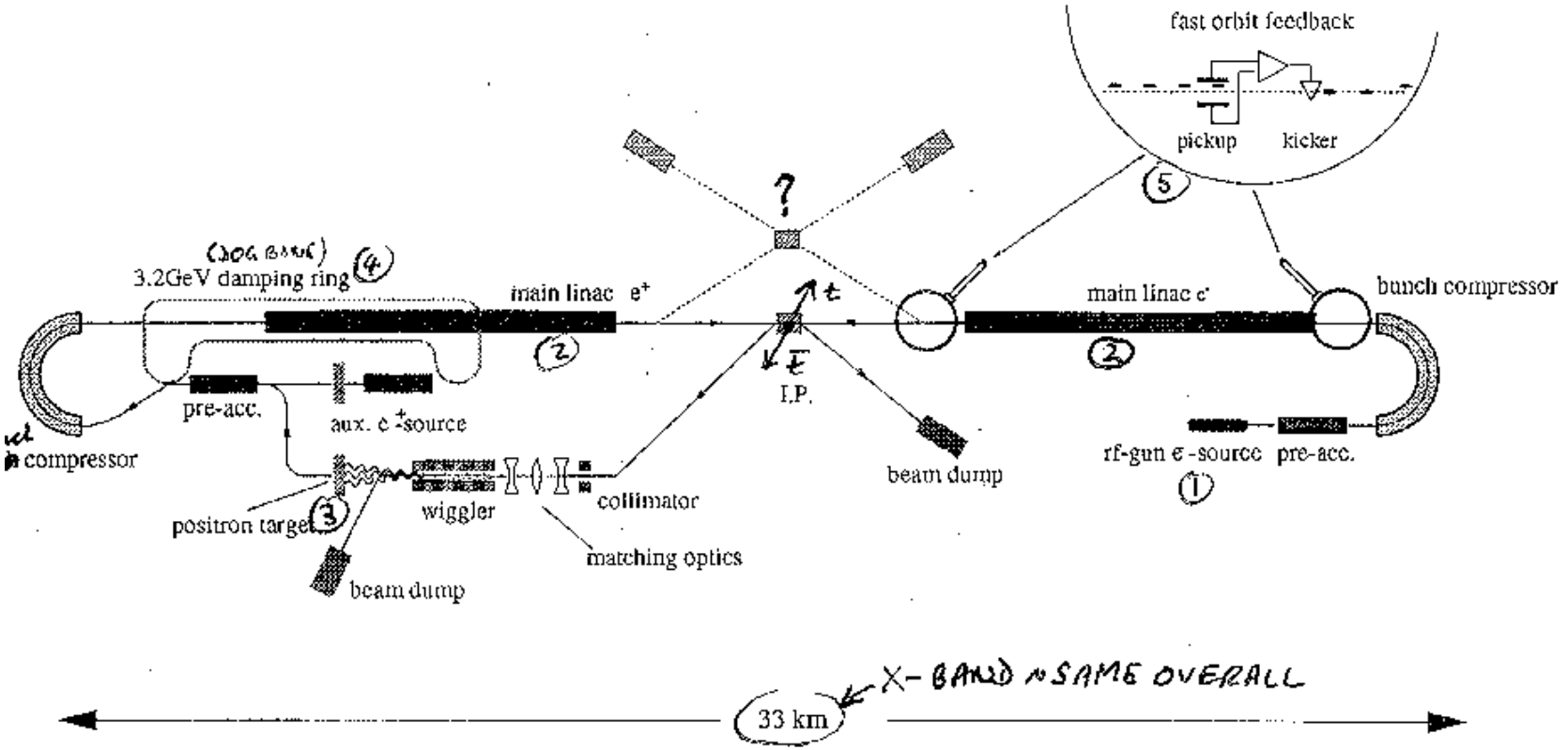
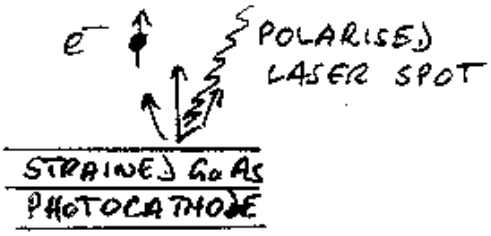


Figure 3.1.4: *Sketch of the overall layout of TESLA.*

RIVAL LABS ARE SHARING IDEAS, DESPITE FIERCE COMPETITION

(1) e^- SOURCE

PIONEERED AT SLAC



POLARISED e^-, ~80-90% ALIGNED AT SOURCE
[~80% AFTER LINAC!!]

THEN R.F. ACCELERATION
TO 10s OF MeV
+BUNCH COMPRESSION

NEED VERY SMALL "EMITTANCE"
= PRODUCT OF (SPOT SIZE) × (RANGE OF ANGLES)

i.e. HIGHEST POSSIBLE "BRIGHTNESS"

∴ WORKING ON • SMALLER SPOTS
• MORE POWERFUL LASERS
• SHORTER PULSES

E.g. FNAL JUST MADE A GUN FOR TESLA TEST FACILITY

(2) MAIN LINAC

	S-band	X-band	Two-beam	TESLA
	(STANFORD)	(CERN KEK/SLAC)	(CERN/SLAC)	(SUPERCONDUCTING DESY+COLLABORATORS)
Accelerating gradient [MV/m]	~~17~~	29...55	~~75~~ 100	25
RF-frequency [GHz]	3	11.4	30	1.3
RF-peak power [MW/m]	12	50...100	144	0.2
Av. beam power [MW]	7.3	4	4	8.2
Beam pulse length [μs]	2	0.1	0.006	800
Bunch spacing [ns]	6	1.4	0.67	~~708~~
Vertical spot size at IP [nm]	15	5	7	19
Luminosity [10^{33}cm^{-2}s^{-1}]	5	6	5	~~181~~

NOW 337ns

NOW 30

Table 3.1.1: *Parameters for different 500 GeV linear collider designs. A more detailed discussion of the TESLA parameters is given in section 3.1.3.*

BEST AT HIGHER ENERGY (LATER BOOST IN SAME TUNNEL?)

THE CONTENDERS

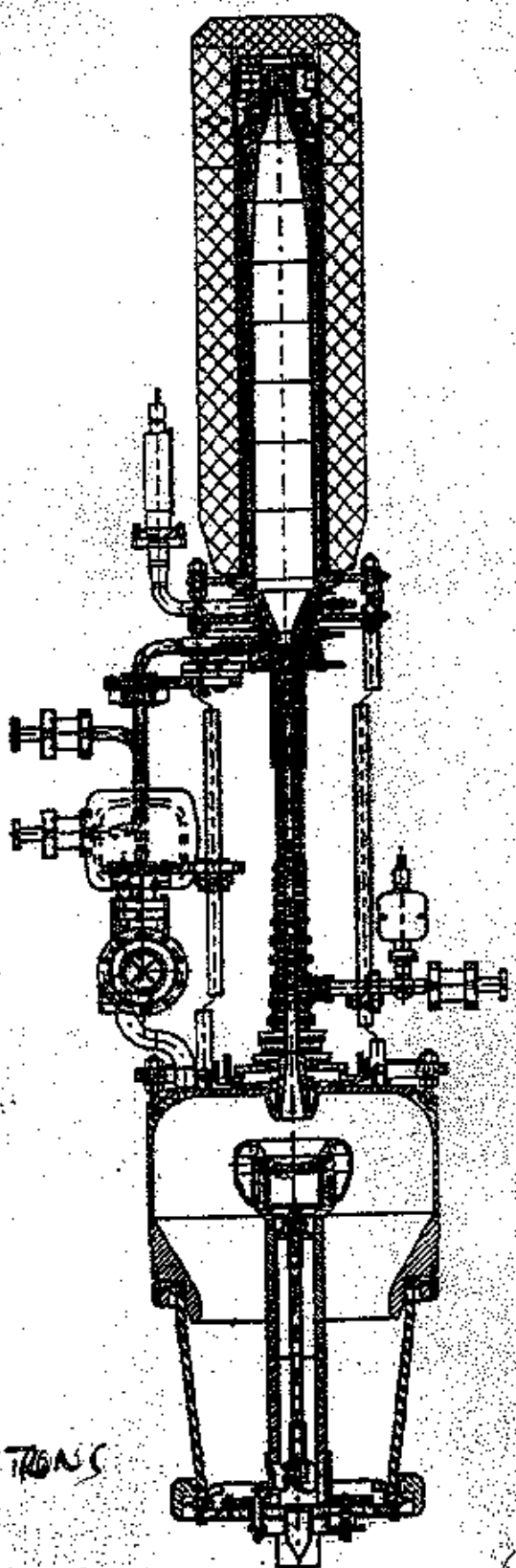
BOTH PLANNING 500 GeV STARTUP

↓

1 TeV LATER.

Periodic
Permanent
Magnet
(PPM)
Klystron

SLAC



50 MW

2.4 μs

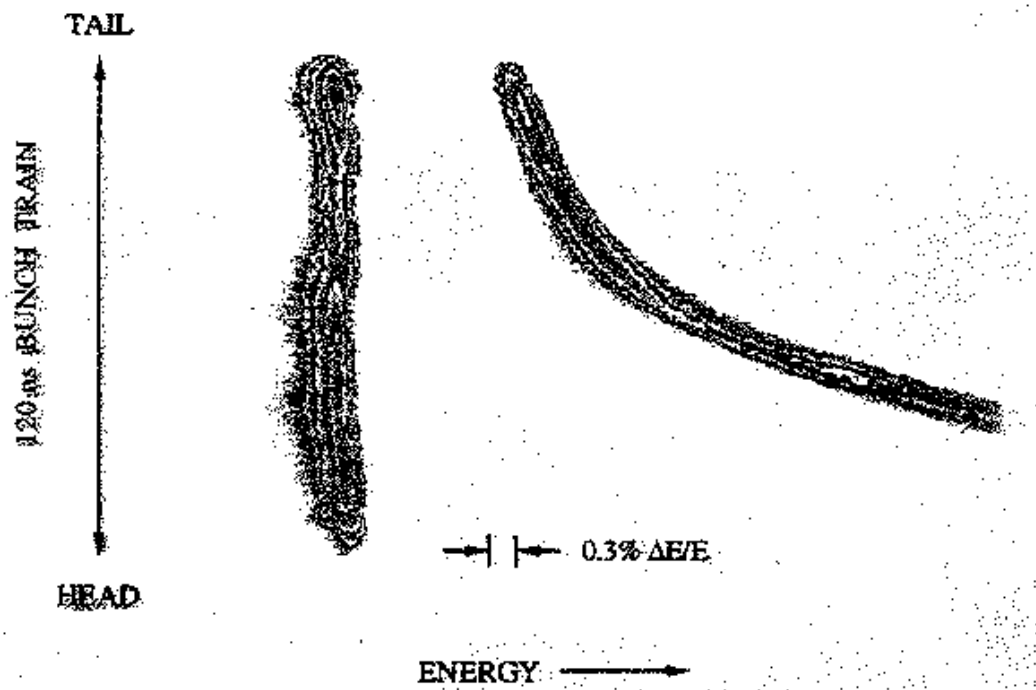
X BAND
NEEDS HIGHER
POWERED KLYSTRONS
THAN ANY ON
MARKET.

EEV
STILL
INVOLVED
(3 CONTENDERS)
~~IN FRANCE~~

MANY BUNCHES IN ONE CAVITY FILLING – TRICKY!

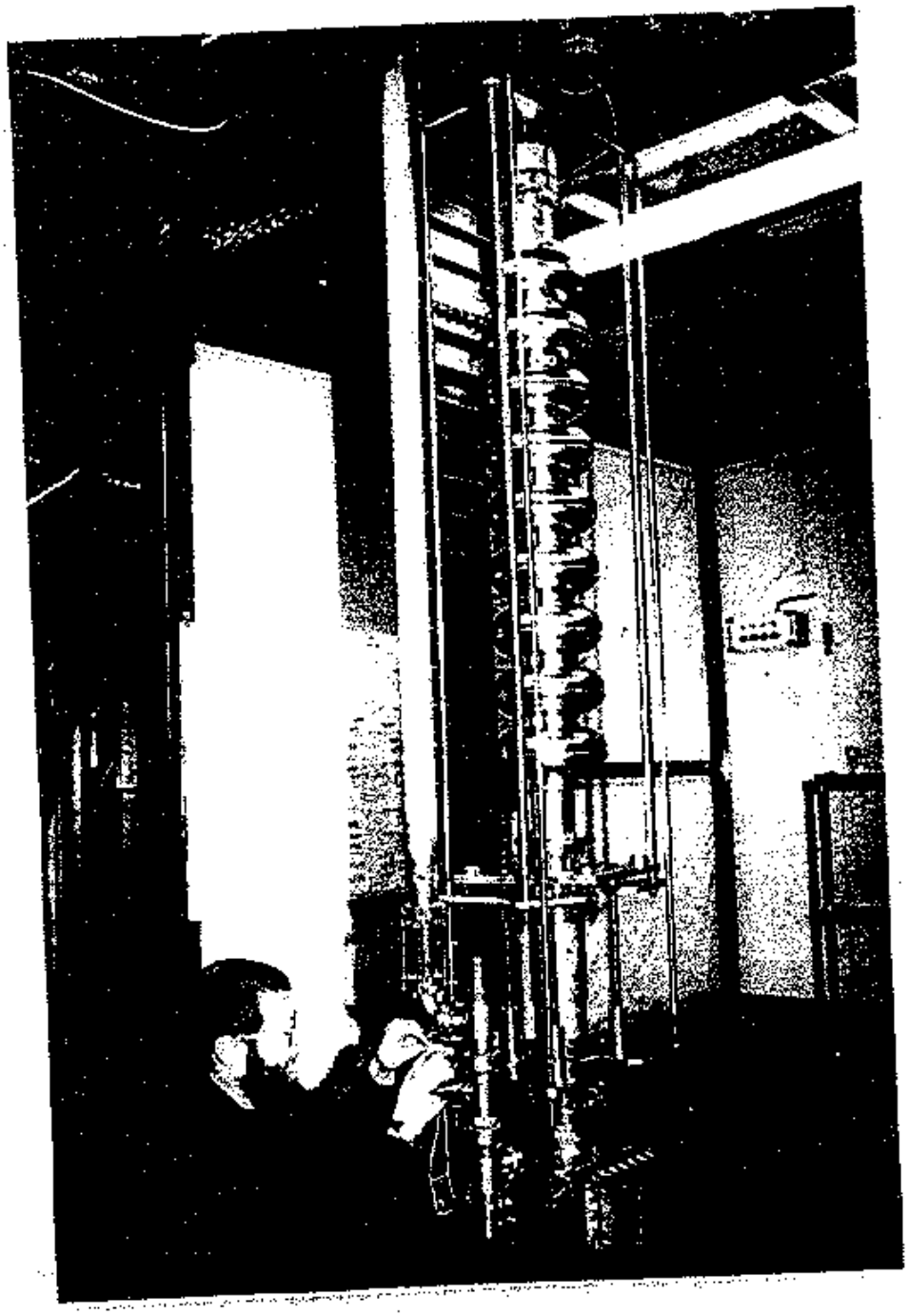
BEAM LOADING COMPENSATION

ONE OF MANY ACCELERATOR CHALLENGES. EXPERTS CONFIDENT!



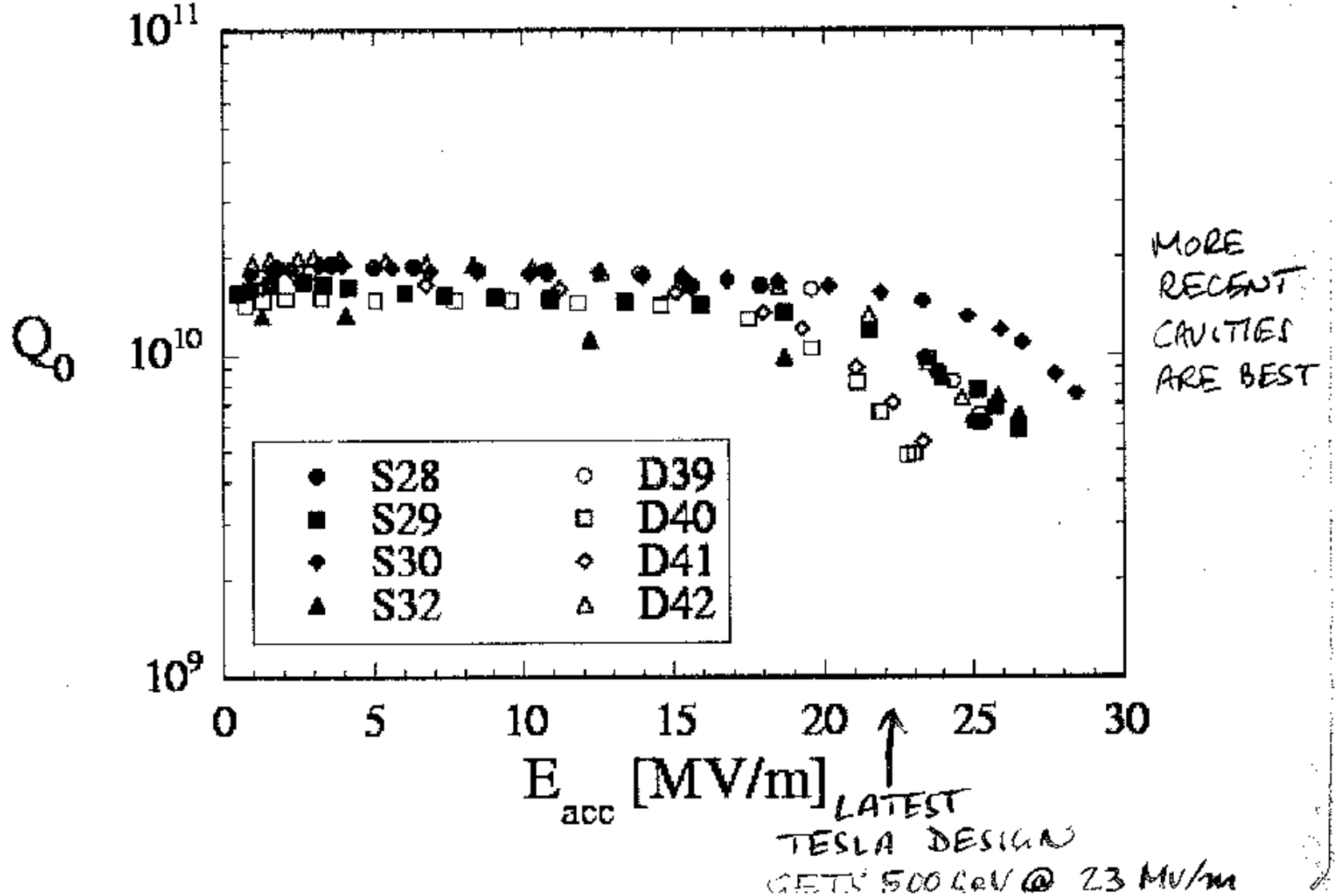
RF Station	Unloaded Gradient (MeV/m)	% Loading
0	47	14
1	44	17
2	37	17

TESLA PROTOTYPE CAVITY



(8)

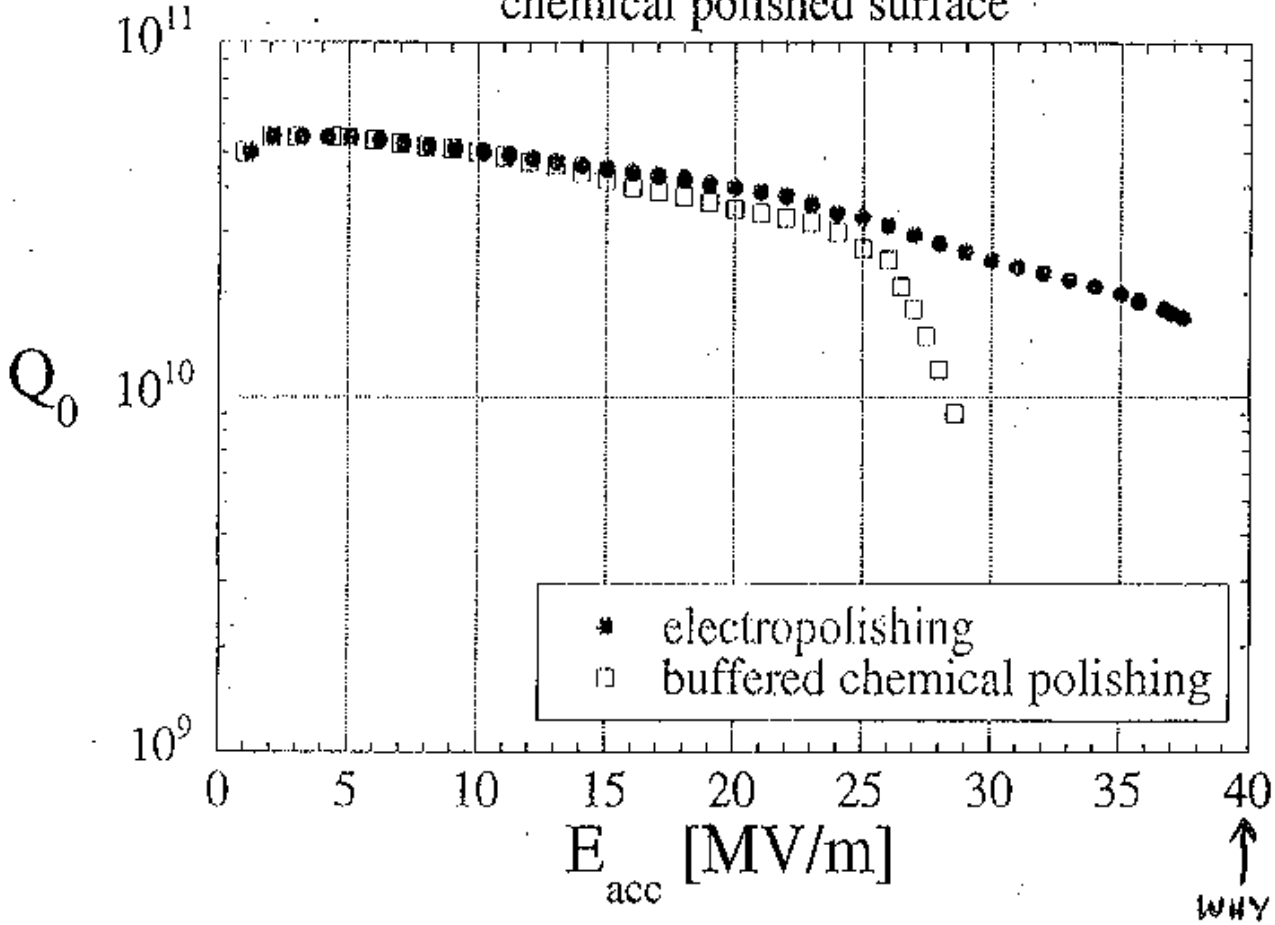
HIGH $\mathcal{L}$ OF TESLA DEPENDS ON LONG ENERGY STORAGE IN CAVITIES



Collaboration between CEA Saclay and KEK:

VERY RECENT

Electropolishing of surface reduces the Q-drop and enhances high field capability compared to chemical polished surface



single cell cavity

$500 \times \frac{40}{23} = 870$ GeV

IN SAME LENGTH

WHY NOT?

(FOR TESLA)

③ e^+ TARGET USES SPENT e^- FROM COLLISIONS

↓

UNDULATOR

↓

POLARISED γs

↓

e^+e^- PAIRS

↙

POLARISED e^+ ~60%

↙

(FOR X-BAND CURRENT PLAN IS LIKE LEP OR SLC)

↓ UNPOLARISED e^+

④ DAMPING RING

USES SYNCHROTRON RADIATION TO SQUEEZE e^+ EMITTANCE (Ref. IN JAPAN ++)

MAINTAIN e^- EMITTANCE

PREPARE BUNCH-TRAIN.

<u>BUT</u> BEAMS ONLY MEET ONCE

(NOT LIKE LEP — STORED BEAMS MEET BILLIONS OF TIMES)

↙

LEP BEAM SPOTS 10s OF μm ACROSS

LINEAR COLLIDER BEAMSPOTS MUST BE ~10nm ACROSS ($\ll \lambda_{\text{VISIBLE LIGHT}}$)

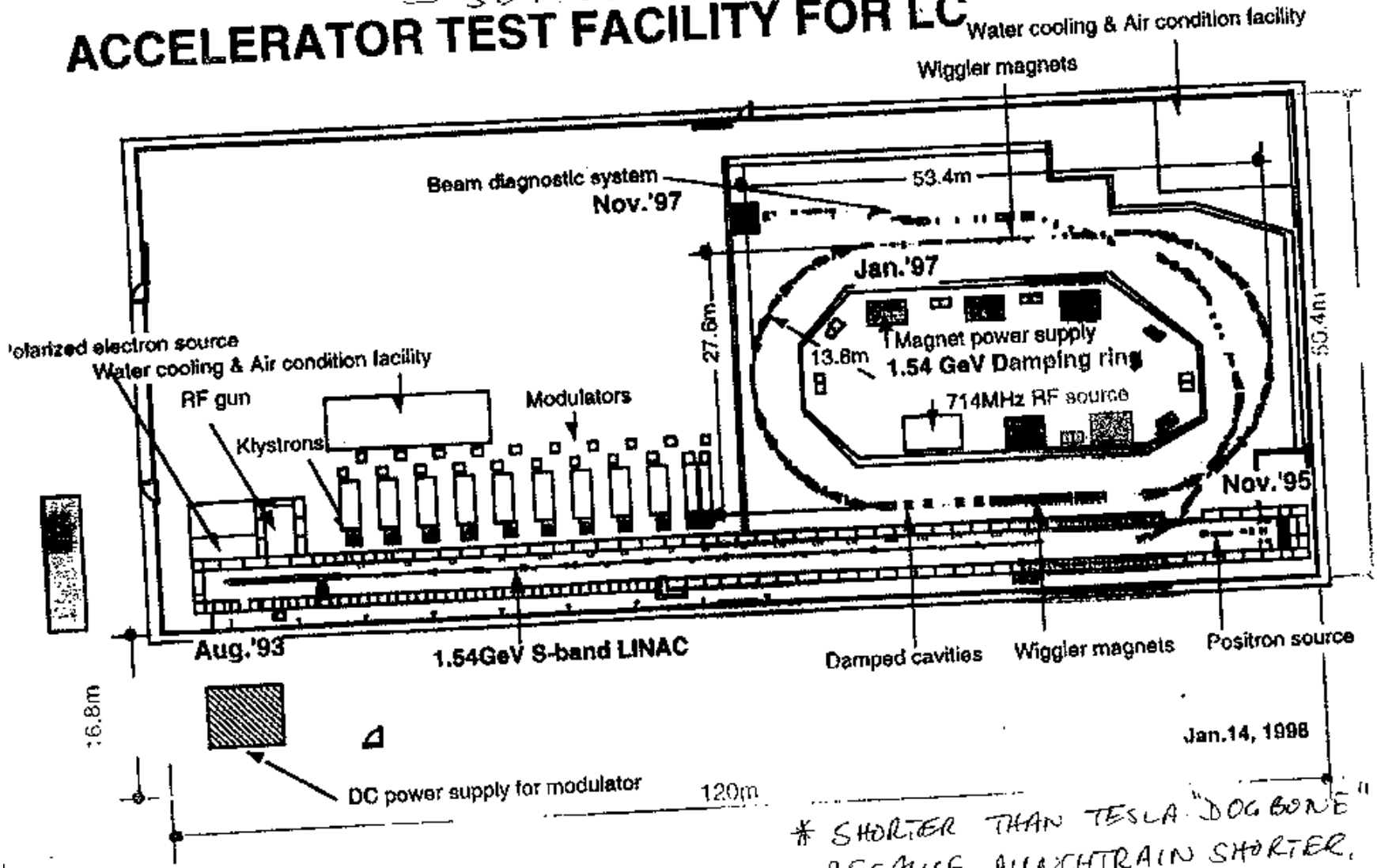
HOW CAN THAT BE DONE?

[SLAC FFTB DEMONSTRATED OPTICS OK.!]

DAMPING RINGS — LOWER EMITTANCE
— SHAPE SPOTS
— SET UP BUNCH TRAIN

AT KEK*

ACCELERATOR TEST FACILITY FOR LC



* SHORTER THAN TESLA "DOG BONE"
BECAUSE BUNCHTRAIN SHORTER.

(5) BEAM STEERING

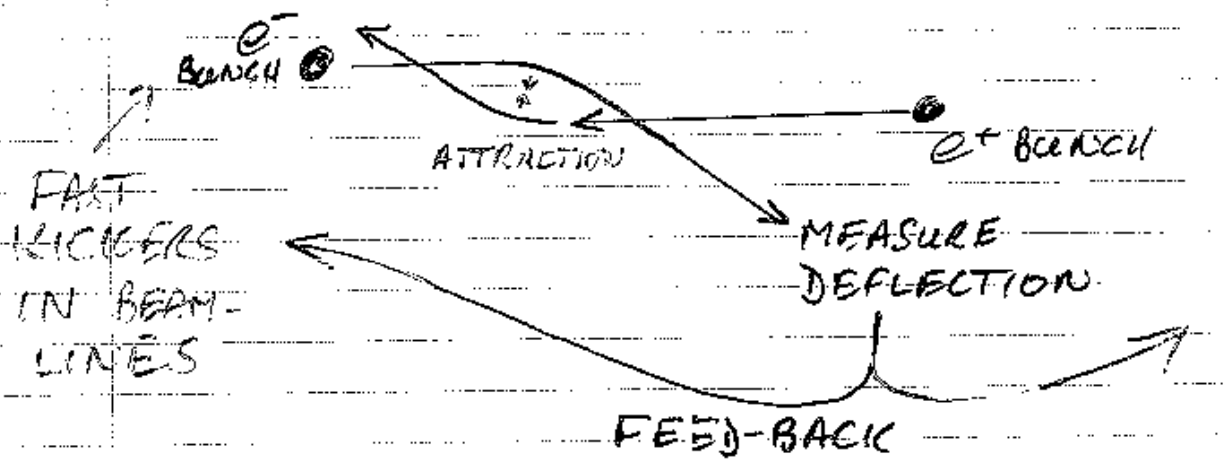
FIRST STAGE OF MAKING SPOTS MEET

— SEE UNBALANCED PULSES ON PICKUP ELECTRODES

↓

FEED BACK MAGNET MICROMOVERS

THEN LET BEAM SPOTS MISS EACH OTHER



AFTER THE FIRST FEW BUNCHES, THE BEAMS WILL COLLIDE.

DESPITE GROUND MOTION

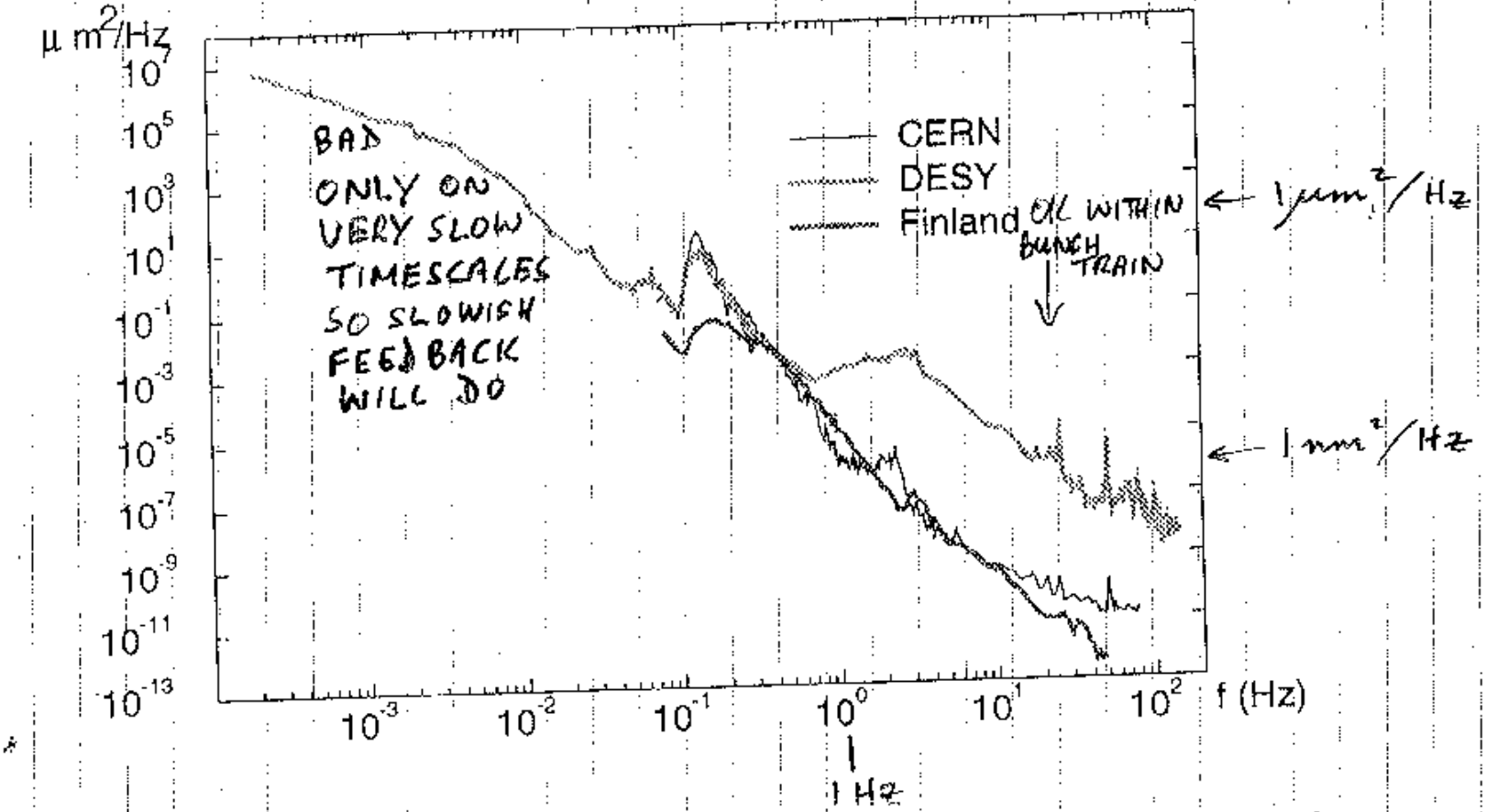
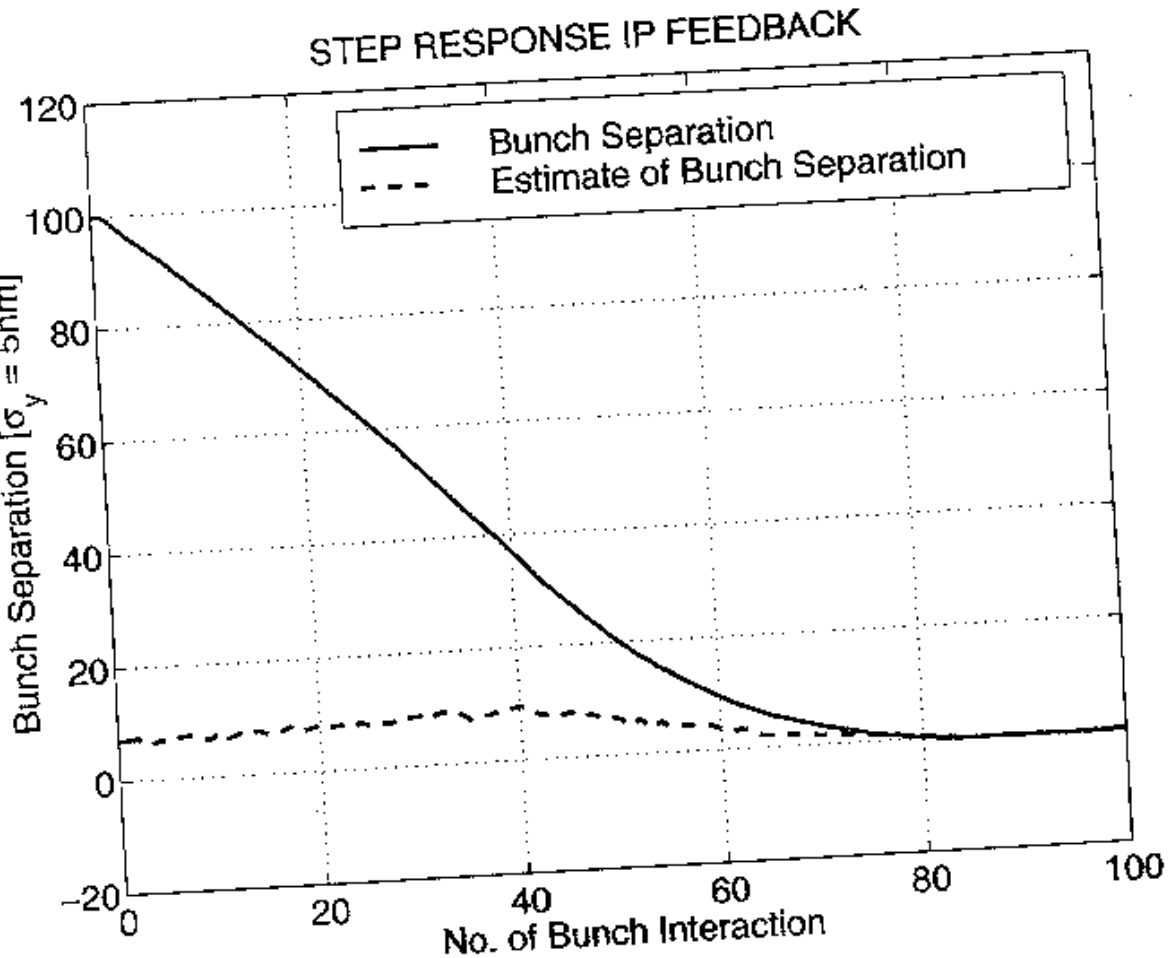


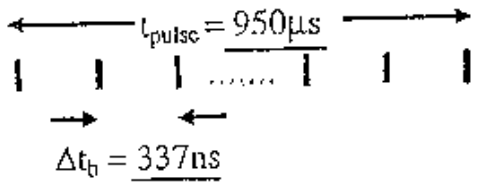
Figure 3.7.11: *Absolute power spectrum measured in quiet (CERN LEP tunnel, shutdown [6]; Finland, cave [7]) and noisy (DESY HERA tunnel, operational condition [8]) condition.*

MODELLING OF
TESLA INTERACTION-
POINT FEED BACK

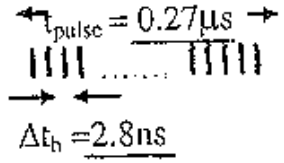


Linear Collider Pulse Structures

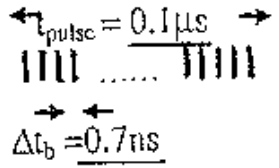
TESLA:



X-Band:



CLIC:

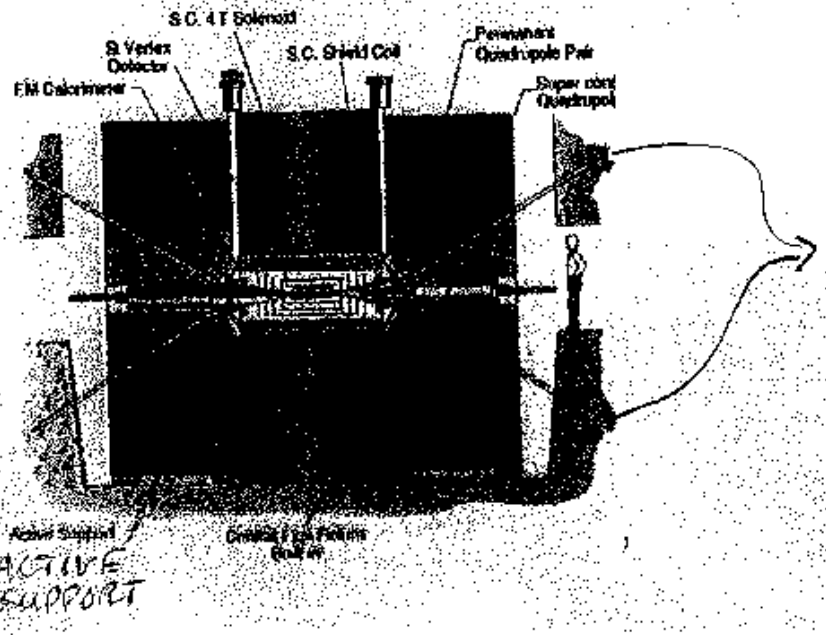


# bunches	f_{rep} [Hz]	duty cycle %
2820	5	0.5
95	120	.003
150	200	.002

Small Spot Size and Vibration Control

Achieve 1nm stability via

- Site requirements: < 10 nm rms for $\nu > 1$ Hz and $\lambda < 200$ m
- Compact detector (to satisfy vibration req. passively)
- Allow for closed loop active feedback with piezo movers on quads (interferometer or inertial sensors)
- Fast intra-train feedback



X-BAND

Snowmass detector with optical anchor

(CLIC "S" DETECTOR)

ACTIVE SUPPORT

INTERFEROMETRIC LASER BEAMS FROM MASSIVE WALLS TO COLLISION REGION.

PROS AND CONS (PERSONAL LIST)

TESLA

PRO
- HIGHER LUMINOSITY.
- 337 ns BUNCH SPACING (0° CROSSING)
- ALIGNMENT ACHIEVABLE.
- e⁺ POLARISED TOO.

CON
- COST NOT YET KNOWN.
- FINAL CAVITY DESIGN NOT READY

X-BAND

PRO
- COST ESTIMATE AVAILABLE (~$5Bn FOR 500 GeV $\sqrt{s}$)

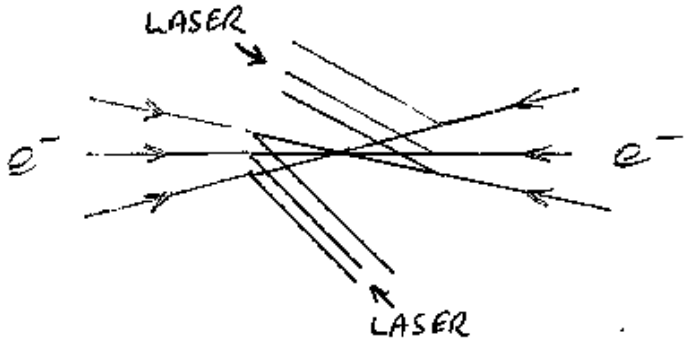
CON
- ALIGNMENT TRICKY
- LOWER LUMINOSITY
- 1.4 ns BUNCH SPACING (CRAB CROSSING)
- FINAL KLYSTRON DESIGN NOT READY

EXTRA MACHINE OPTIONS

REAL $\gamma\gamma$ OR γe ? (e^-e^- EASY!)

TELNOV, GINZBURG et al.

AT SECOND I-R
(+ SECOND DETECTOR)



INTERCEPT COLLIDING POLARISED e^-e^- BEAMS A FEW mm FROM COLLISION POINT.

$\sqrt{s_{\gamma\gamma}} \lesssim 0.8\sqrt{s_{e^-e^-}}$ $\quad \mathcal{L}_{\gamma\gamma} \lesssim 0.5\,\mathcal{L}_{e^-e^-}$

CORRECT POLARISATION COMBINATIONS GIVE "MONOCHROMATIC" HARD γ SPECTRUM

SUITABLE LASERS COMING
(VAN BIBBER / LIVERMORE @ LCWS ITRES)

NO SHOW-STOPPERS, BUT LOTS OF R&D STILL NEEDED. WILL COST A BIT (~10%?)

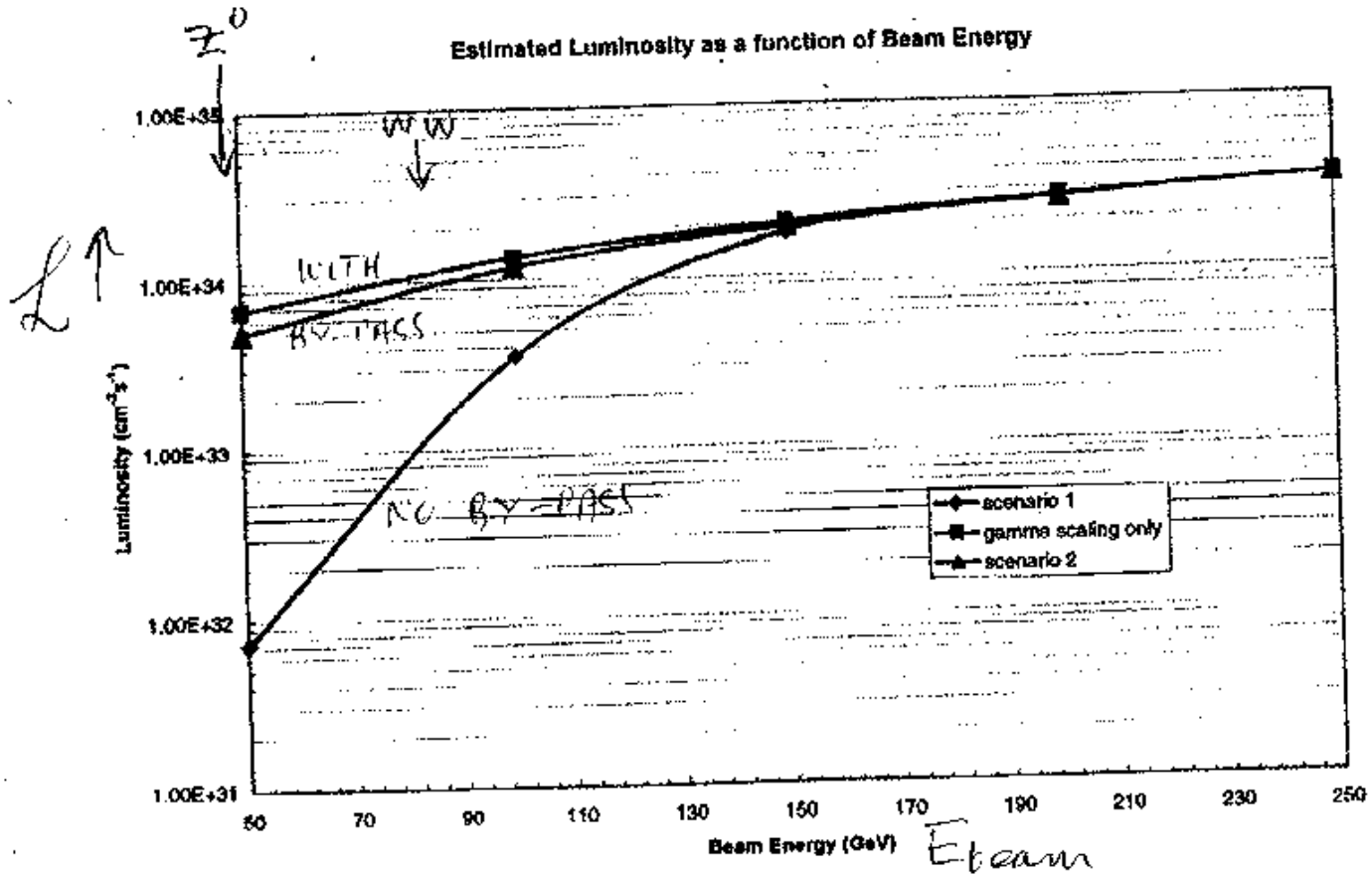
HIGH LUMINOSITY AT Z OR WW ?

NEW TESLA BY-PASS DESIGN COULD GIVE e^+ AND e^- POLARISATION WITH ~ 10× LEP LUMINOSITY

WILL COST A BIT (< 10%?) ⟹

R&D NEEDED.

High-$\mathcal{L}$ at $E_{beam} \lesssim 150$ GeV with 2nd e^+ source / bypass line



Z^0

WW

$\mathcal{L}$ ↑

WITH BY-PASS

NO BY-PASS

E_{beam}

PROTECTED TESLA PERFORMANCE AT LOW ENERGY

DETECTOR OPTIONS

SO FAR ↓

"LARGE"

$\phi_{COIL} \geq 3m$

PRO
- GASEOUS TRACKER → GOOD $\delta p/p$
- EM CALORIMETER INSIDE COIL
- GOOD ENERGY FLOW MEAS'T

CON
- LOWER FIELD TO SQUEEZE BACKGROUND
- EXPENSIVE MAGNET

"SMALL"

$\phi_{COIL} \leq 1.5m$

PRO
- HIGH FIELD SQUEEZES BACKGROUND
- ALL-SILICON TRACKING (+CALORIMETRY?)

CON
- POORER ENERGY FLOW

CON FOR BOTH

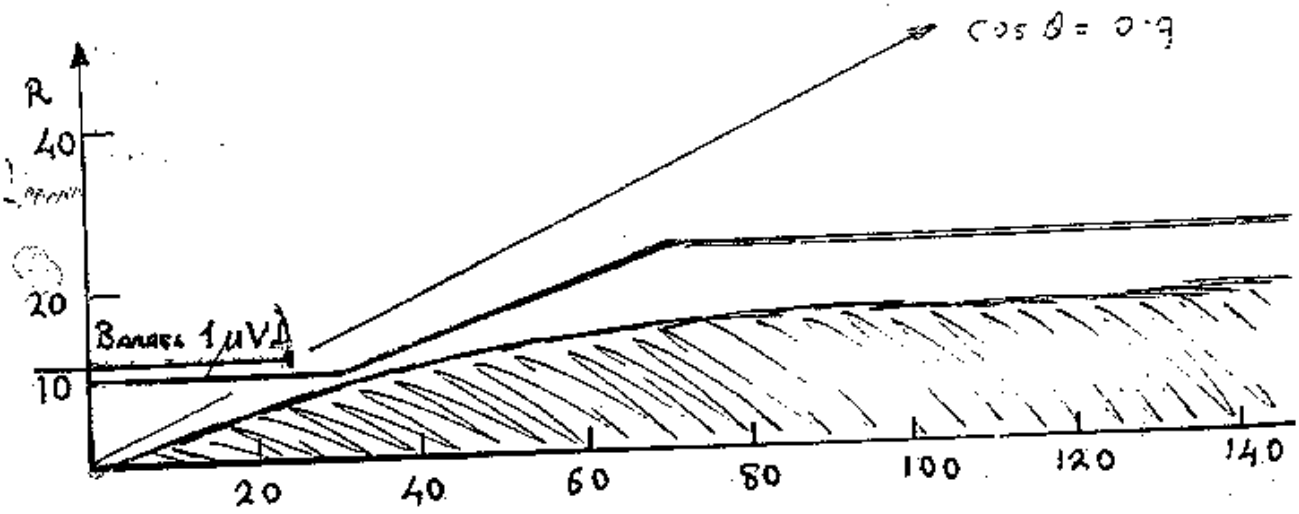
- SMALL ANGLES HAVE INTENSE BACKGROUND
  - ∴ NEED MASKING ($\theta \geq 100$ mrad)
  - HARD TO ACHIEVE HERMITICITY FOR SEARCHES
  - AND TO TAG AT LOW ANGLES.

UCL / HOLLOWAY GETTING INVOLVED HERE.
$\partial \mathcal{L}/\partial\sqrt{s}$, γ^* TAGS, SUSY VETOS, MINIJET BACKGROUNDS

ENVELOPE SMALLER AT HIGHER FIELD

PAIR BACKGROUND: MAIN ENVELOPE AT 4 T

(TESLA/NLC/JLC)
(APRIL '96)

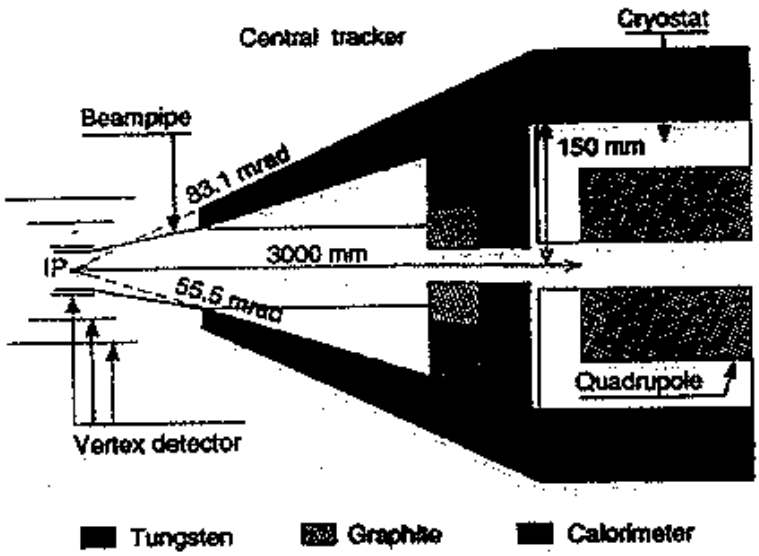


PAIR PRODUCTION BY $e^{\pm}$ FROM ONE BEAM ON INTENSE E-M FIELD OF OPPOSITE BUNCH. SOFT $e^{+}e^{-}$ SPIRAL DOWN FIELD LINES.

TESLA IP Layout and Issues

Main Characteristics at the Interaction Point

- Solenoid Field : 3 T (4 T)
- Crossing-Angle : zero
- Distance to 1st magnet : ± 2.75 m
- Dead angle : 83 mrad (< 5°), cos(θ) = 0.997
- Beam Tube Radius @ IP : 22 mm (11 mm)



INSIDE MASK WILL BE HOT
LOTS OF SOFT SHOWERS EVERY CROSSING

BASELINE ECFA/DESY "LARGE DETECTOR" → (TO BE UPDATED THIS SUMMER)

Subdetector	Technique chosen (Radiation Lengths)	Alternative techniques
Barrel		
Beam pipe	(0.3% X_0)	
Vertex detector	CCD or APS (1.6% or 2.4% X_0)	Silicon strip
Intermediate tracker	Honeycomb straw tubes (0.23% X_0)	Scintillating fibers with drift chamber; Silicon strip
Intermediate layer	Double-sided silicon strip (1% X_0)	
Main tracker	Time projection chamber (L) (3% X_0 to outer field cage)	MSGC; Silicon strip (S)
(Total thickness to outermost tracking radius = 6.1% (CCD) or 6.9% (APS) X_0)		
Presampler	Scintillating fibers	
E-M calorimeter	Pb-scintillator Shashlik cal.	Spaghetti calorimeter; Crystals
Hadron Calorimeter	Cu-scintillator Shashlik	
Tailcatcher, muon identifier	Resistive plate chambers	Limited streamer
Forward		
"Luminosity calorimeter" OR TAGGER	Scintillating fibers in Pb	Spaghetti calorimeter Silicon-tungsten Shashlik
Instrumented mask	Quartz fibers in W	
Forward tracker	Silicon strip and/or pixels	
Forward muon tracker	Toroids with honeycomb tubes	

UK

UK?

Table 2.1.3: *Techniques chosen for the LC detector.*

ECFA/DESY I

UNDERLINES MEAN "R&D HAPPENING OR NEEDED."

ORGANISATIONS AND POLITICS

- **MACHINE STUDIES**

  TECHNICAL REPORTS KEK, DESY 2001
  STANFORD 2002
  (JUST HAD SUPPORTIVE LEHMANN REVIEW)

  ALL PLANNING FOR ~500 GeV
  BY ~2010. (TO ~1 TeV LATER)

- **PHYSICS & DETECTOR STUDIES** (INCLUDING MACHINE/DET. INTERFACE)

  2nd ECFA/DESY STUDY (WEB-PAGES VIA DESY)

  PHASE II JUST STARTING.
  GOOD TIME TO JOIN

  PHASE I WENT TO OXFORD MARCH 1999 (>150 ATTENDEES (WEBPAGES))

  DETECTORS MINI-WORKSHOP, CERN 6/7 JULY → WORKSHOP AT OBERNAI (NEAR STRASBOURG) 16–19 OCTOBER 1999

  - COMPARISONS WITH LHC PHYSICS
  - FINALISATION OF DETECTOR MODEL
  - PREPARATION TO MAKE PHYSICS CASE IN T.D.R.

  ITALY SPRING 2000

  DESY AUTUMN 2000
  - FINALISE PHYSICS CASE FOR T.D.R.

  UK CONVENERS:-
  WILSON, BUTTERWORTH, BURROWS, BLAIR, SEYMOUR, PHILLIPS DAMERELL

- WORLD-WIDE STUDY (WEB PAGES)

CHAIRS: KOMAMIYA, BALTAY, DJM } UNIVERSITY PEOPLE!

∃ CONTACTPERSONS FOR ALL WORKING-GROUPS

HIGGS, SUSY, TOP, QCD, E-W, ALTERNATIVE.
GENERATORS+SIMULATION.
DETECTOR TECHNIQUES, MACHINE-DETECTOR, BX.

PARALLEL ACTIVITIES IN
- EUROPE (ECFA/DESY)
- NORTH AMERICA
- ASIA (ACFA)

NEXT WORLD-WIDE LCWS
WILL BE IN USA (FERMILAB?)
AUTUMN 2000

('91 '93 '95)
(SAME SERIES AS SAARISELKA, WAIKOLOA, MORIOKA
& SITGES MAY 1999)
(WEBPAGES)

WORLD-WIDE REPORT-LIBRARY
ON WEB SOON.

SCOPE FOR MORE UK EFFORT NOW

ON
- PHYSICS SIMULATION (THEORISTS + EXPERIMENTERS)
- DETECTOR R&D
- ACCELERATOR R&D (MAY BE LINKED TO RAL INITIATIVE)

UK INDUSTRY SHOULD BE PULLED IN →