MDI, Beamline and Options

T. Tauchi, KEK

The 2005 International Linear Collider Workshop,
Stanford University, 18 March, 2005

What is MDI ?

MDI is Machine Detector Interface.

Machine : Beam Delivery System (BDS)
from LINAC-end to beam dump

collimation, energy/polarization, final focus,
extraction (energy/polarization) and beam dump

Detector : Interaction Region

experiment (physics; Higgs, Top, W/Z, SUSY, extra-D ...)

luminosity, background and minimum veto-angle

Under the GDI/GDE

(Global Design Initiative/Effort)

Detector /Physics

WWS
detector R&D panel
concept costing panel
concept support
MDI panel

MDI ⟷

collective view of requirements from detector /physics

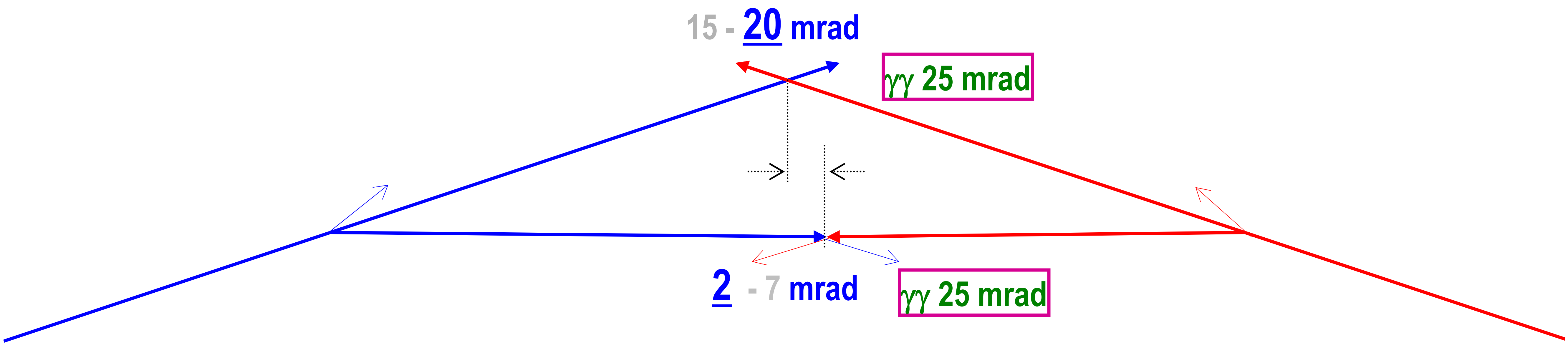
Machine

ILC-WG4
for BDS Design

MDI consists of WWS-MDI and ILC-WG4, and it is coordinated by the MDI panel.

Recommendations from the WG4

Tentative, not frozen configuration, working hypotheses, "strawman"

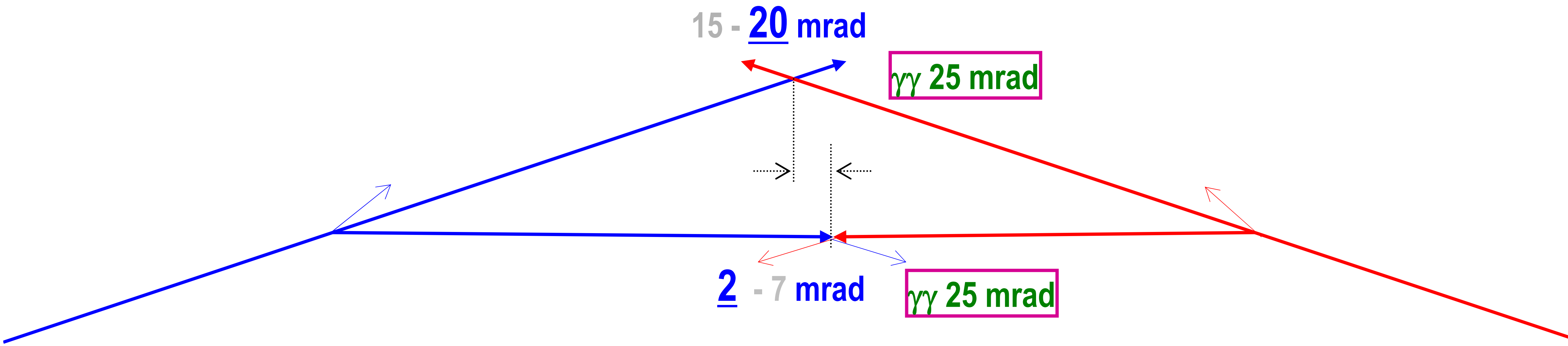


- **Urgent work for next 8 month**
  - **Improve and enhance communication within groups working on the design, and with detector community**
  - **Complete optics design for both IRs with all diagnostics and extraction**
  - **Request the physics community to evaluate physics impact of the "strawman" configuration**
  - **Evaluate how detector concepts affect optimization of L*, and what FD technologies are suited best**
  - **Develop civil engineering plans, including provision for γγ option possible at 1st or 2nd IR at maximum energy**

MDI issues

Recommendations from the WG4

Tentative, not frozen configuration, working hypotheses, “strawman”



- **Urgent work for next 8 month (continued)**

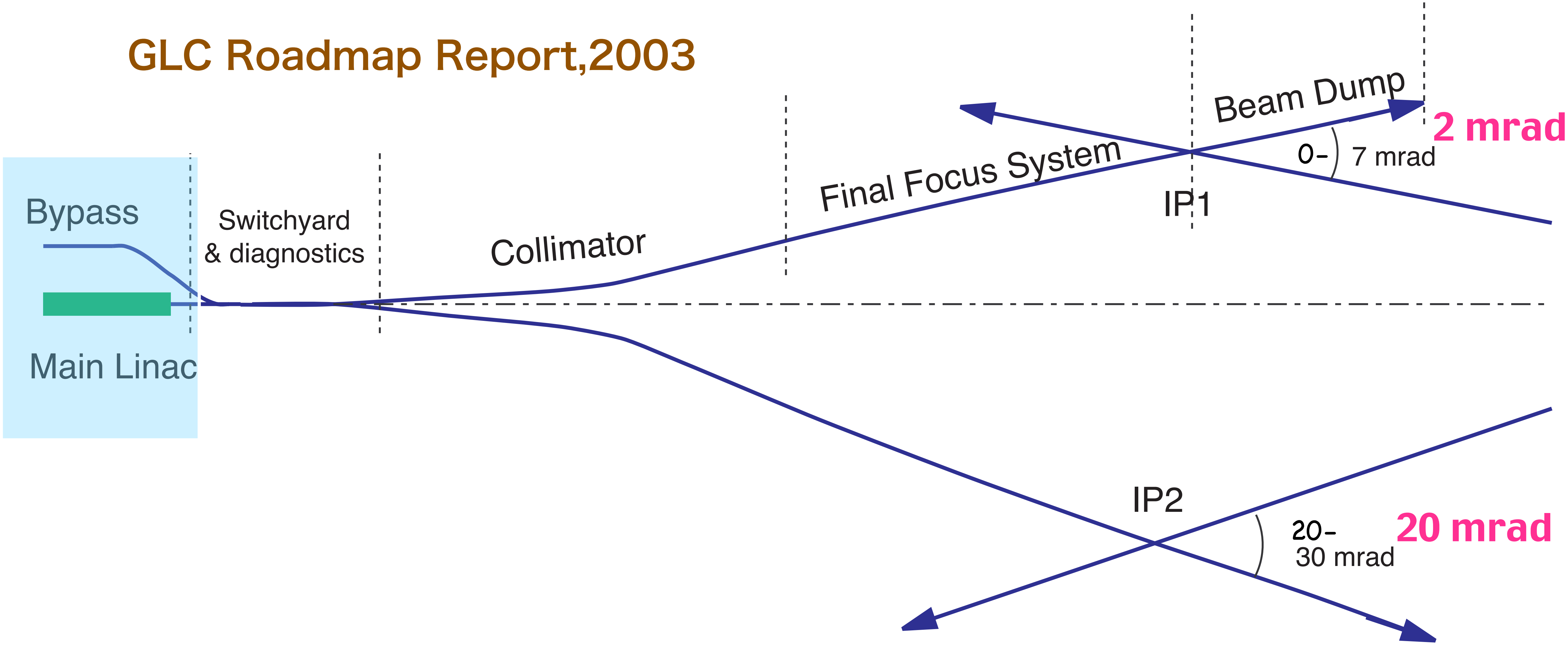
MDI issues

- **Reevaluate background tolerances of the detectors**
- **Develop engineering design of crab cavity with electronics**
- **Energy deposition and accidental beam loss studies, reevaluate the beam-beam induced loads in IR**
- **Evaluate parameter changes options considered by WG1 (e.g. smaller IP beta-functions, bunch charge, separation) and parameters needed for γγ (smaller x size)**
- **Make more realistic simulations of feedbacks and diagnostics**

BDS

TESLA, NLC, JLC has the designs;
GLC case is shown as an example.

GLC Roadmap Report,2003



Crossing angle (headon, V–0.3mrad, 2mrad, 7mrad, 20mrad, >30mrad@γγ)

2 IP's for 2 "identical experiments"

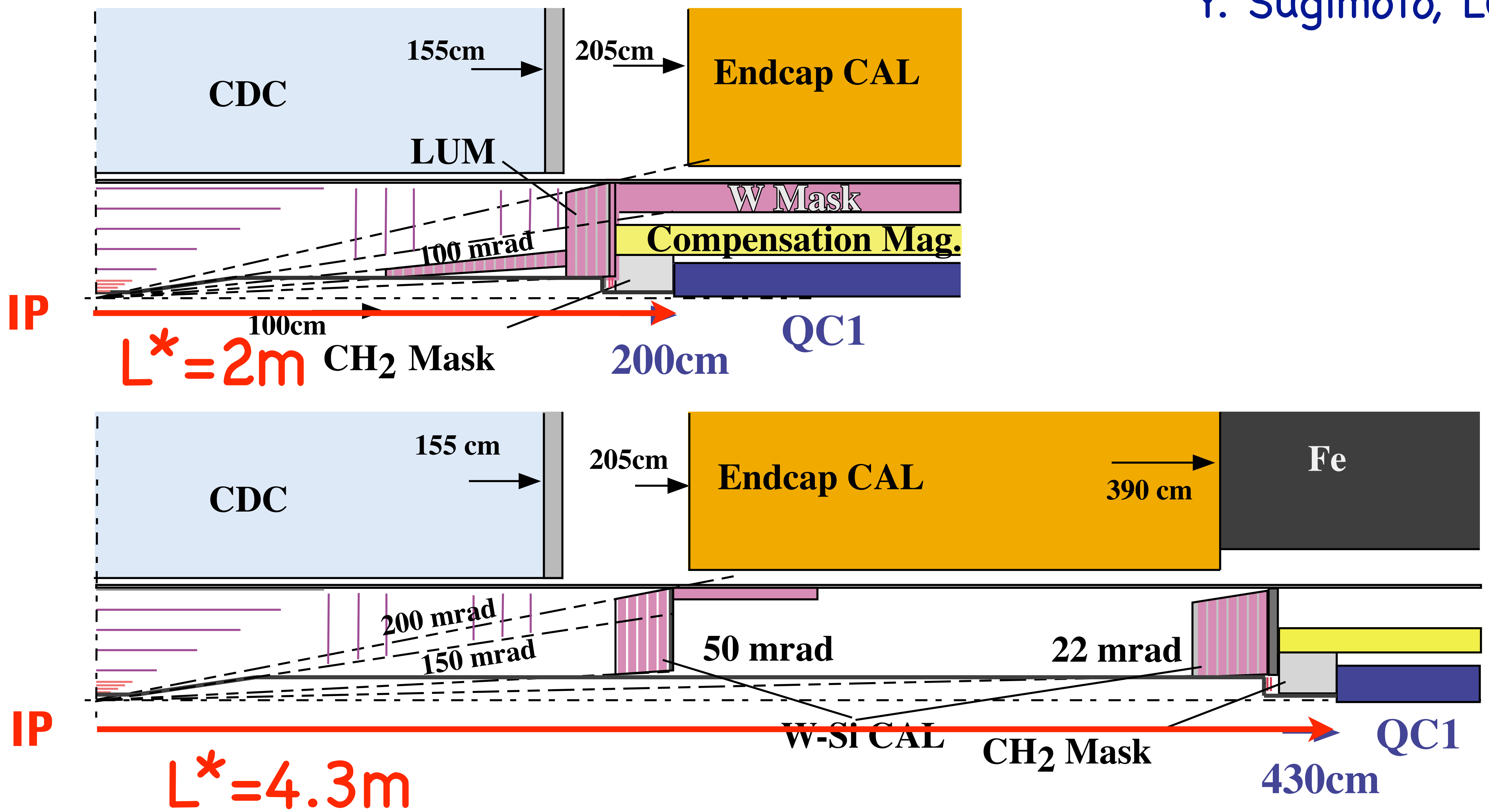
Precise energy and polarization measurements

Backgrounds (muons and synchrotron radiations)

Two main Linac's alignment issue is beyond WG4 and MDI.

IR

IR of JLC/GLC detector,
Y. Sugimoto, LCWS2000



L* : Distance of QC1 from IP

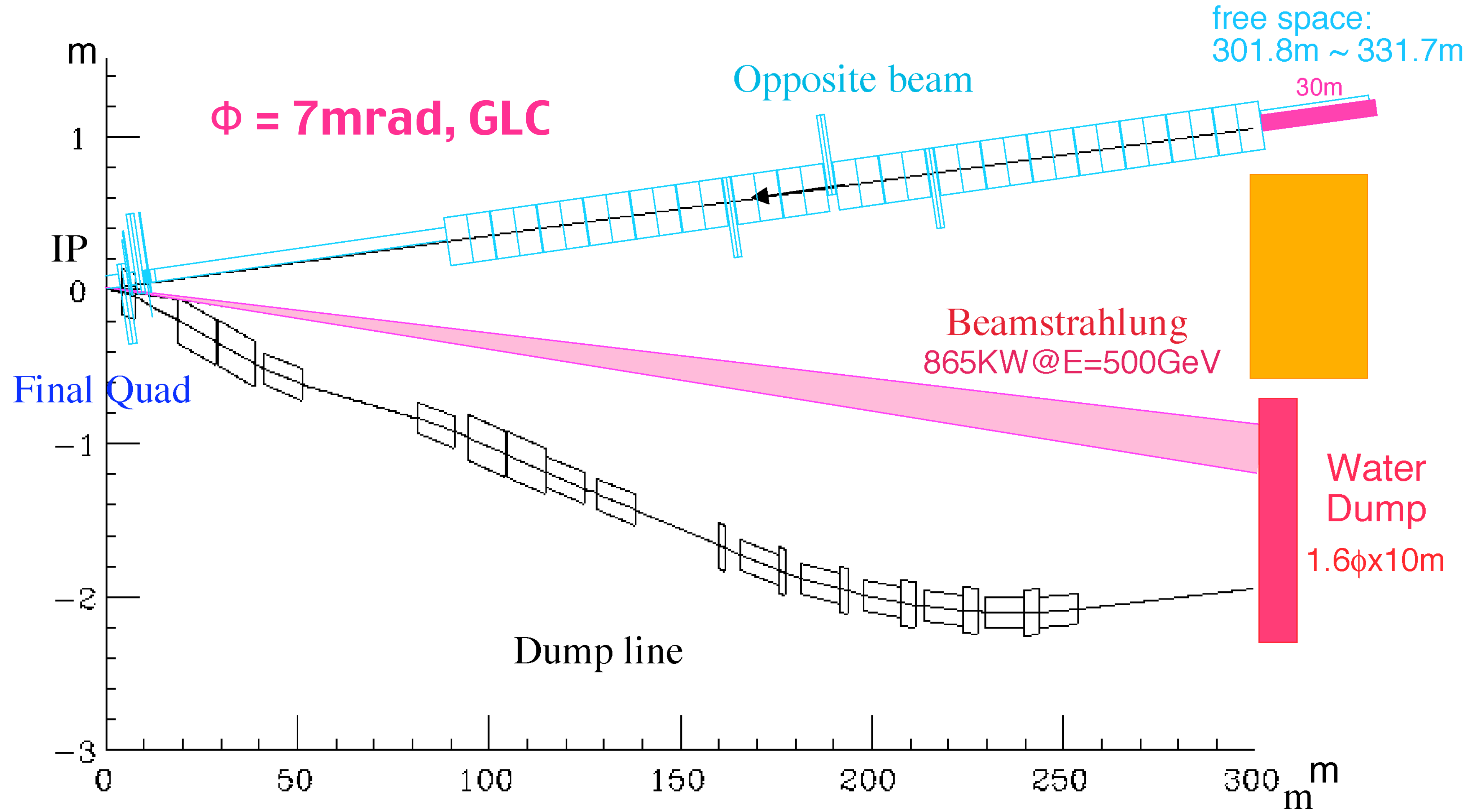
Vertex R (the innermost radius)

Minimum veto-angle (very forward calorimeter)

Backgrounds (pairs, mini-jets, backscattered γ and n)

Instrumentations (pair monitor, feedback, Shintake monitor …)

BDS: Extraction Line



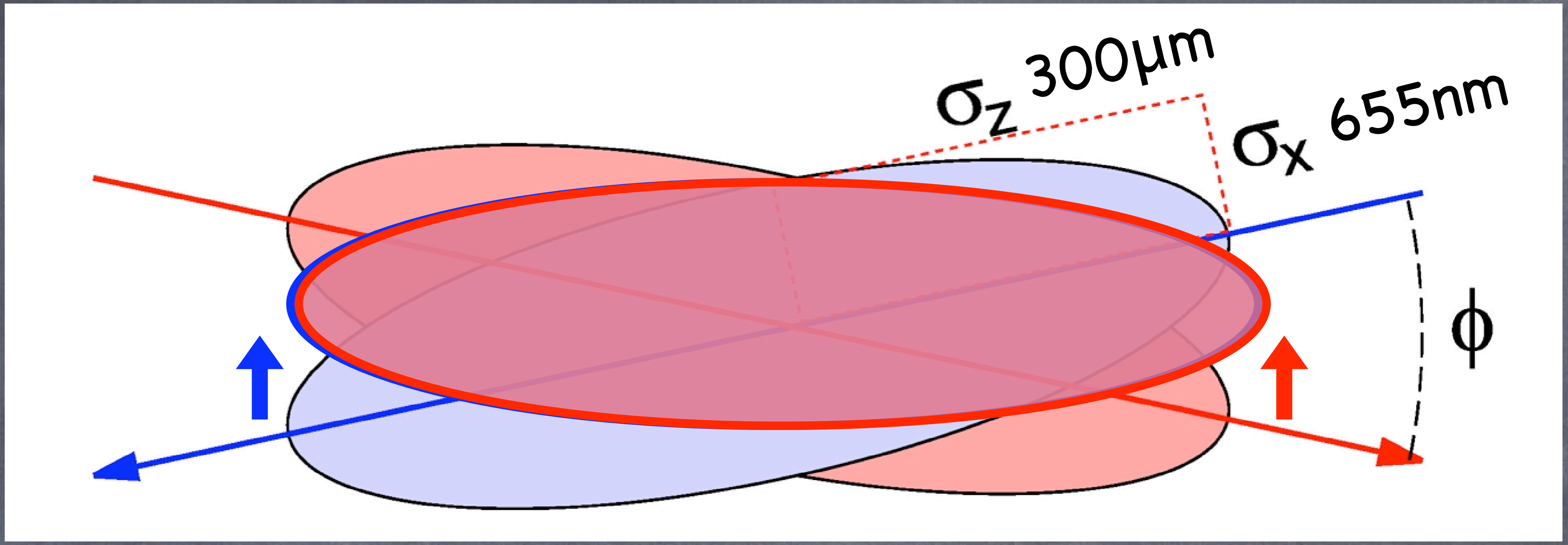
Crossing angle

Choice of final quadrupoles (L*)

Precise energy and polarization measurements

Backgrounds (disrupted beam, back-scattered n and γ.)

Horizontal Crossing Angle



Small angle : $\Phi < 2\sigma_x/\sigma_z > \Phi$: Large angle

~ 4 mrad

timing of two crab cavities
16(50)fsec at Φ=20(7)mrad

easy extraction line

smaller dead cone (θ)

smaller back scattering ?

radiation/bend in solenoid

$\Delta\sigma_y^2 \approx (B\Phi L^*)^5$, $\Delta y' = B\Phi/(2B\rho)$

Δ(spin)=3.25°/100μrad (E/250GeV)

multi-bunch instability
irrelevant in "cold"

Options

parameter	symbol	unit	ILC	"ILC-γγ" V.Telnov's idea	CLIC
energy	E	GeV	250	250	1,500
emittance	$\gamma\epsilon_x/\gamma\epsilon_y$	μm	10/0.04	2.5/0.03	6.8/0.01
IP beta function	β^*_x/β^*_y	mm	21/0.4	1.5/0.3	8/0.1
IP beam size	σ^*_x/σ^*_y	nm	655/5.7	88/4.3	60/0.7
<Upsilon>	U_{ave}		0.046	0.33	2
"disruption" angle	θ_d	mrad	0.4	10 (e^-)	10 (coh.pair)
crossing angle	Φ $>\theta_d+R_Q/L^*$	mrad	0 - 20	25 L^*=4m, R_Q=6cm	20 L^*=2m, R_Q=2cm
				γ dump	

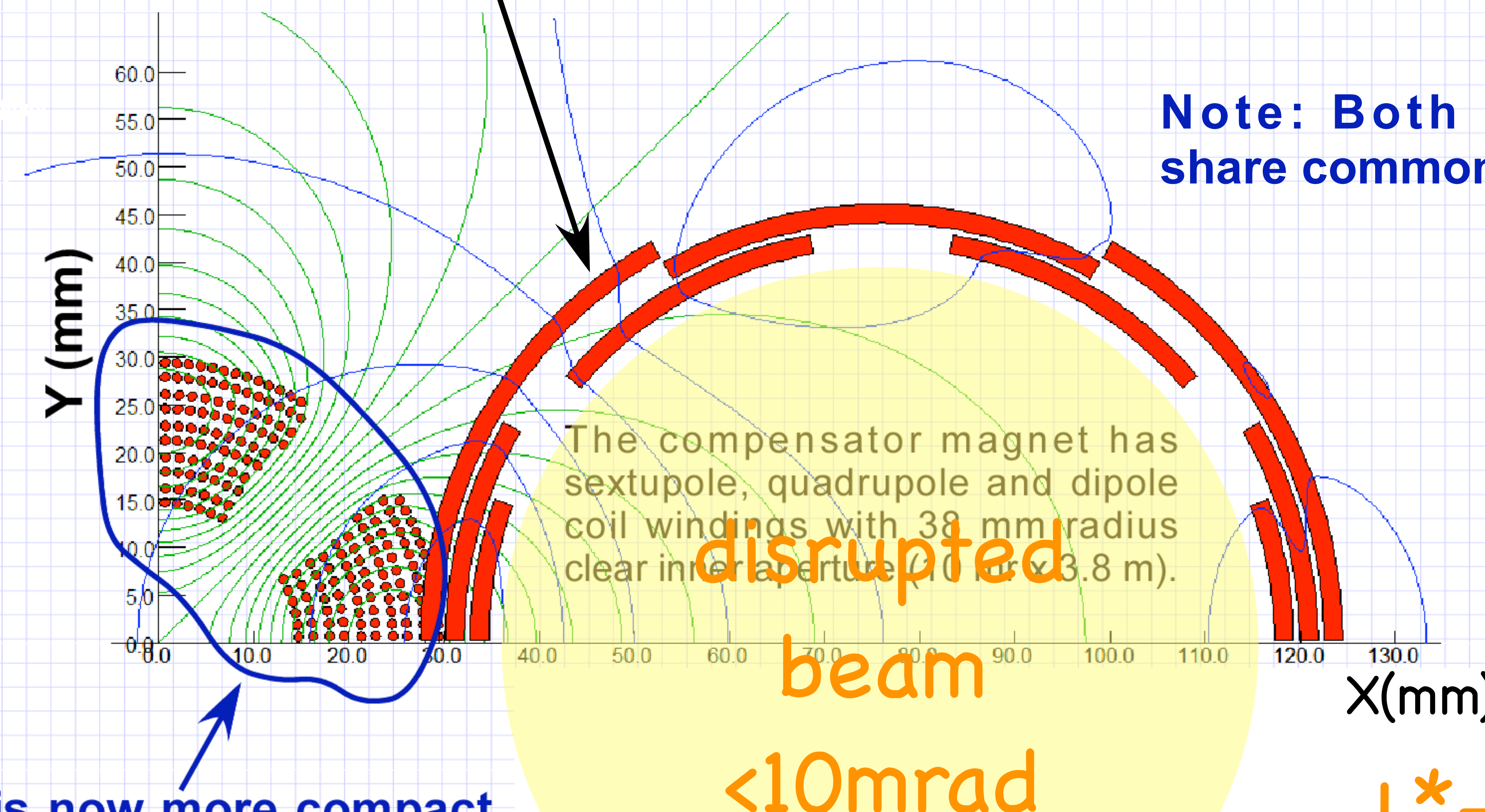
International Linear Collider

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

A Motivation for Making QD0 Coil Even More Compact.

This is the first of two coil geometries proposed for a gamma-gamma IR.

Note: Both magnets share common cryostat.

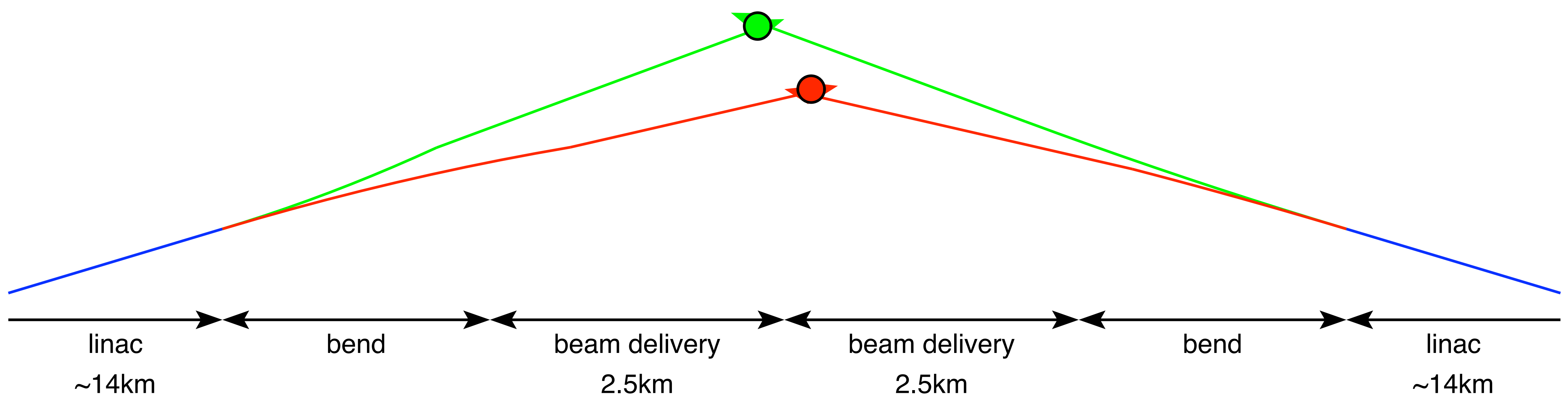


QD0 is now more compact and made only from cable with inner coil gone (outer layers have moved inward).

$L^*=3.8m$,

$\Phi=20mrad$

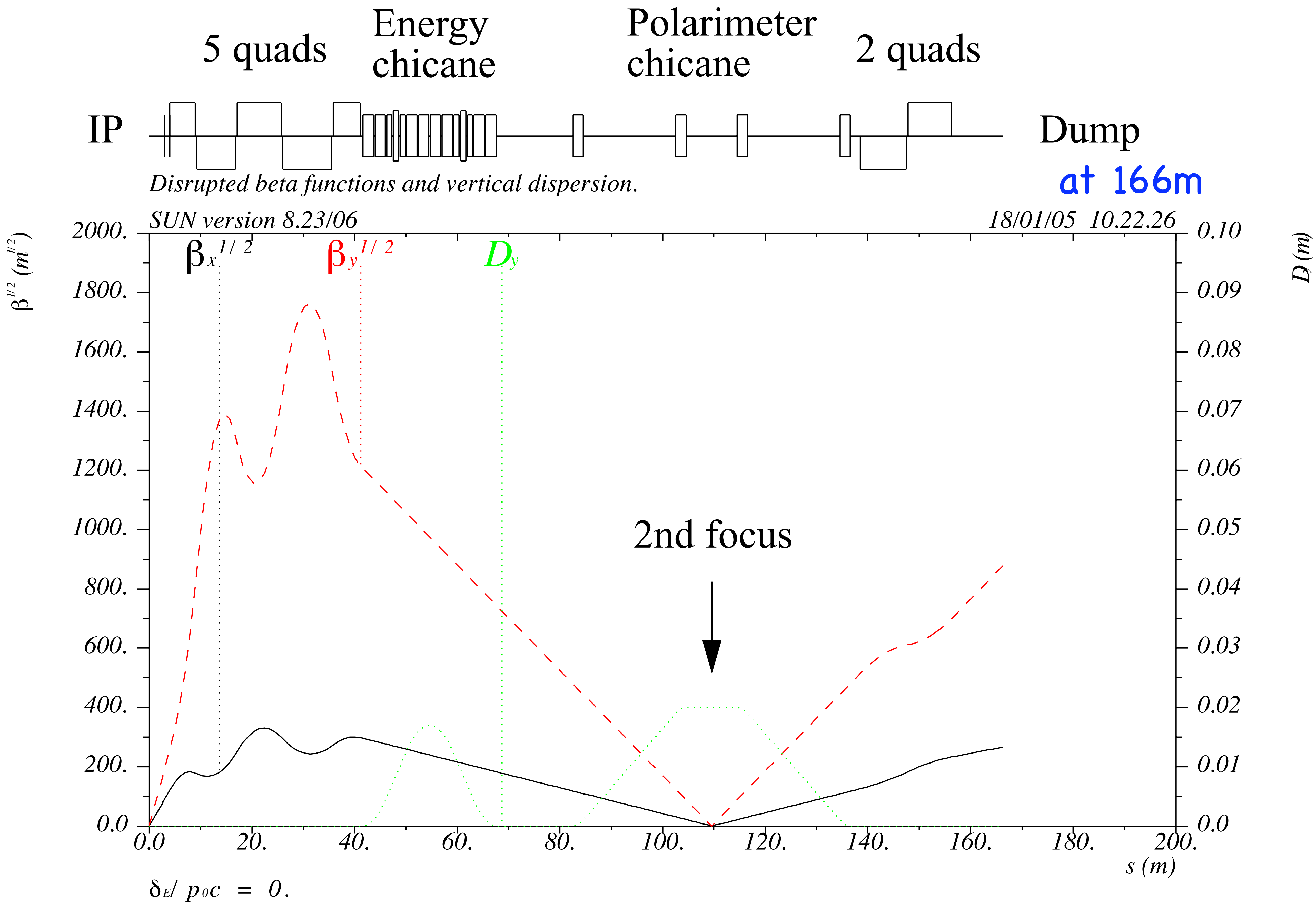
possible layout of a multi-TeV collider with two IPs



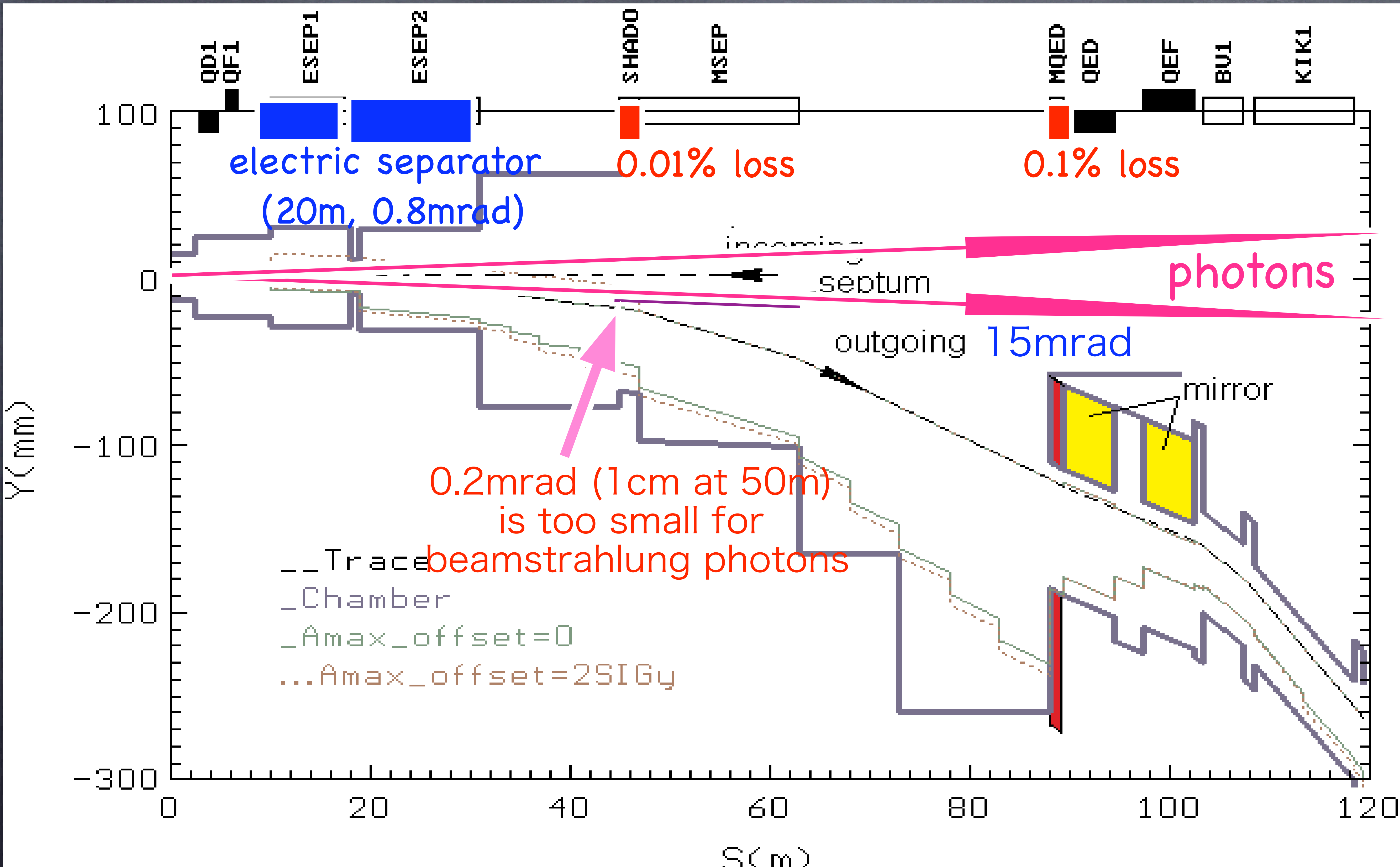
- the two linacs must be oriented at the multi-TeV crossing angle
- angles generated in the beam-delivery system are negligible compared with θ_c

20mrad Crossing : Extraction Line Design

Yuri Nosochkov, 18 January, SLAC ILC-BDS meeting



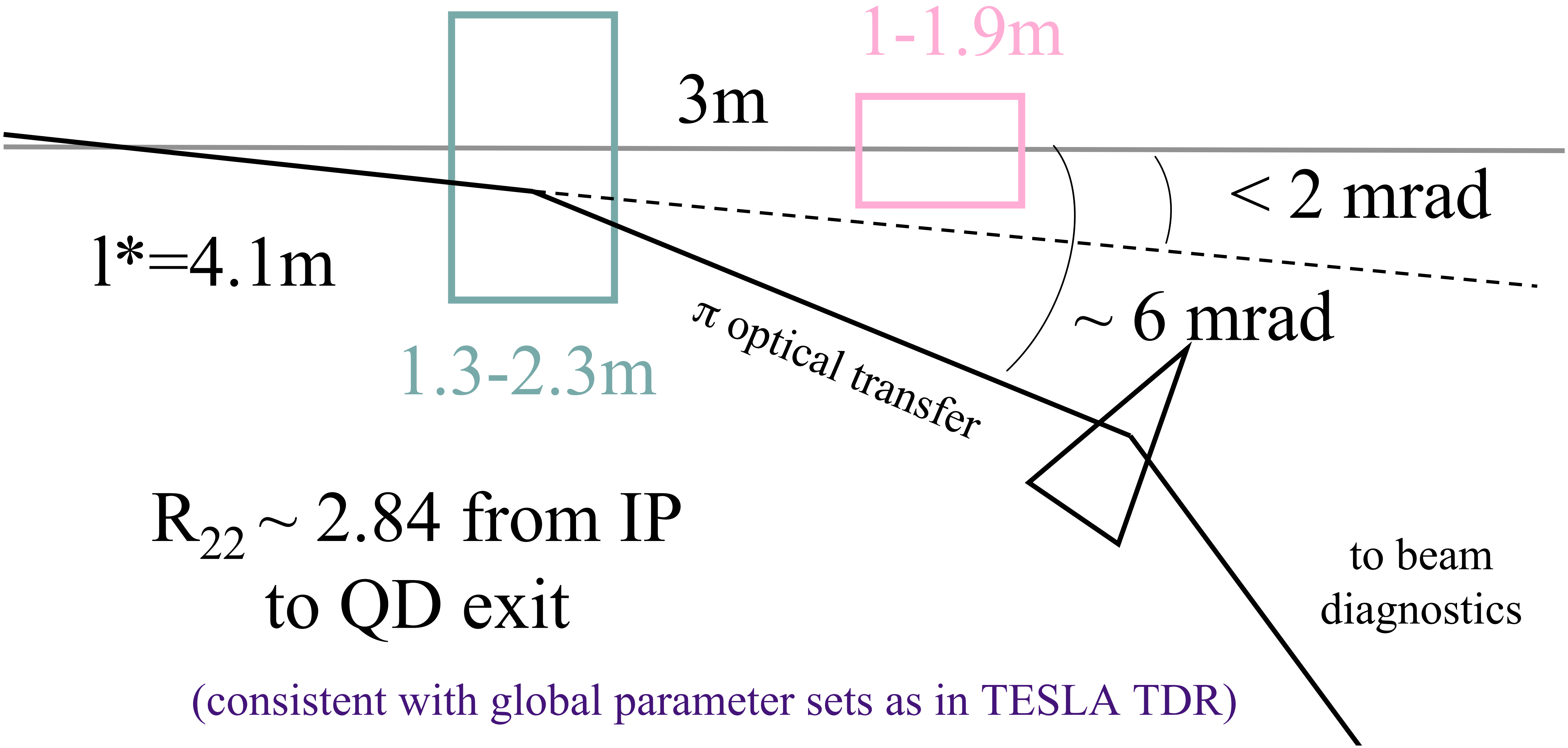
Extraction line (head-on) at TESLA-TDR



Possible doublet parameters for 0.5-1 TeV

SC QD (r = 35mm) 214-228 T/m

warm QF (r ~ 10mm) 140-153 T/m



$R_{22} \sim 2.84$ from IP to QD exit

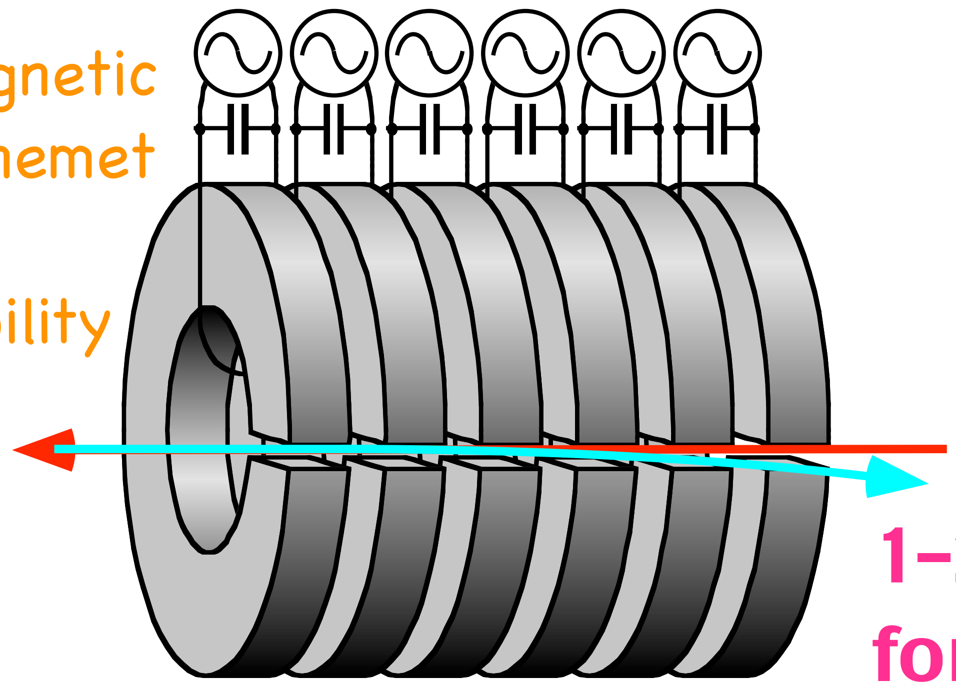
(consistent with global parameter sets as in TESLA TDR)

Y. Iwashita, MDI workshop, 7 Jan.05
corrected on 23 Feb.05

RF Kicker for Head-ON Collision

DC+3MHz (+9MHz)

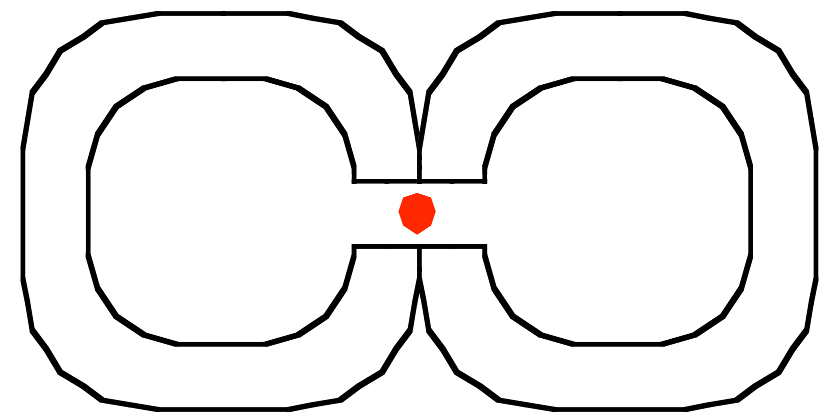
Soft magnetic alloy :Finemet
High permeability



L=4m

1–2 mrad for 250GeV beam

Variant



Double C-type

Better shielding

Step at center?

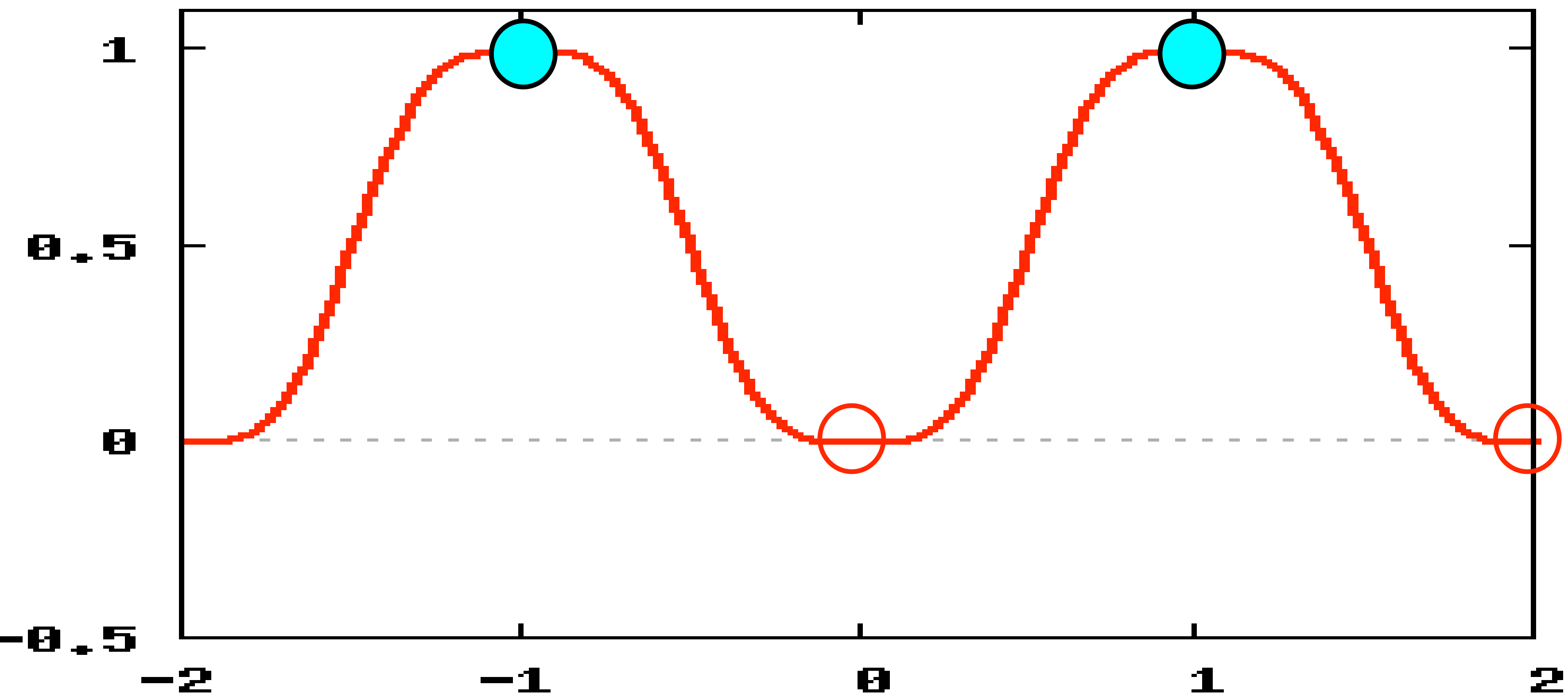
Stored Energy W ~ 100[J] @0.25T

x3MHz/Q(~100?)/(4m/3cm) ~ 45kWpk /unit

(x133 units –> 6 MWpk in total)

H. Souda, ILC-Asia WG4 meeting
2 Feb. 2005

(1) Waveform: $f(t) = \frac{8}{9} - \cos(\omega t) + \frac{1}{9}\cos(3\omega t)$



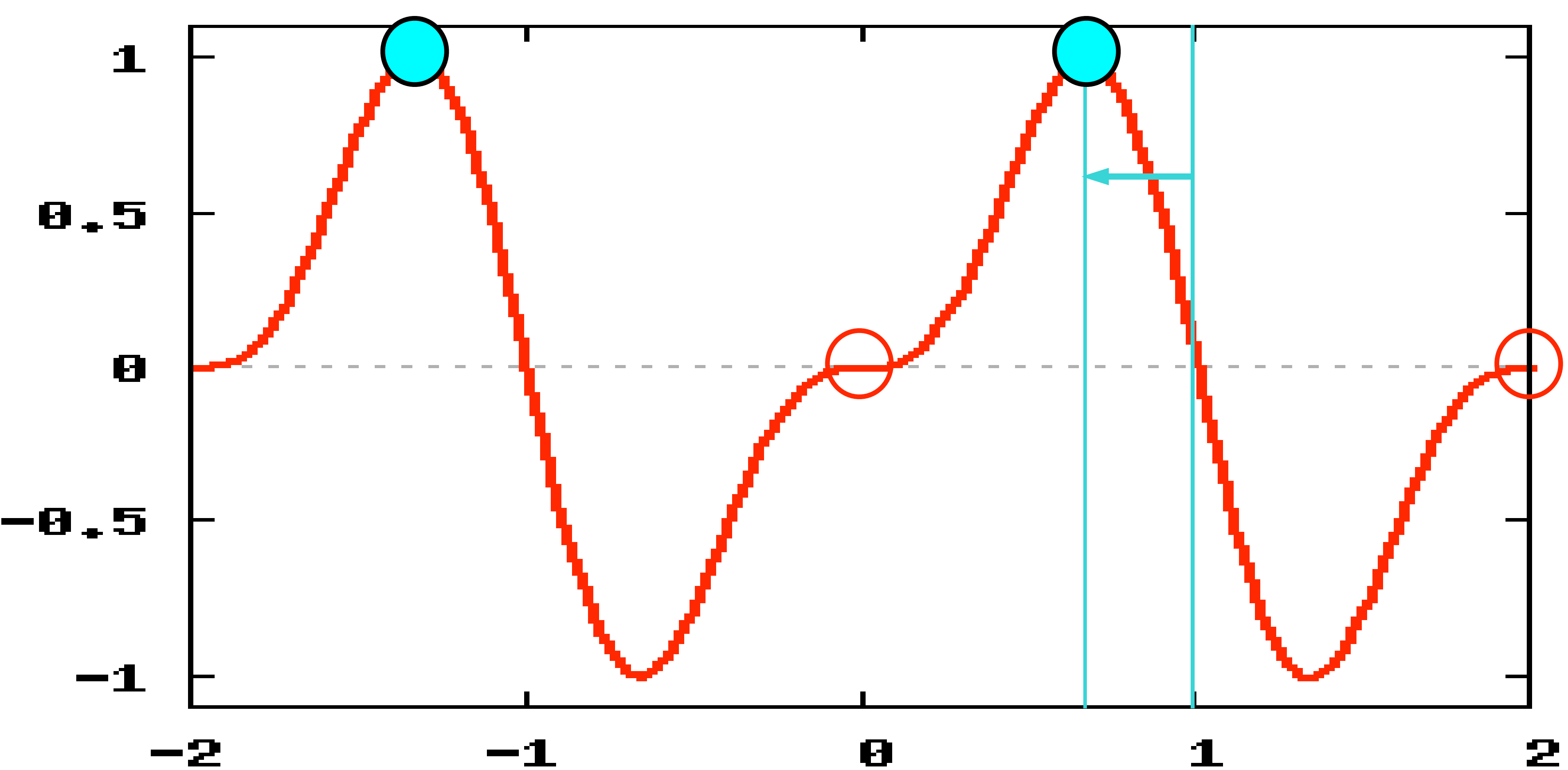
Phase division=1

$\theta_x = 4.65\times10^{-8}$ at ○

$\theta_x = 1\times10^{-3}$ at ●

$\theta_x < 3\times10^{-7}$

(2) Waveform: $f(t) = -\sin(\omega t) + \frac{1}{2}\sin(2\omega t)$



Phase division=2

$\theta_x = 9.58\times10^{-8}$ at ○

$\theta_x = 1\times10^{-3}$ at ●

Dark current?

MPS?

L,E,P Measurement Goals

Luminosity, Luminosity Spectrum

- Total cross sections: absolute $\delta L/L$ to ~0.1%
- Z-pole calibration scan for Giga-Z: relative $\delta L/L$ to ~0.02%
- threshold scans (ex. top mass): relative $\delta L/L$ to 1%
  +L(E) spectrum: core width to <0.1% and tail population to <1%

Energy

- Top mass: 200 ppm (35 MeV)
- Higgs mass: 200 ppm (25 MeV for 120 GeV Higgs)
- W mass: 50 ppm (4 MeV) ??
- 'Giga'-Z A_{LR}: 200 ppm (20 MeV) (comparable to ~0.25% polarimetry)
  50 ppm (5 MeV) (for sub-0.1% polarimetry with e^+ pol) ??

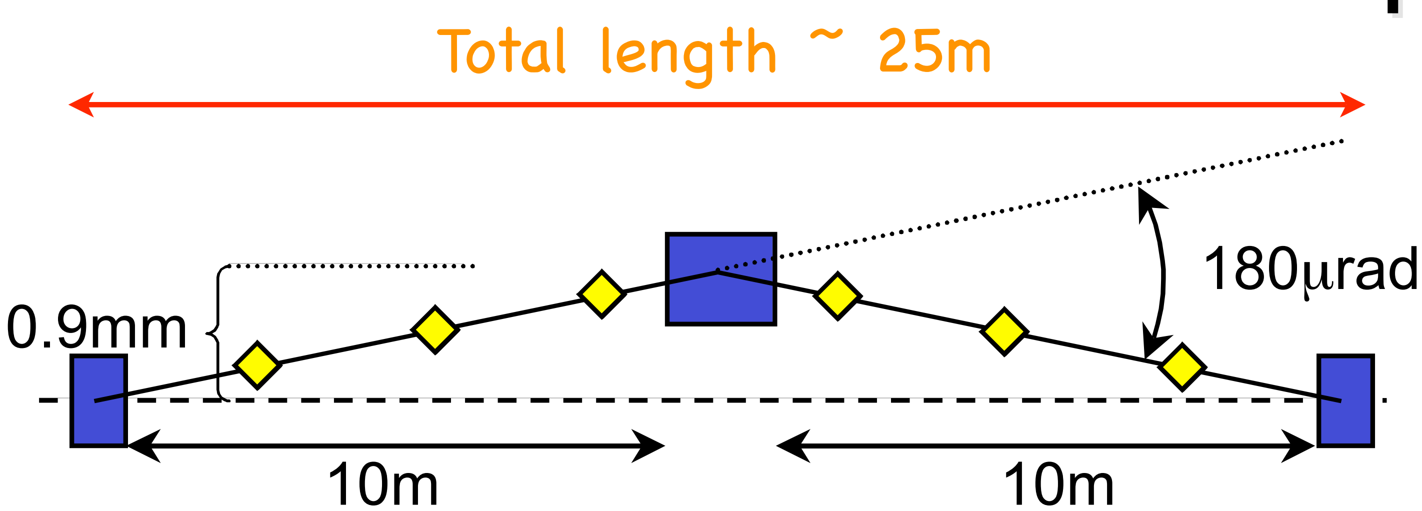
Polarization

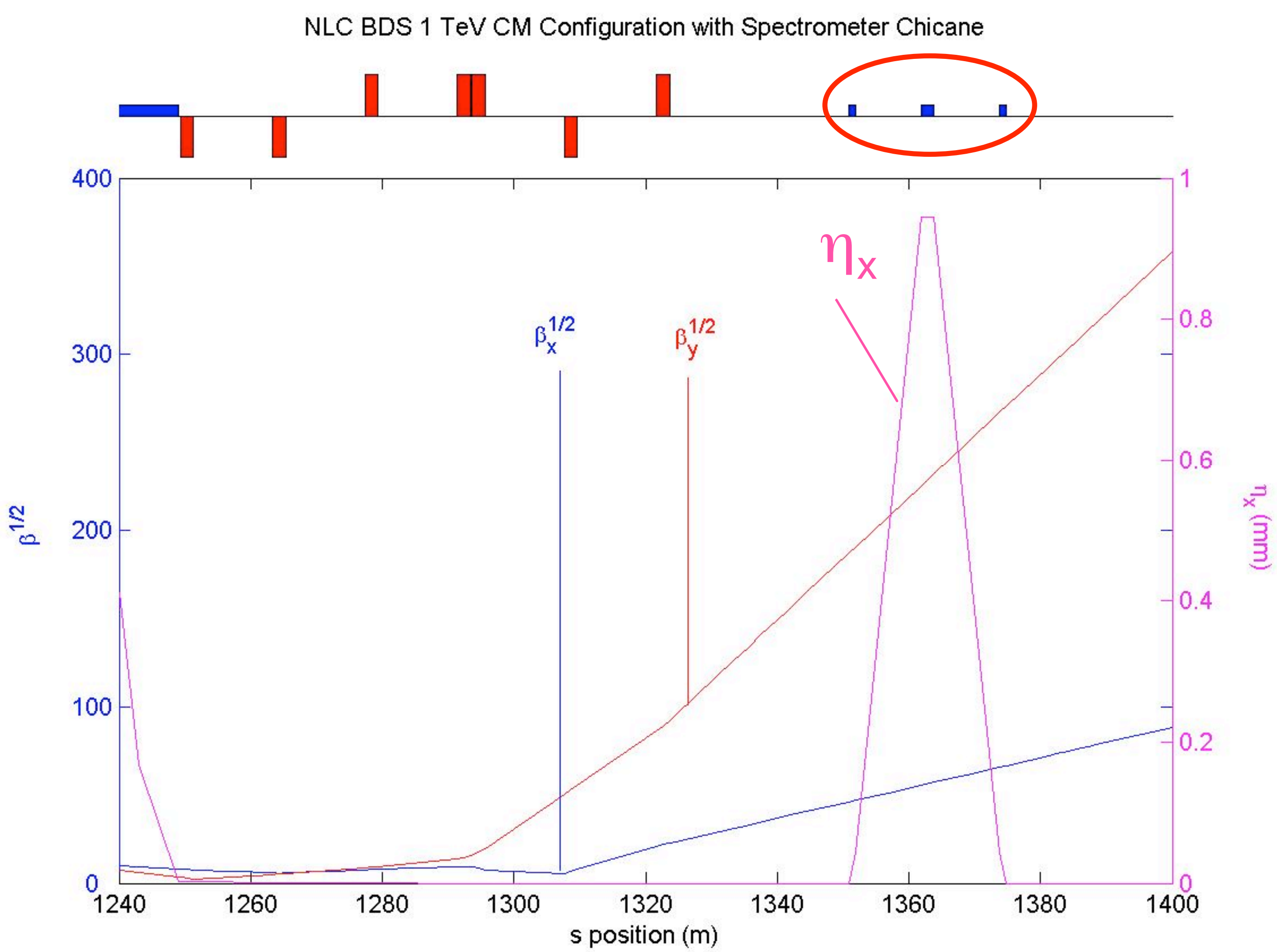
- Standard Model asymmetries: < 0.5%
- 'Giga'-Z A_{LR}: < 0.25% (<0.1% with e^+ pol)

upstream: E measurement TESLA-TDR

M.Hildreth, LCWS04, 21 April 2004

BPM-based Spectrometer





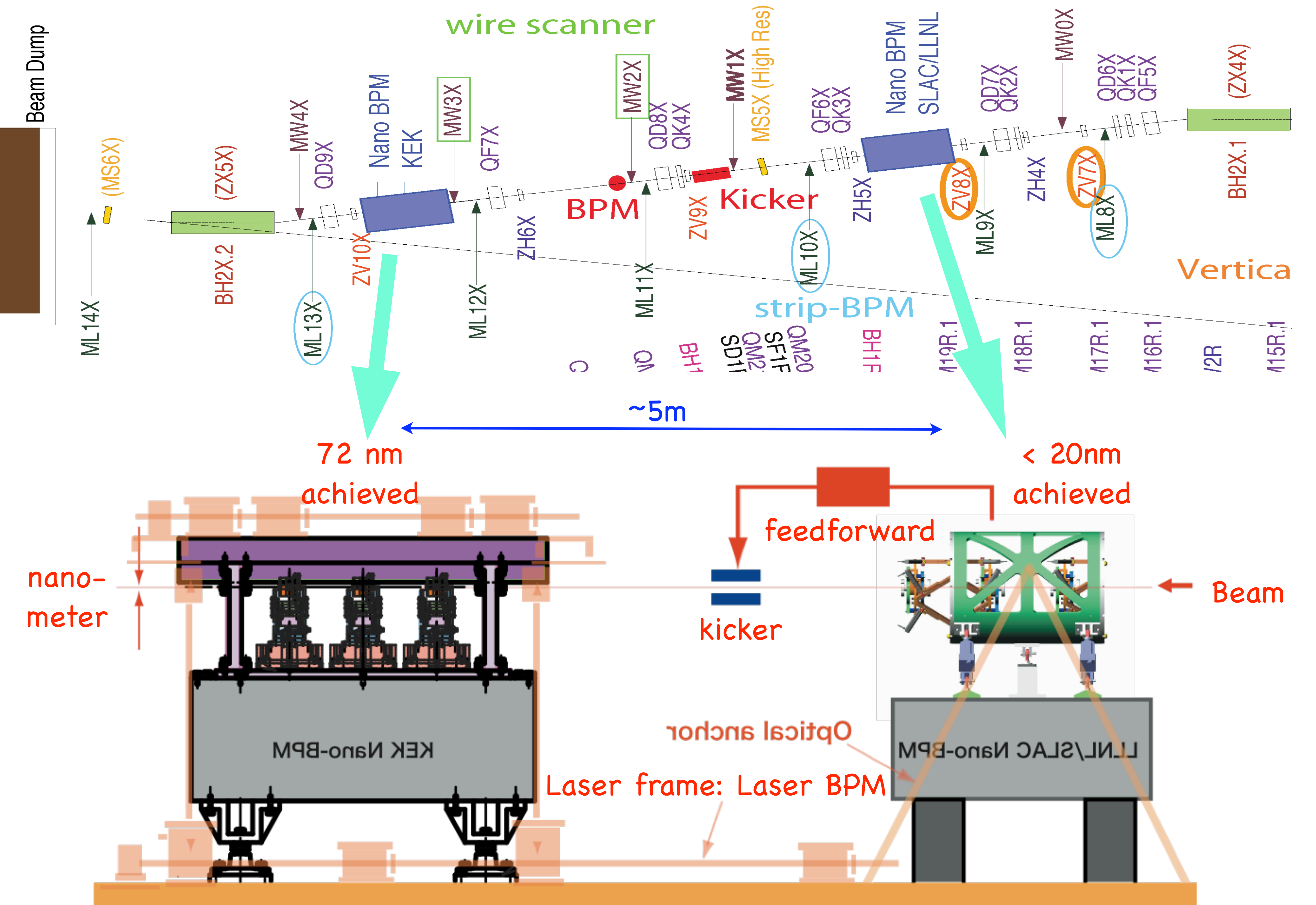
Design Considerations:

- limit SR emittance growth
  - 360μrad total bend ⇒ 0.5%
- available space in lattice
  - no modifications necessary, yet
- 10m drift space maximum one can consider for mechanical stabilization, alignment
- 37m total empty space allows for BPMs outside of chicane to constrain external trajectories
- *Tiny* energy loss before IP
- non-ideal β-variation?

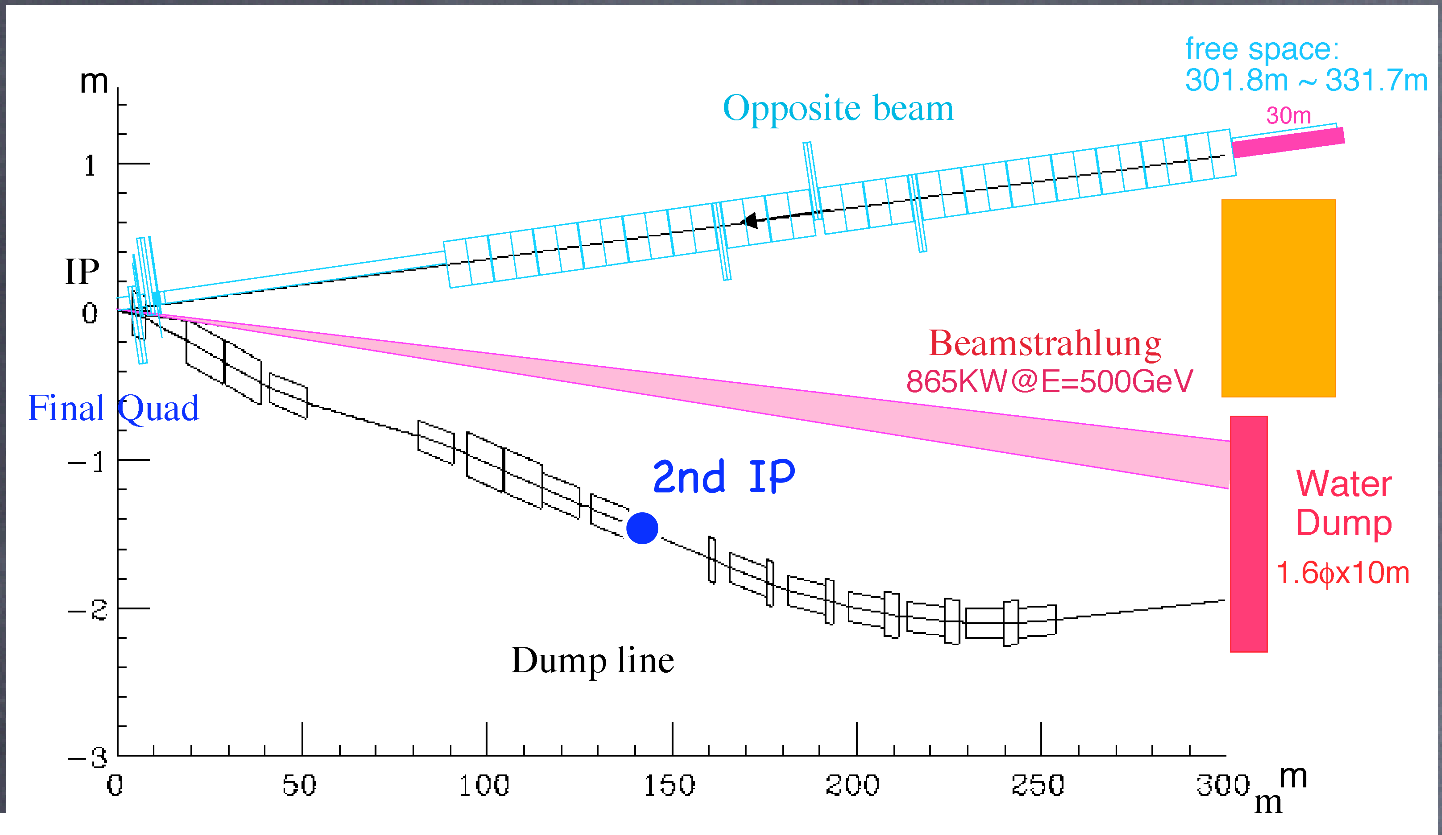
⇒ Constraints lead to a required BPM resolution of ~100nm (Resolution ⊕ Stability)

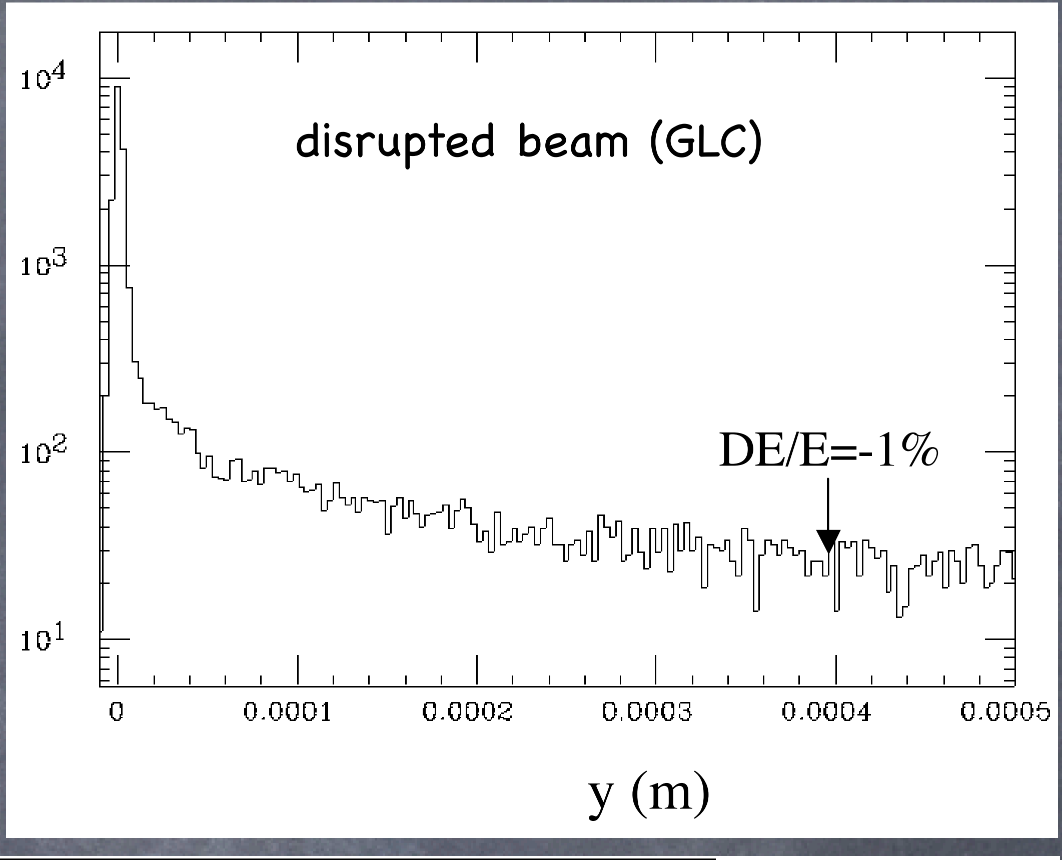
$\Delta E/E = O(100\text{ppm})$

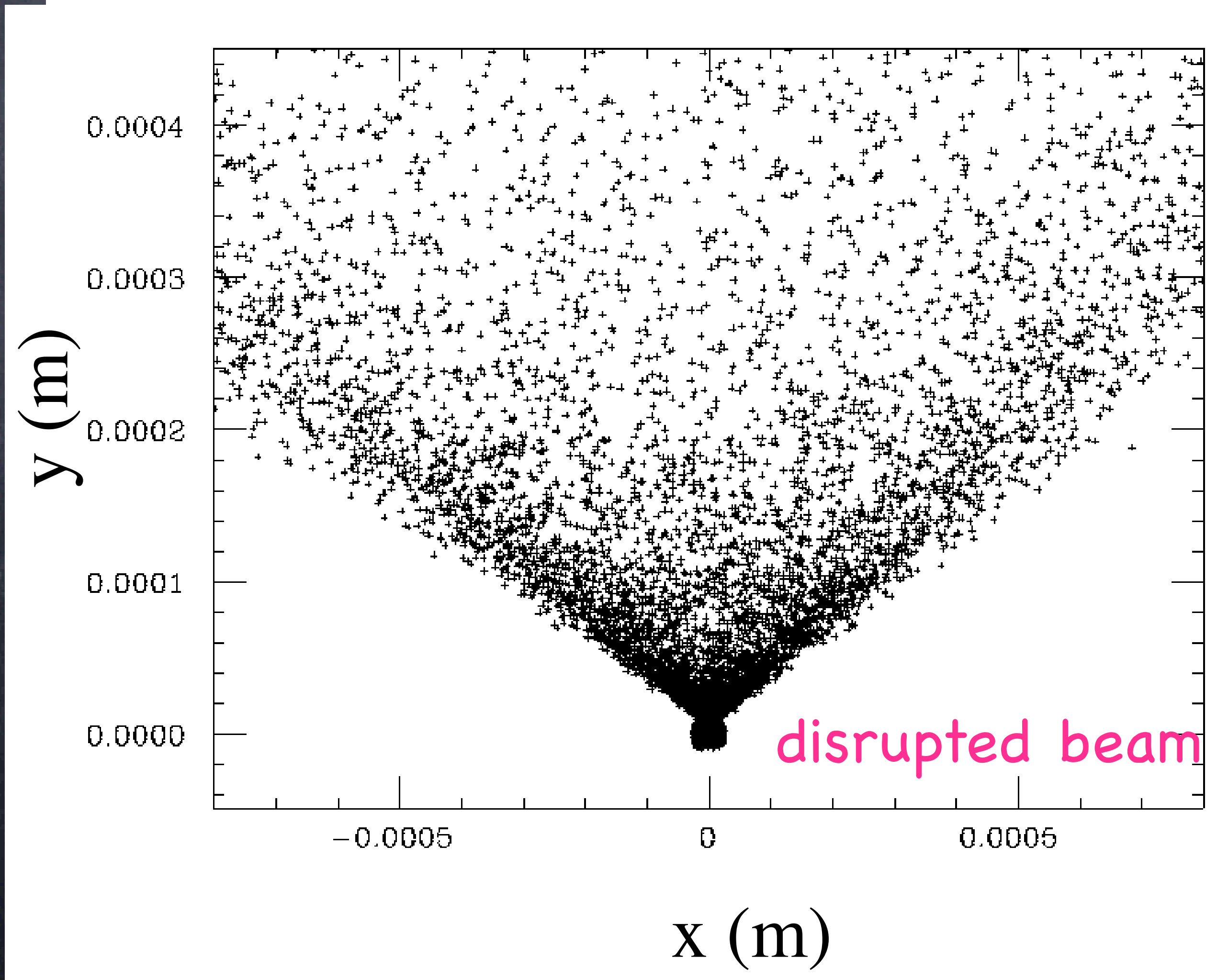
Nano-BPMs at ATF extraction line, KEK

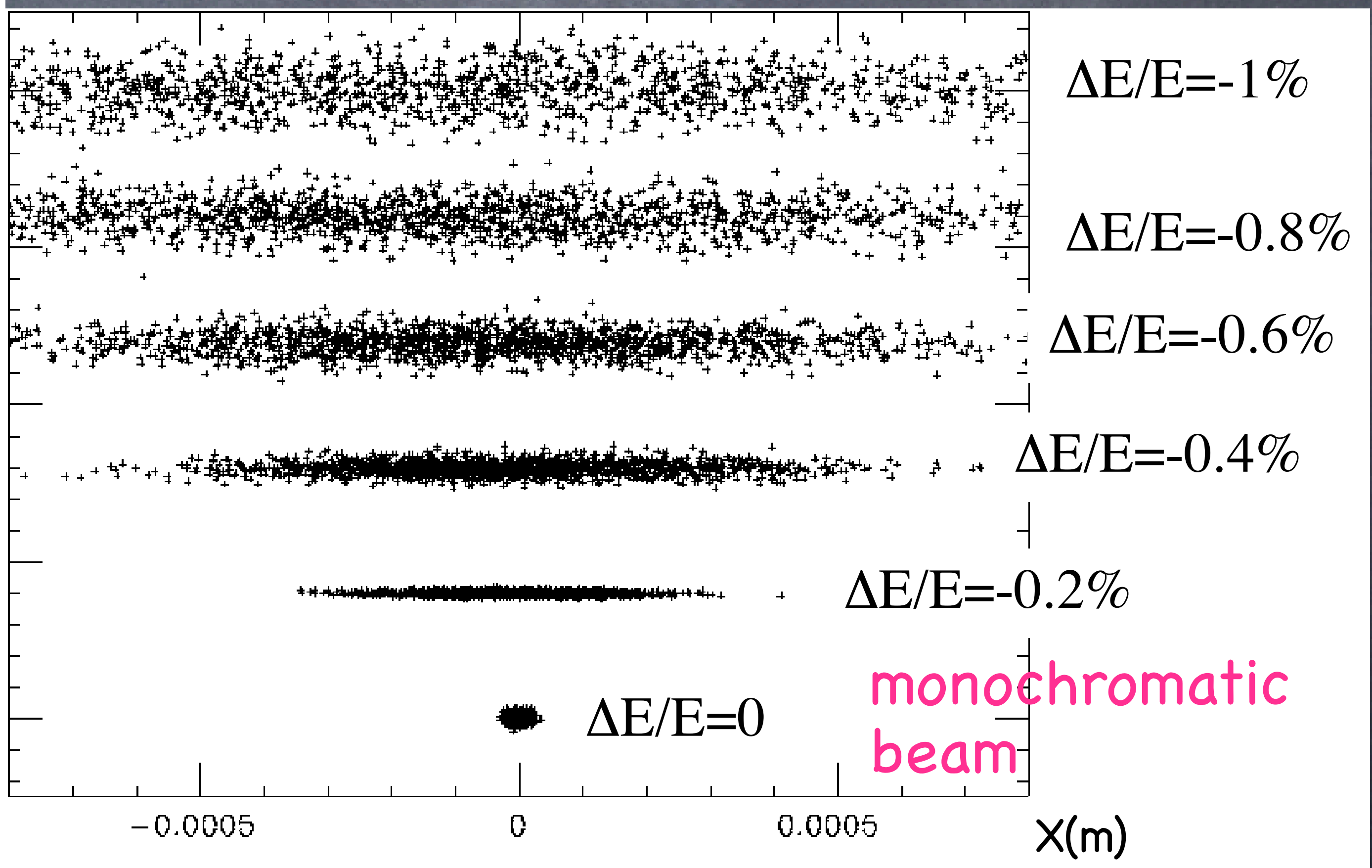


GLC: E spectrum measurement at the 2ndIP





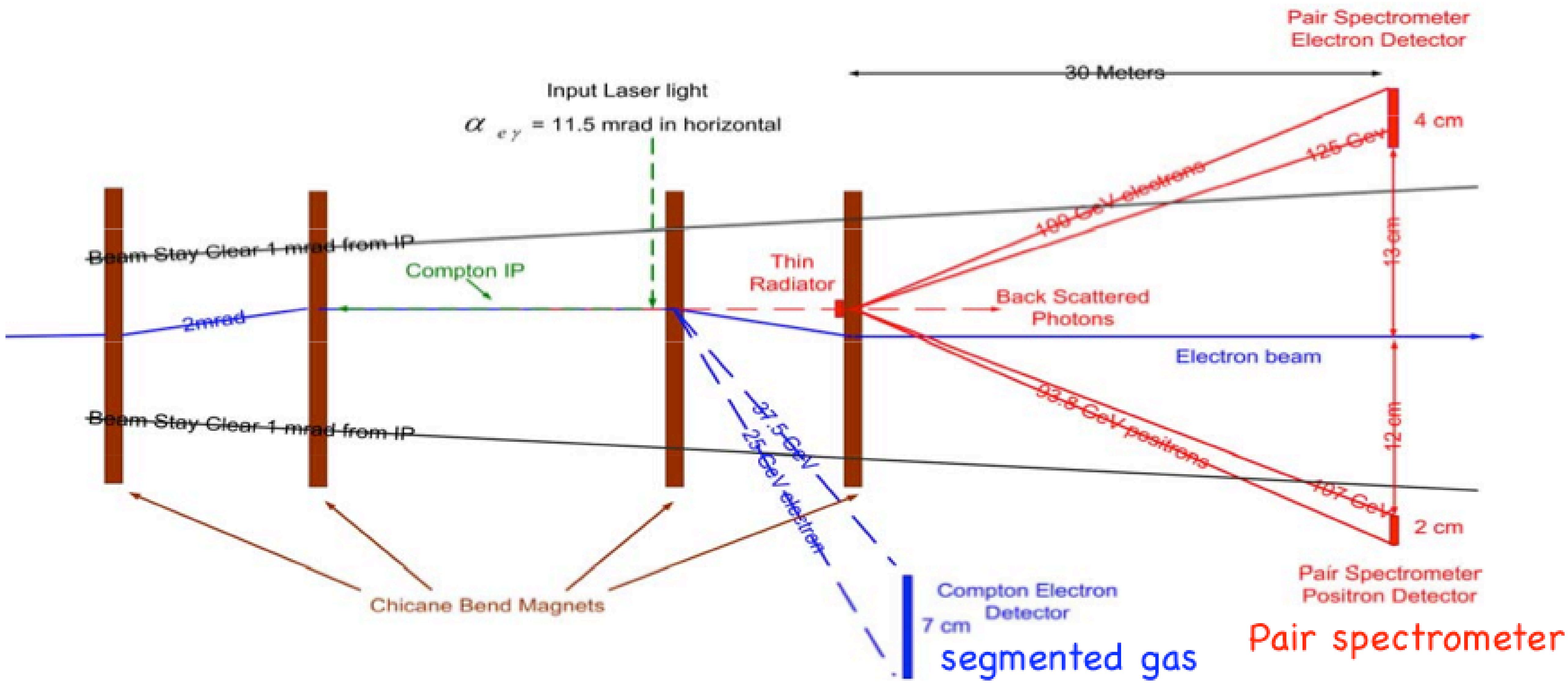




K.Kubo, LCWS2004

Downstream Polarimeter

M.Woods, LCWS2004



- Compton IP 60 meters downstream of e^+e^- IP
- 2mrad bend angle from analyzing magnet
- segmented gas Cherenkov detector, similar to SLD design
- multi-Compton mode with high power pulsed laser at ~17Hz

Also considering,

- pair spectrometer for backscattered photon measurement
- alternate detector technologies (ex. quartz fiber)

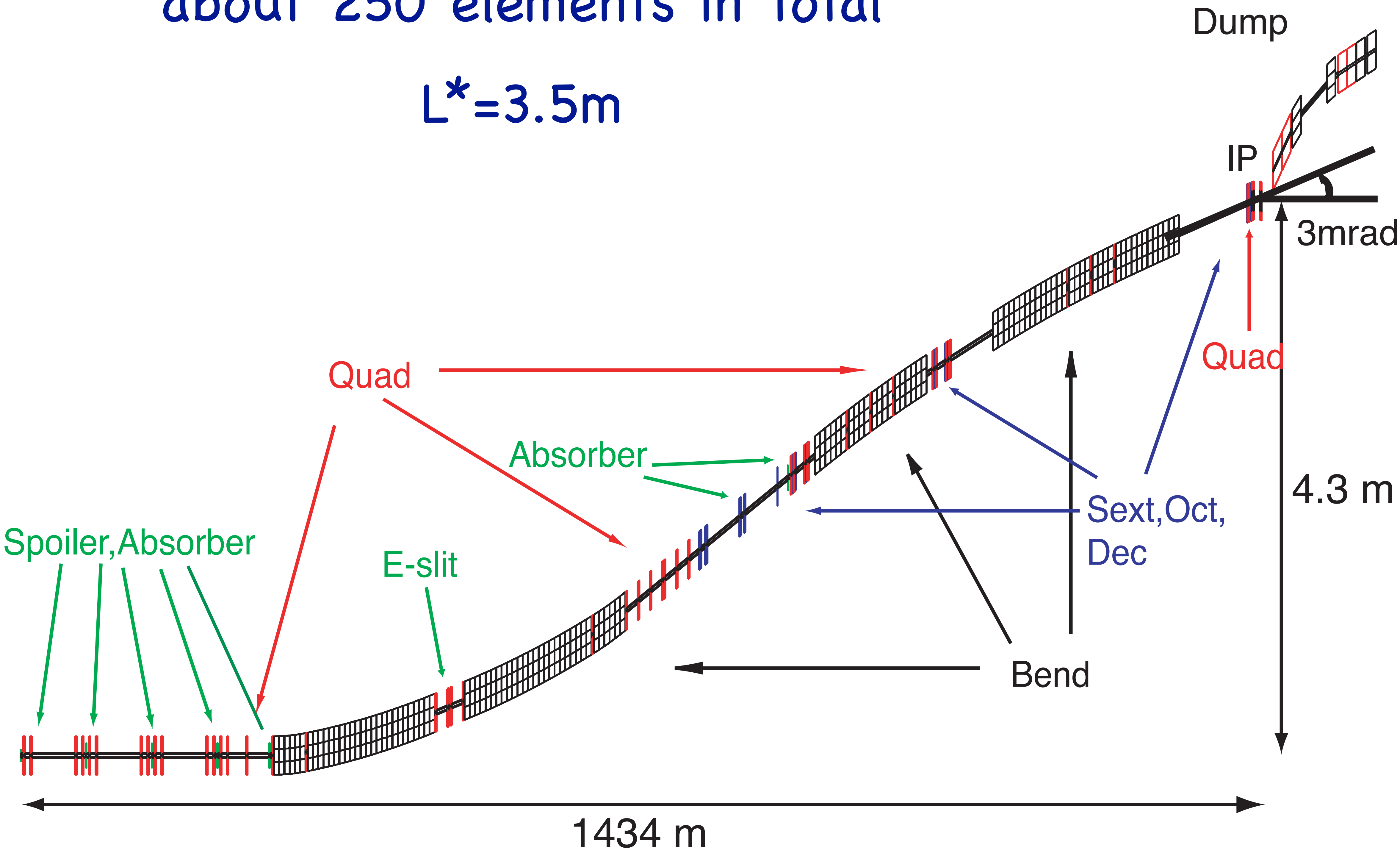
BDS Simulation

GLC Roadmap Report,2003

Also, G. Blair's talk at this workshop

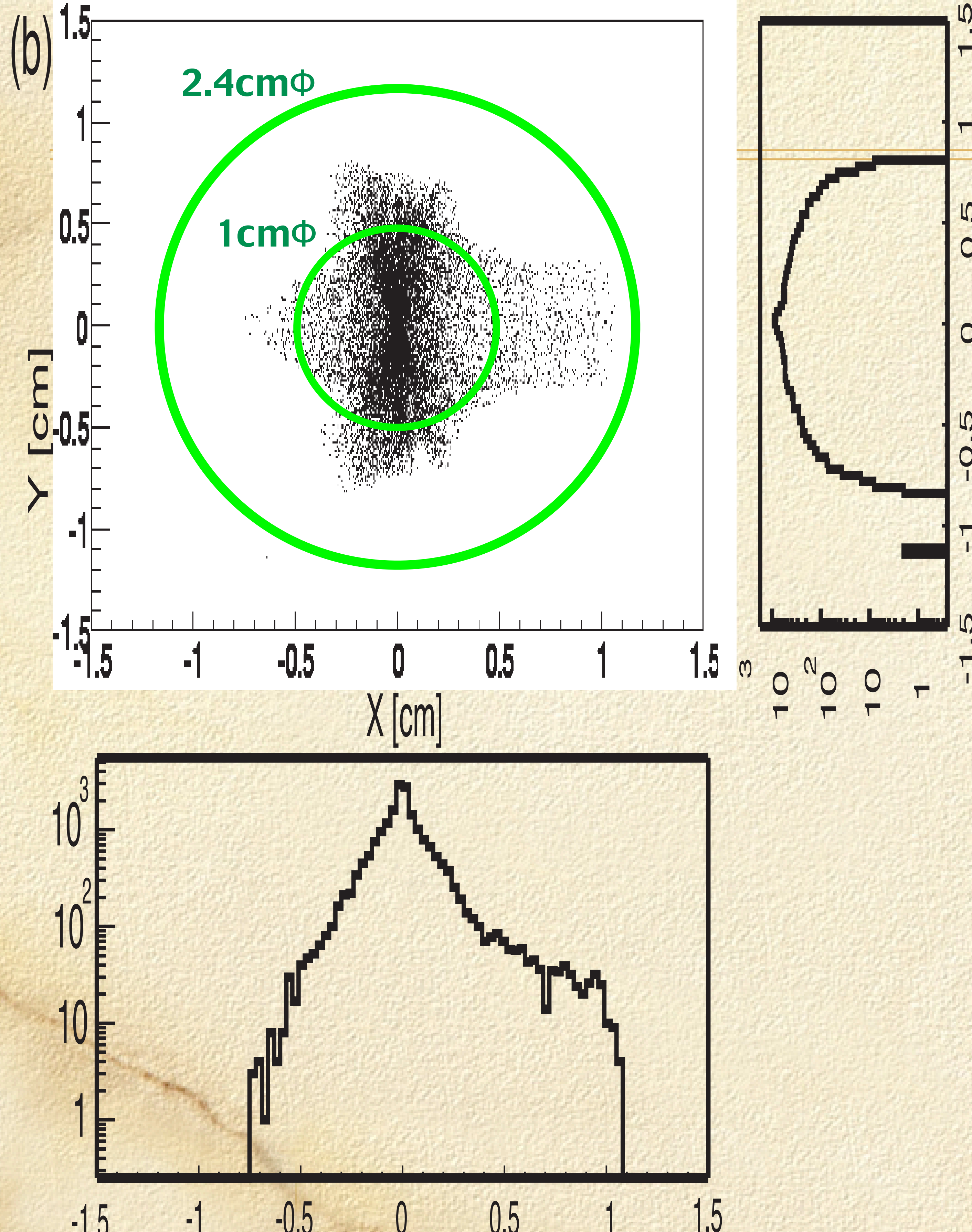
about 250 elements in total

$L^*=3.5m$



Vertex R : Synchrotron Radiations

BDS-Simulation (GEANT4) by K.Tanabe

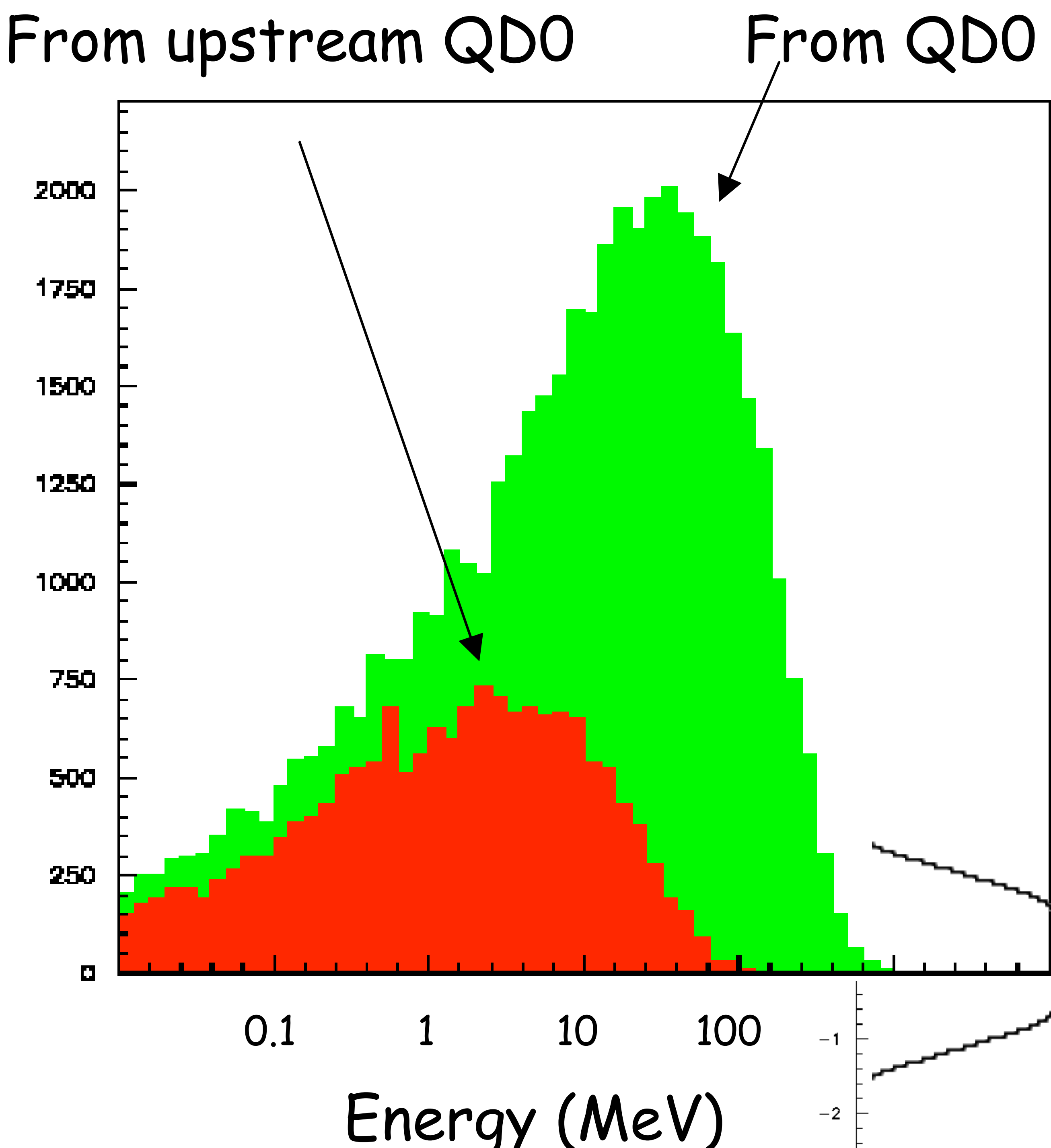


from Halo at IP
<E>=4.8MeV

GLC: L^*=3.5m
θ_c=7mrad
L/L_0=0.6
$12\sigma_x$ $53\sigma_y$

Takashi Maruyama, MDI workshop, 6 Jan.05

Sync radiations in 2mrad crossing

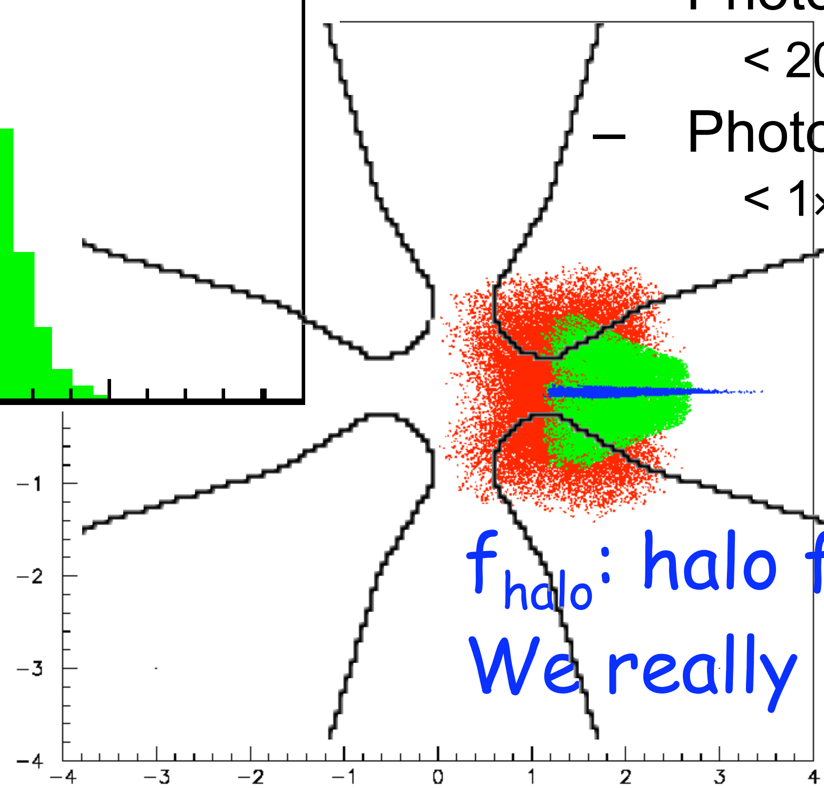


- No sync radiations from beam core or disrupted beam would hit QF1.
- Sync radiations from beam halo hit QF1.

	QD0	upstream QD0
<E> (MeV)	43.	5.7
# N/e-	23.5	8.6
Hit rate (%)	4.4	35.
Power (kW)	$2.0*f_{halo}$	$0.78*f_{halo}$

– Photons backscattered to IP
  - < 200 photons/BX for $f_{halo}=10^{-3}$

– Photo-neutrons (FLUKA)
  - < 1×10^{8} neutrons/cm^2/yr for $f_{halo}=10^{-3}$



f_{halo}: halo fraction

We really don't know.

Minimum Veto Angle

Primary requirement from SUSY

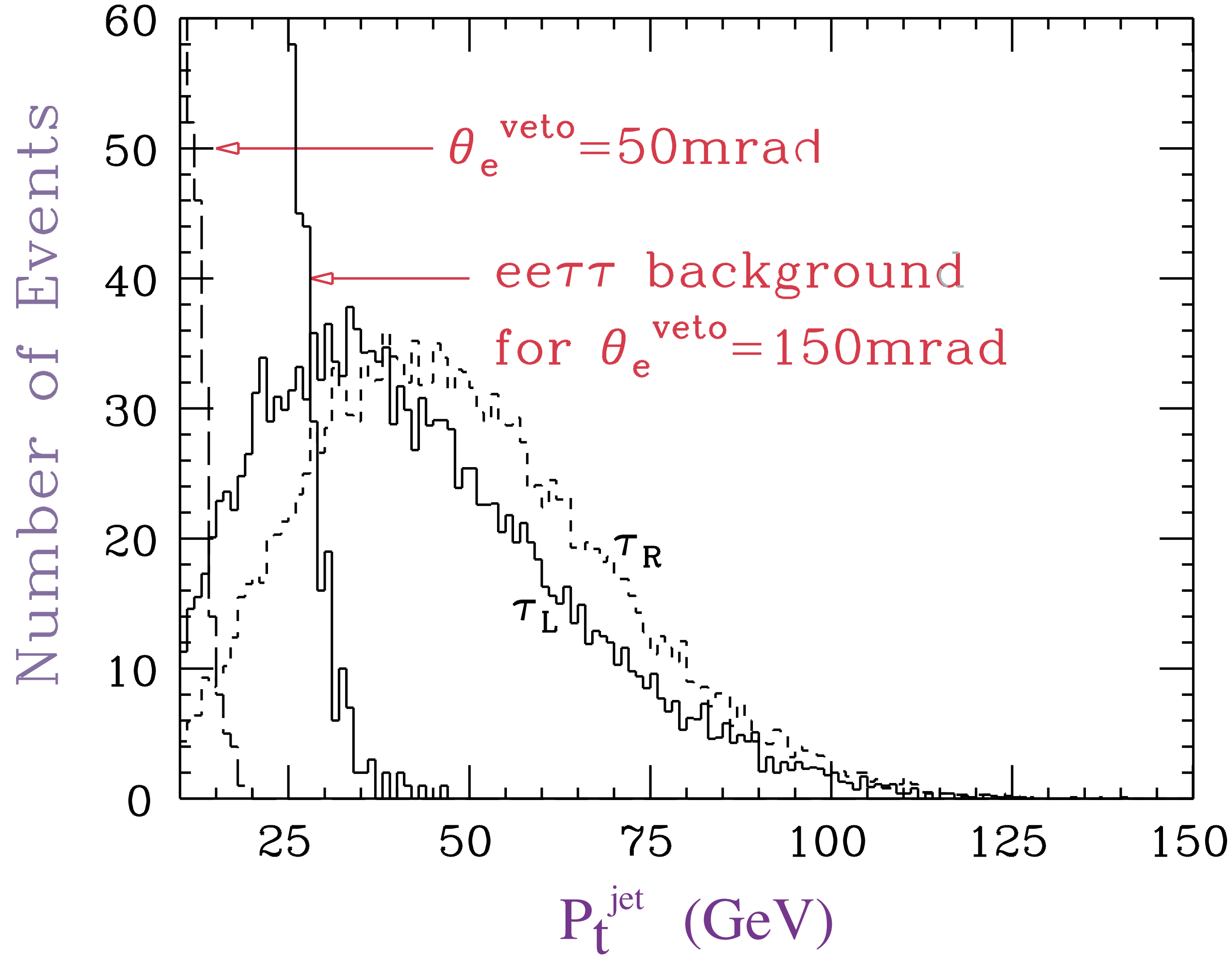
$e^+e^- \rightarrow \tilde{\tau}^+_{L(R)}\tilde{\tau}^-_{L(R)}$

M.Nojiri, K.Fujii and T.Tsukamoto, Phys. Rev. D54(1996)6756.

$\sqrt{s} = 500\text{GeV}$

$m_{\tilde{\tau}} = 150\text{GeV}, \; m_{\tilde{\chi}^0_1} = 100\text{GeV}$ → Δm=50GeV

θ_{veto} =50mrad



mSUGRA
WMAP data

$\Omega_{CDM}\,h^2$ =0.094 - 0.129
(2 σ)

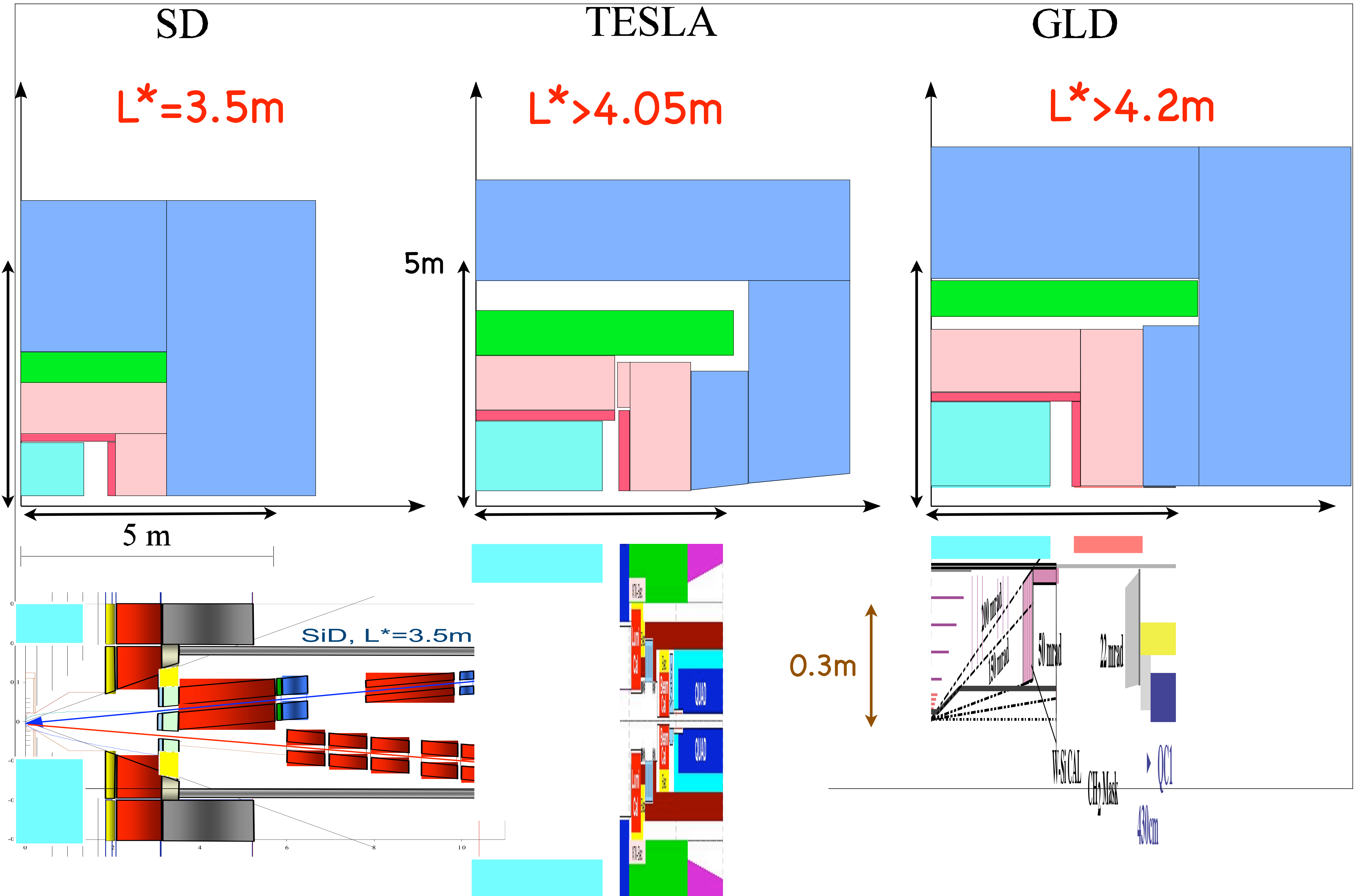
more stringent

Δm=5GeV

θ_{veto} =5mrad

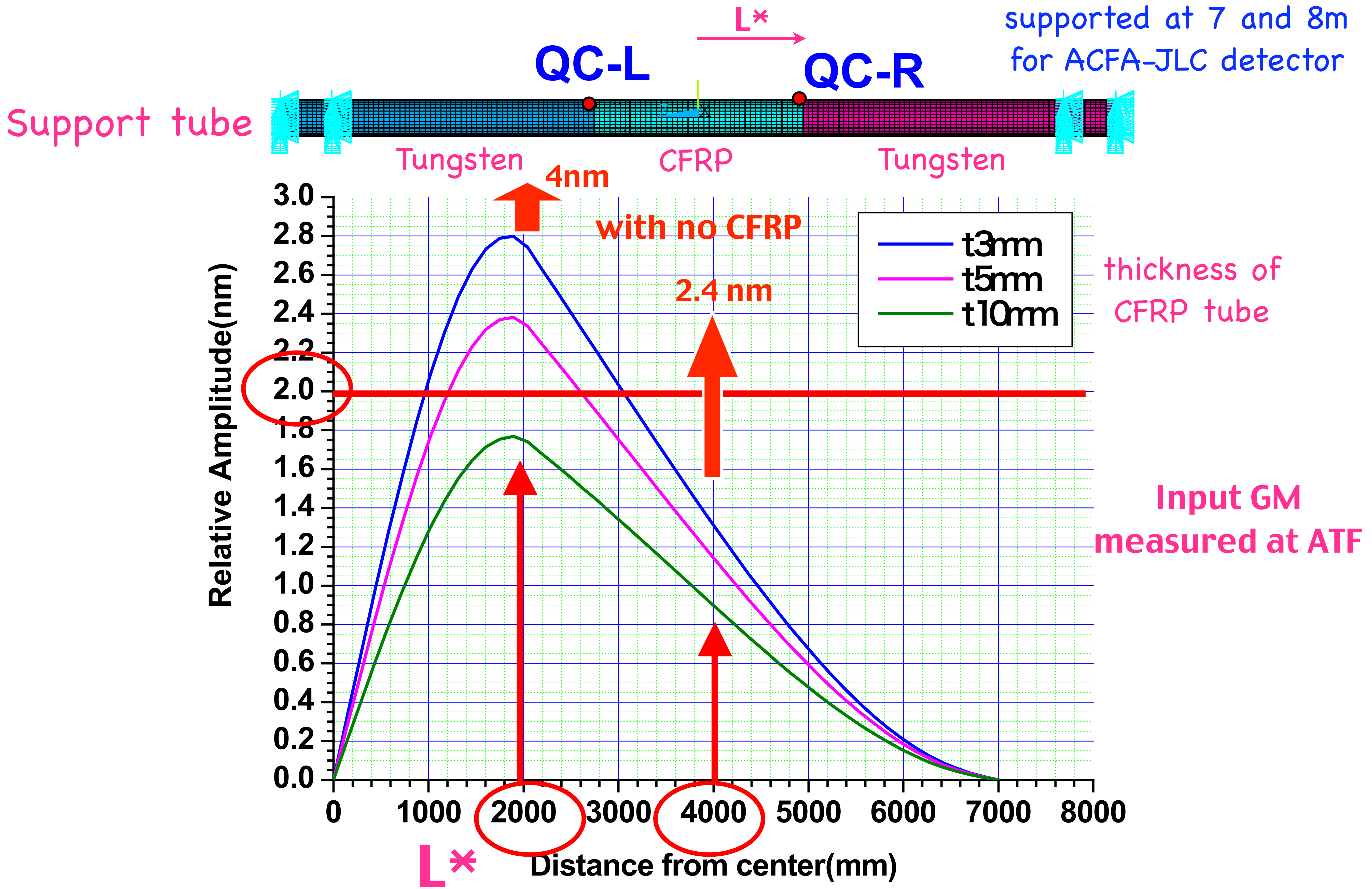
P. Bambade et al.
hep-ph/0406010

Choice of L*


SD
TESLA
GLD
L*=3.5m
L*>4.05m
L*>4.2m
5m
5 m
SiD, L*=3.5m
QUAD
QUAD
0.3m
200 mrad
150 mrad
50 mrad
22 mrad
W-Si CAL
CH2 Mask
QC1
430cm

H.Yamaoka's talk at LCWS2005

Relative displacement of two final quadrupoles



MDI Critical Issues

1. Two IPs for two experiments concurrently, with same luminosity and energy ?

   cross check of physics results,

   large number of experimentalists (multiple detector concepts)

2. Choice of crossing angle (Φ) and final quadrupoles (iron, super, permanent ..)

   Small angle:0-2mrad; minimum veto angle and luminosity without crab cavity,

   but, difficult extraction line design; background and beam diagnostic (E,Pol)

   also difficult for γγ, $e^-\gamma$ collisions and no multi-TeV (Ecm > 3TeV)

   Large angle:20mrad; opposite to the above issues

   but, we may need to control the spin precession, i.e. $\Delta y' = B\Phi/(2B\rho)$

3. L^* and R_Q; L^*=3.5m for SiD, >4.3m for GLD, >4m for LCD; R_Q< 0.01 L^* at Φ=0.02
4. Collimation depth from vertex innermost radius (Rvtx=1cm?)
5. Energy spectrometer : upstream or downstream or both
6. Polarimeter : upstream or downstream or both
7. Options for beam parameters and IR/extraction line layout

   e^-e^- , $e^-\gamma$, γγ collisions with round beams

   fixed target experiment; e.g. lepton number violation, c,b physics

MDI Subgroups toward the CDR

	Topics	Current Sub Group Conveners		
I	IP Layout , crossing angle	T.Tauchi	P.Bambade	T.Markiewicz
II	Background	A.Sugiyama	K.Busser	T.Maruyama
	Very forward region	H.Yamamoto	W.Lohmann	E.Torrence
	Beam RF effect	Y.Sugimoto		M.Woods
III	Energy, luminosity spectrum	K.Kubo	S.Boogart	M.Hildreth
	Polarization	T.Omori	K.Moenig	K.Moffeit

Schedule of workshops

- 13-15 November 2004, 1st ILC workshop at KEK; WG4
- 6-8 January 2005, MDI mini-workshop at SLAC
- 18-22 March 2005, LCWS05 at SLAC
- 20-23 June 2005, BDIR workshop at Oxford/RHUL
- 11-14 July, 8th ACFA LC workshop at Taegue, Korea
- 14-27 August 2005, 2nd ILC workshop at SNOWMASS

Prepare for the CDR