American Linear Collider Physics Group

Layout and Optics Summary

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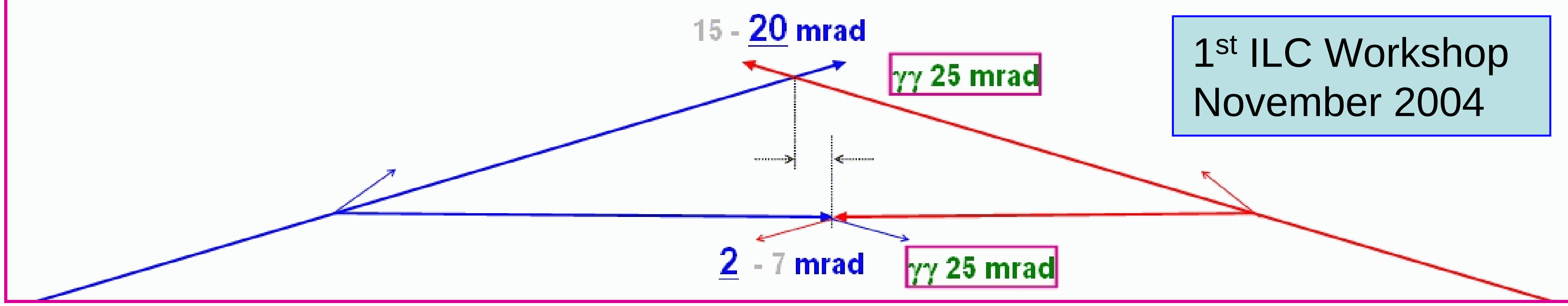
ILC workshop, Snowmass, 14 - 27 August 2005

Contents

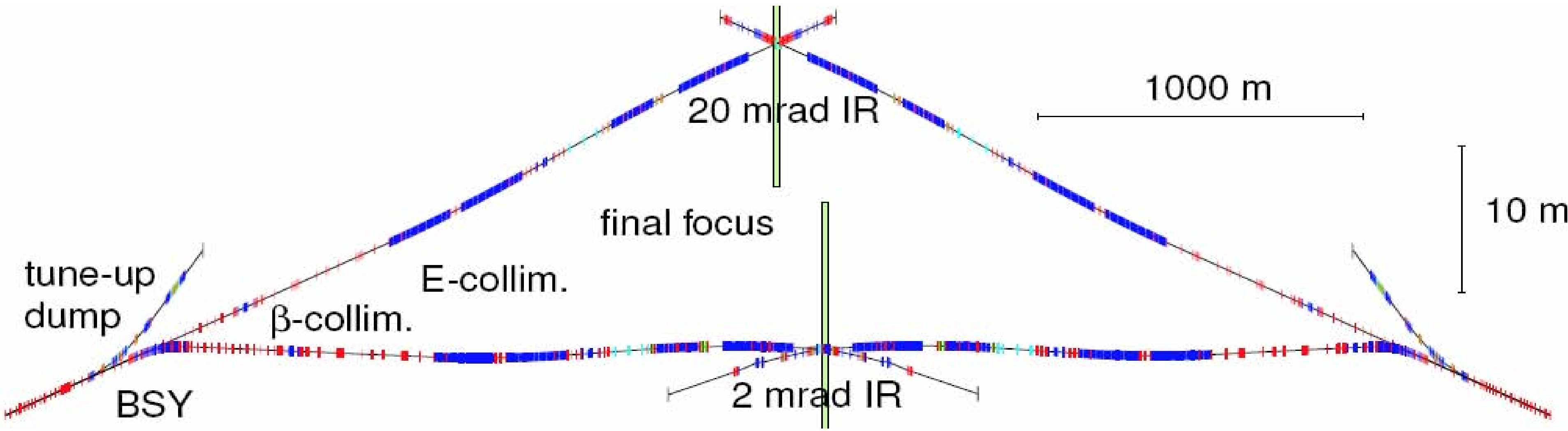
- Optics status and issues
- Layout options
- Layout/optics Issues

Recommendations from the WG4

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



International BDS group has put the Strawman tentative configuration into real design.

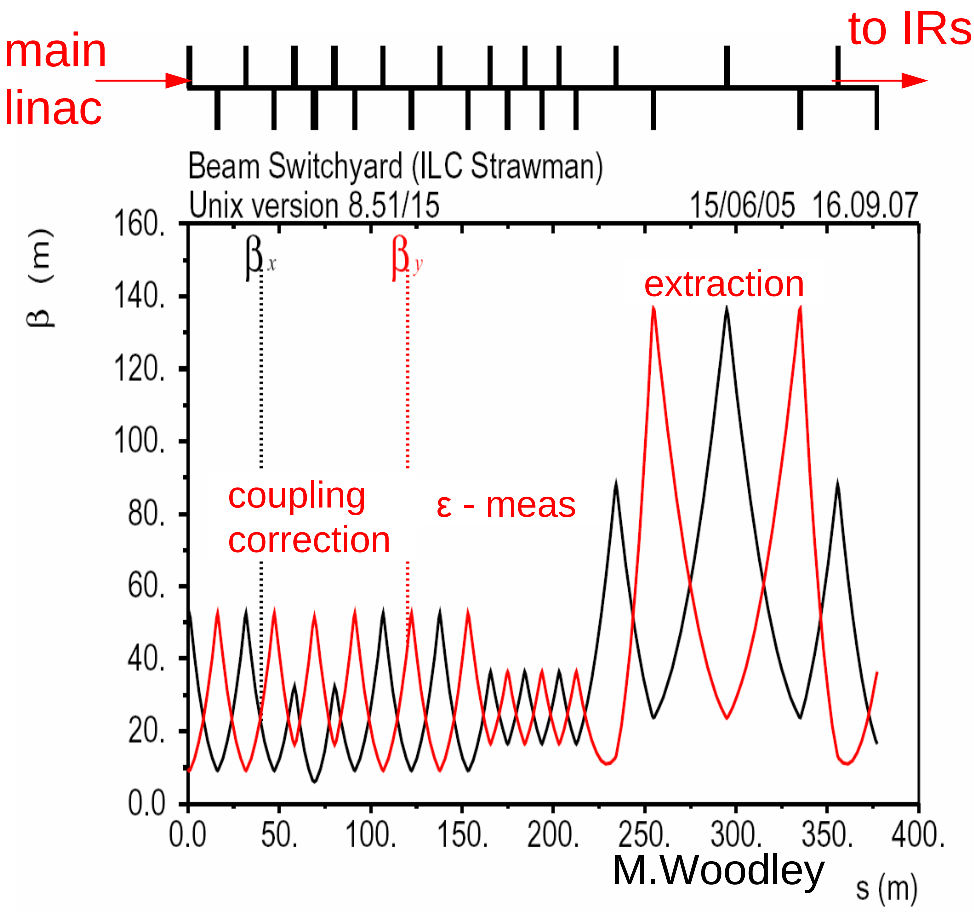


Upstream BDS optics

- Beam diagnostics section
- Tuning dumps/fast extraction
- Energy spectrometer chicane
- Polarimeter chicane
- Final focus optics
  - Good bandwidth for 20 mrad/optimisation not finished for 2 mrad
- Collimation optics
  - Collimation efficiency good for 20 mrad but still not as good as that for NLC [F. Jackson’s talk]

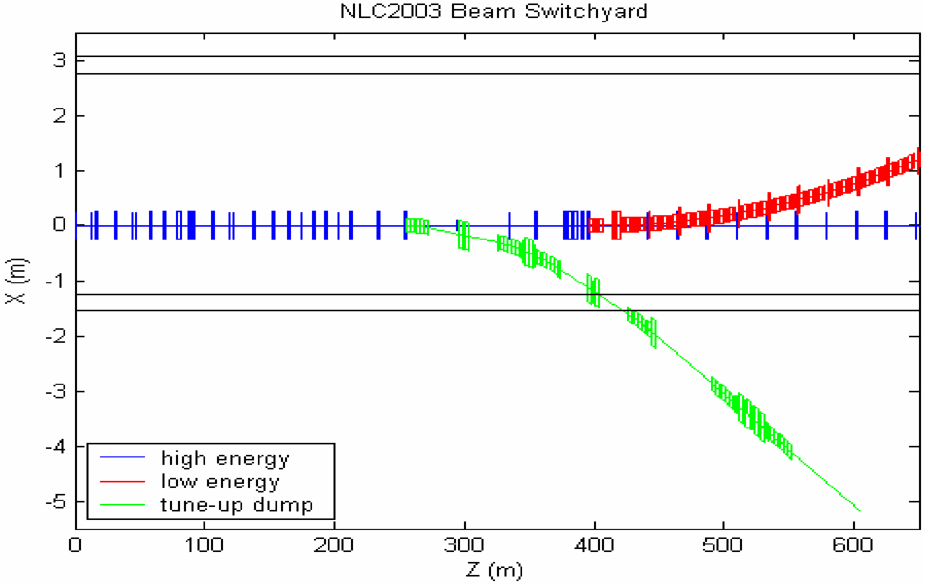
Beam Measurements at Linac exit

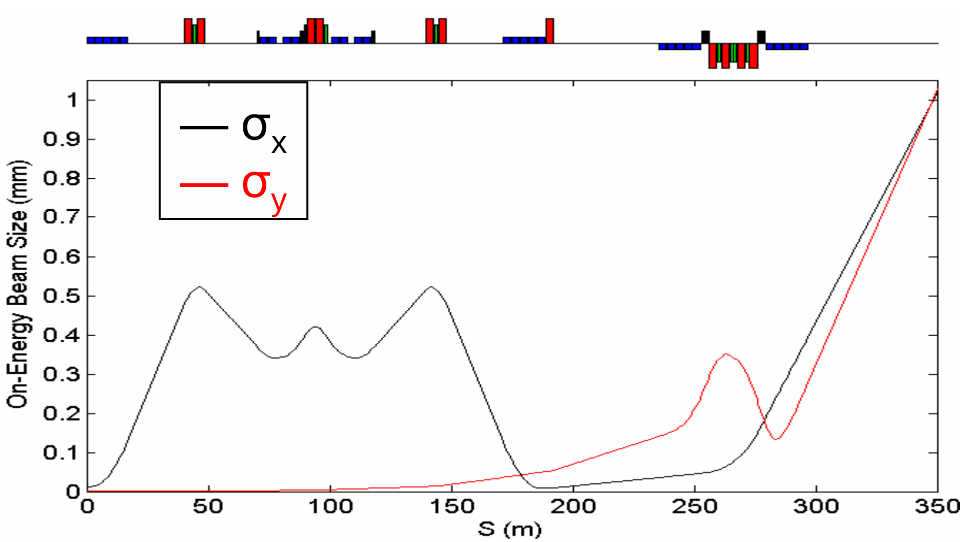
- •Beam spot < μ
Laser wire measurement accuracy ~10%
- •Performance simulations needs to be done.
- •If predicted accuracy not enough, length will be increased.
- •Laser wire - signal detection



Post-Linac Fast Extraction/Tuneup Dump Line

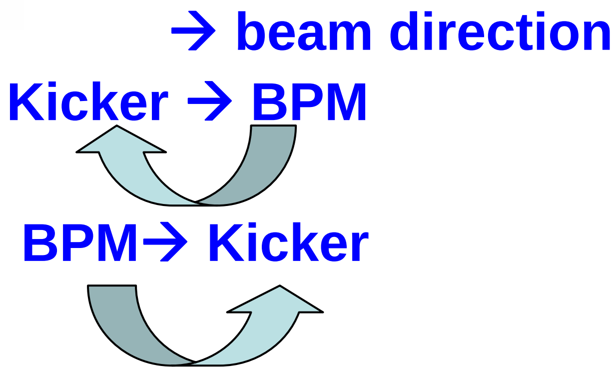
Issues





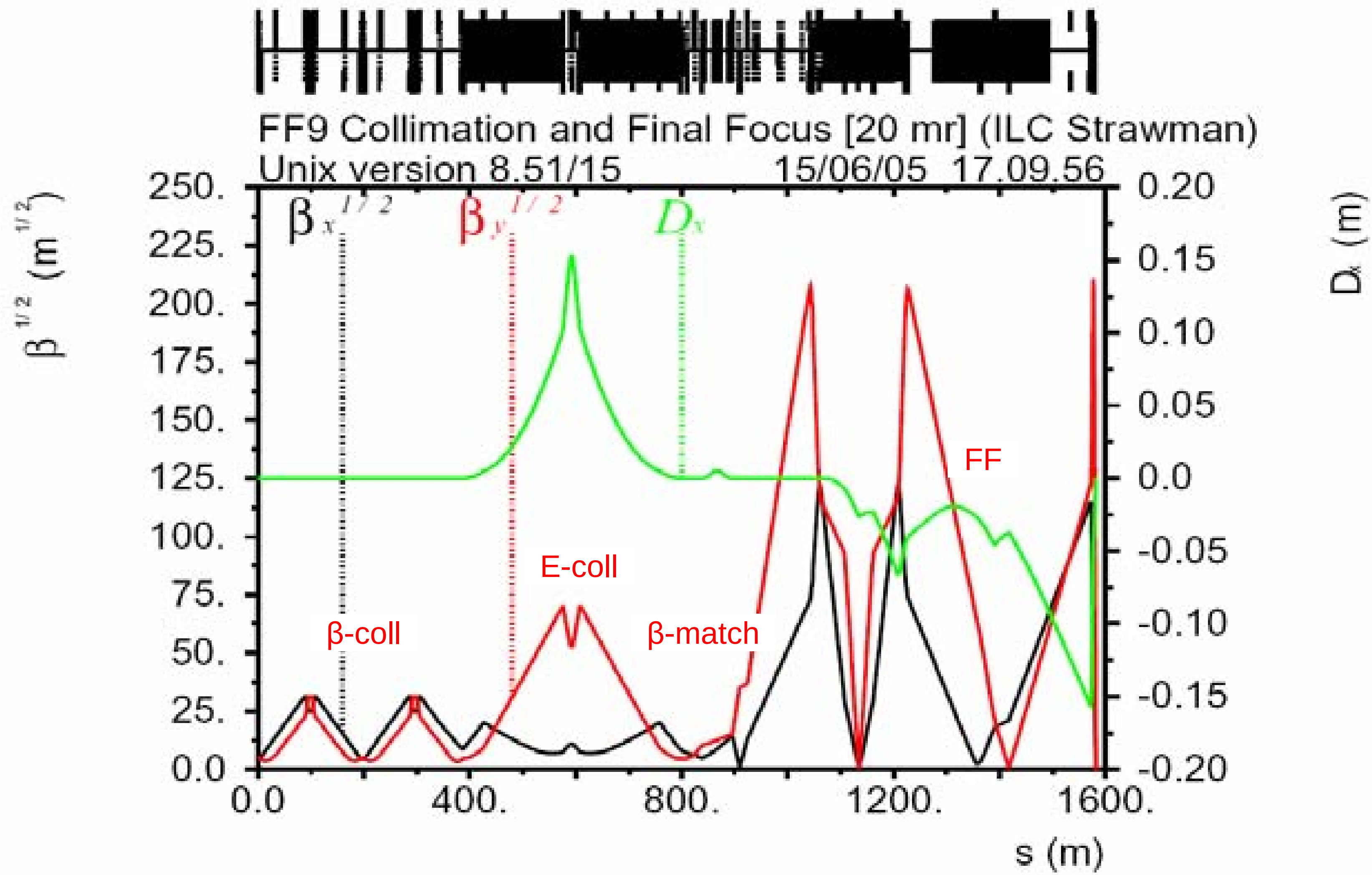
- **Energy detection: at energy collimator (upto 30 bunches @500GeV CM get through before kickers fire)**
- **At polarimeter chicane (upto ~10 bunches get through)**

or at a new BSY diagnostic chicane (1-2 bunches get through)? Will add dispersion in this line + beam spot at LW

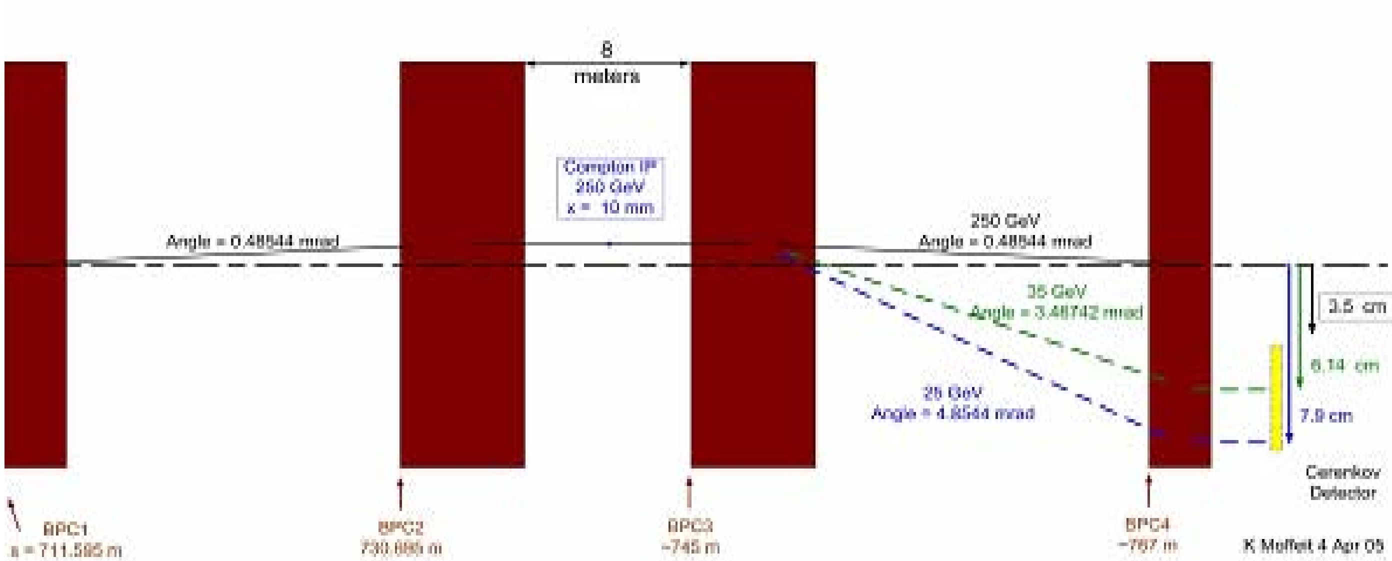


- **SR growth**
- **Beam spot at the beam dump**

Collimation / Final Focus (20 mrad crossing)



Polarimeter Chicane



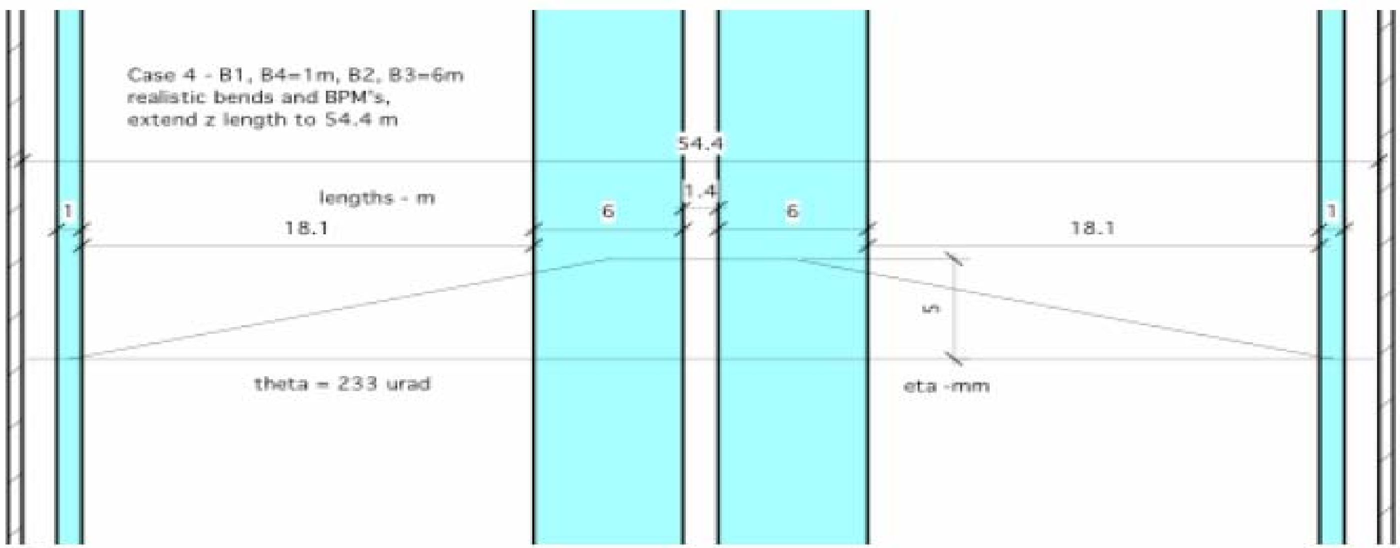
ISR (from chicane):

$$\gamma\varepsilon_{x0} = 10\times10^{-6}\,\text{m}$$

$$E_{\text{beam}} = 250\ \text{GeV}$$
$$\eta_{\text{chicane}} = 20\ \text{mm}$$
$$\Delta\gamma\varepsilon_x / \gamma\varepsilon_{x0} = 0.49\ \%$$

$$E_{\text{beam}} = 500\ \text{GeV}$$
$$\eta_{\text{chicane}} = 5\ \text{mm}$$
$$\Delta\gamma\varepsilon_x / \gamma\varepsilon_{x0} = 0.07\ \%$$

Energy Spectrometer Chicane

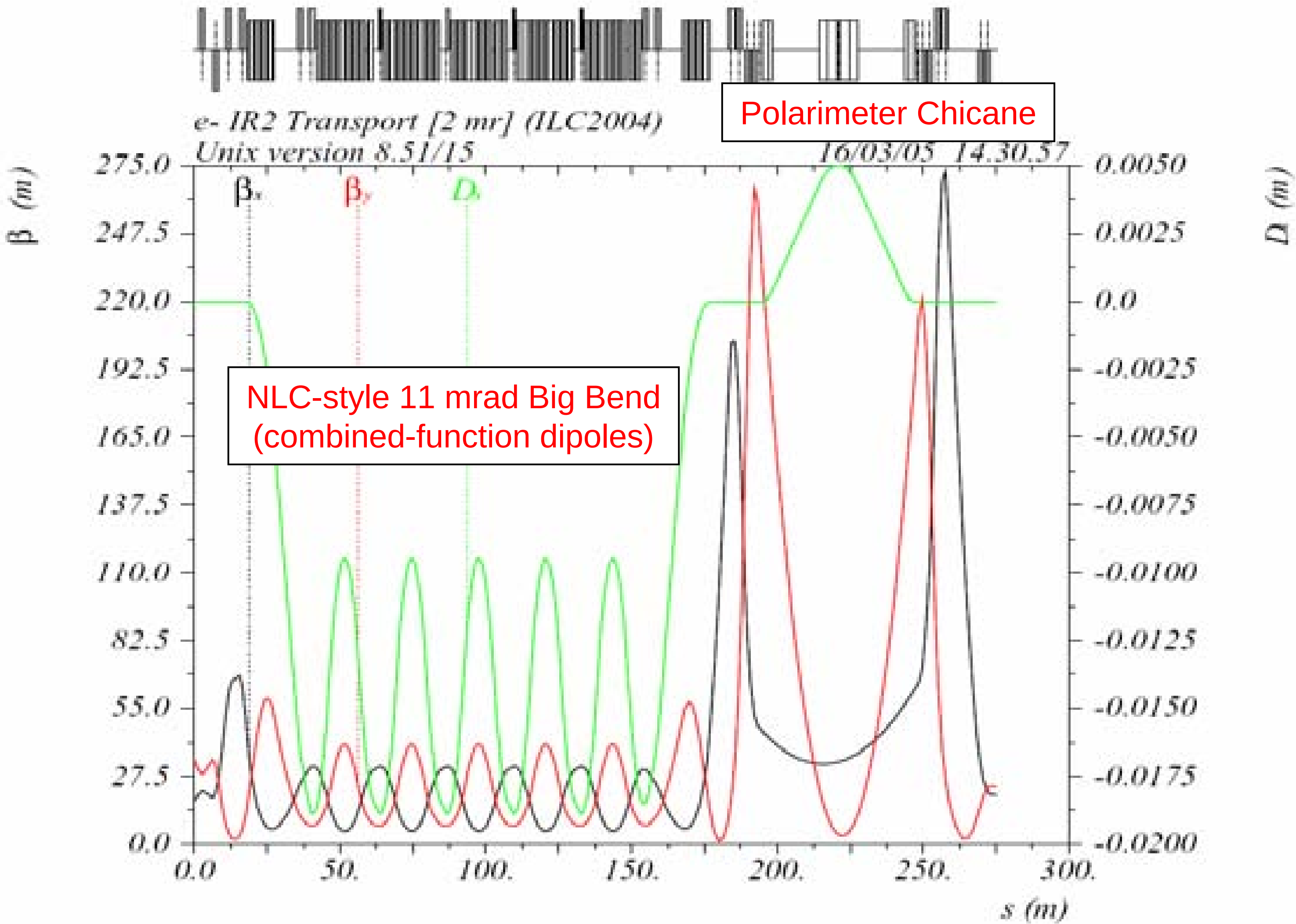


$$\gamma\varepsilon_{x0} = 10\times10^{-6}\,\text{m}$$
$$\eta_{\text{chicane}} = 5\ \text{mm}$$

$$E_{\text{beam}} = 250\ \text{GeV}$$
$$\Delta\gamma\varepsilon_x = 1.2\times10^{-10}\,\text{m}$$

$$E_{\text{beam}} = 500\ \text{GeV}$$
$$\Delta\gamma\varepsilon_x = 7.5\times10^{-9}\,\text{m}$$

Beam Transport to 2 mrad IR



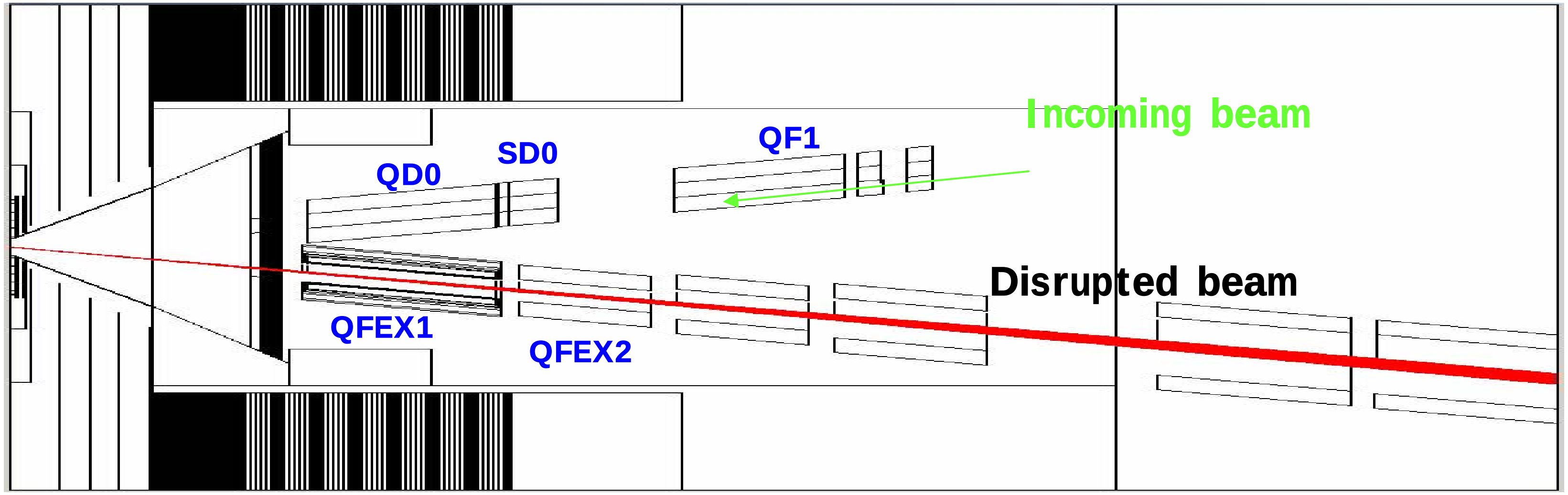
ISR (total):

$$\gamma\varepsilon_{x0} = 10\times10^{-6}\,\mathrm{m}$$

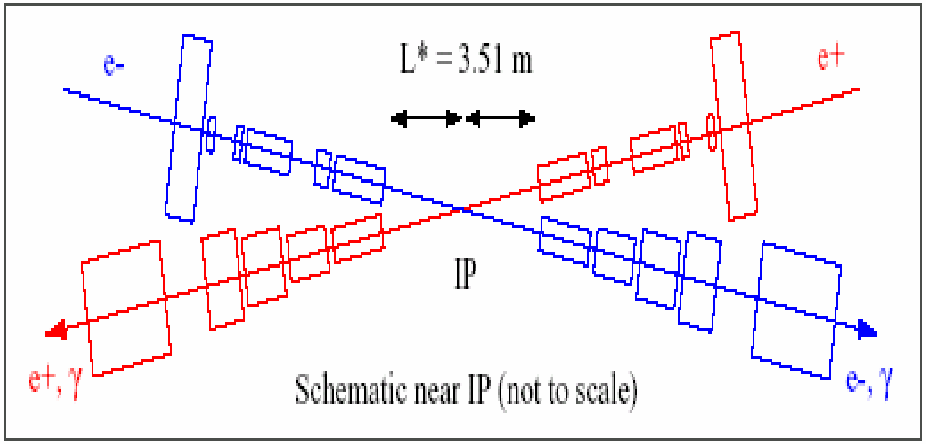
$$E_{beam} = 500\ \mathrm{GeV}$$

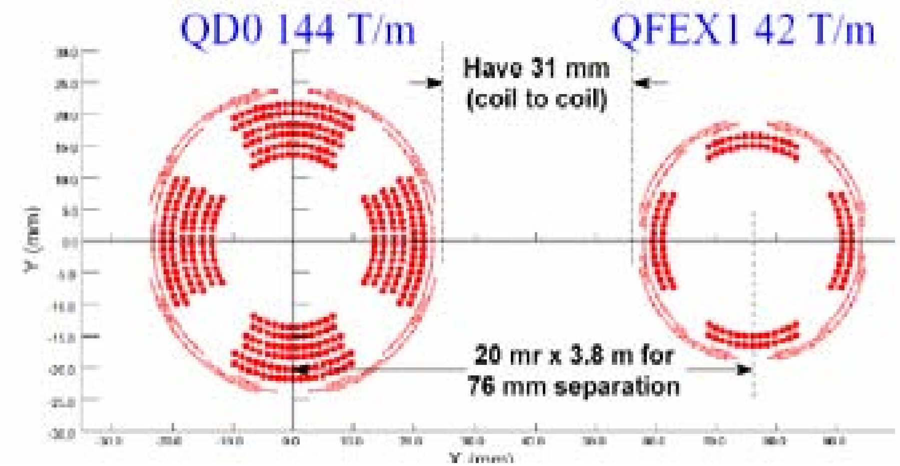
$$\frac{\Delta\gamma\varepsilon_X}{\gamma\varepsilon_{x0}} = 11.6\,\%$$

20 mrad extraction line



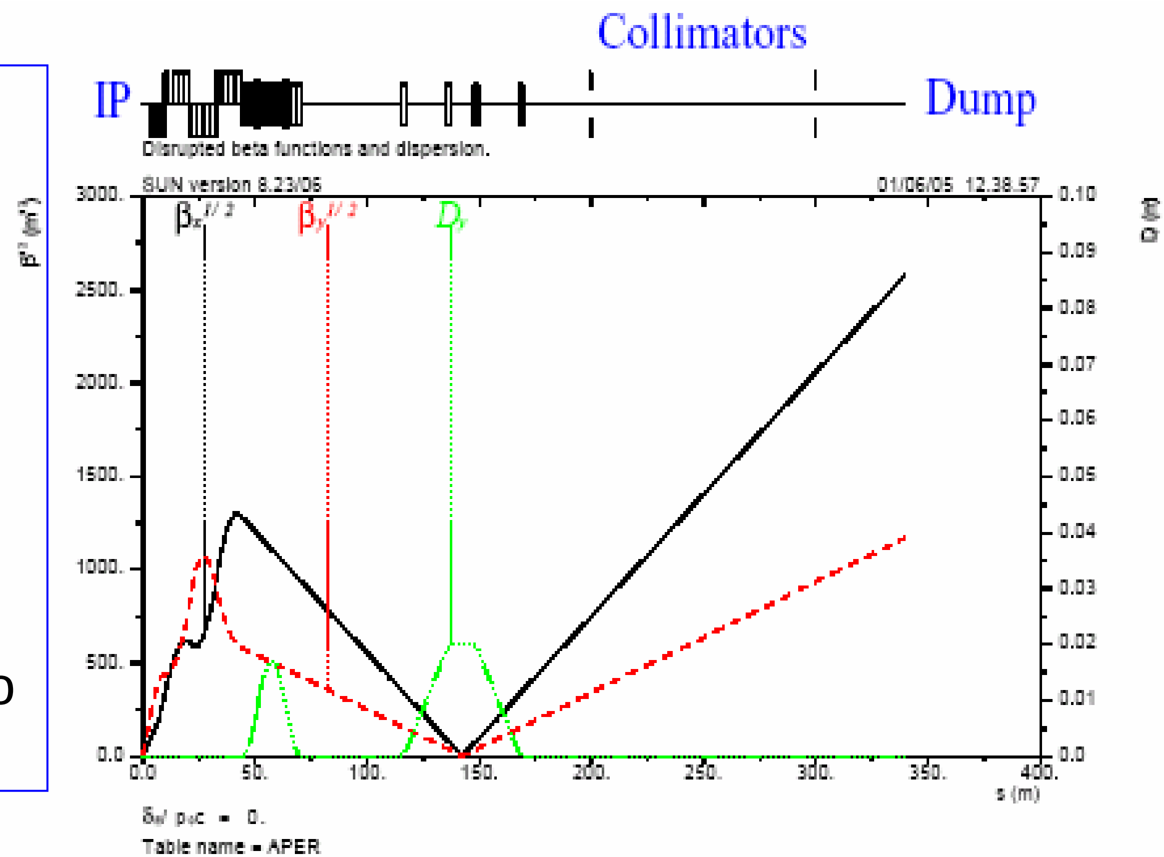
Based on compact SC quads [B.Parker's talk]





20 mrad extraction line

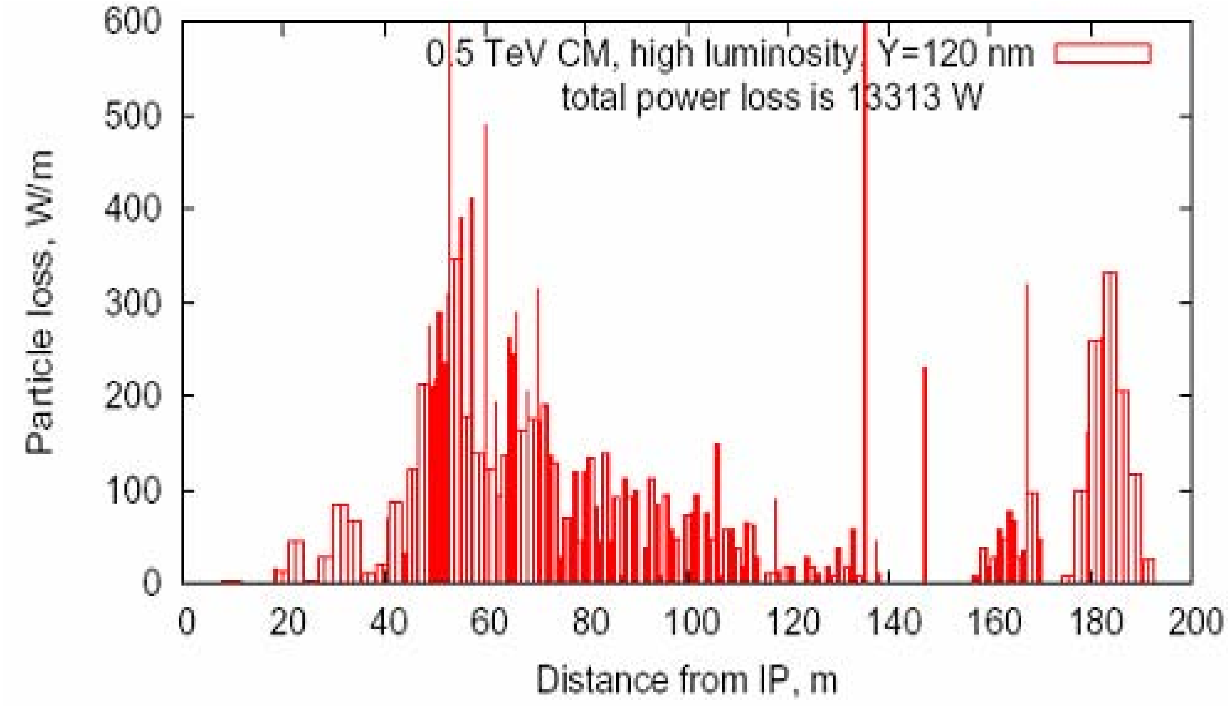
- Dedicated vertical chicanes and 2nd Focus for energy and polarization diagnostics.
- Undisrupted beam spot at beam dump is big enough.
- Disrupted electron and photon beams collimated to fit in the dump window.



Acceptable losses in SC magnets ~ 1-2 W/m
Losses on warm magnets < 50 W/m
Losses on collimators: acceptable for high luminosity case up to 1 TeV
Unacceptable losses on magnets for 1 TeV CM high Luminosity

Y.Nosochkov

20 mrad Extraction line losses at high Luminosity estimated with STRUCT



-Beam losses are equal to 100-400 W along the last 300 m of extraction line.

- No beamstrahlung photon loss in the beam line for nominal luminosity.

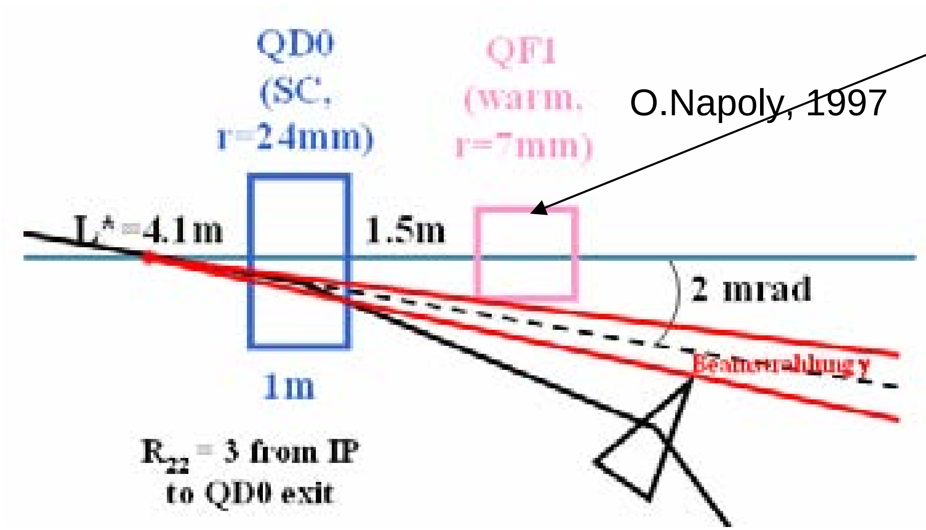
- Beamstrahlung photon losses ~ 200W/m along the 20-m long region downstream of QEXF2 for high luminosity parameters.

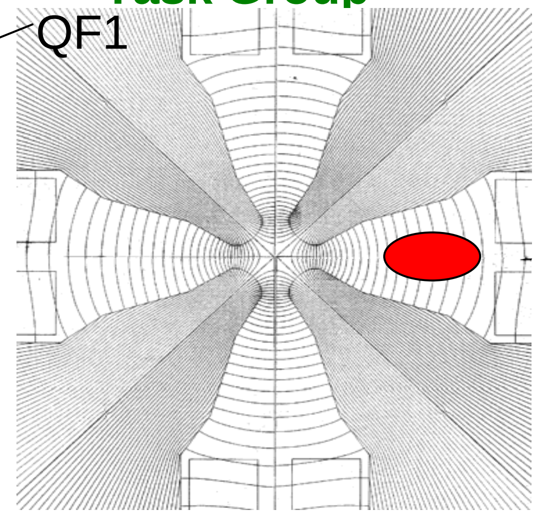
A.Drozhdin

2mrad IR: from concept to optics

Main focus after KEK workshop

SLAC-BNL-UK-France Task Group





pocket coil quad

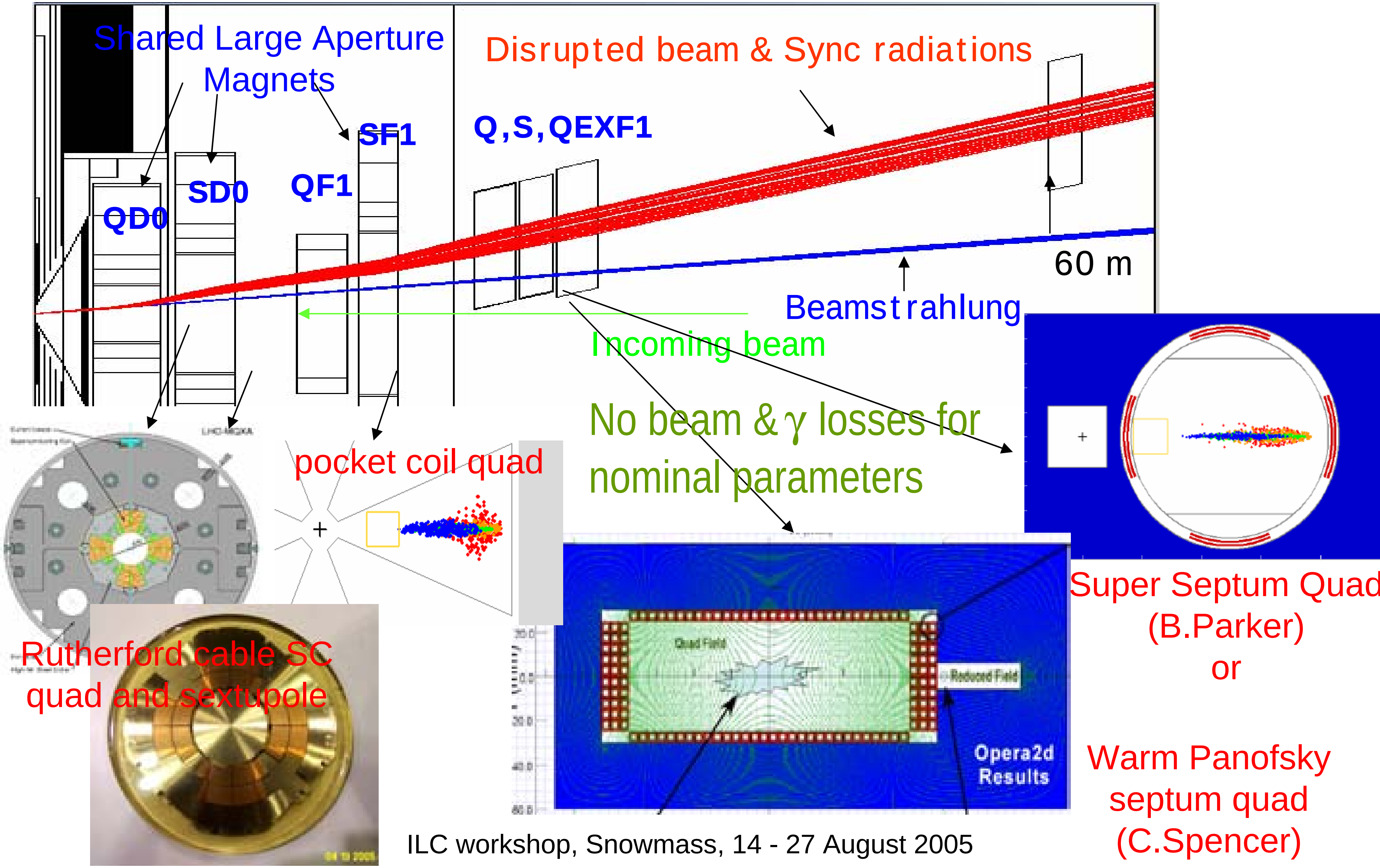
- FF and extraction line optimized simultaneously
- Quads and sextupoles in the FD optimized to
  - – cancel FF chromaticity
  - – focus the extracted beam

2 mrad Extraction Line

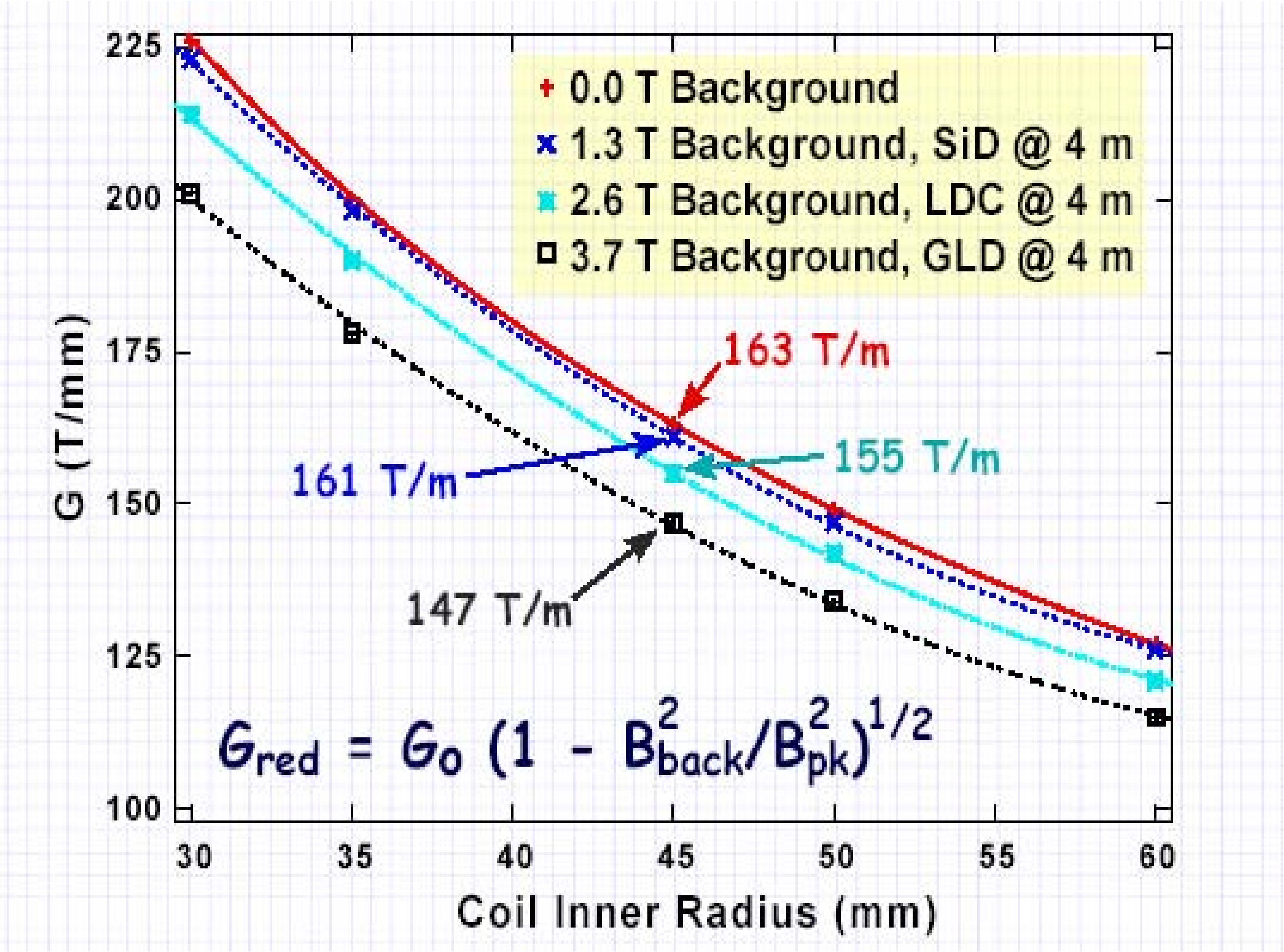
- Several versions of optics, with long and short final doublet.
- The large bore SC quad is needed for 2mrad IR. Non-trivial as it is inside the detector.
- After discussions with the magnet experts, task force has decided that 500GeV CM QD0 would be made with NbTi technology, while the more advanced and more difficult Nb3Sn materials would be left for 1TeV upgrade.
- Earlier short doublet version were optimised for 1.6 mrad to keep the power losses due to radiative bhabhas within acceptable limits. Conservative approach with beam size effects off.
- 1.6 mrad crossing angle – tight constraints on the extraction line design.
- For new design, 2 mrad possible with beam size effect is on.
- Collimation depth tighter for 2 mrad compared to 1.6mrad

  [F. Jackson's talk]
- L* is taken as 4.5m in this design to satisfy all the detectors.

2mrad IP Extraction Line in Geant

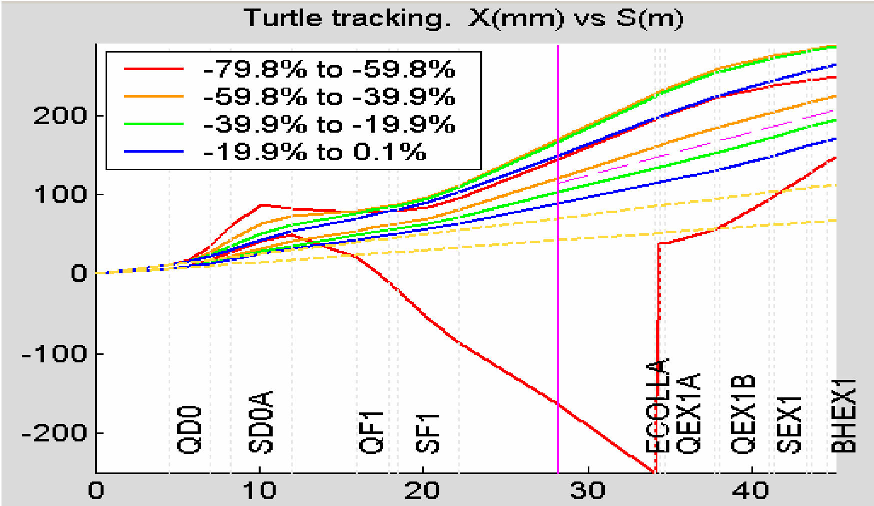


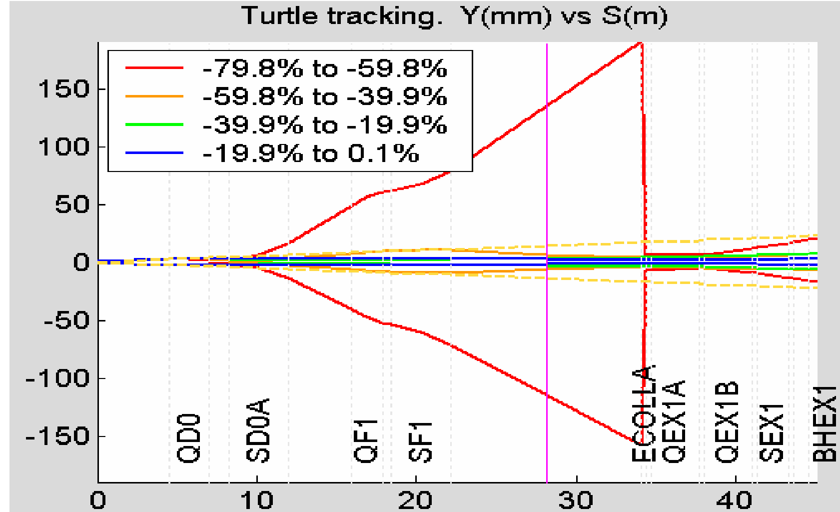
Available gradient for 2 mrad QD0

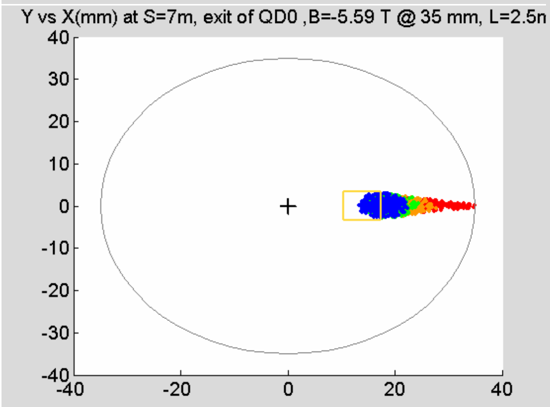


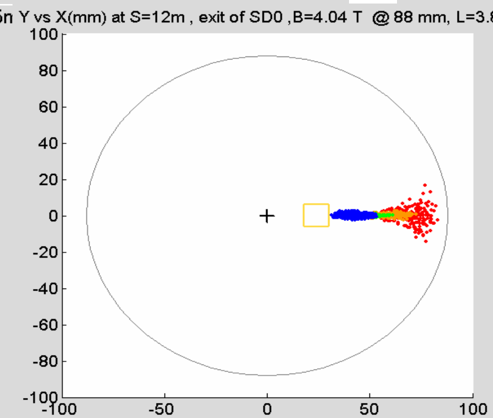
B. Parker's scaling model of gradient versus inner aperture for NbTi quadrupole, versus background field.

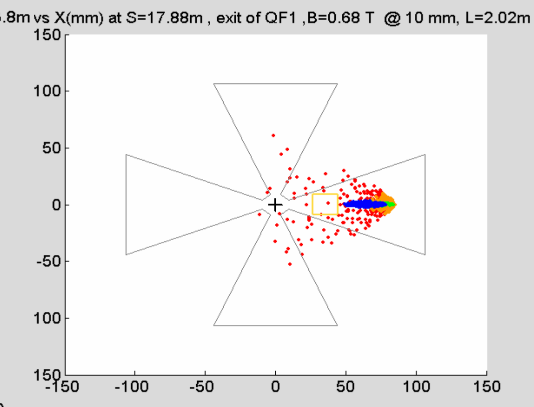
TURTLE Tracking of the beam for 2 mrad







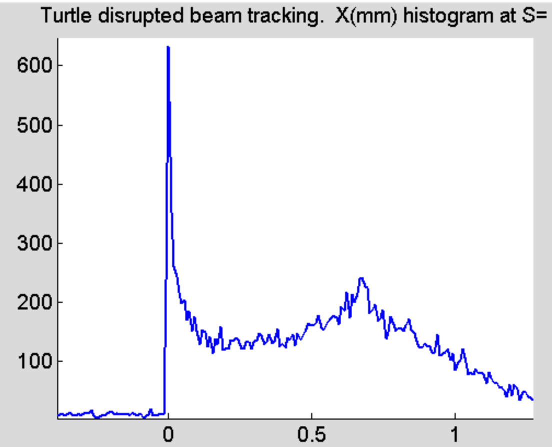


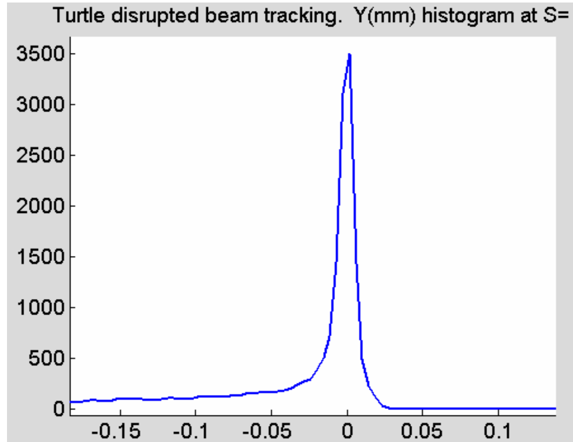


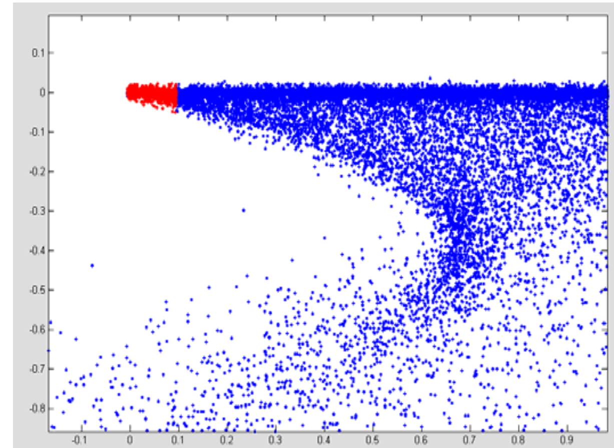
Losses on QD0 at 1TeV nominal beam parameters
Beam : 1.4 W
Radiative bhabhas : 1.3 W
(including beam size effects)

Backscattering being evaluated by J. Carter

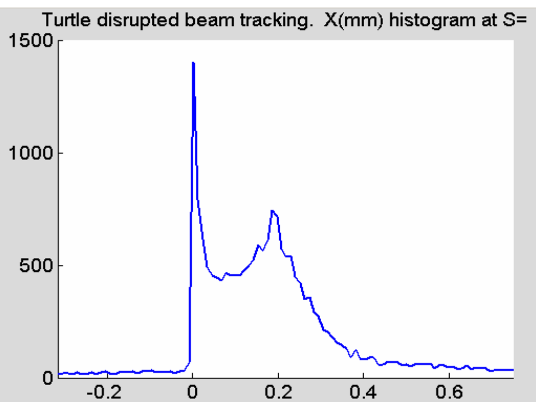
TURTLE tracking of disrupted beam at second focus

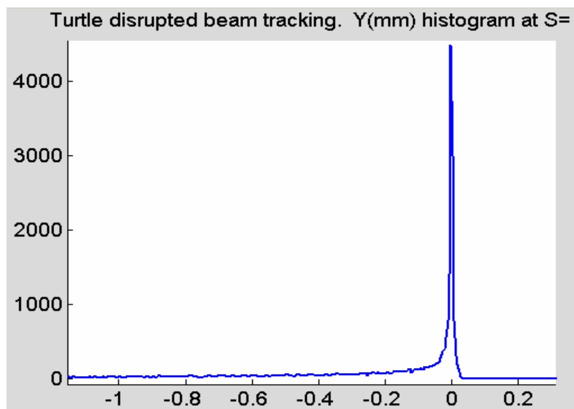


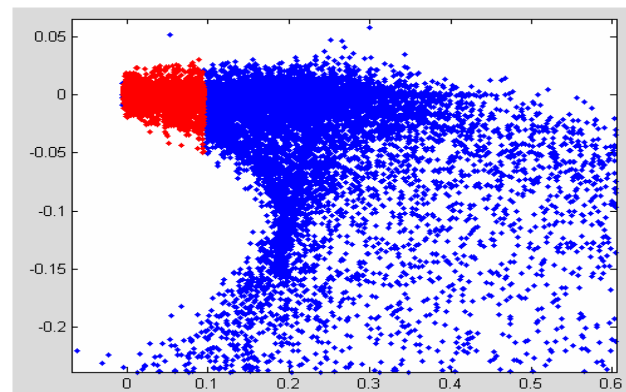




With sextupoles : Total losses for 1 TeV beam with offset ~ 228 KW





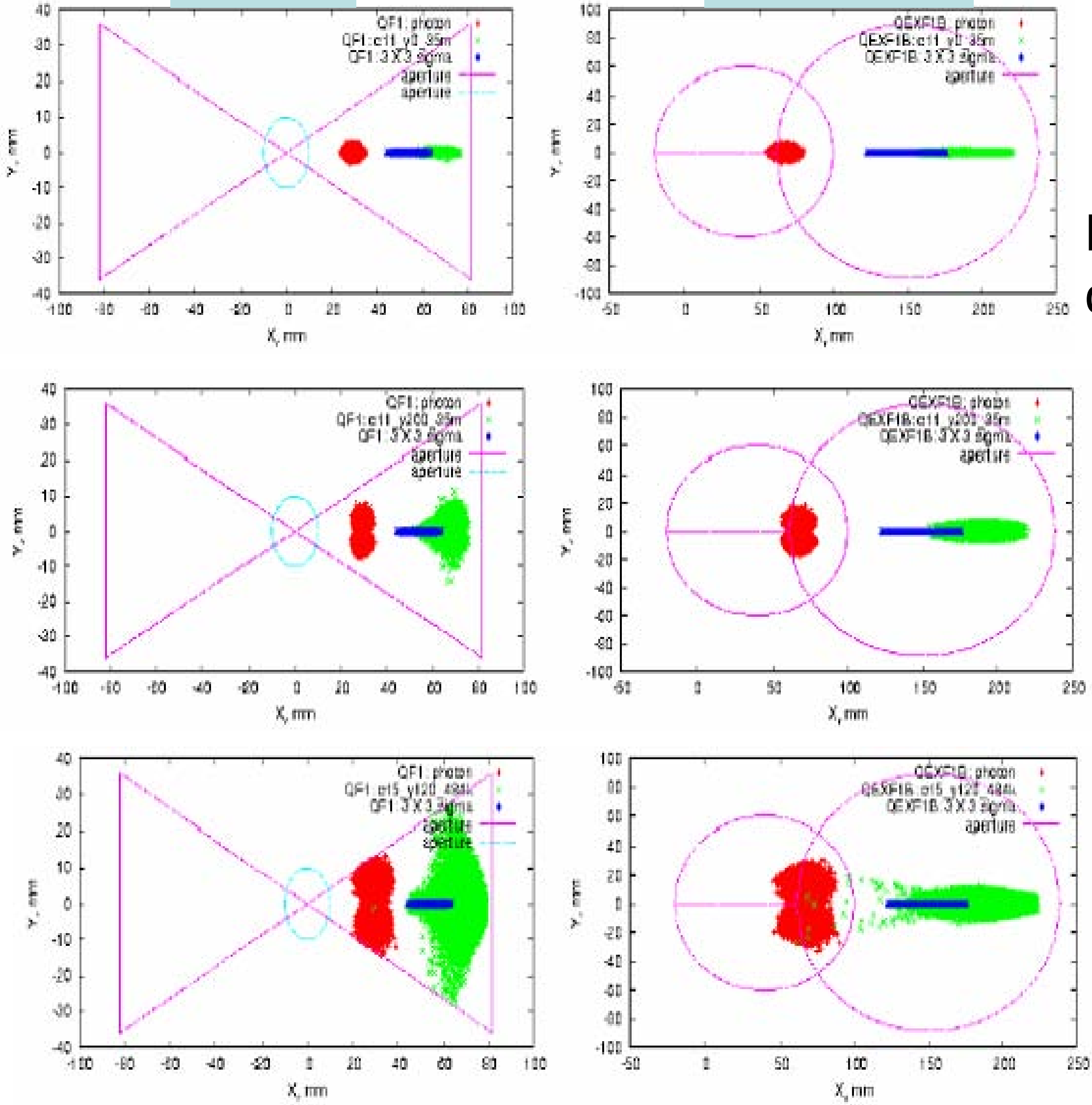


Without sextupoles : Total losses for 1 TeV beam with offset ~ 246 KW

Spot size acceptable for polarimeter chicane?

Beam tracking through the 2 mrad extraction line (old version) : STRUCT

QF1 exit | QEXF1B exit



Beamstrahlung photons
Disrupted beam
$3\sigma_x$ X 3 σ_y beam

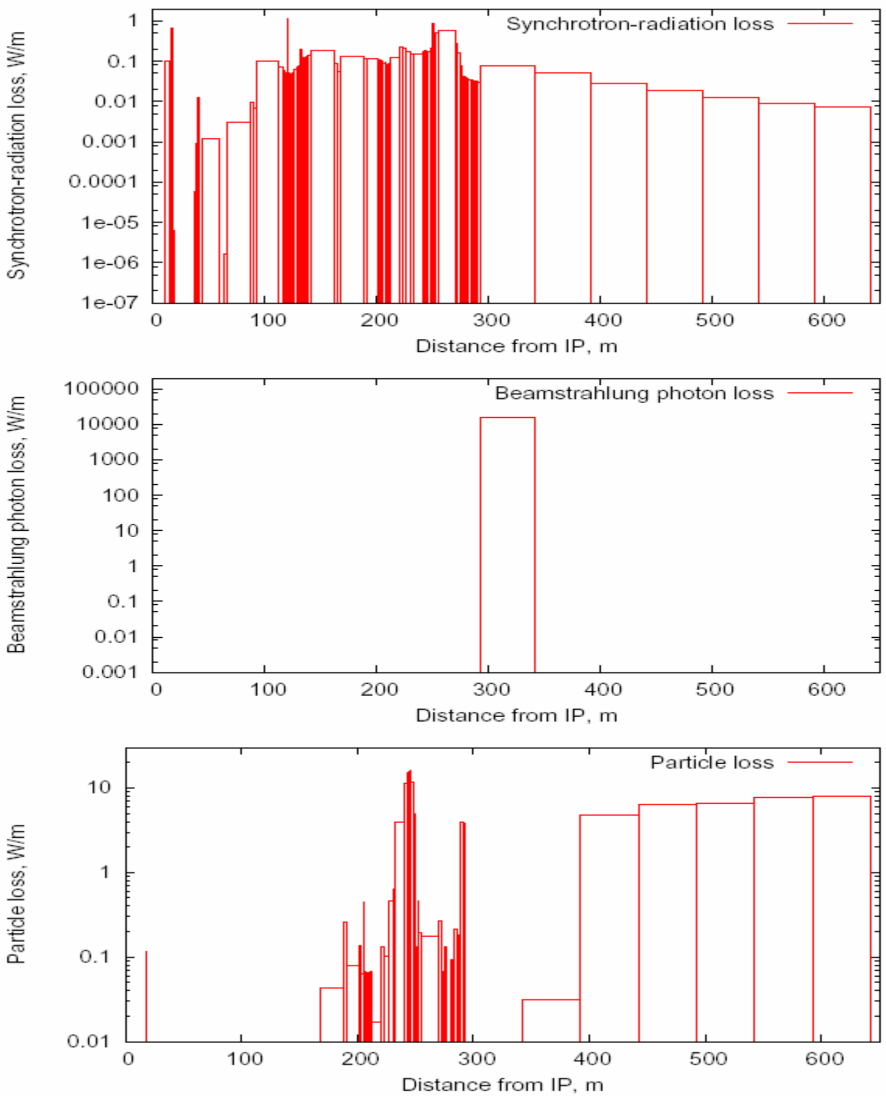
Nominal 250 GeV without vertical offset

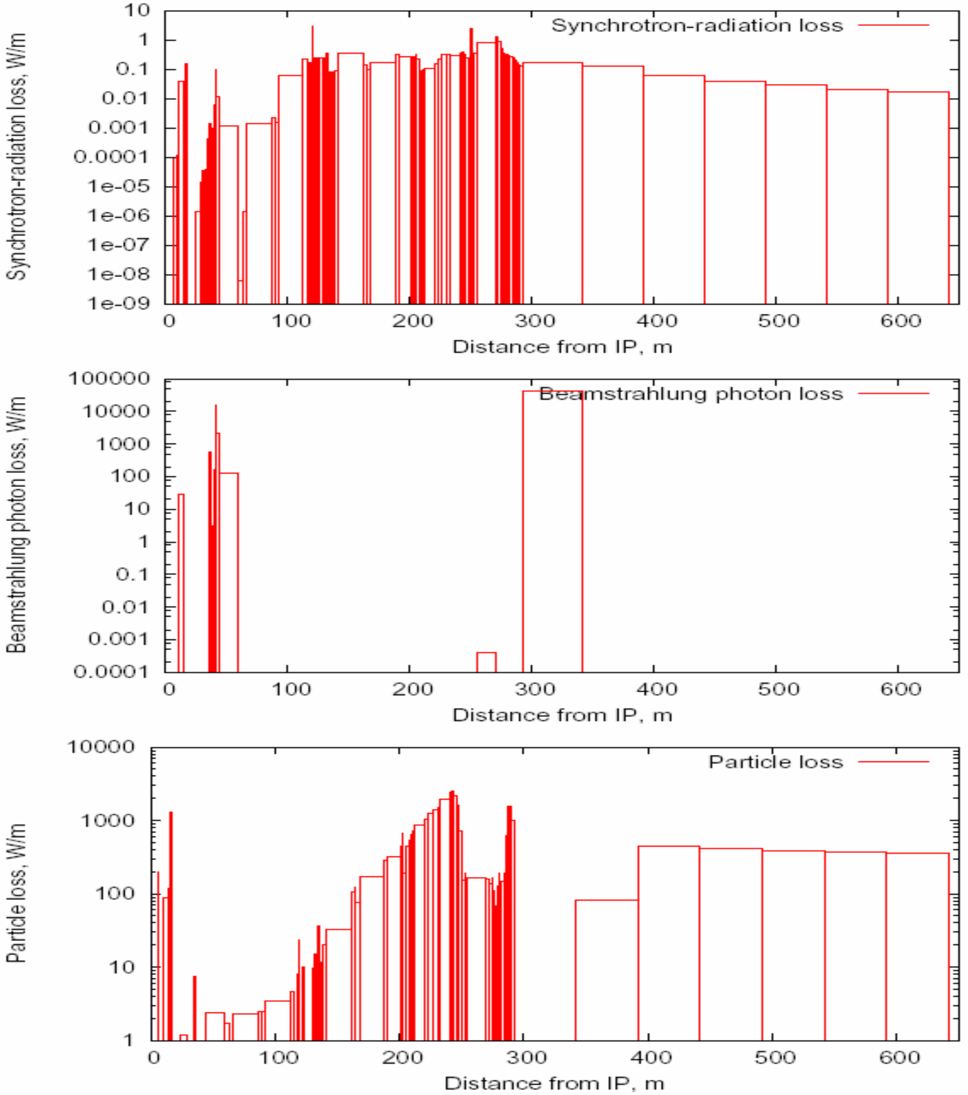
Nominal 250 GeV with vertical offset

High L 250 GeV with vertical offset

A.Drozhdin

Loss distributions along 2-mrad extraction line at 500 GeV CM
Old version – estimated with STRUCT

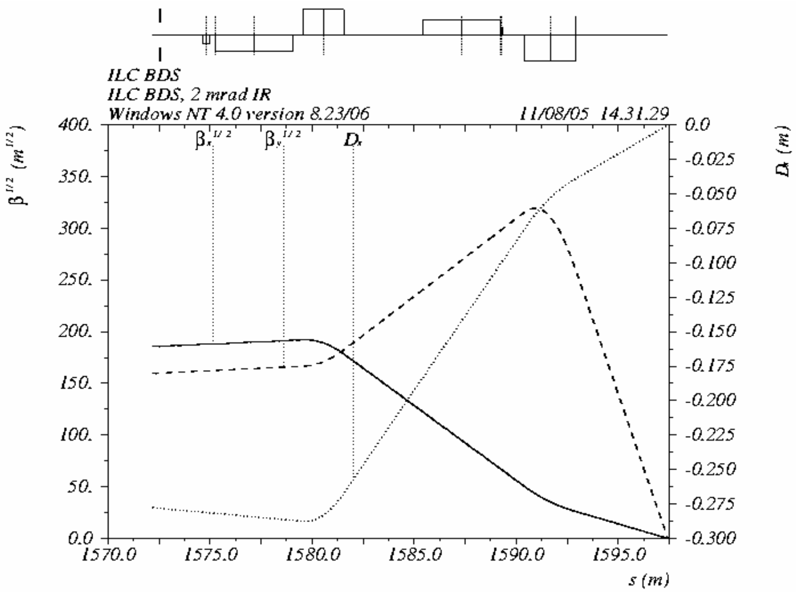


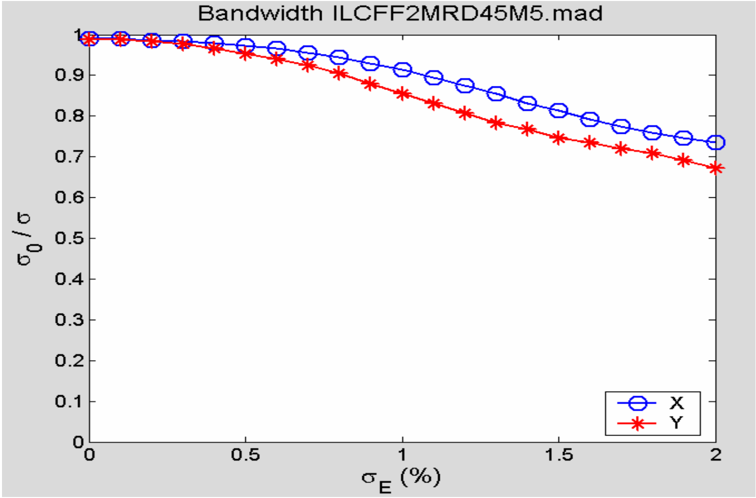


Nominal with vertical offset of 200 nm

High L with vertical offset of 120 nm

2mrad final focus optics design



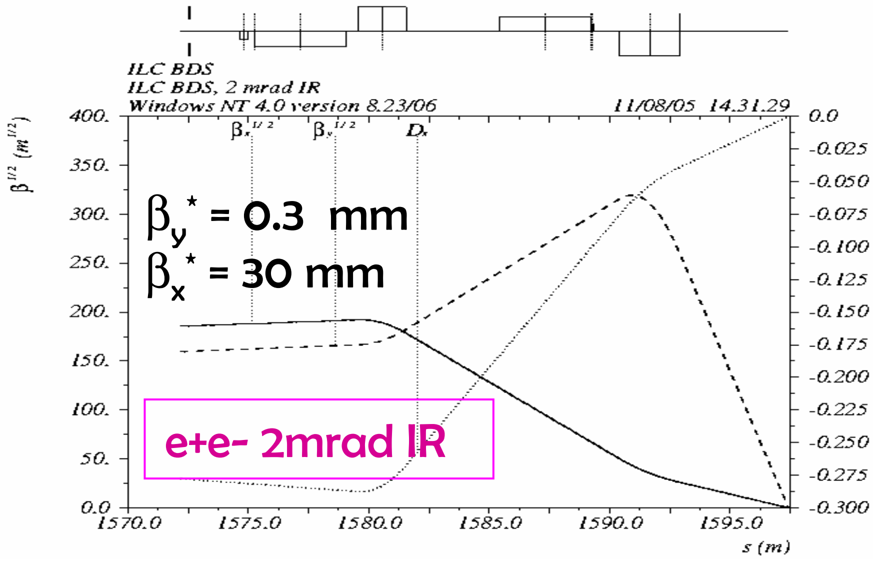


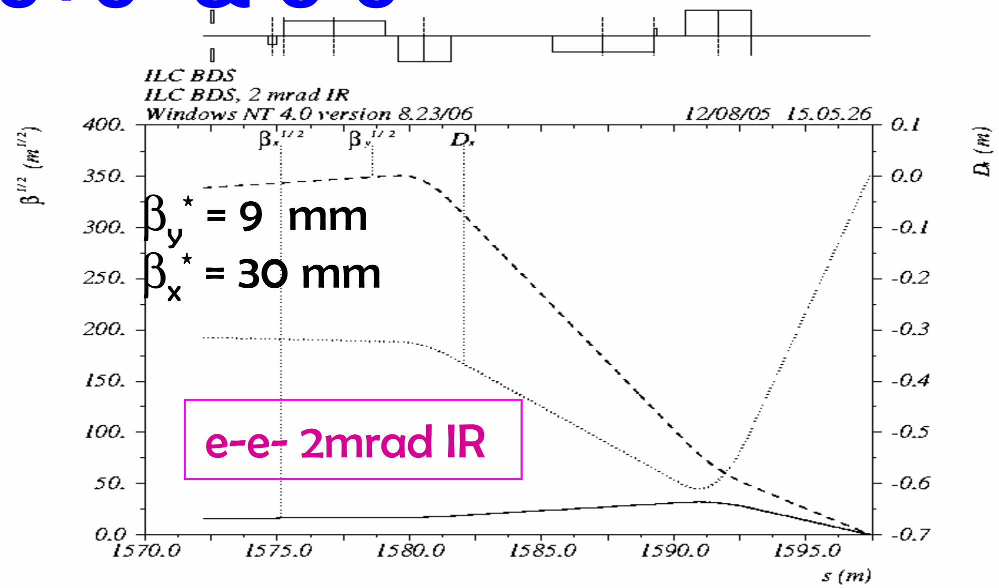
After full FF optimization, the FD parameters are slightly different than what resulted from FD 2mrad extraction optimization.

Optics is not fully optimized:

- Phase advances between collimators and FD are not exact
- Betatron collimator is not fully optimized
- Bandwidth need to be improved, in particular the FD bandwidth (which is important for good collimation properties)

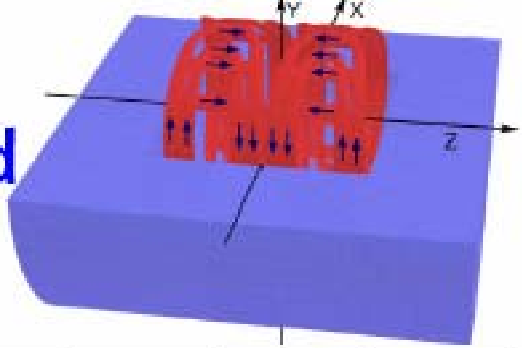
FD for e+e- & e-e-



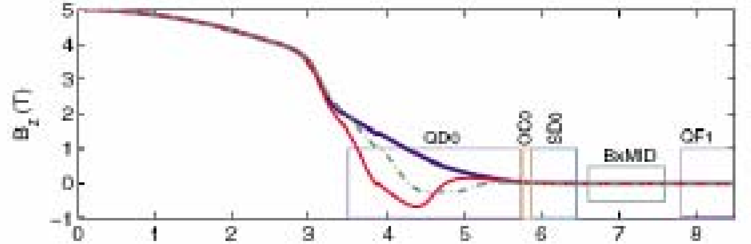


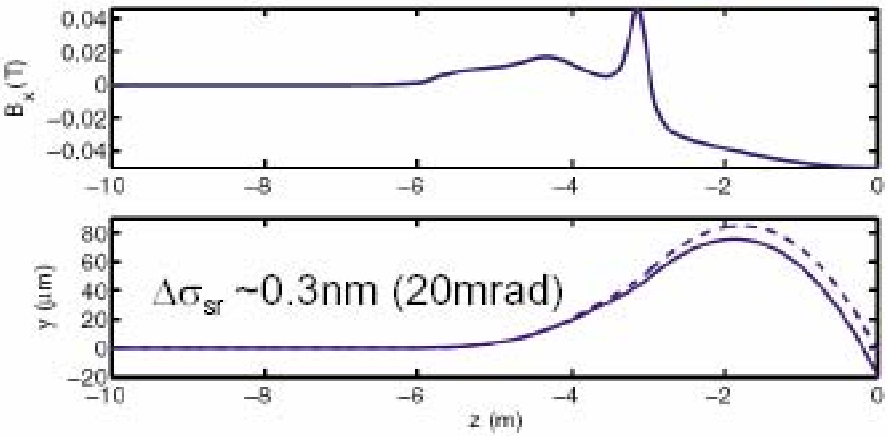
- From the incoming and extraction optics point of view, e-e- in 2mrad IR is feasible
  - Optics constraints require reversing polarity of FD and thus increasing betaY* by about factor of 30
  - The incoming FF optics would require retuning for e-e- option
- The ideal e-e- luminosity is about 8% of e+e-
  - The increased Y size also decreases the disruption of e-e collisions
  - Keep X size similar as in e+e-, to minimize energy tail for extraction
- Increasing increasing Y size is good for feedback and should also be done in 20mrad IR.

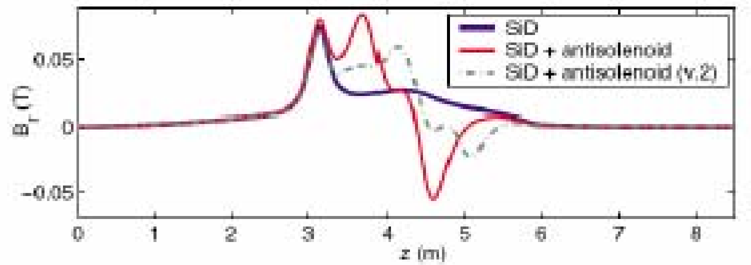
Detector integrated dipole

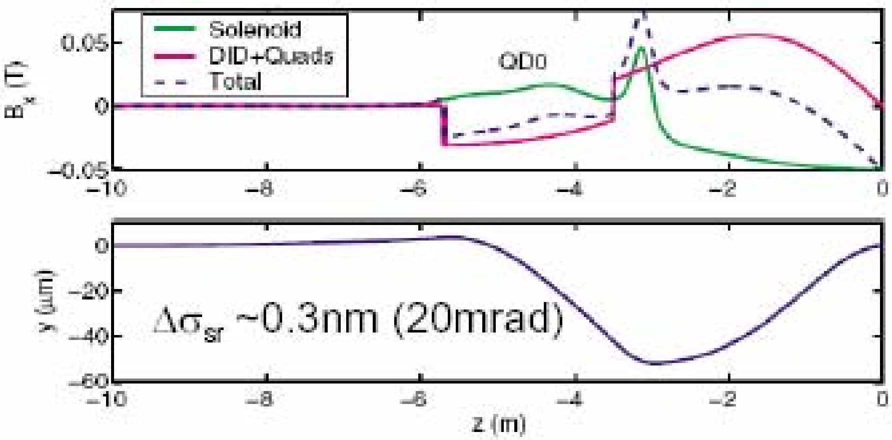


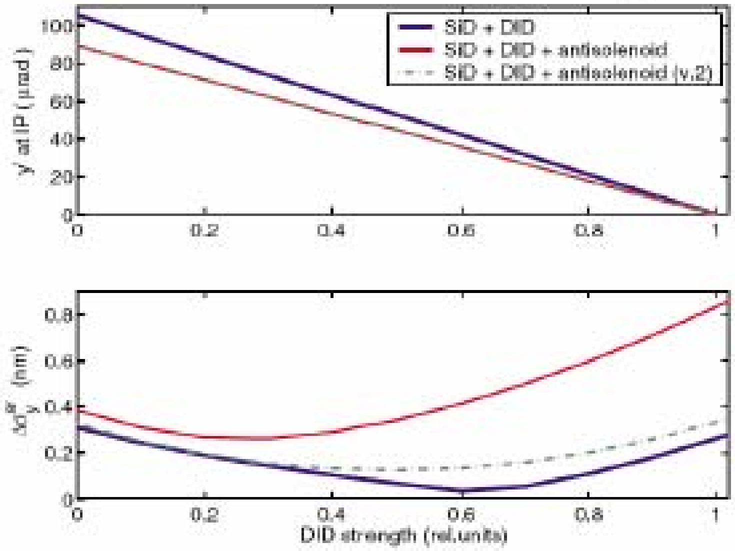
Reduce or zero the vertical angle at IP and simultaneously minimize of SR beam size growth (PRSTAB 8, 041001 (2005))



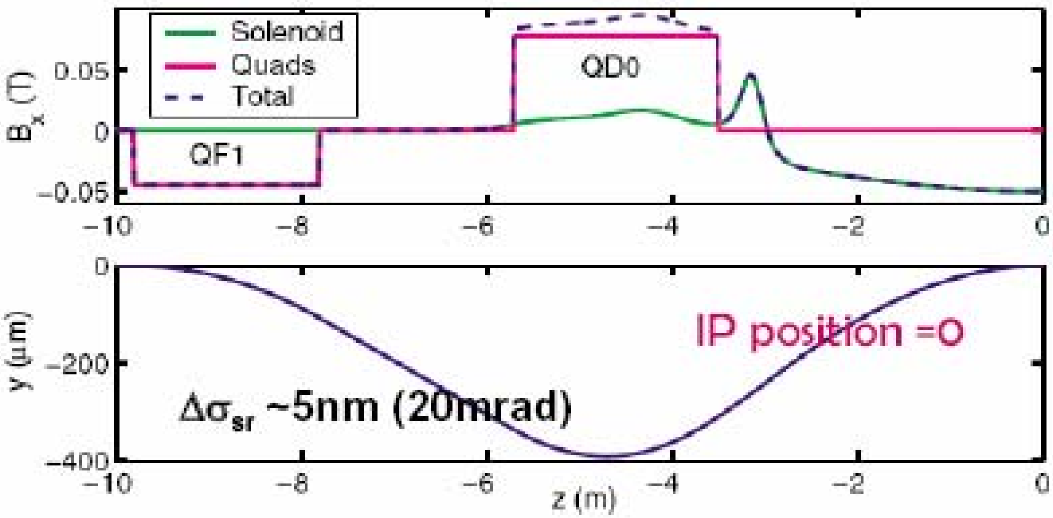




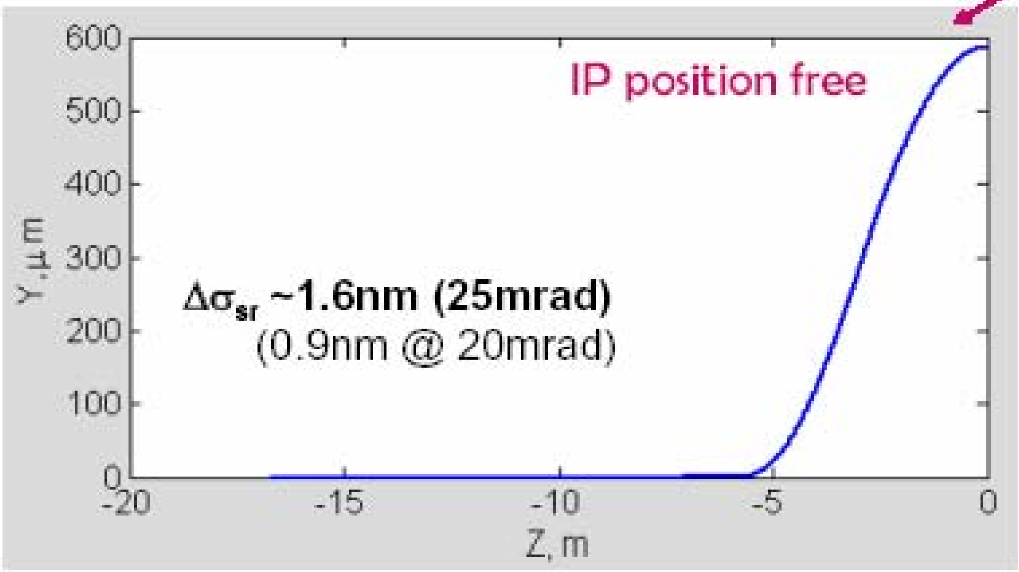




If DID is not used, and angle compensated by FD



- Offset QD0 & QF1 to cancel IP angle & IP offset => too large SR beam size growth



- If one abandon the constraint of IP position fixed w.r.to beamline [V.Telnov, LCWS05], can in principle use only offset of QD0 and SR beam size growth is reduced
- But variation of IP position in the vertex (by 3mm at Z!) created many problems such as reduced collimation depth, etc
- Example shown are for SiD with L*=3.5m and will be worse for longer detectors and L*

Zero Degree Extraction using an Electrostatic Separator

Take another look at using an electrostatic separator and a weak dipole to allow a zero degree crossing angle a la the TESLA TDR.

Problems with the TDR:

1. Dipole, thin copper septum absorbed several kW of beamstrahlung radiation under some steering conditions.

   Proposed solution: **Extract in the horizontal plane to get the dipole septum completely outside the beamstrahlung cone.**

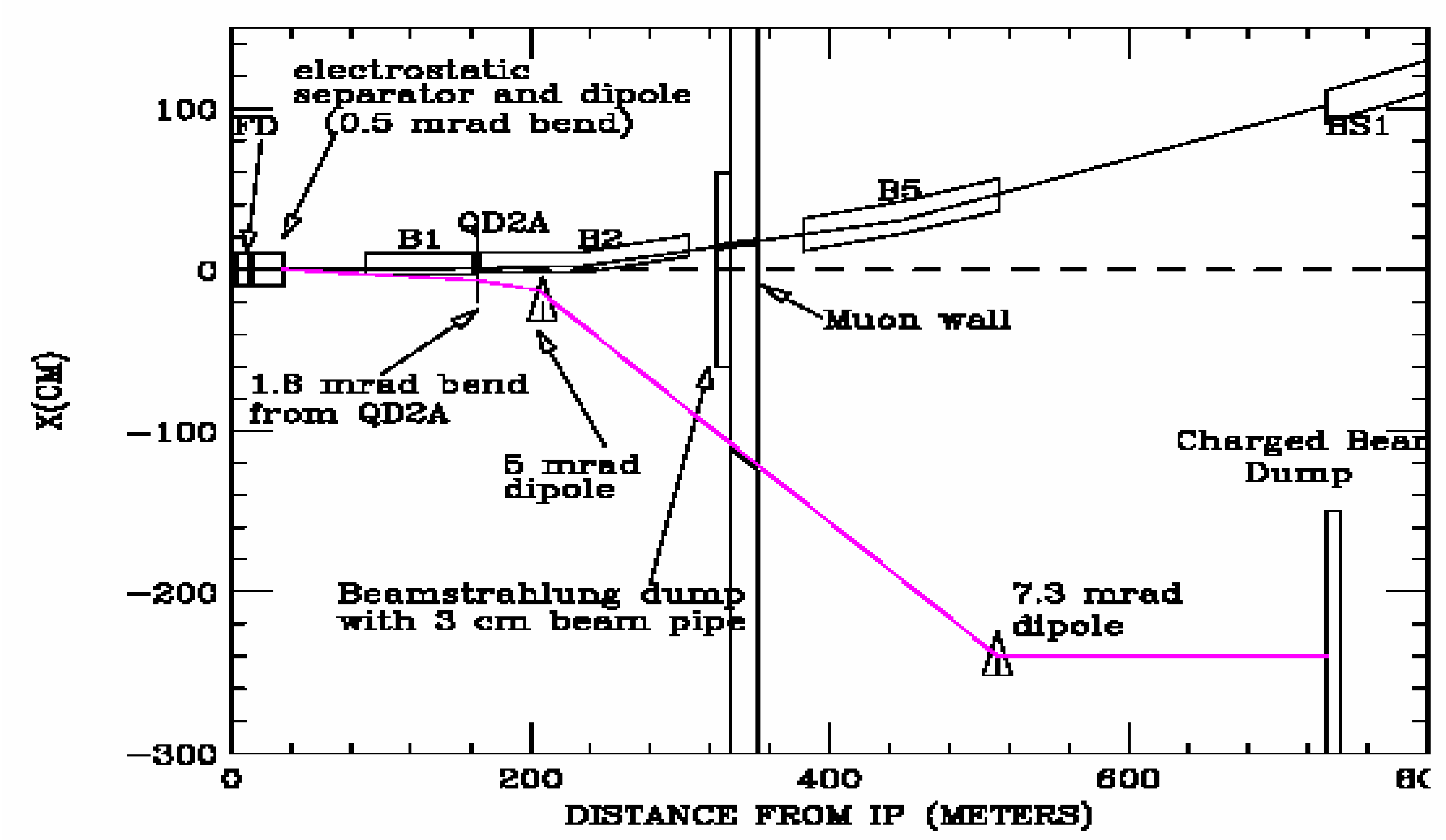
2. Too much beam loss on a synchrotron radiation mask between the separators.

   Proposed solution: **Move the mask closer to the IP and the separator further from the IP, add another mask inboard from the separator for the outgoing synchrotron radiation.**

3. Large electric field (≈100 kV/cm) needed for 1 TeV CM probably not realistic.

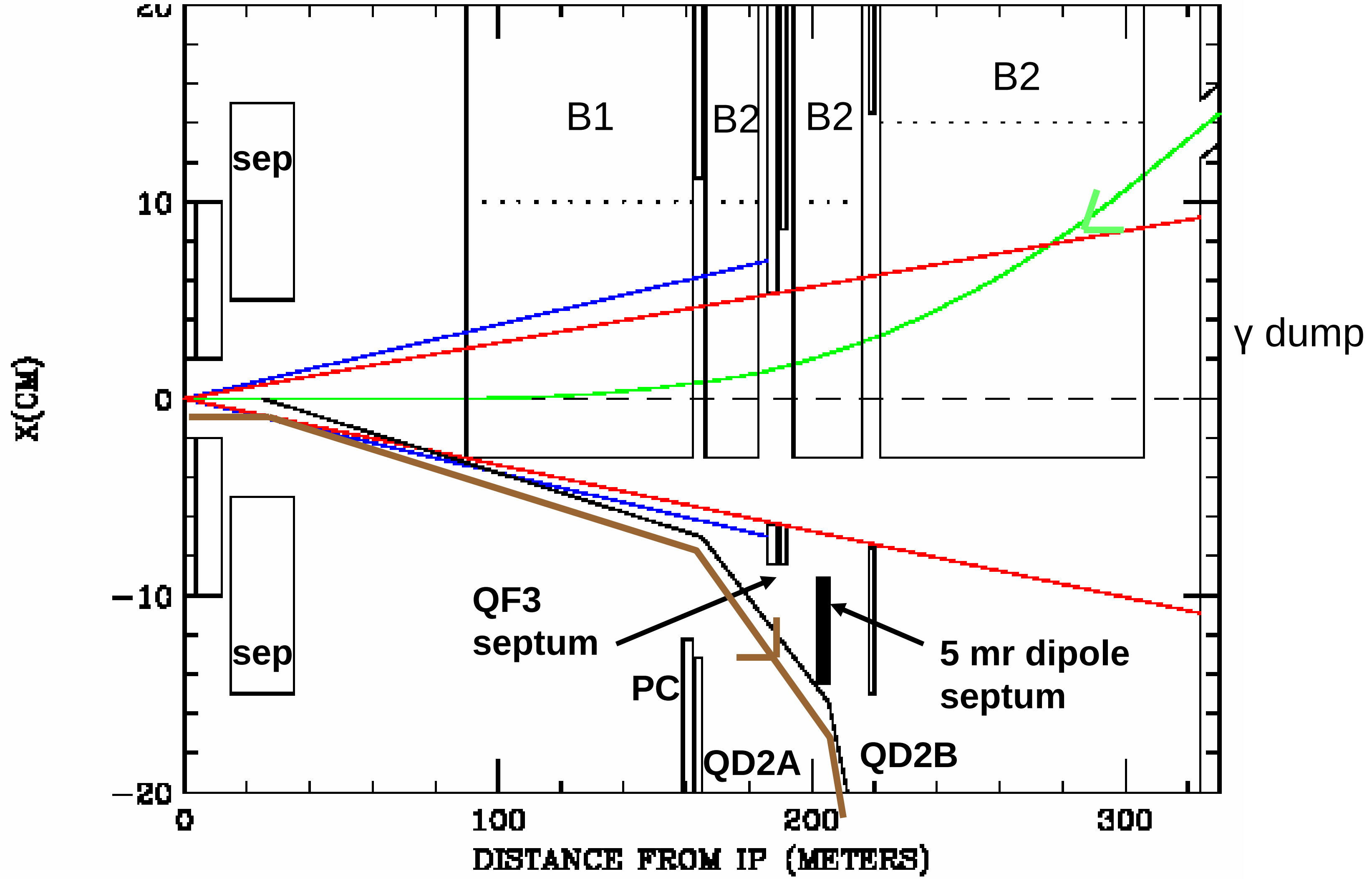
   Proposed solution: **Reduce the maximum electric field to 50 kV/cm at 1 TeV CM (31 kV/cm @ 500 GeV CM).**

Plan View of Zero Degree Extraction from IP to Charged Beam Dump



L. Keller

Plan View of Zero Degree Extraction Showing Beamstrahlung Collimation



L. Keller

Zero Degree Extraction using an Electrostatic Separator

Issues

• Required bunch Separation to avoid parasitic bunch crossing
At 50 m ~ 1.25 cm (@500GeV CM) (horizontal)
~ 2.5 cm for TESLA TDR (in vertical)
Much smaller separation ~650 μ at 1 TeV?
Need to check if these separations are acceptable (O. Napoly).

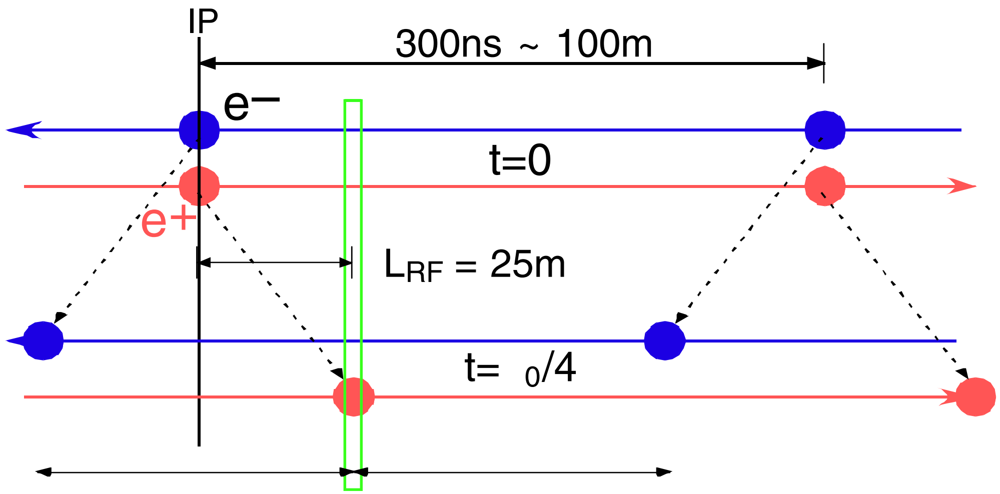
• Overfocussing of low energy tail particles – no quads ~180m, will need to split final doublet into quadruplet.

• Whether energy and polarisation measurements will be possible?

• Beam losses for high luminosity parameters @500 GeV CM (several hundreds of kW on QD2A), effects need to be evaluated.

• To show the feasibility of such design, collaborative efforts needed if this option **could be considered for the baseline design.**

Head-On Collision Option using RF kicker



Out-bunch at the Center of In-bunch

Based on travelling wave concept

• Out-bunch meets the phase velocity Vp→ kicked

•In bunch is placed at the zero position → no kick to first order

→ net deflection is small even in wrong buckets due to wrong Vp

Issues for the RF kicker

- Seek for material for kicker core (FINEMET, **Sedust (solid, dust), Ferrite)**
  - **Prototypes being tested**
- Q-values at large gap? (electrical)
- Vertical kick by fringing field? (mechanical)
- Beam chamber has to be made of insulator. <Shield by thin metal (copper)?>
- **Abort kicker (MPS) (failure of dipoles may cause more serious problems?)**
- **Chain of kickers with higher frequency? (similar to crab cavity)**

Y.Iwashita

Layout : Issues

- Design strategy for fast extraction and tune up
- Detailed performance evaluation of 2 mrad
- Collimation depths and performance
- L*, VTX radius, solenoid field updates, DID
- Detector assembly procedures : large external sizes of QD0, SD0, QF1, SF1
- R22=+0.5 for polarisation measurement to reduce polarisation systematics as suggested by K. Mönig.
- Location and space required for the crab cavities
- Head-on? {possible modifications to TESLA scheme, RF kicker}
- Beam dumps in the present layout, cost?