Beam Delivery Systems at ILC-TDR

T. Tauchi (KEK)

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Beam Delivery Systems strategy in TDP

In TDP I & II plan, the scope of work changed, and the focus is shifted

→

- Focus on a few critical directions. Selection criteria:
  - –Critical impact on performance versus cost;
  - –Advanced ideas promising breakthrough in performance;
  - –Broad impact and synergy with other worldwide projects

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- Three critical directions:
  - –General BDS design
  - –Test facilities, ATF2
  - –Interaction Region optimization

beam dump
photon collider
crystal collimation
crab cavity
MDI diagnostics …

ATF2 commissioning & operation
Develop methods to achieve small beam size
Diagnostics, Laser Wires, Feedbacks …

IR interface document & design
SC FD prototyping and vibration test
ILC-like FD for ATF2 …

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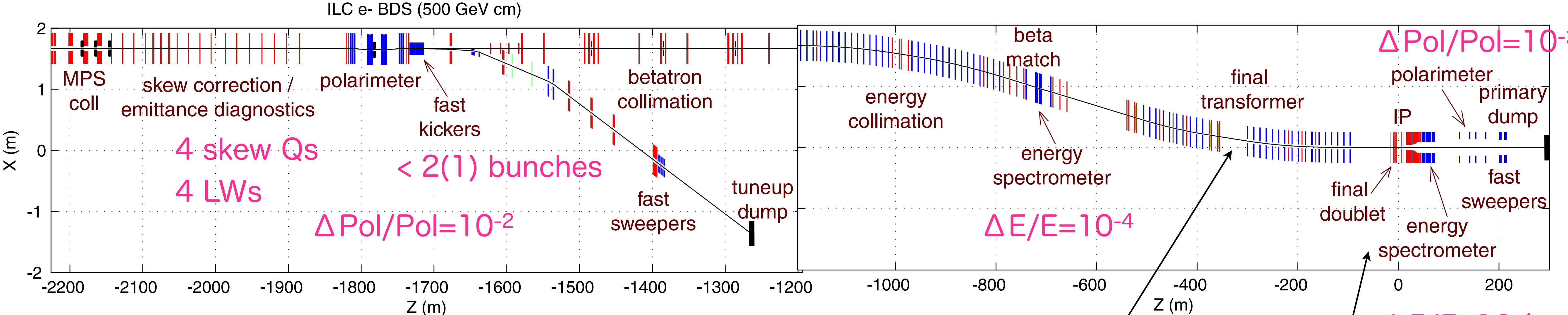
ILC-like FD for ATF2 … △

ILC BDS, E_{cm} =500GeV

to accommodate the upgrade to 1TeV center-of-mass energy

electron beam →

Diagnostics Collimation Matching Final Focus IR EXT& Dump



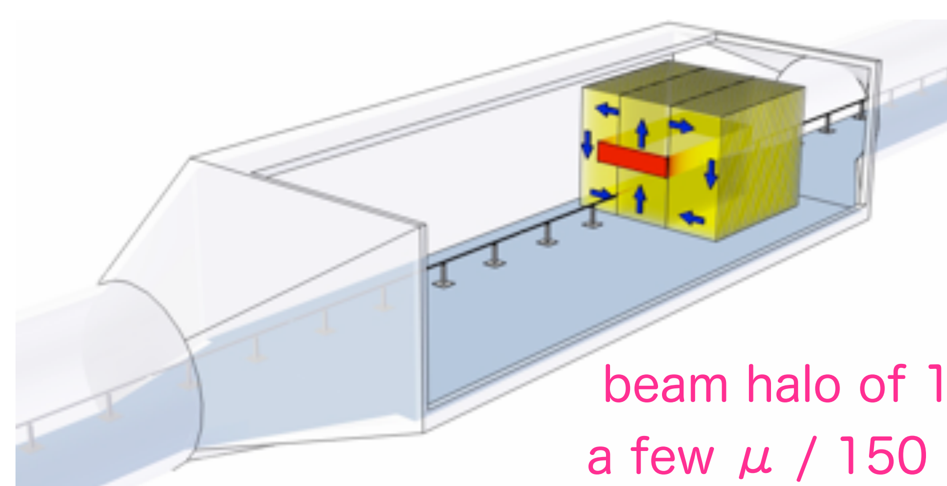
ΔE/E=10^{-4}

5m-long magnetized muon shield(1.5T)

σ_x=474nm
σ_y=5.9nm
Horizontal crossing angle =14mr

$\Delta \varepsilon_x$<1% at chicanes of polarimeter and energy spectrometer

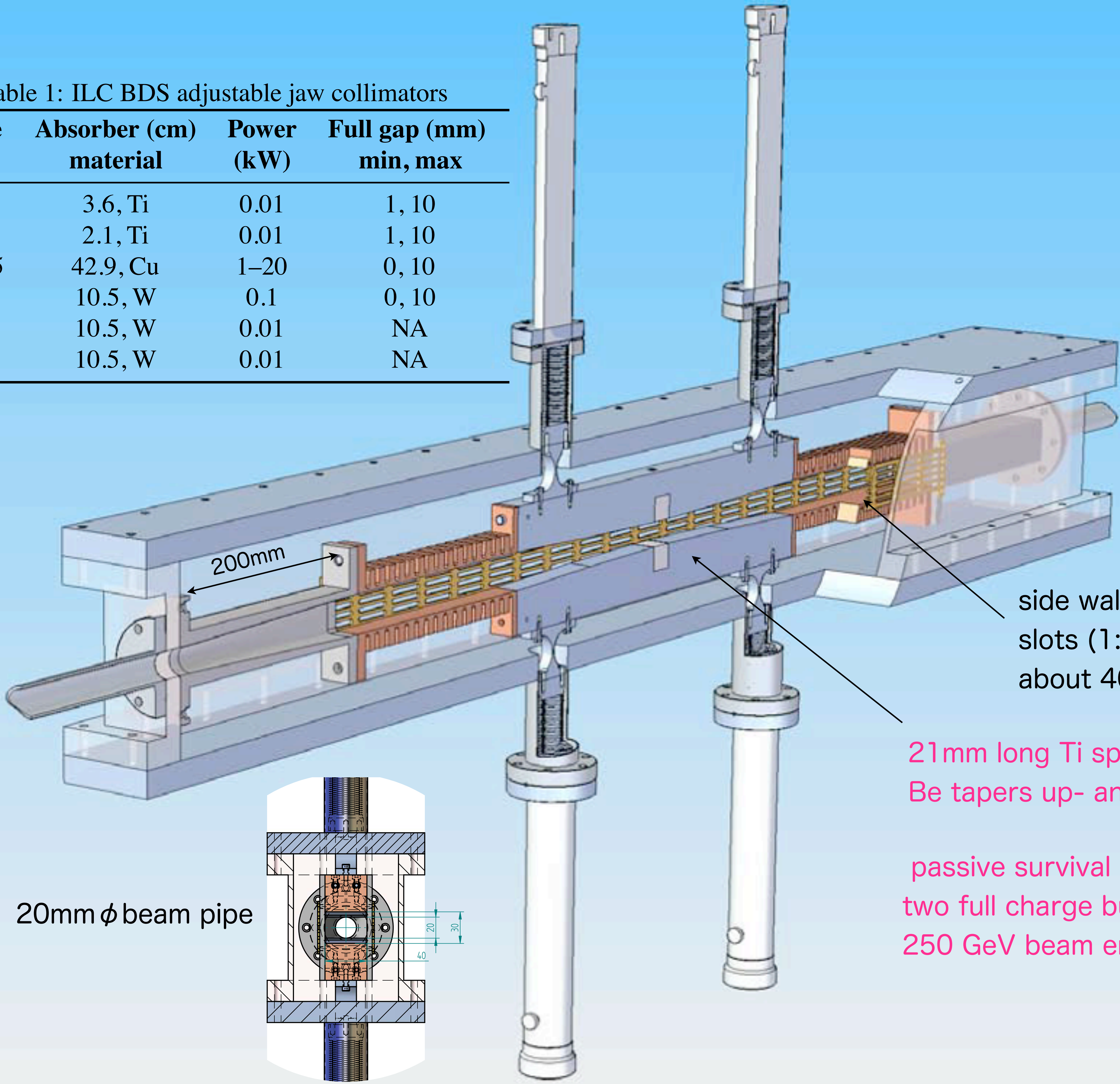
$\Delta \varepsilon_x$<0.5(1)% in bends at E_{cm}=0.5 (1) TeV



beam halo of 10^{-5} hit the collimators
a few μ / 150 bunches at IP

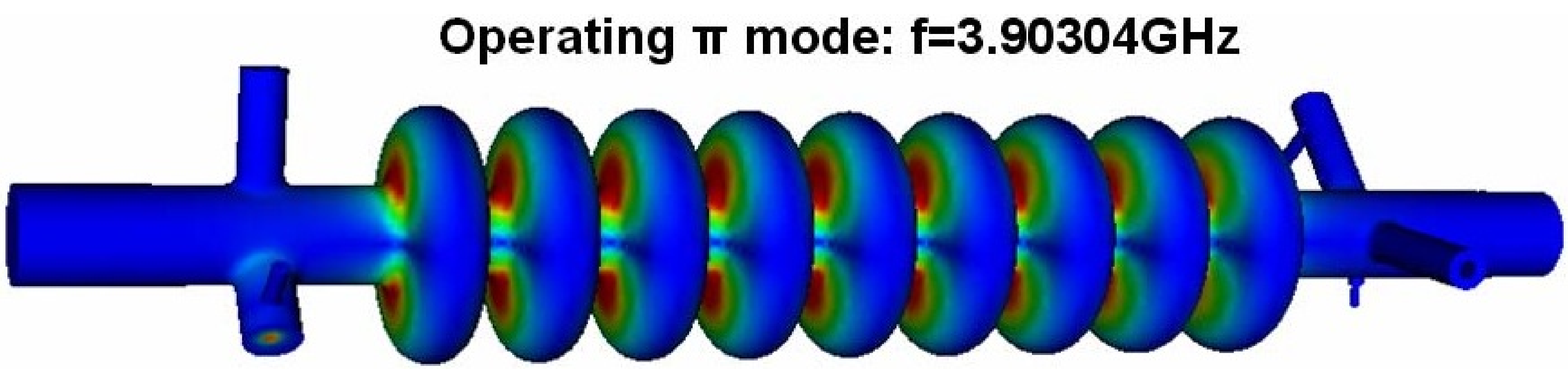
Table 1: ILC BDS adjustable jaw collimators

Device	Absorber (cm) material	Power (kW)	Full gap (mm) min, max
SPEX	3.6, Ti	0.01	1, 10
SP1–5	2.1, Ti	0.01	1, 10
AB2–5	42.9, Cu	1–20	0, 10
ABE	10.5, W	0.1	0, 10
MSK1	10.5, W	0.01	NA
MSK2	10.5, W	0.01	NA



3.9GHz Crab Cavity

2 cavities at 13.4m from IP, 2~3m long, the phase jitter < 61fsec
5MV/m enough for a 500GeV beam and 100% redundancy for a 250GeV beam



Field distribution for the operating mode of the 3.9 GHz crab cavity

ILC-BDS/FF Optics

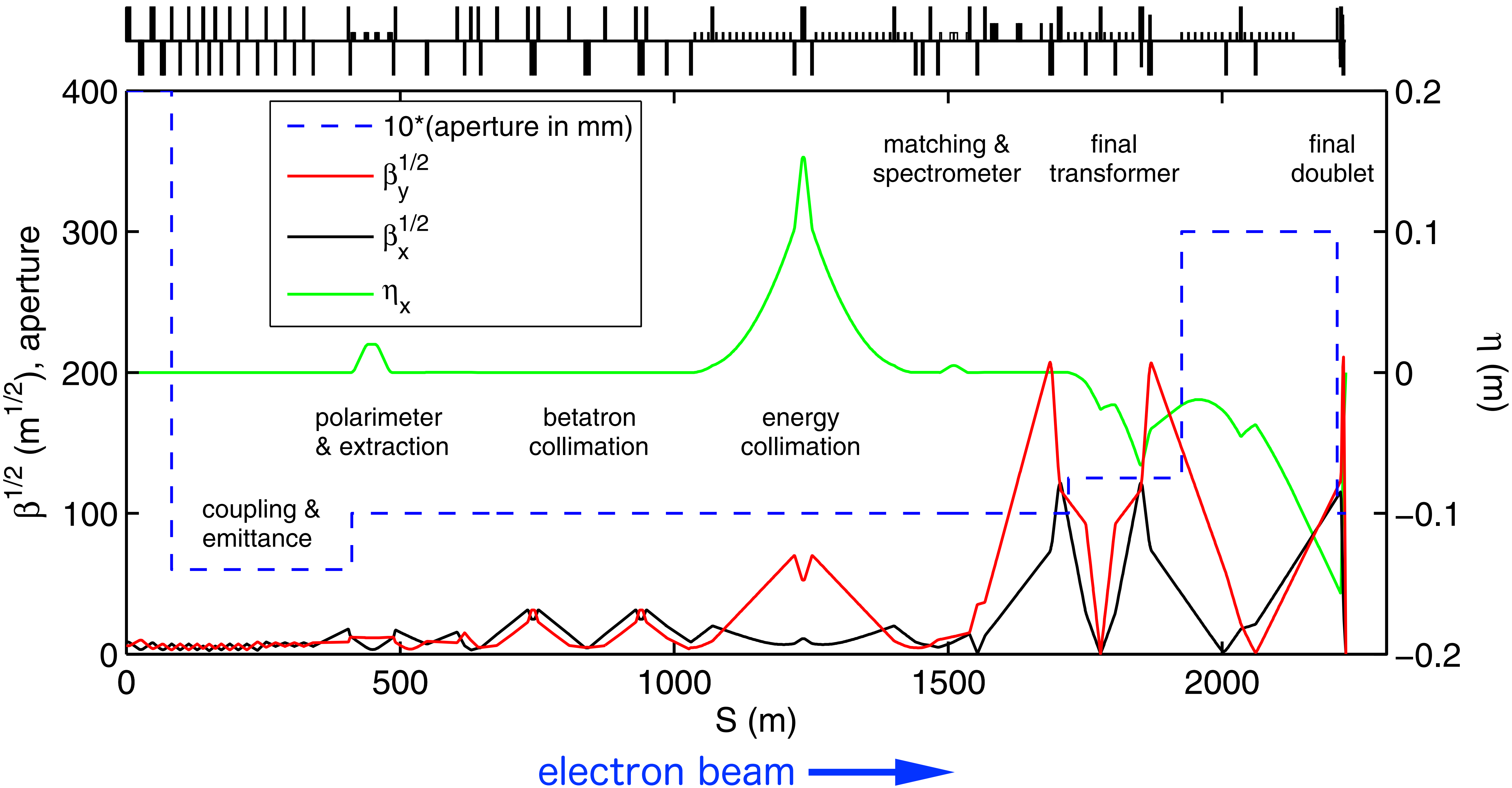


Figure 8.3. BDS optics, subsystems and vacuum chamber aperture; S is the distance measured from the entrance.

Upstream Polarimeter

$\delta P/P \sim 0.1\%$ averaging over 2 entire trains with opposite helicity

1800m upstream from IP

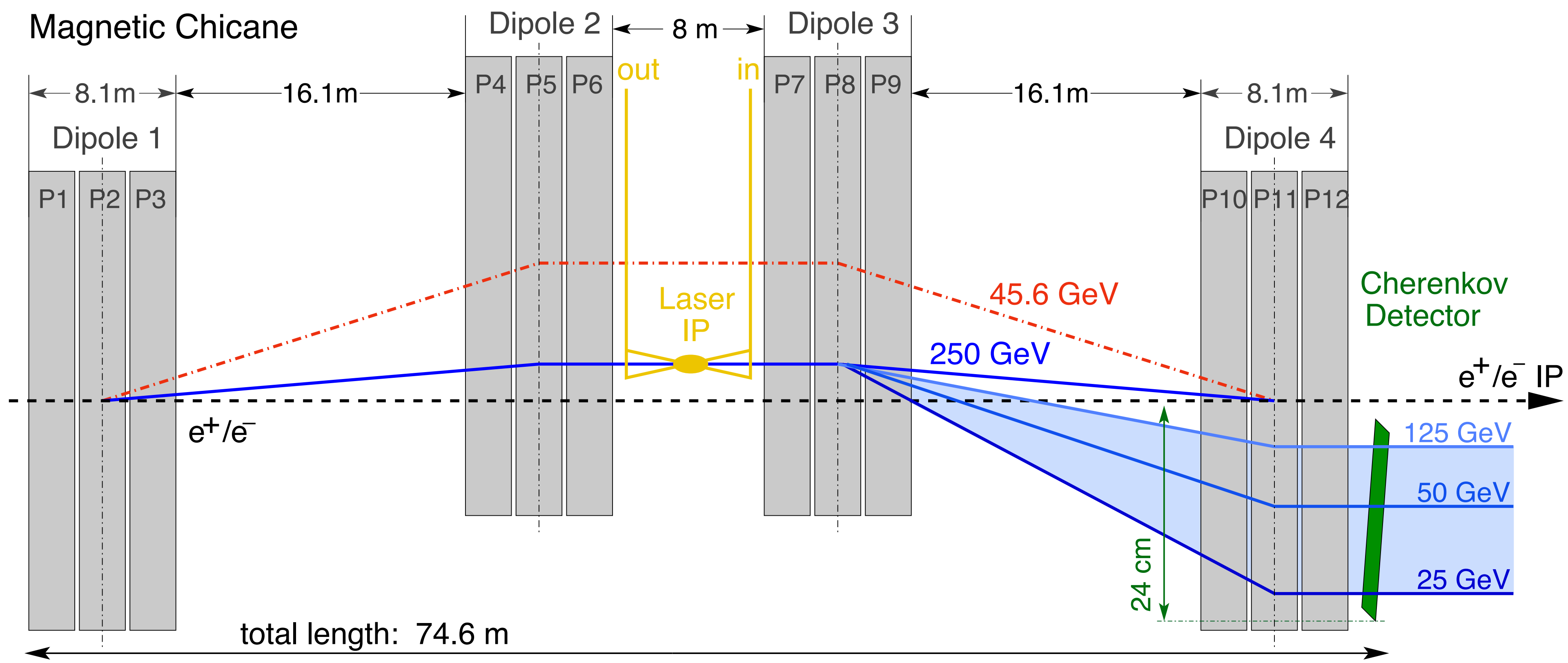


Figure 2.4.3: *Schematic of the upstream polarimeter chicane.*

Upstream Energy Spectrometer

E = 45.6GeV to 500GeV

700m upstream from IP

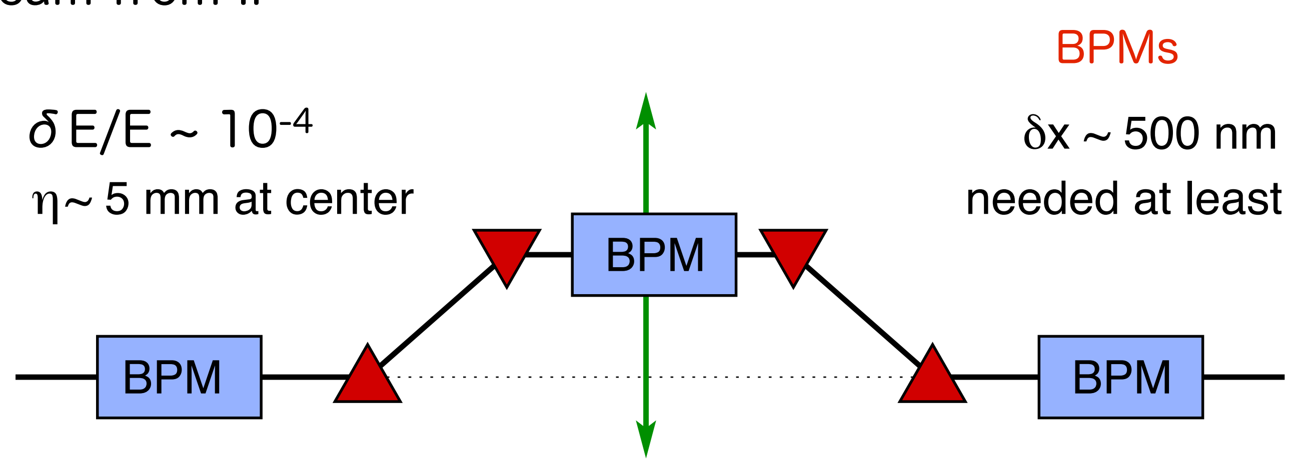


Figure 2.4.1: *Schematic for the upstream energy spectrometer using BPMs.*

Downstream Polarimeter and Energy Spectrometer

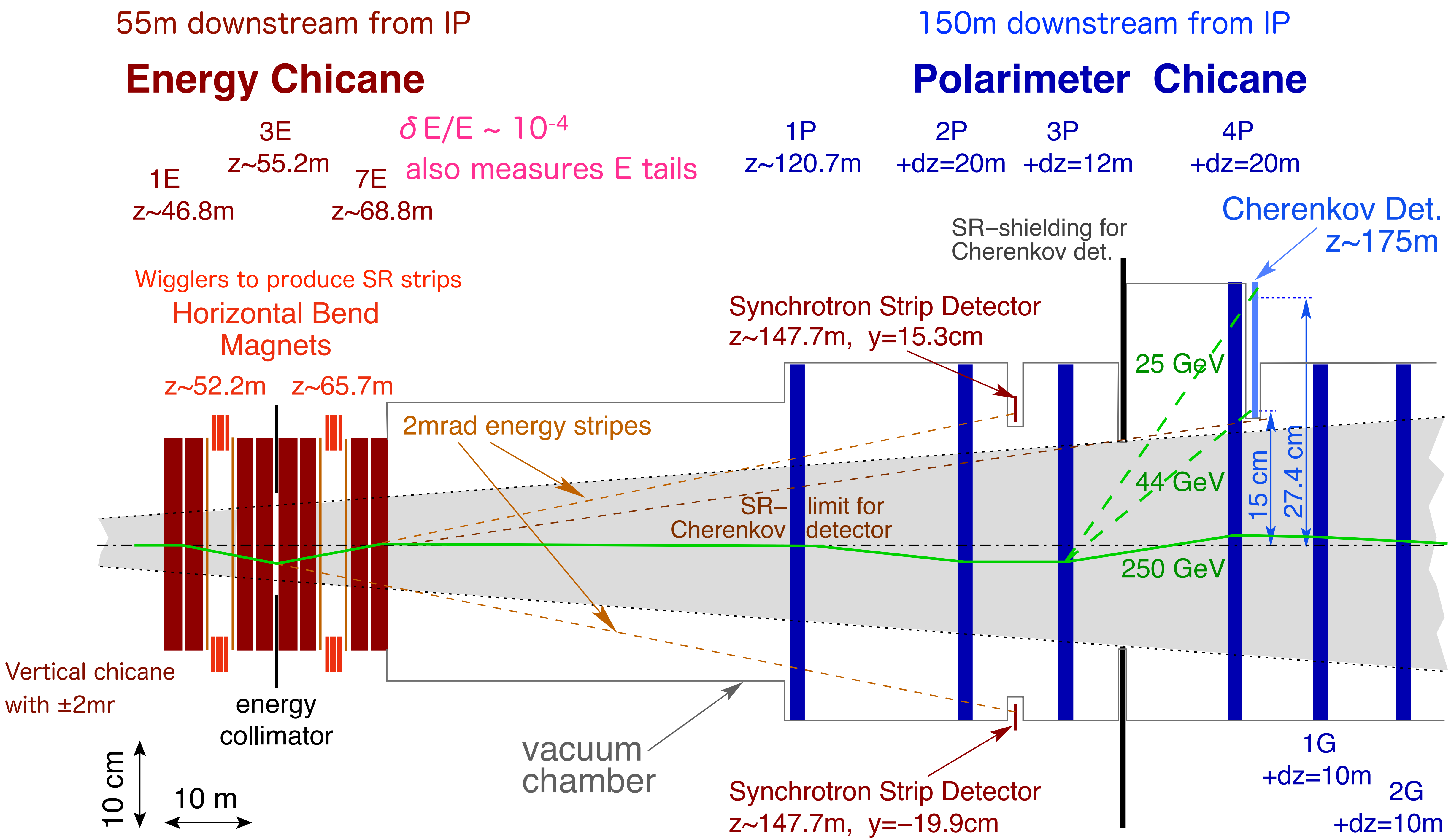
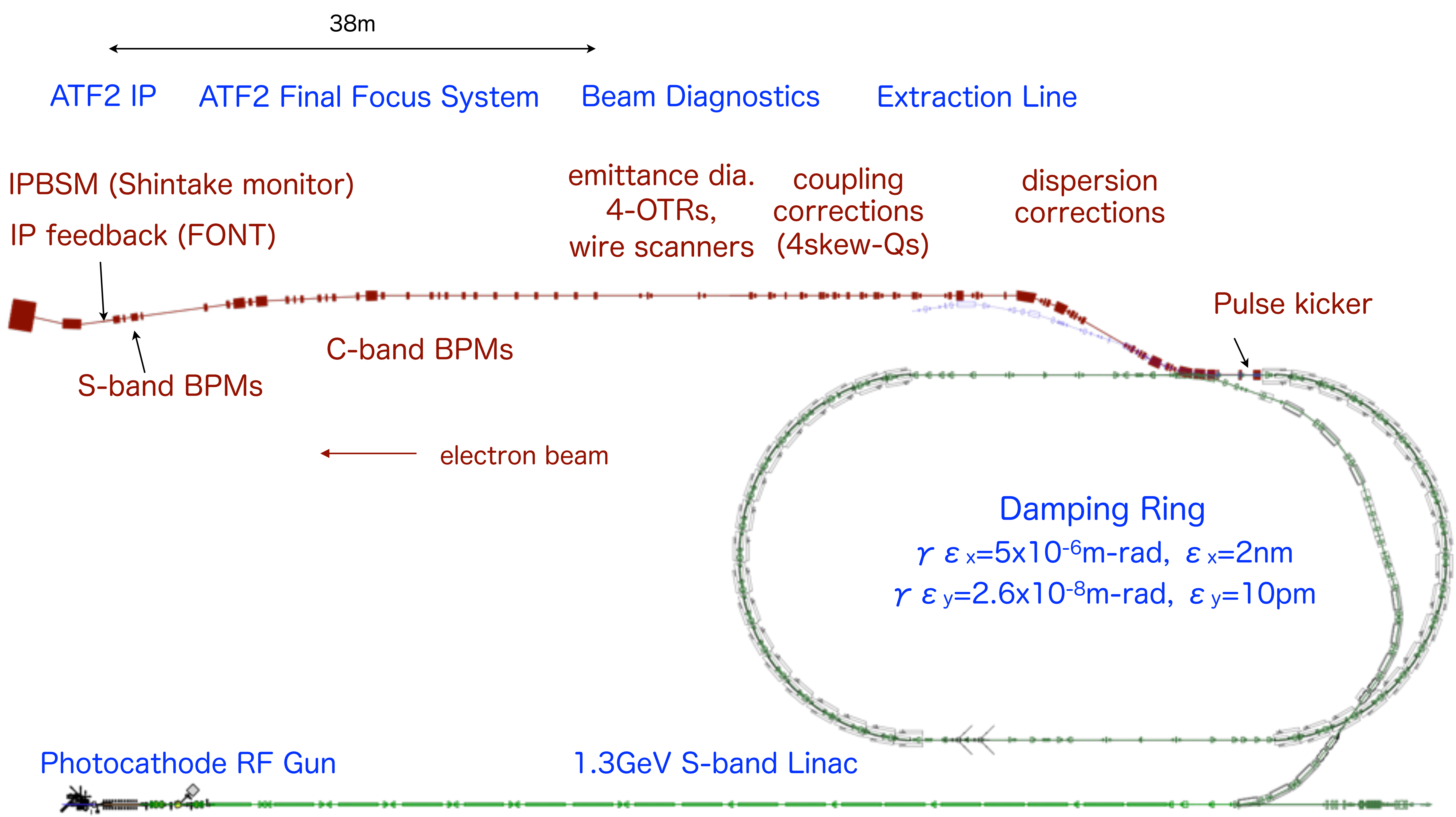
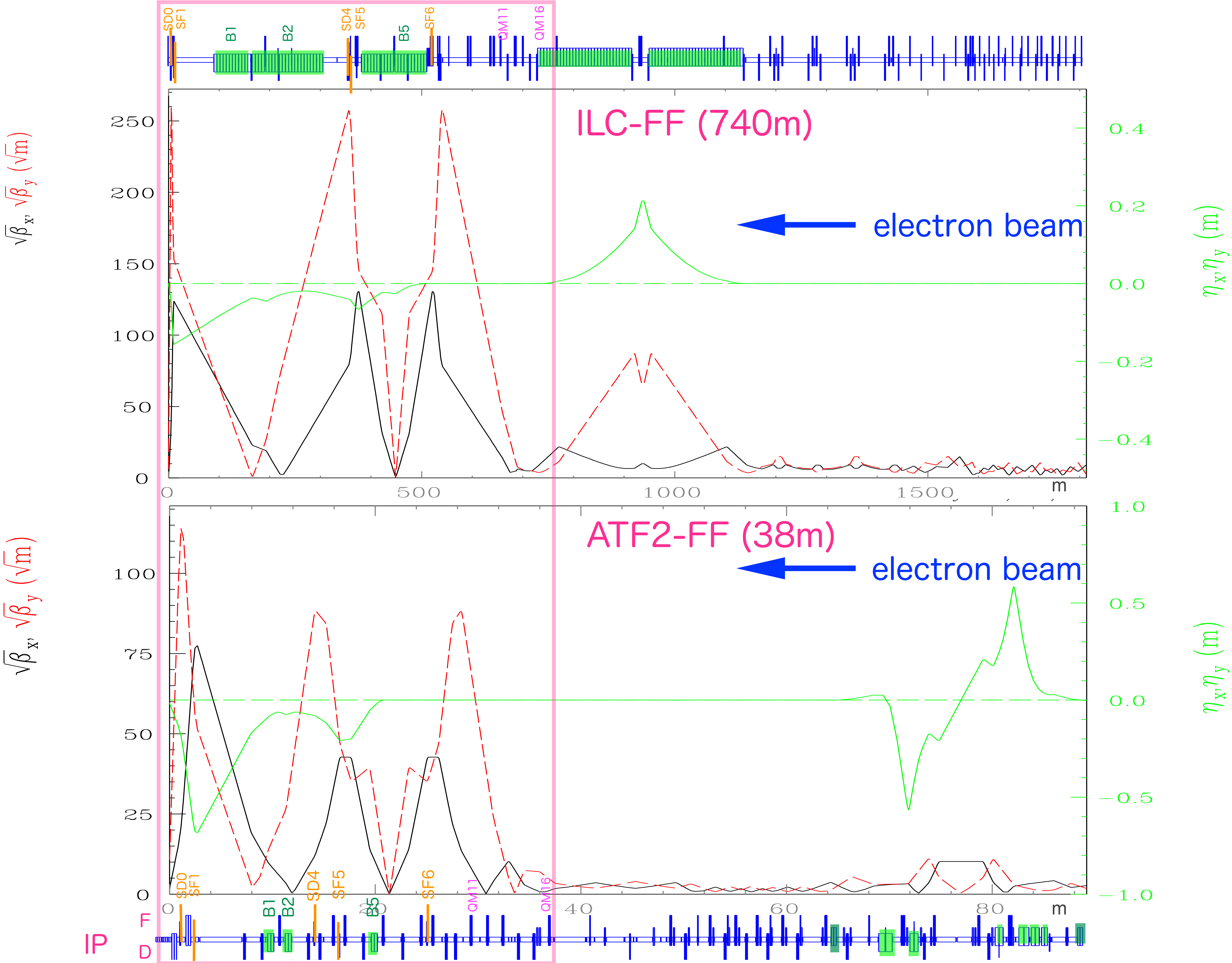


Figure 2.4.2: *Schematic of the ILC extraction line diagnostics for the energy spectrometer and the Compton polarimeter.*

WISRD:Wire Imaging Synchrotron Radiation Detector
consisting of radiation-hard 100um quartz fibers

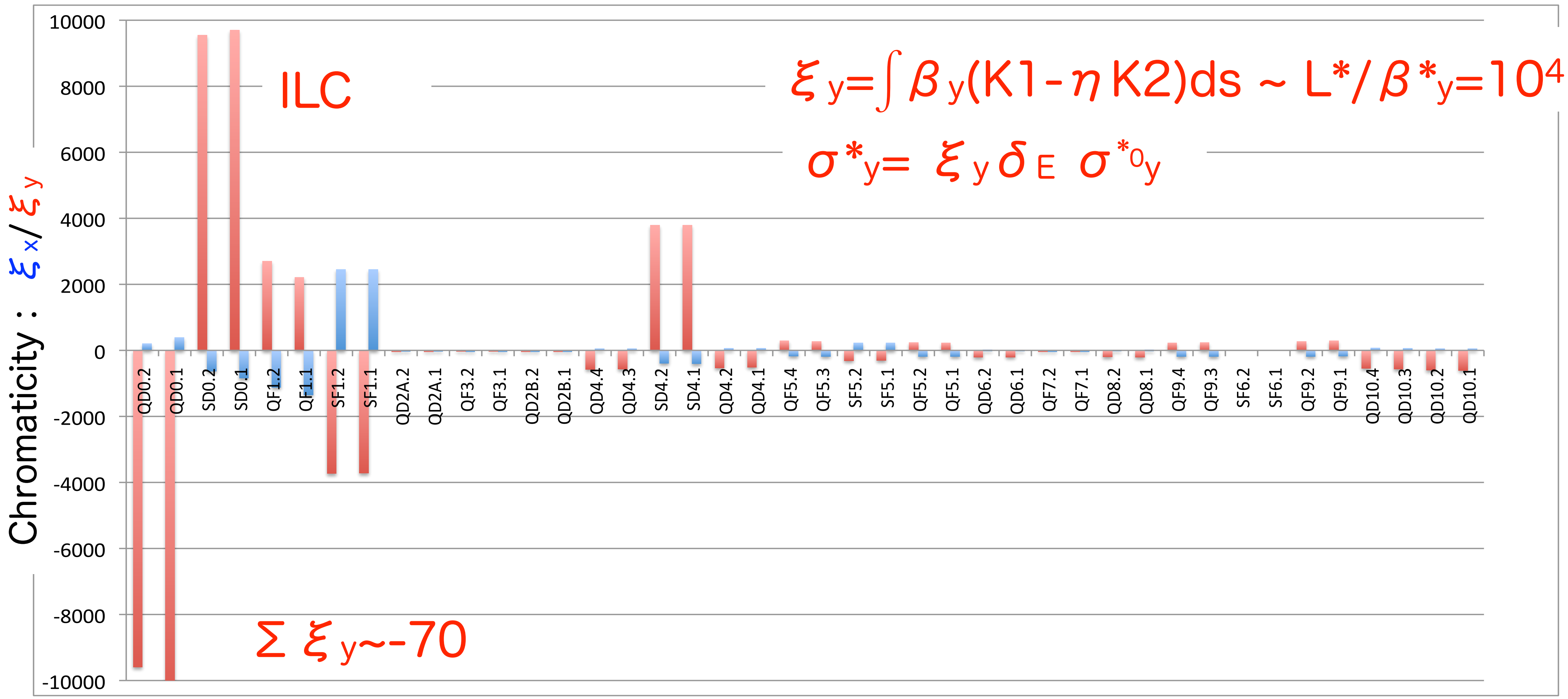
Test Facility : ATF2

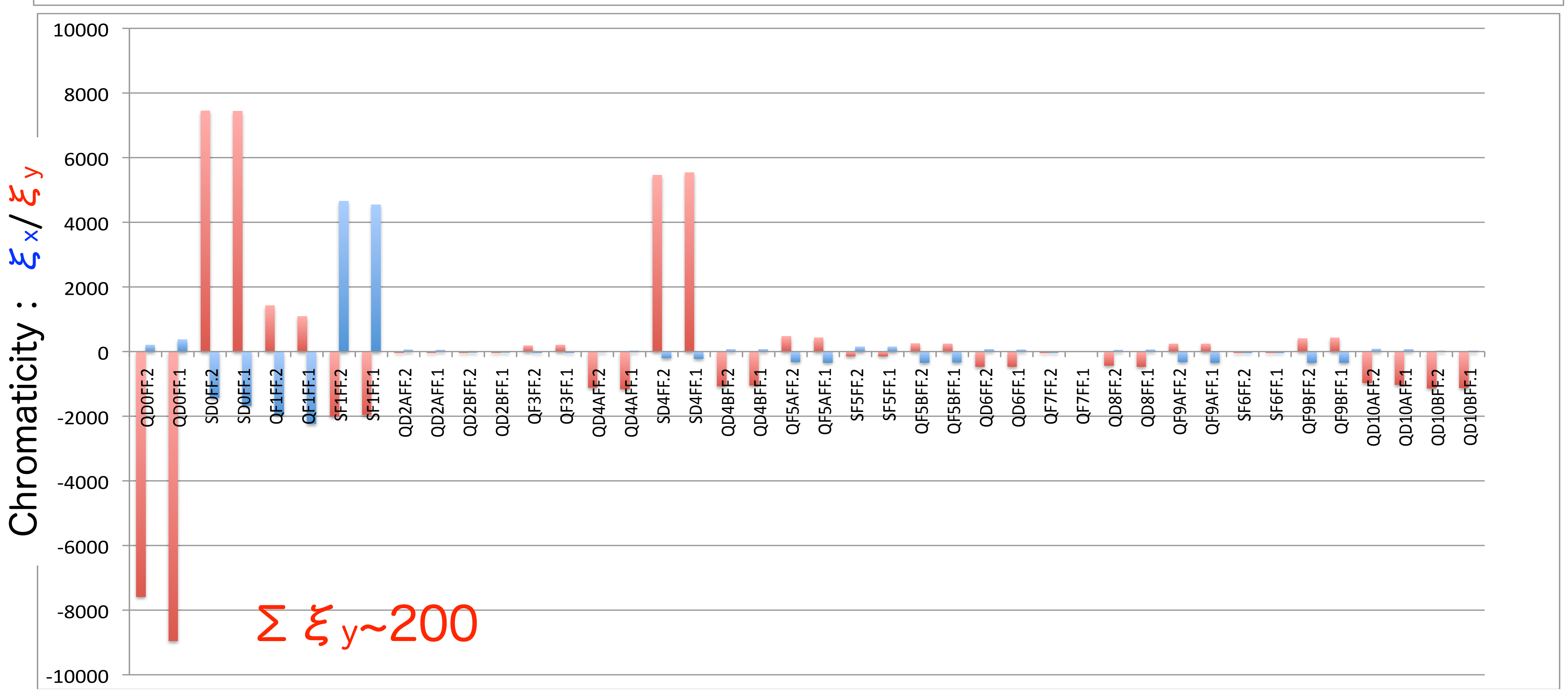


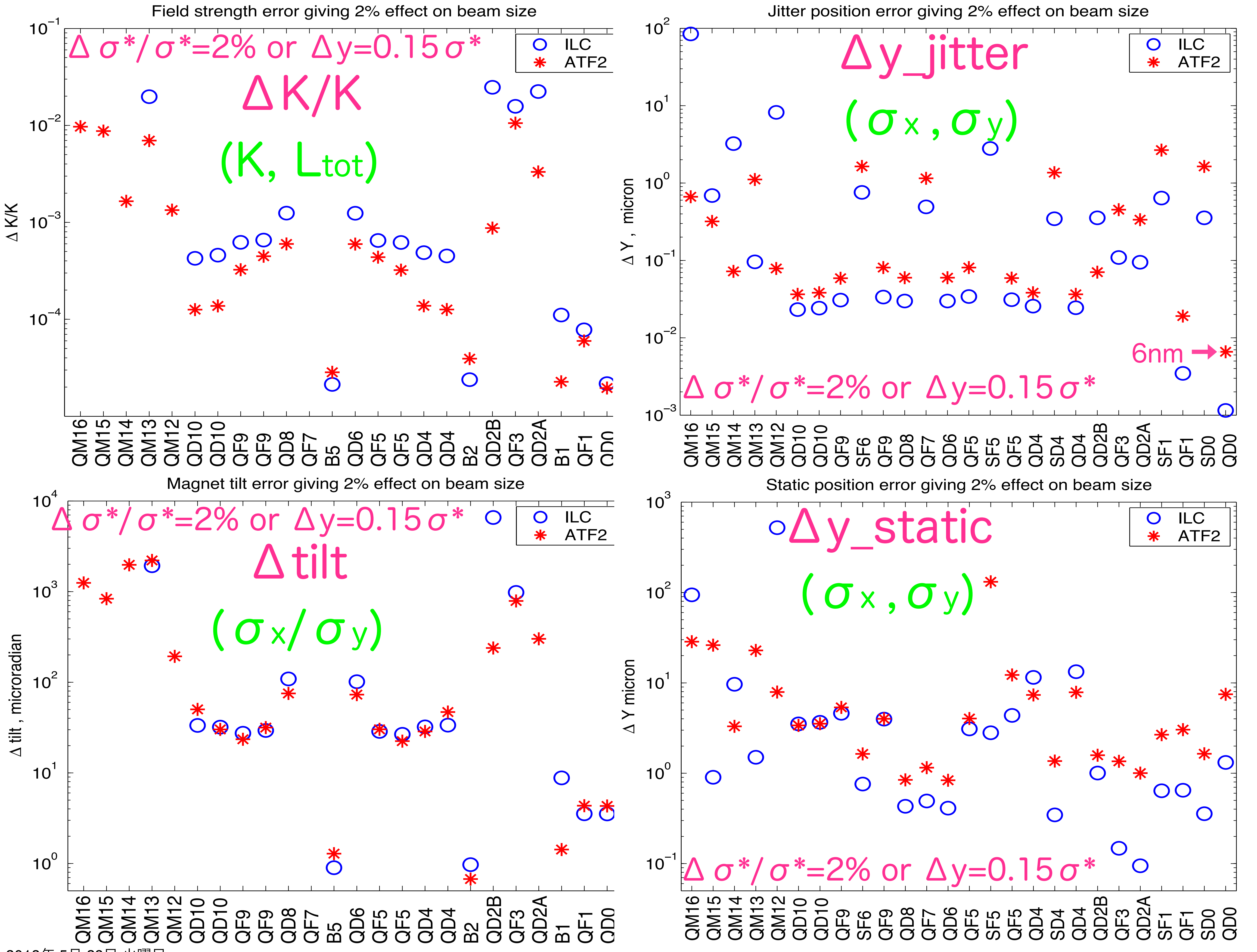


2013年 5月 28日 火曜日

Chromaticity at quadrupole and sextuple magnets







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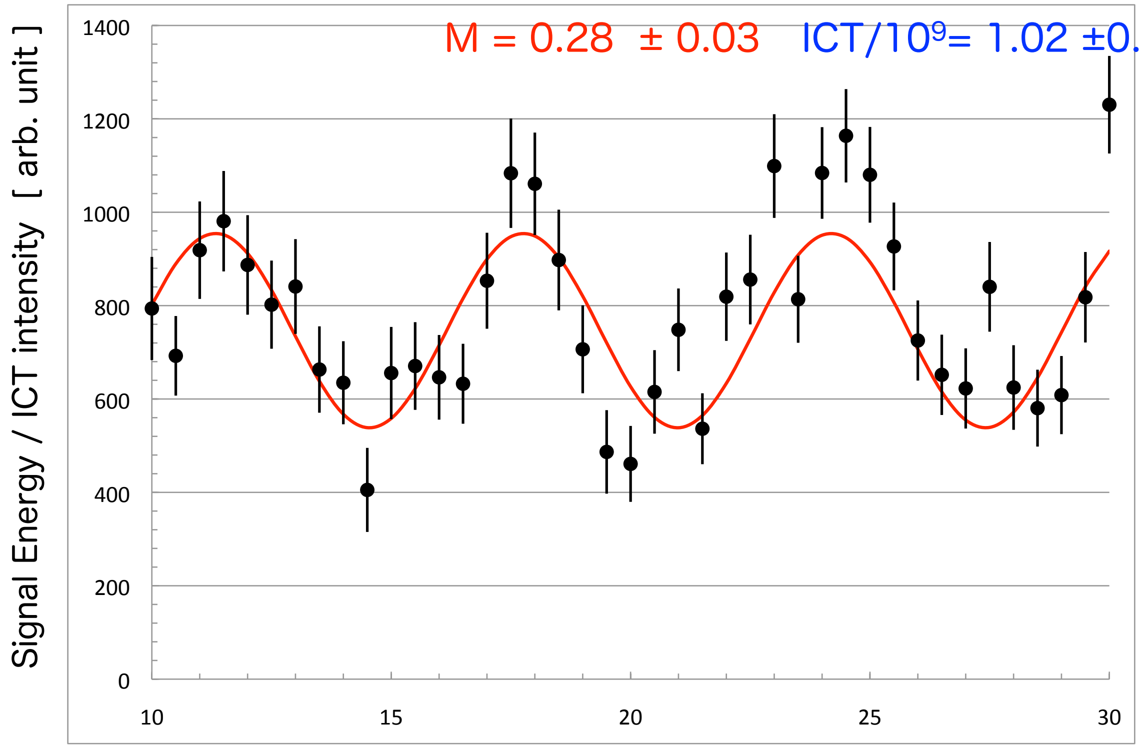
Preliminary ATF2@KEK meas121221_183019

M = 0.28 ± 0.03 ICT/10^9= 1.02 ±0.11(rms)



at 174 degree mode
266nm/pitch

FFTB@SLAC

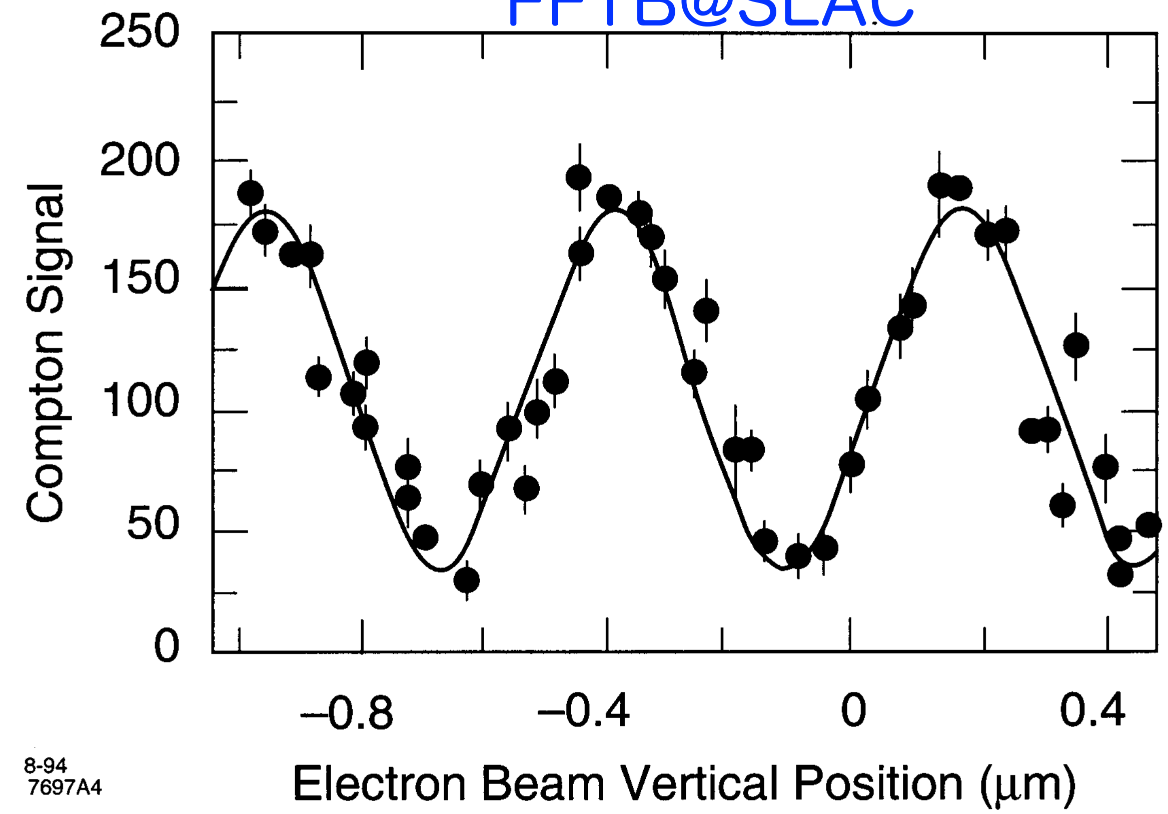


Figure 5.6: Laser-Compton beam size measurement performed in May of 1994. The measured size is 77±7 nanometers.

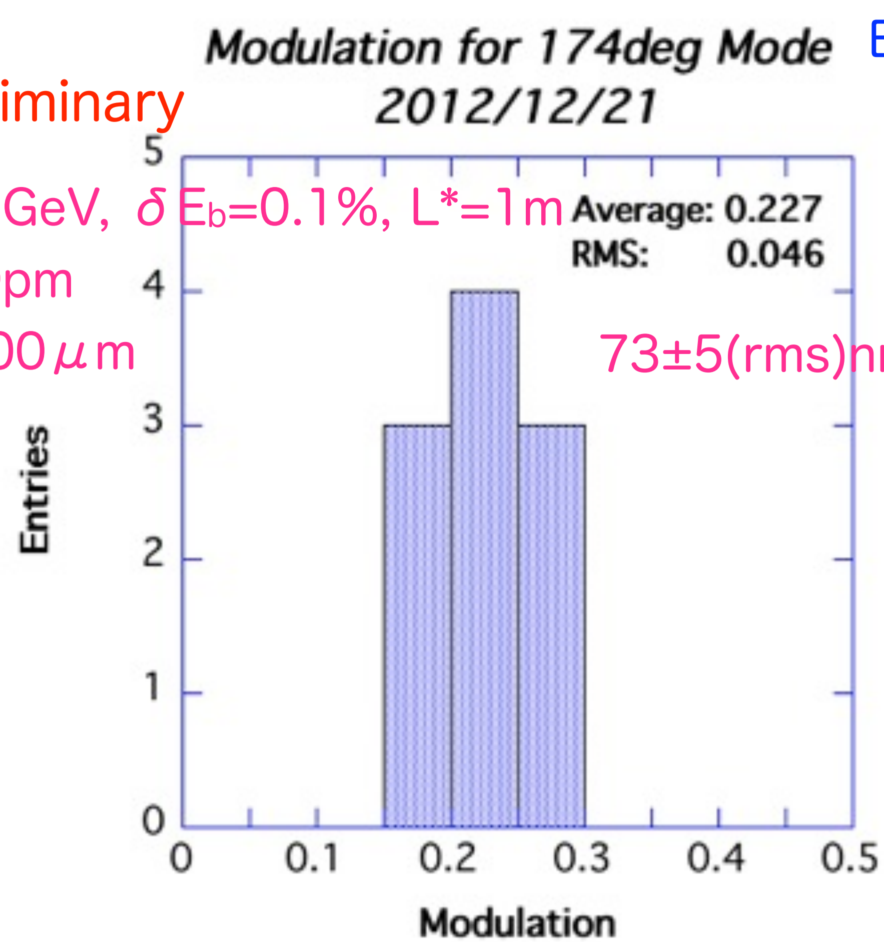
Both assumes no modulation reduction

Preliminary

E_b=1.3GeV, δE_b=0.1%, L*=1m

ε_y=20pm

β^*_y=100μm



73±5(rms)nm

rms of laser size = 17/12um

E_b=46.6GeV, δE_b=0.05%, L*=0.4m

ε_y=20pm

β^*_y=100μm

77±7(rms)nm

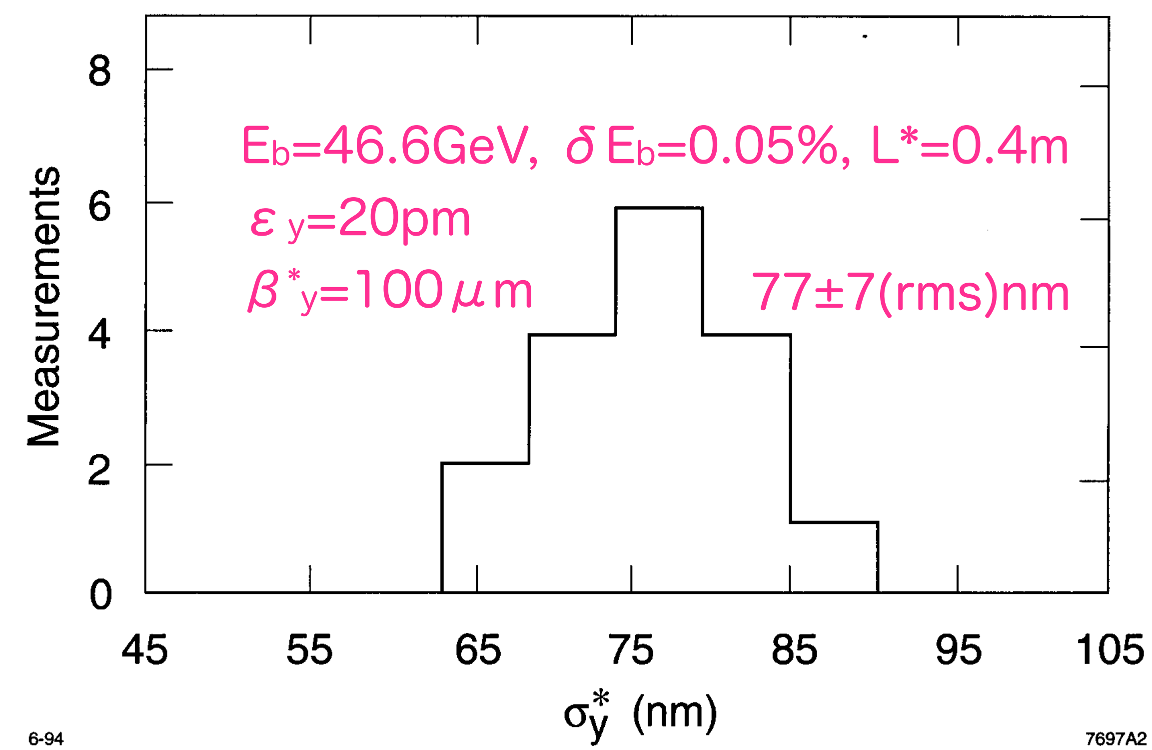


Figure 5.7: Histogram of measurements made during the last 3 hours of the May, 1994 FFTB run. Average size measured was 77 nm, with an RMS of 7 nm.

rms of laser size = 50um -> M reduction of 10%

IR arrangements

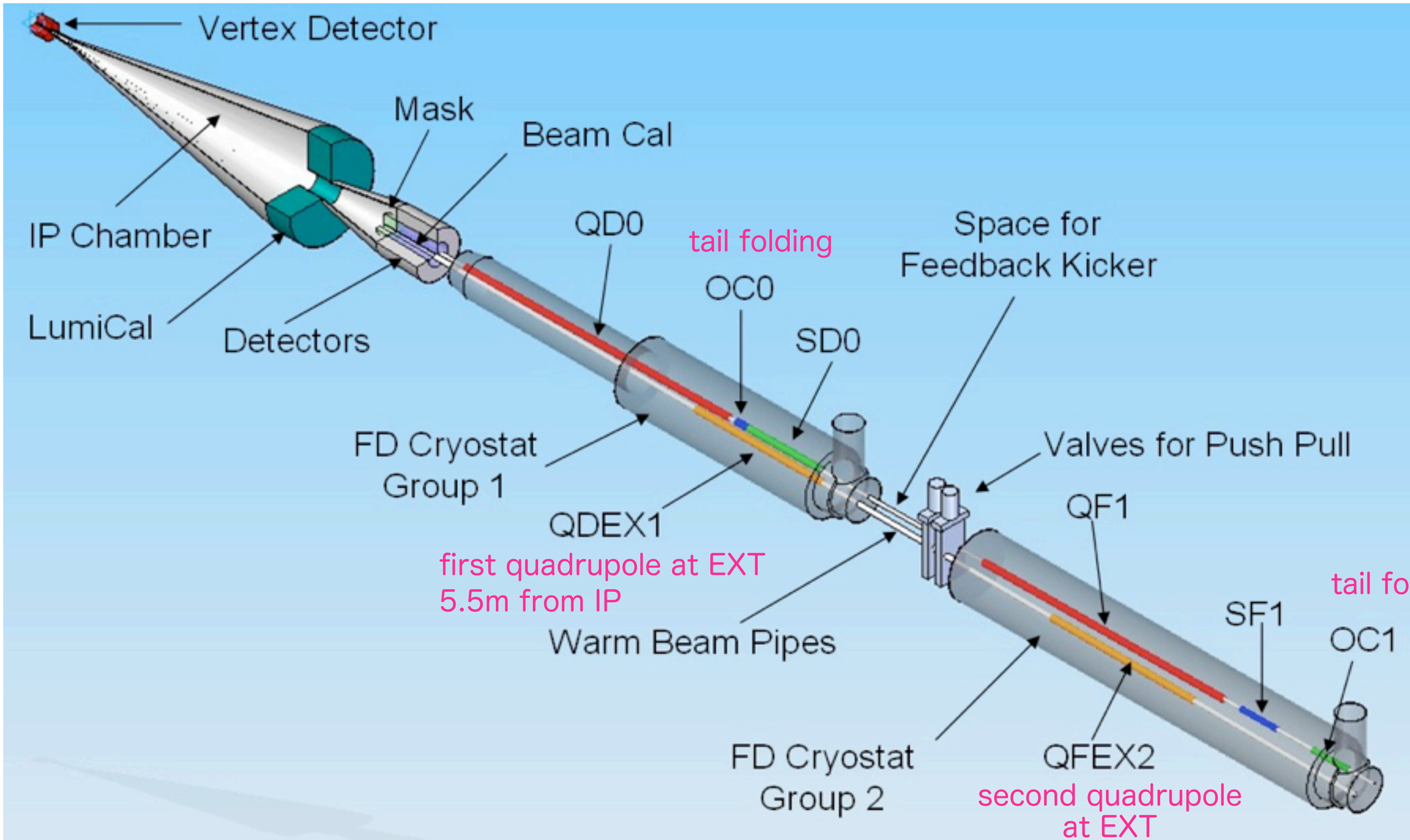
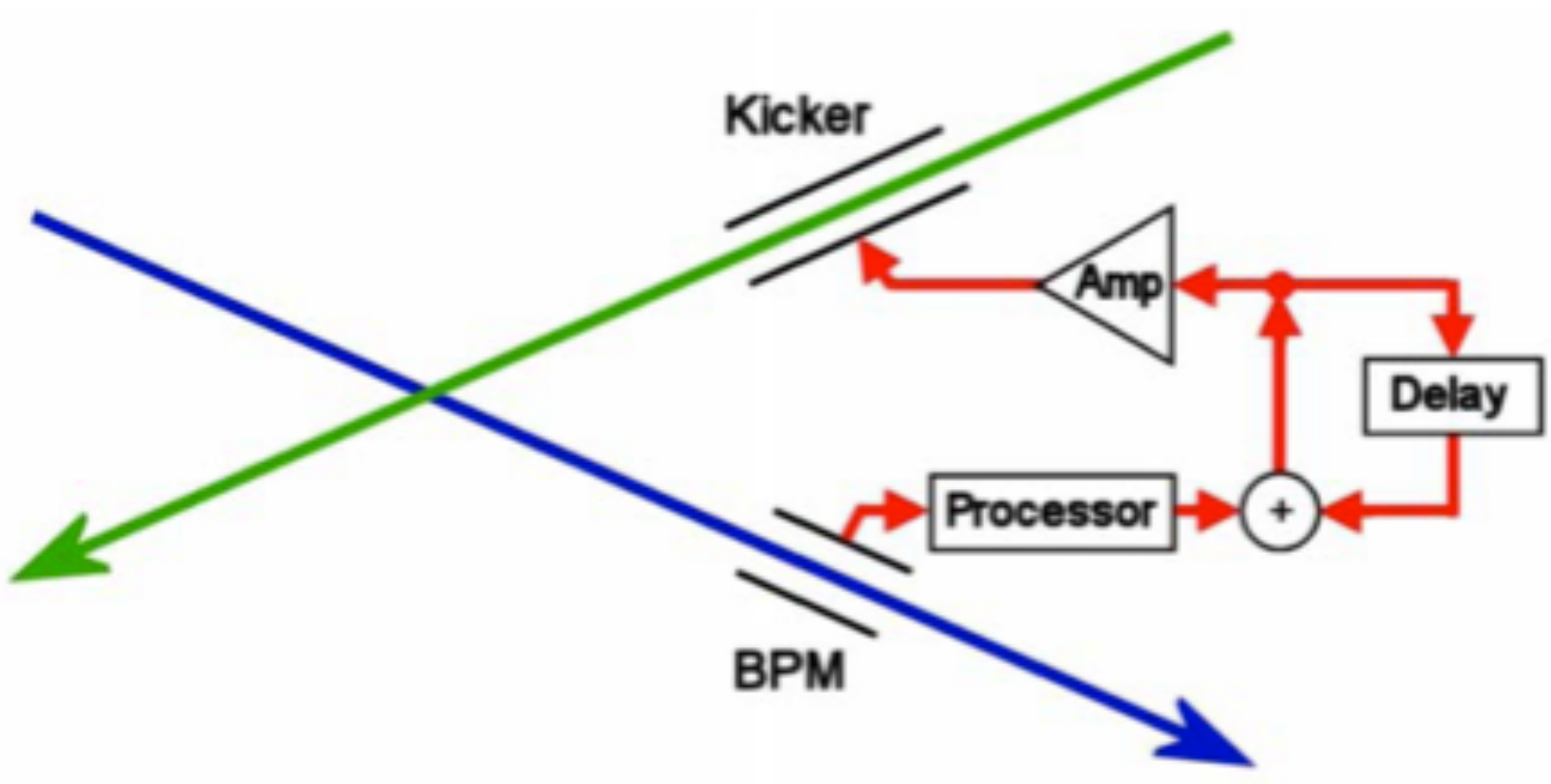


Figure 2.7-11 in RDR

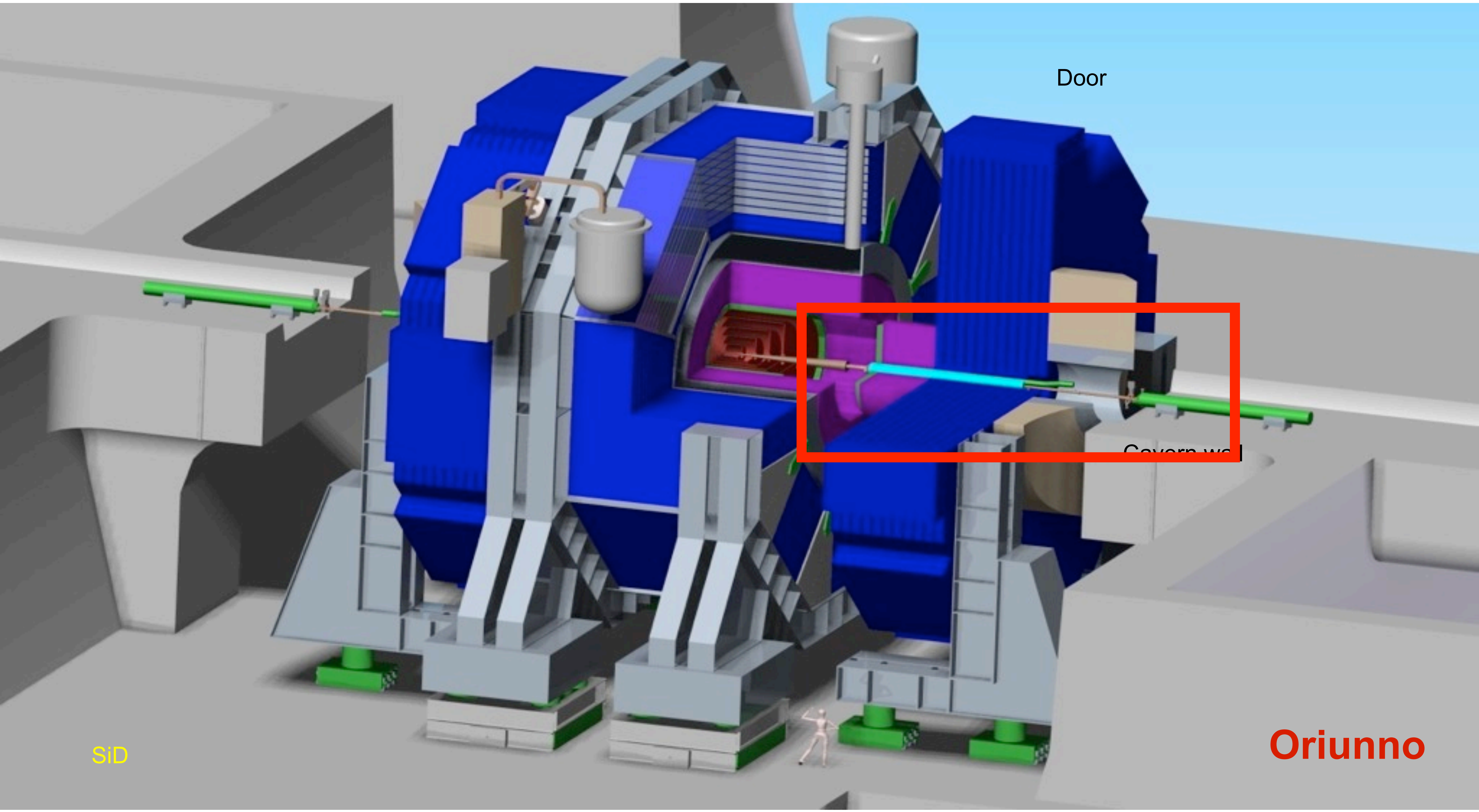
IP beam feedback concept

- Last line of defence against relative beam misalignment
- Measure vertical position of outgoing beam and hence beam-beam kick angle
- Use fast amplifier and kicker to correct vertical position of beam incoming to IR



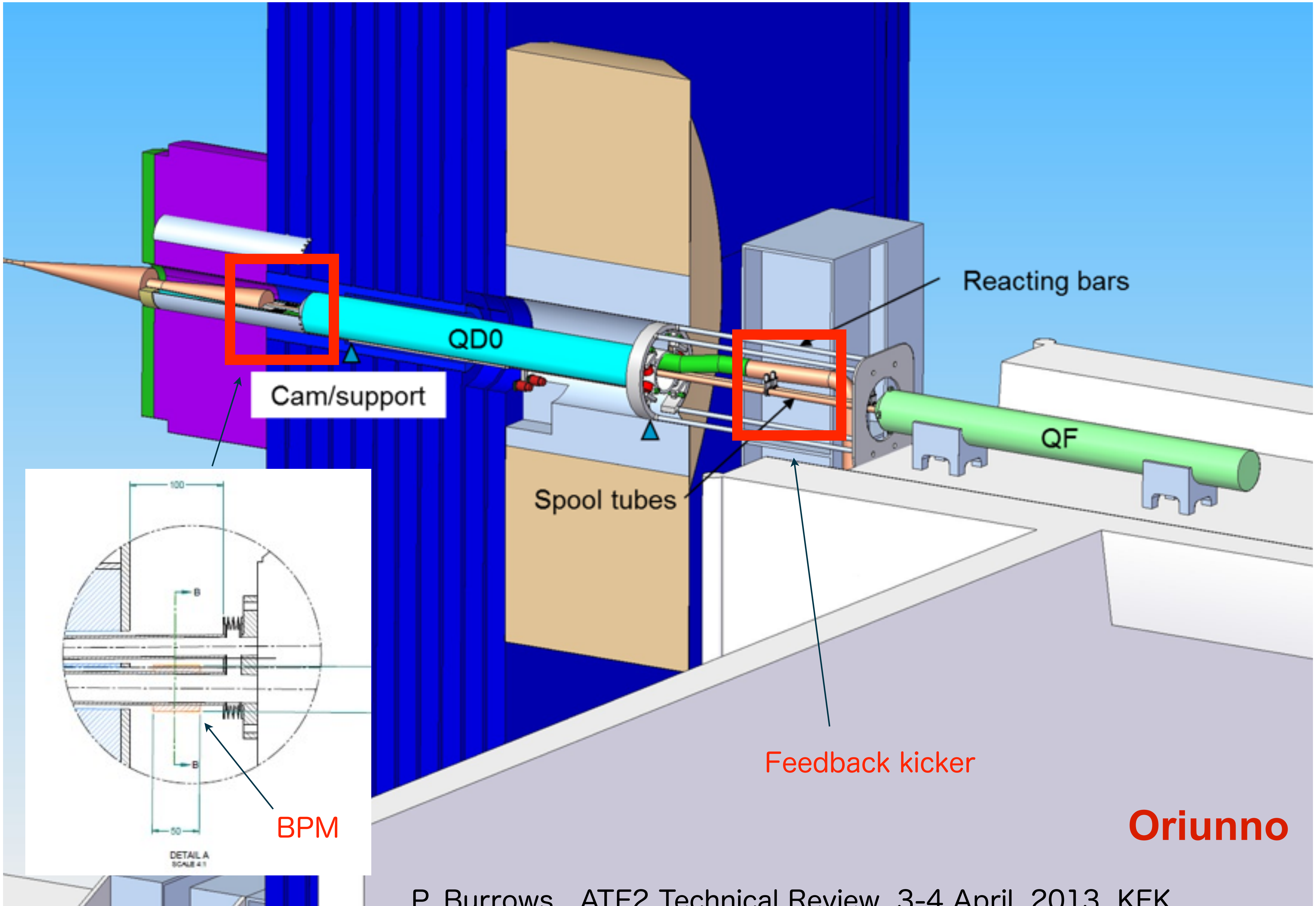
FONT – Feedback On Nanosecond Timescales

ILC IR: SiD for illustration



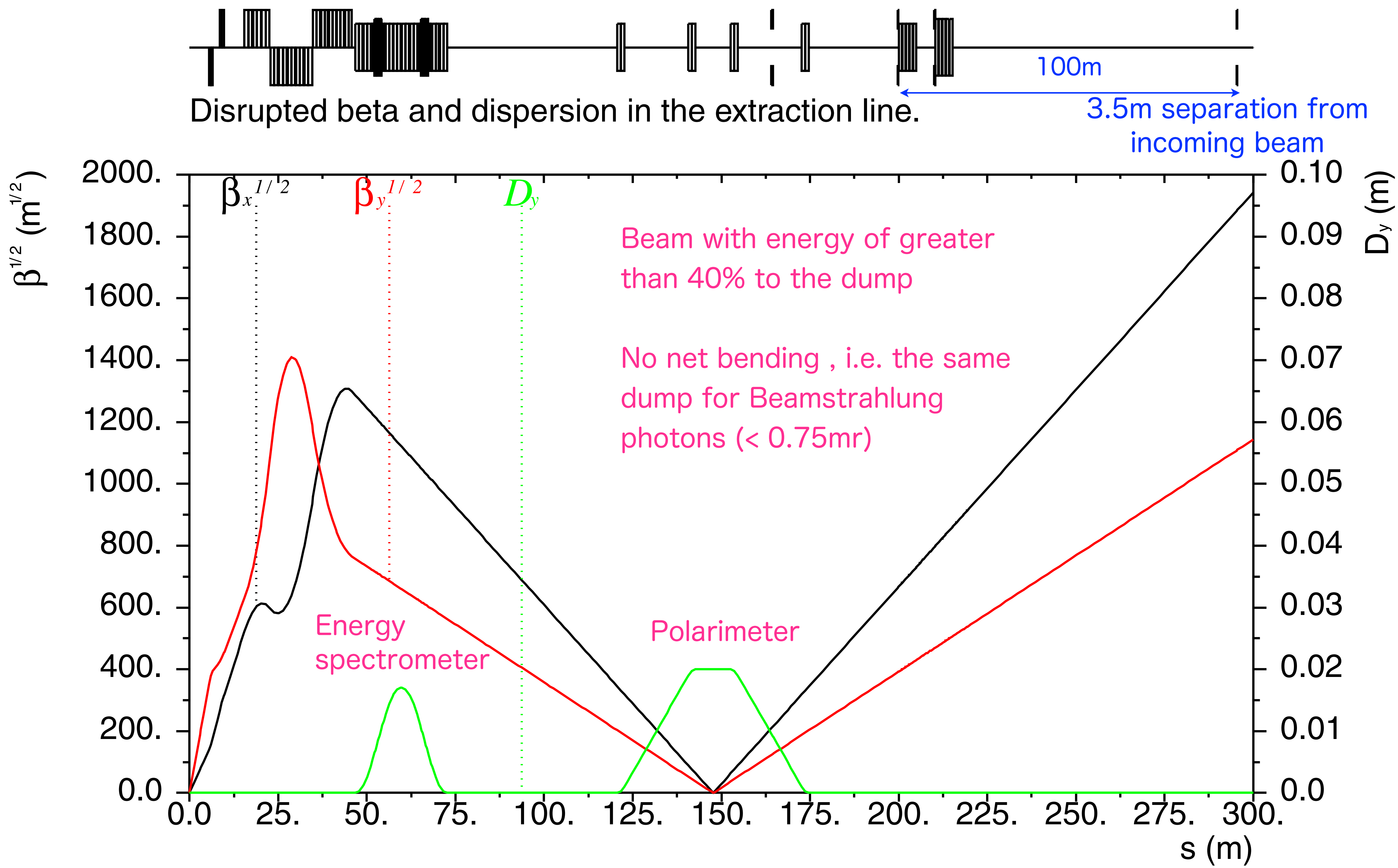
P. Burrows, ATF2 Technical Review, 3-4 April, 2013, KEK

Final Doublet Region (SiD)



P. Burrows, ATF2 Technical Review, 3-4 April, 2013, KEK

ILC-BDS/EXT Optics



electron beam →

3cm circle by raster kickers

in a 15cm radius dump window

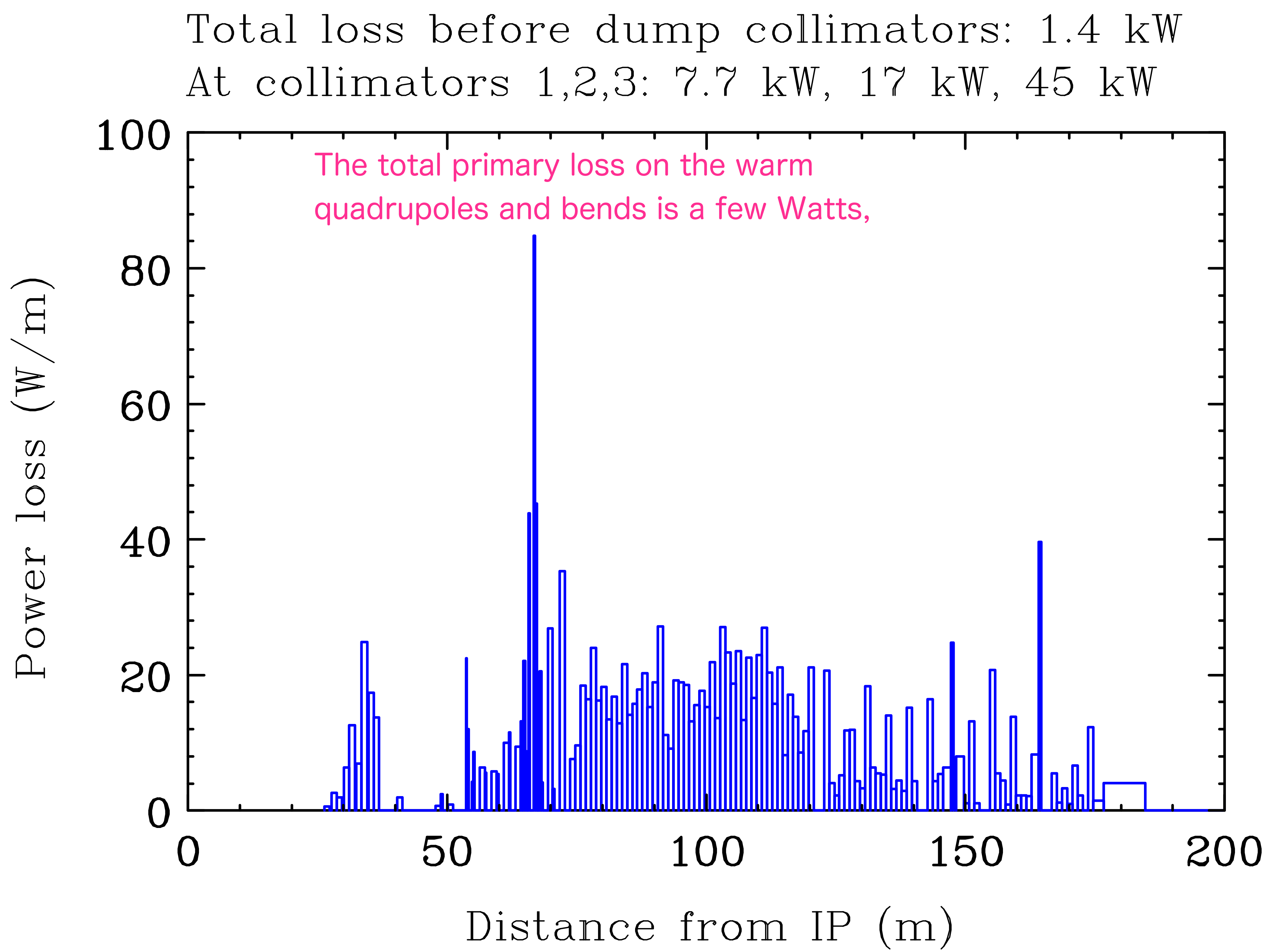


Figure 8.5. Power loss density in the magnet region for disrupted beam at 250 GeV, for high-luminosity operation.

Luminosity degradation due to the collimators

ILC-TDR : collimation depth = $9\sigma_x$ x $65\sigma_y$, $\Delta\varepsilon_{x/y}/\varepsilon_{x/y}$=0.08%/4.4%

1. Collimation depth, wakefield and emittance growth

ILC-TDR’

$C_{dep\_y} = \theta_y^{max} / \sigma^{*\prime}_y$/safety_factor → 34.6(y), 6.6(x)@Eb=100GeV

$A_y = 0.0482\ \gamma^{-1}\ C_{dep\_y}^{-1.5}\ \varepsilon_y^{-0.75}$ → 4.4 55(y), 15(x)@CLIC

Emittance growth in y = $(0.4 * Jitter_{train} * A_y)^2$ → 0.12

Values in ILC-TDR’ (CLIC-CDR) ;

θ_y^{max} = 1 mrad, e.g. no syn.rad hit 20mmϕ beam pipe for ±10m around IP

safety_factor = 1.5

$Jitter_{train}$ = 0.2 (0.2), scaled by beam size with “FONT” feedback

note: emittance growth ∝ Jitter**2

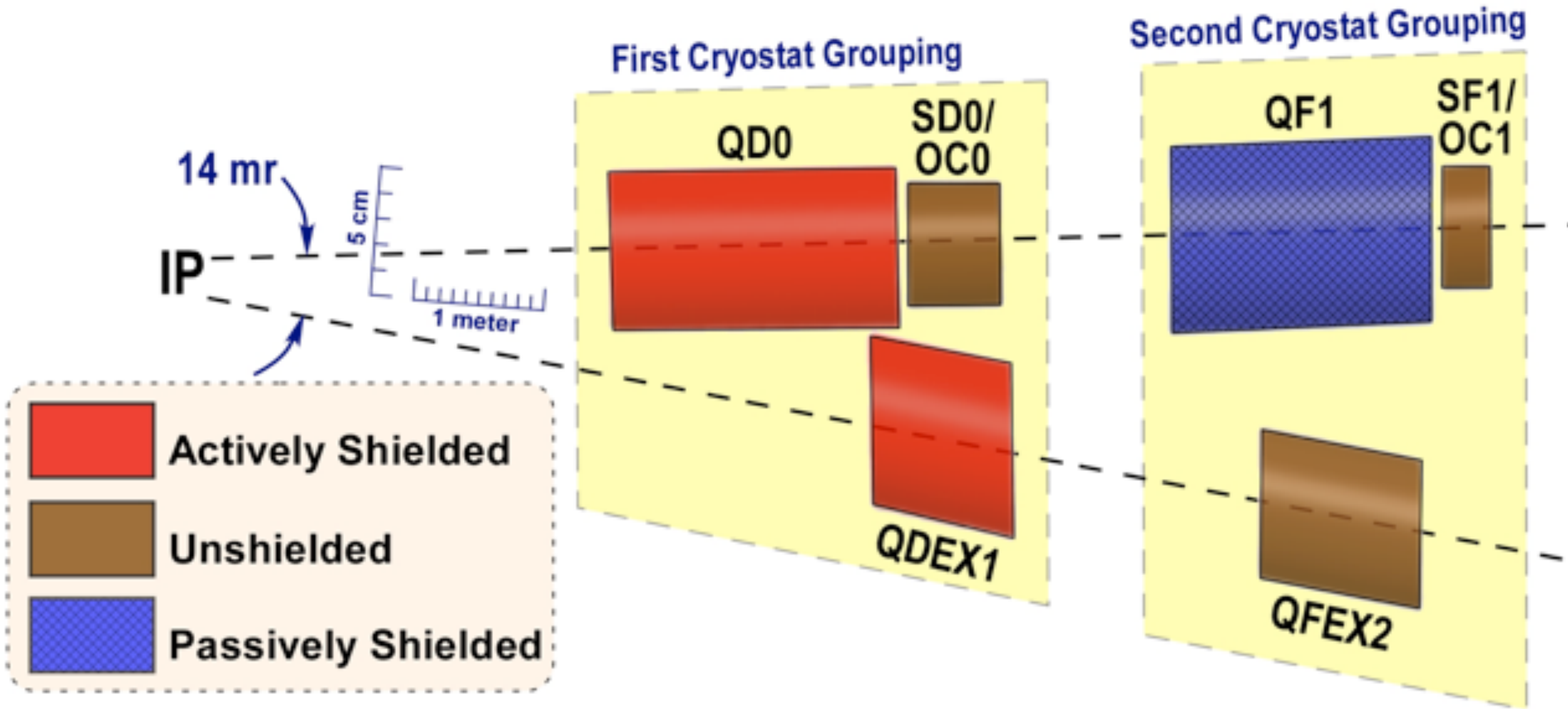
$Jitter_{b\_b}$ = 0.1 (0.05), scaled by beam size

2. Bunch-to-bunch jitter effect on the luminosity

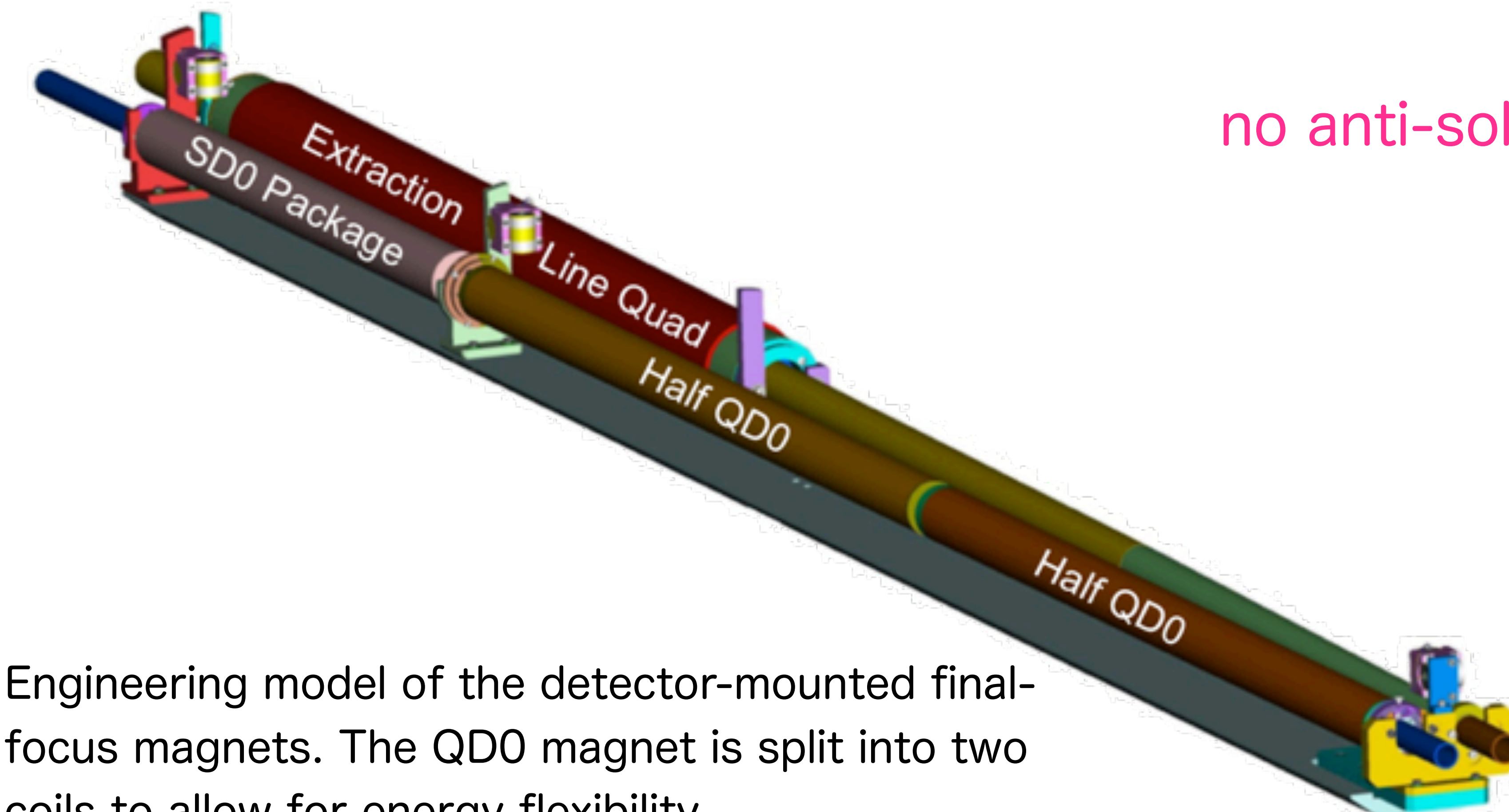
$\sigma_{b\_b} = Jitter_{b\_b} * (1 + A_y^2)^{0.5}$, jitter amplification → 0.45

$L_{b\_b} - \Delta L_{b\_b} = EXP(-(\sigma_{b\_b}^2)/4)$ → 0.95 ~0.95

3. Energy jitter at the collimators 1% jitter → 2.2% emittance growth

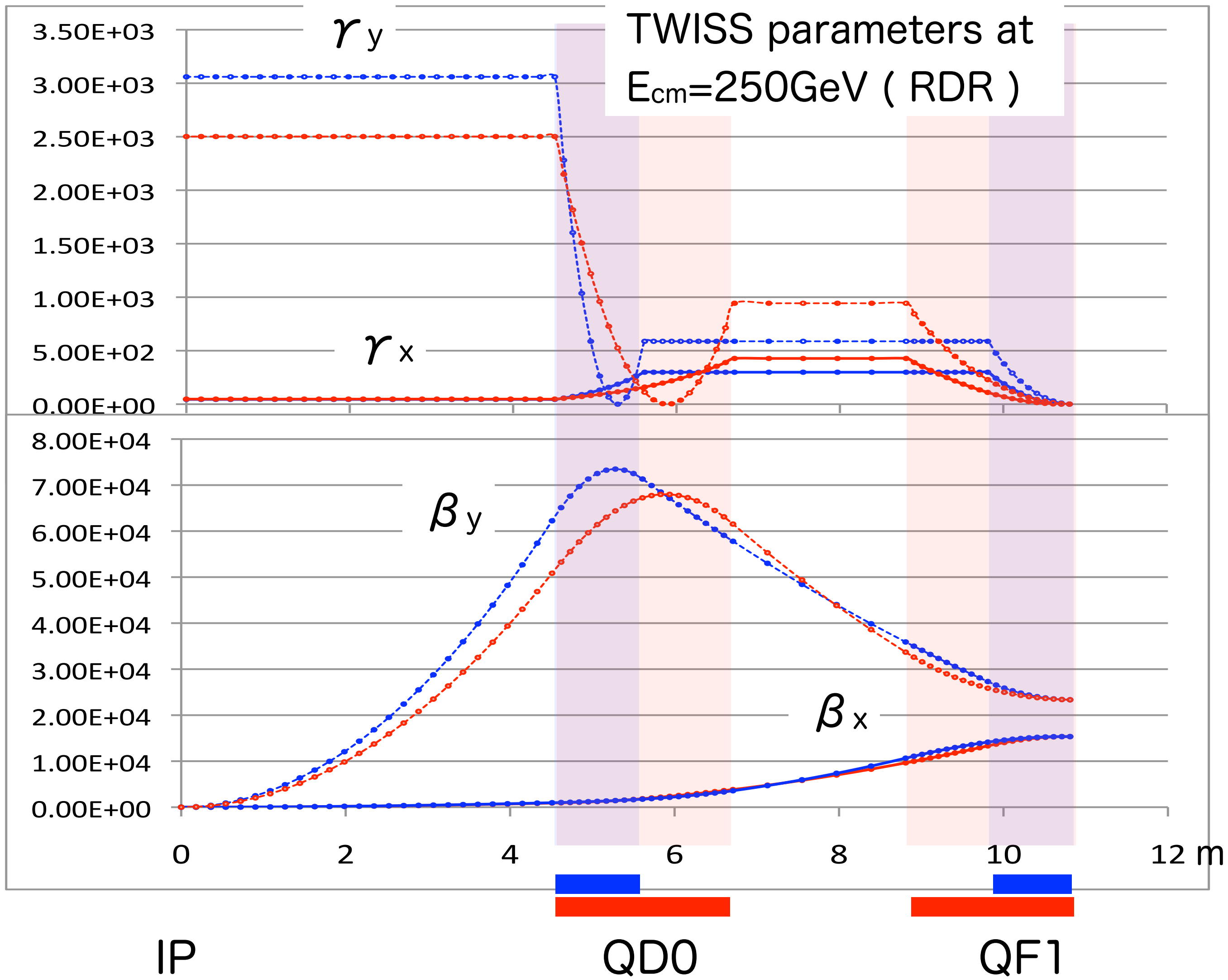


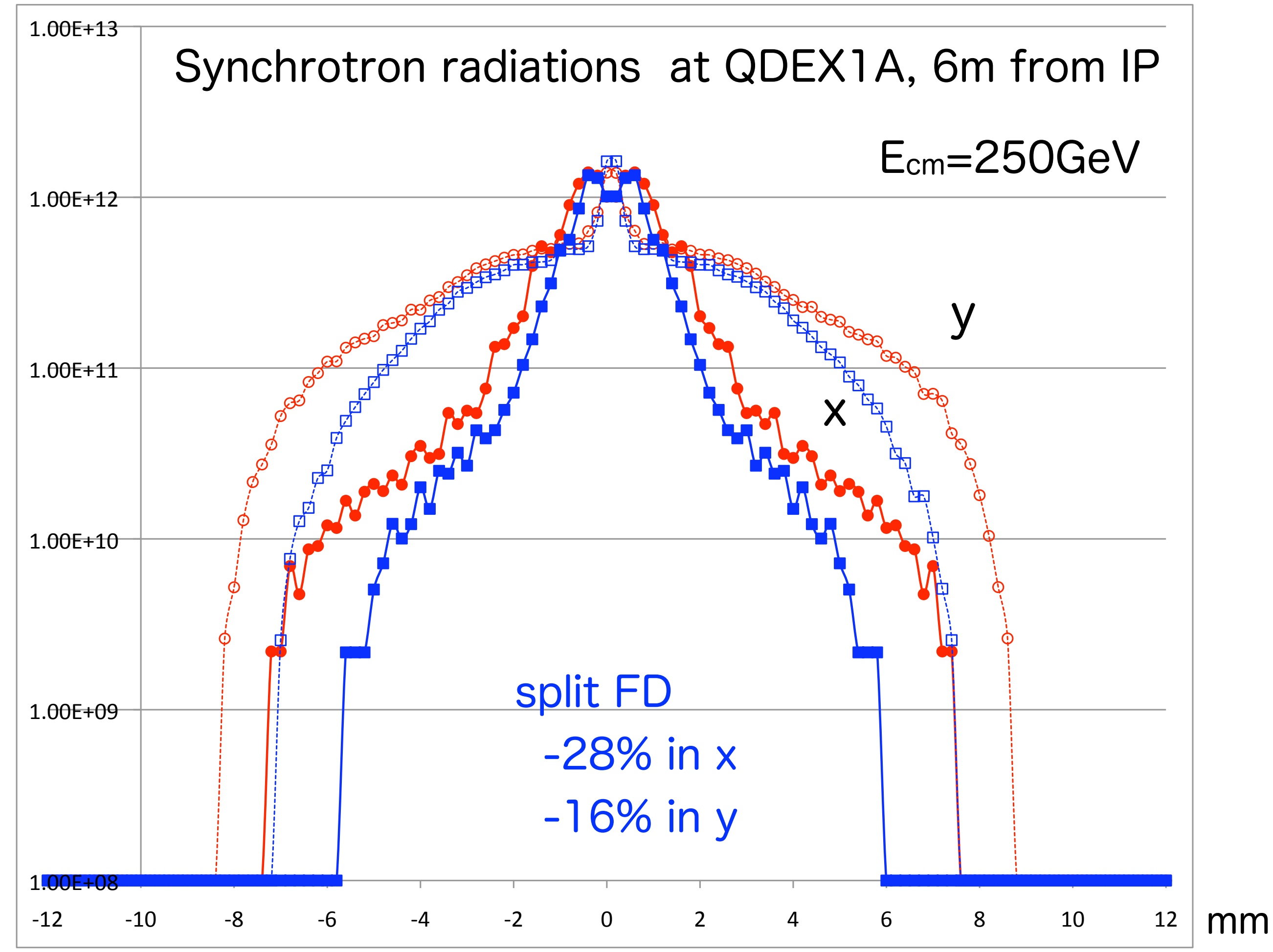
Schematic layout of magnets in the IR.



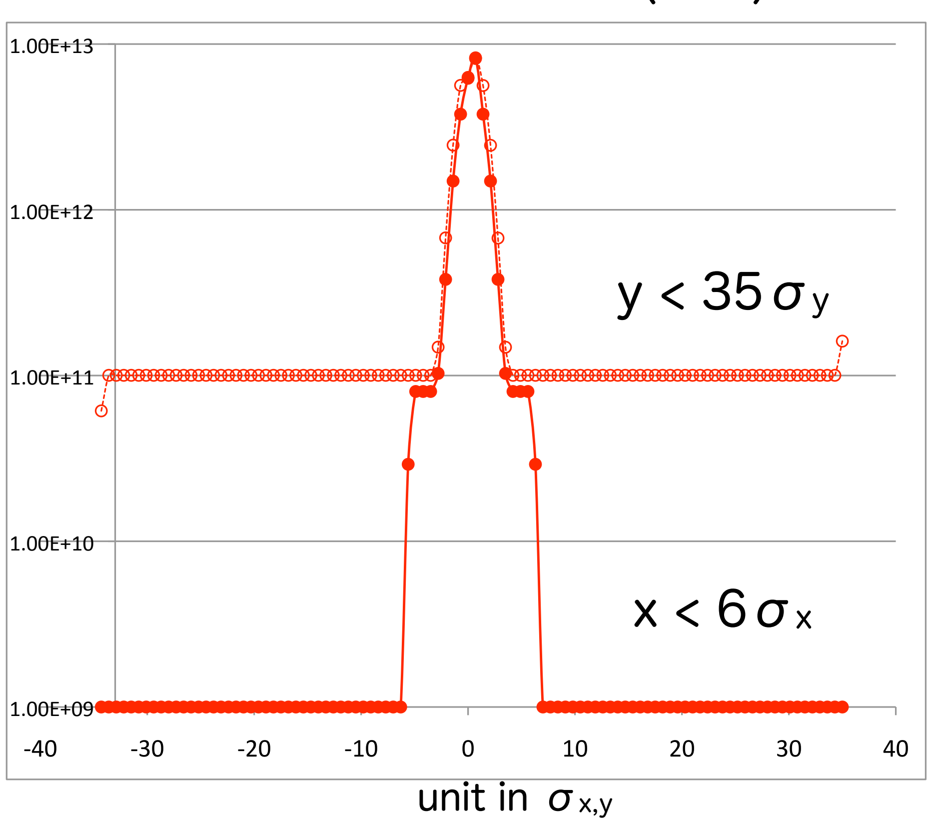
no anti-solenoid

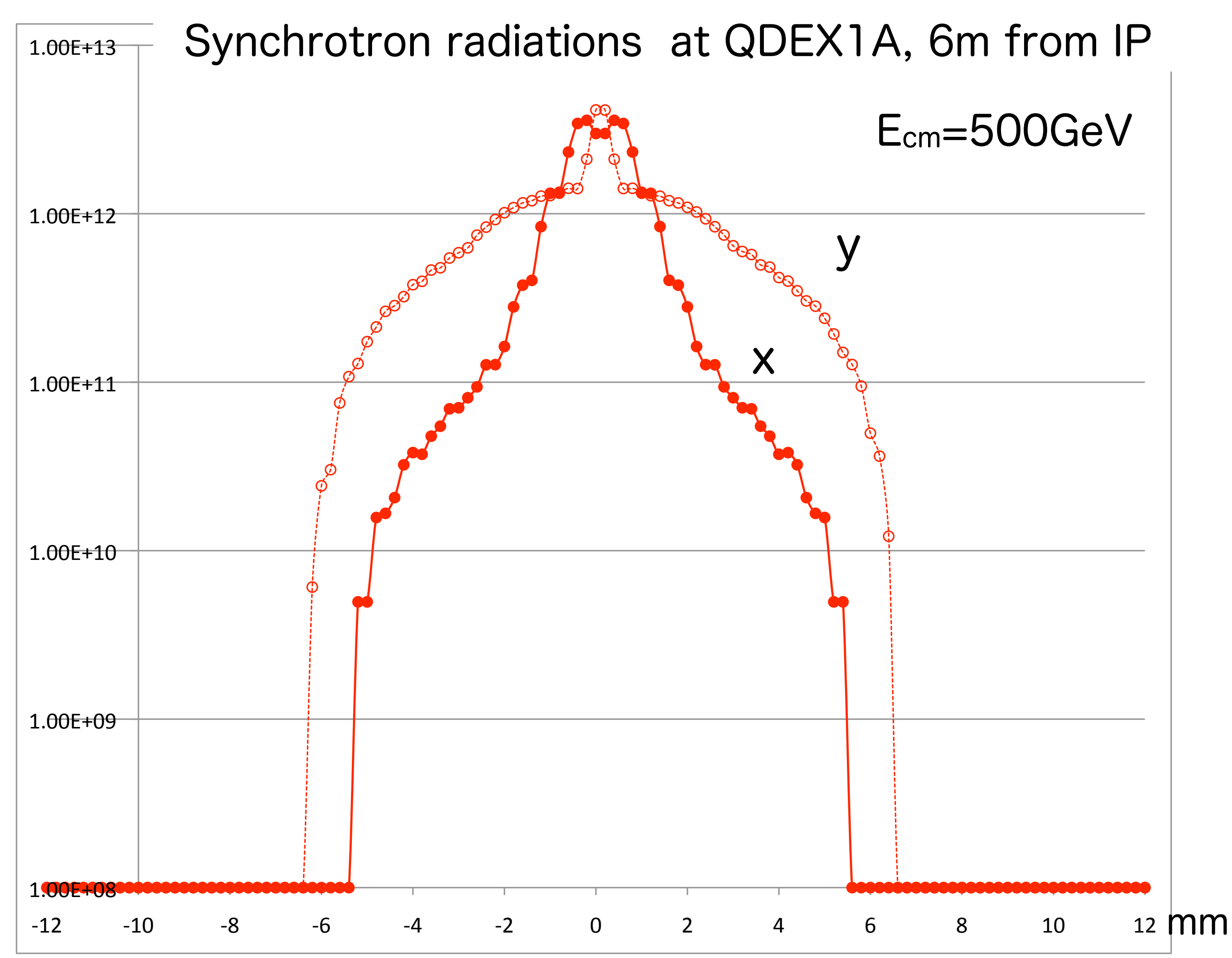
Engineering model of the detector-mounted final-focus magnets. The QD0 magnet is split into two coils to allow for energy flexibility.





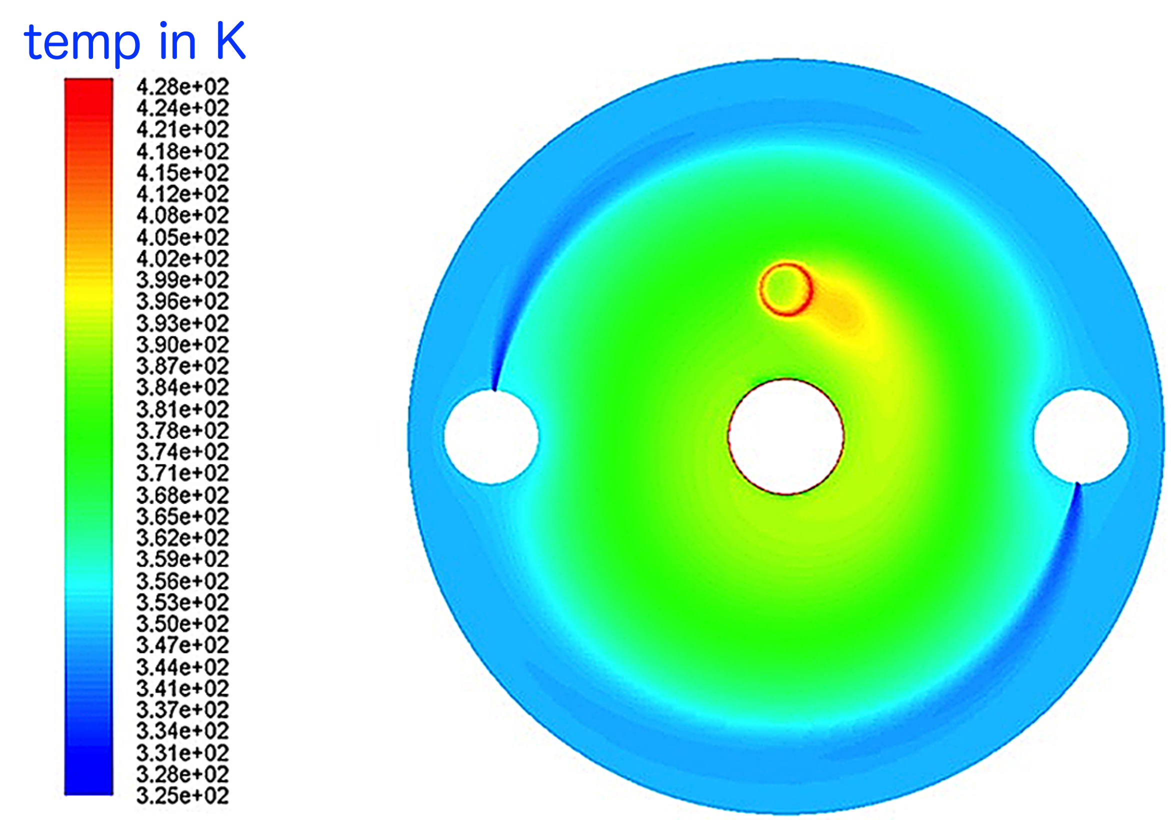
Beam Profile : Gaussian (<3σ) + flat

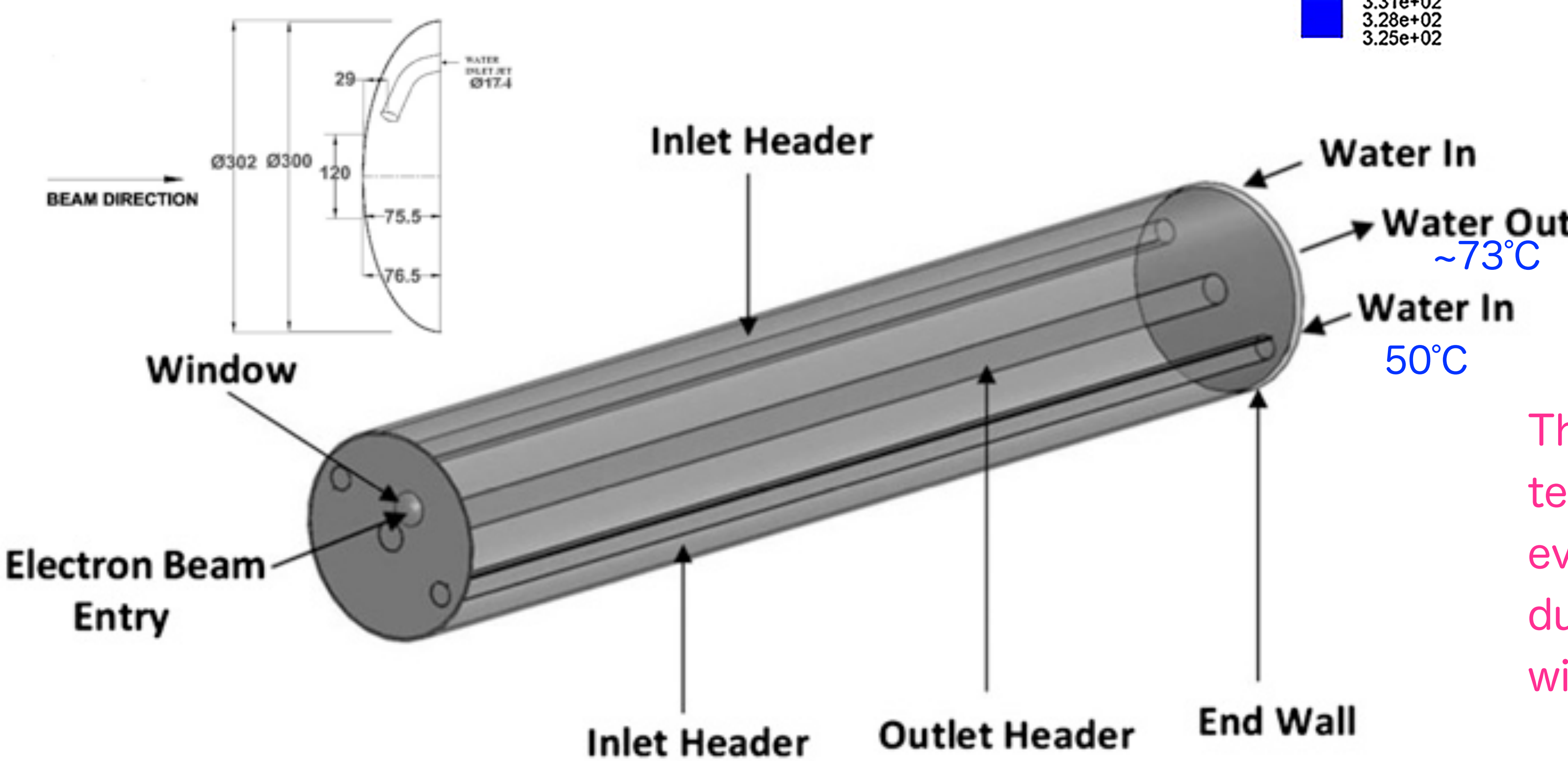




Beam dump

1.8 m-diameter cylindrical stainless-steel high-pressure (10 bar) water vessels with a 30 cm diameter, 11m(30X_0) length, 1 mm-thick Ti window.





18MW/500GeV per beam
z=2.8m (8.1X_0)
Maximum temperature = 155℃
with the beam train passage
and beam sweep radius 6cm

The pressurisation raises the boiling temperature of the dump water; in the event of a failure of the sweeper, the dump can absorb up to 250 bunches without boiling the dump water

Shielding and protection of site ground water

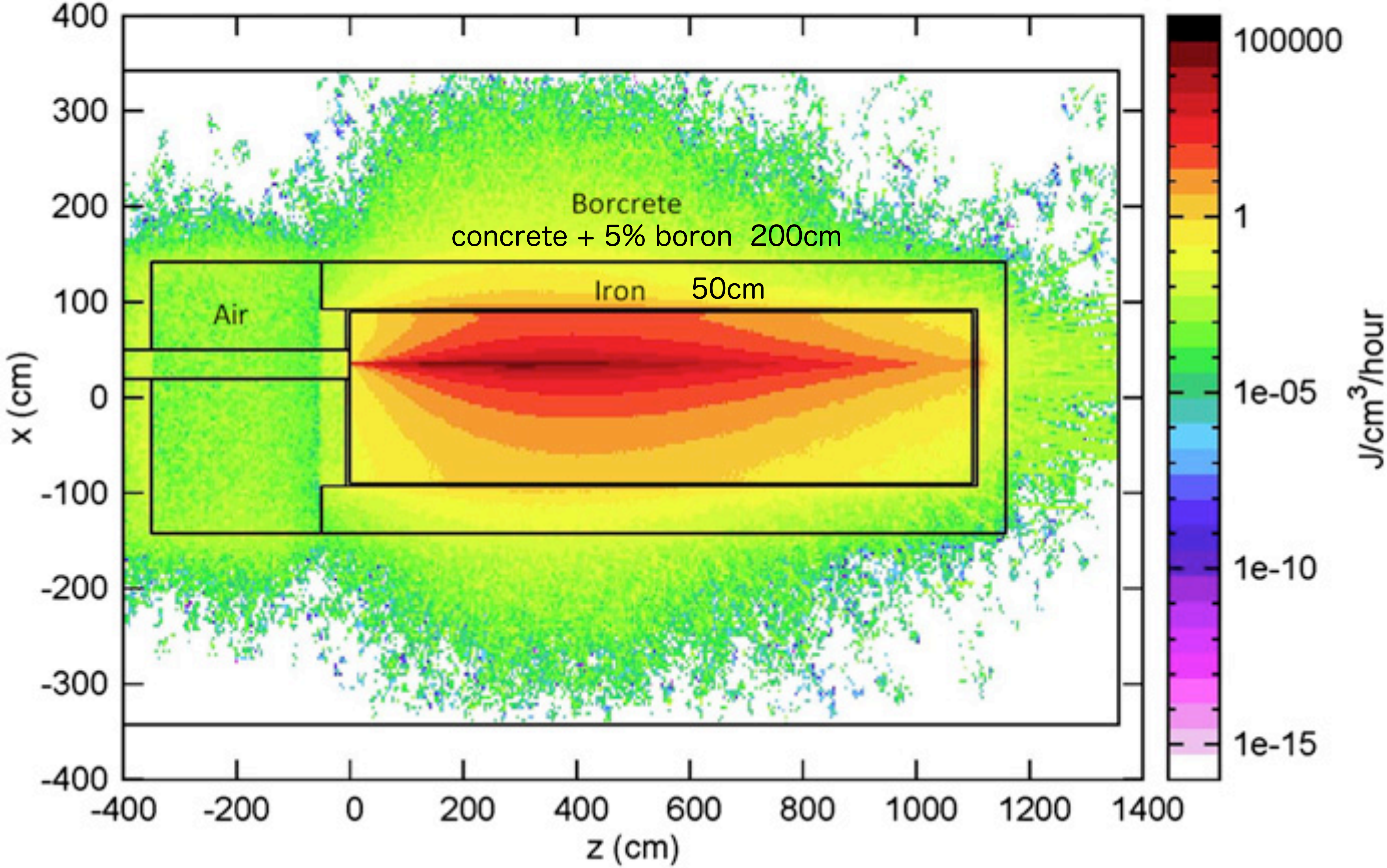


Fig. 29. Power depositions in the entire dump region (average of y=-342.5 cm and +342.5 cm).

Remarks of Wakefield effects in the BDC, ILC

In the BDS of the ILC the RW wakefield of the beam pipe and the geometric wakefield of the transitions, coupled with incoming (transverse) drift/jitter and/or beam pipe misalignment, will generate emittance growth. To keep the growth to an acceptable level, the BDS vacuum chamber needs to be coated in copper and aligned to an accuracy of 100 μm rms, and the incoming beam jitter needs to be limited to $\frac{1}{2}\sigma_y$ train-to-train and $\frac{1}{4}\sigma_y$ within a train. Then this source of emittance growth will be kept to 1-2%.

dipole resistive wall (RW) with SS beam pipes : W = 56V/(pC-mm-km)
step of beam pipes : W=0.36V/(pC-mm), a_1=1cm, a_2 large

WAKEFIELD EFFECTS IN THE BEAM DELIVERY SYSTEM OF THE ILC, K. Bane, A. Seryi, Proceedings of PAC07, Albuquerque, New Mexico, USA

Conclusions

1. ATF2 is successfully operated as the FF prototype, i.e. small beam size and nanometer stabilization, at ILC and at CLIC in future. The local chromaticity scheme is experimentally verified at ATF2.

2. Major components have technical designs to be able to evolve into engineering ones.

3. Commissioning strategy should be made with and without detectors.

4. Collaboration with CLIC-BDS should be promoted as much as possible.