2 mrad crossing-angle IR challenges

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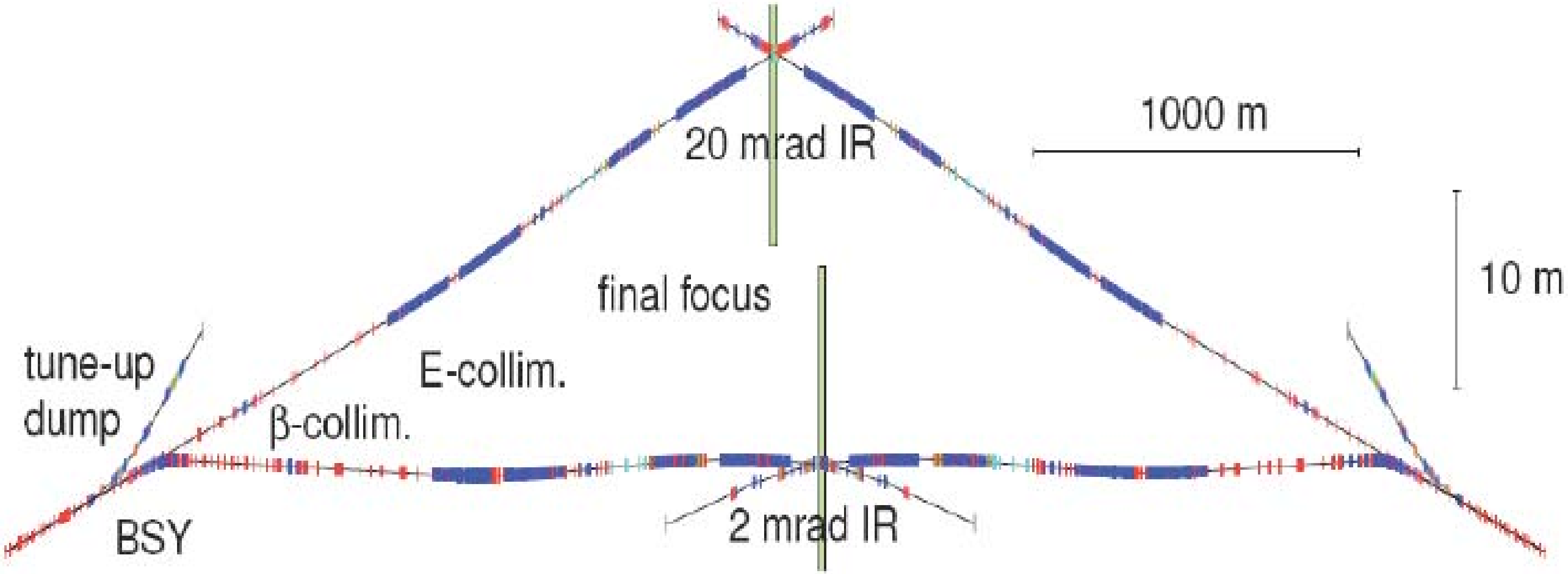
Mini-worshop of small x-angle design challenges

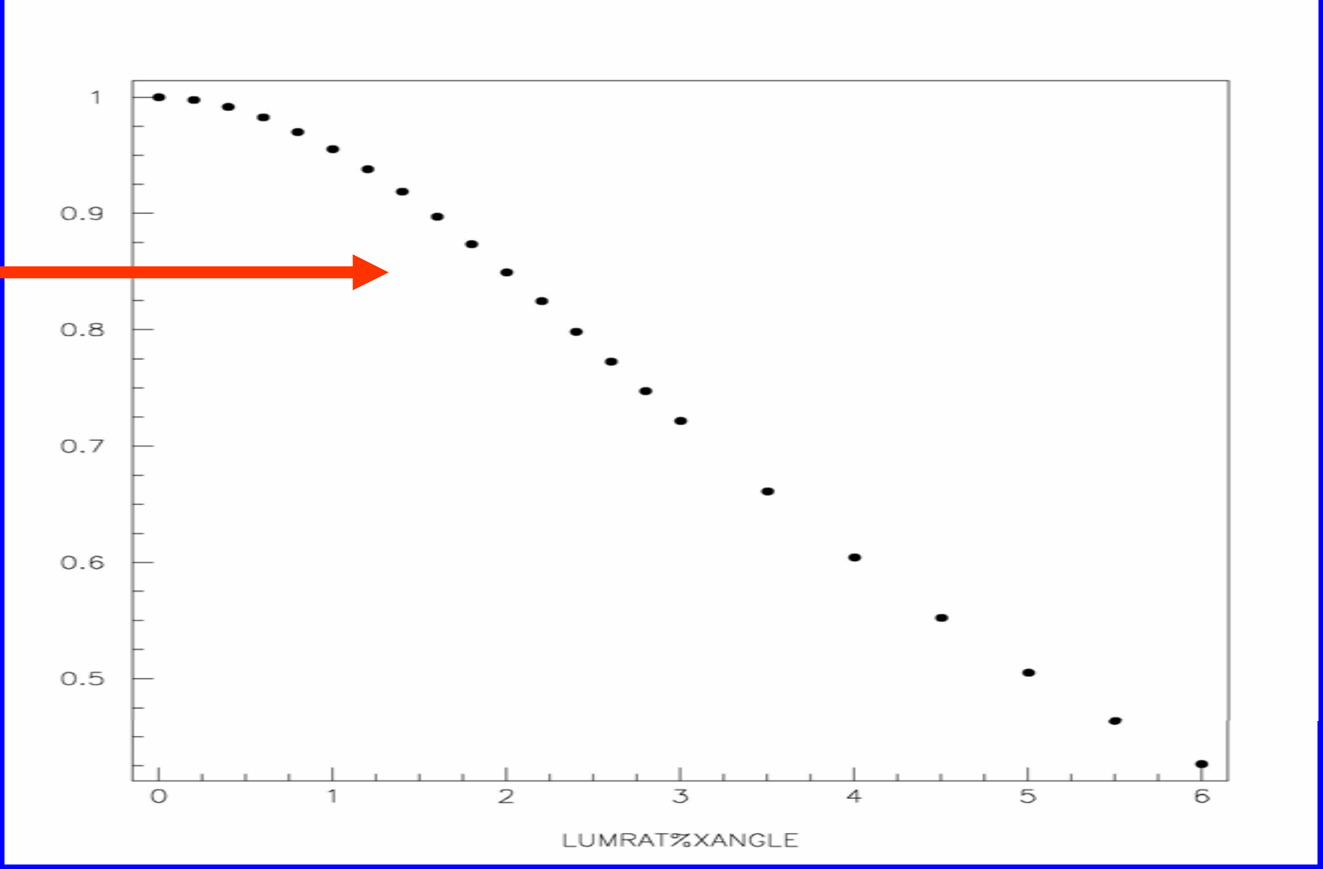
Orsay & Saclay, 19-20 October 2006

The **old** baseline



The baseline is now 14mrad/14mrad (14mrad was derived from the 20mrad and is technological easier and cheaper than the 2mrad)

Luminosity loss without crab-crossing (perfect conditions)



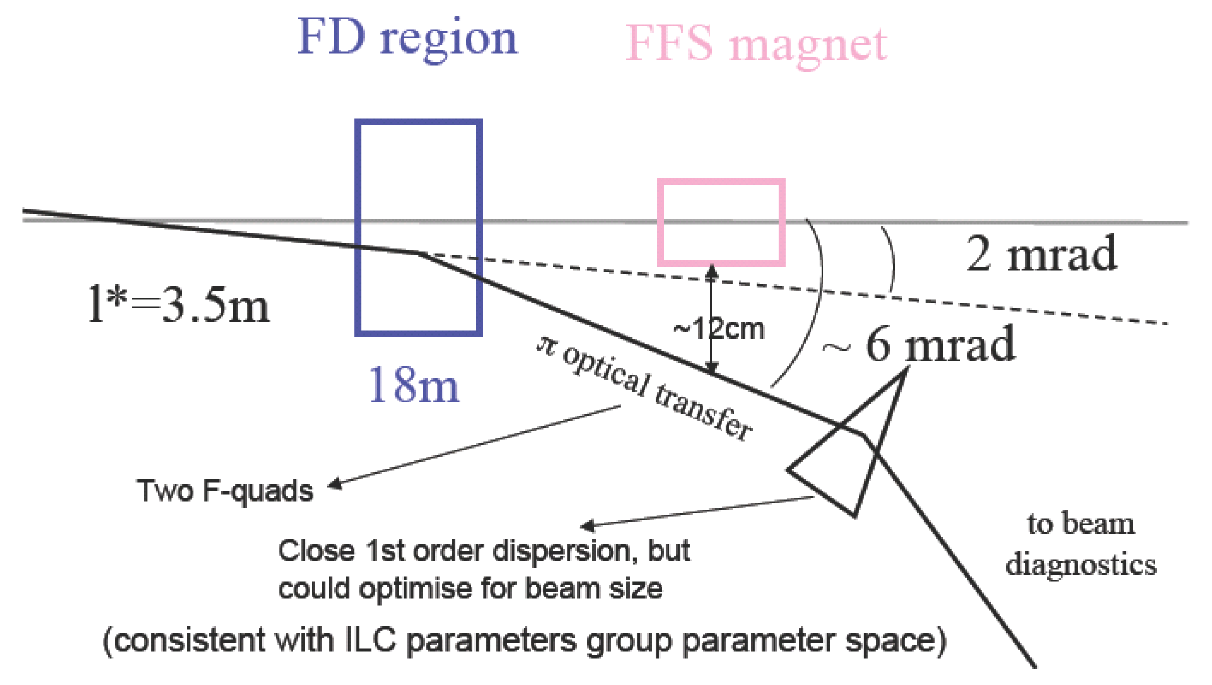
L/L_0

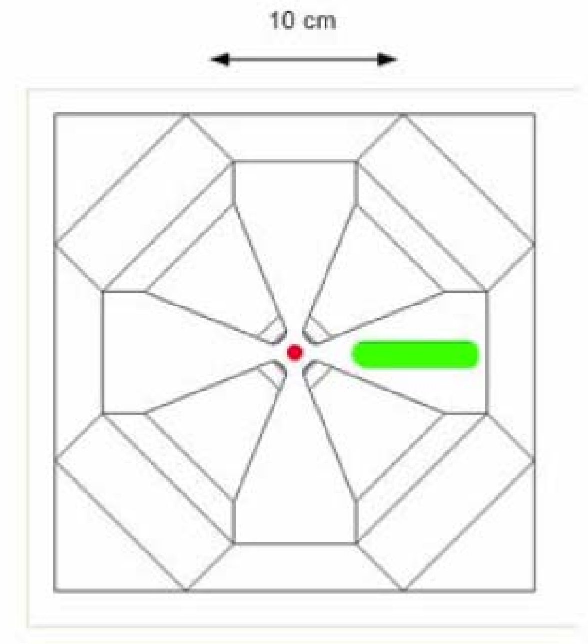
~ 0.85

2θ[mrad]

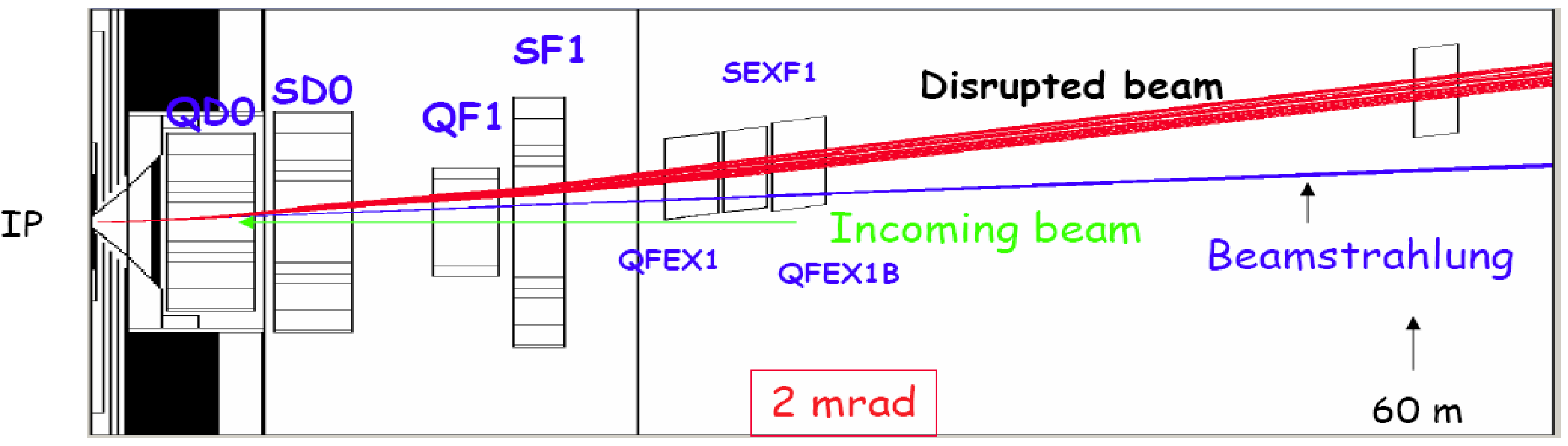
20 mrad → $L/L_0 \sim 0.2$

Principle of 2 mrad extraction

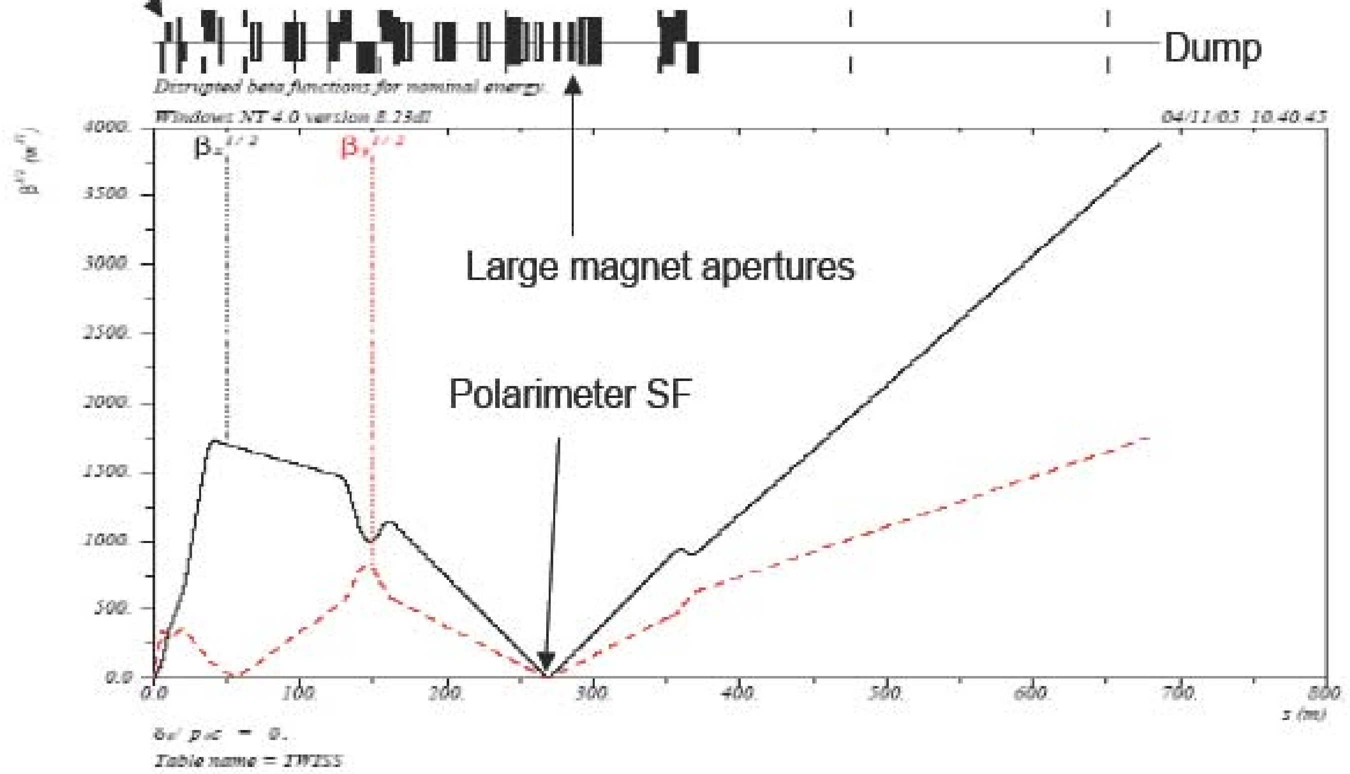




QF1



Status of the 2mrad line



Large power losses

Dump

Large magnet apertures

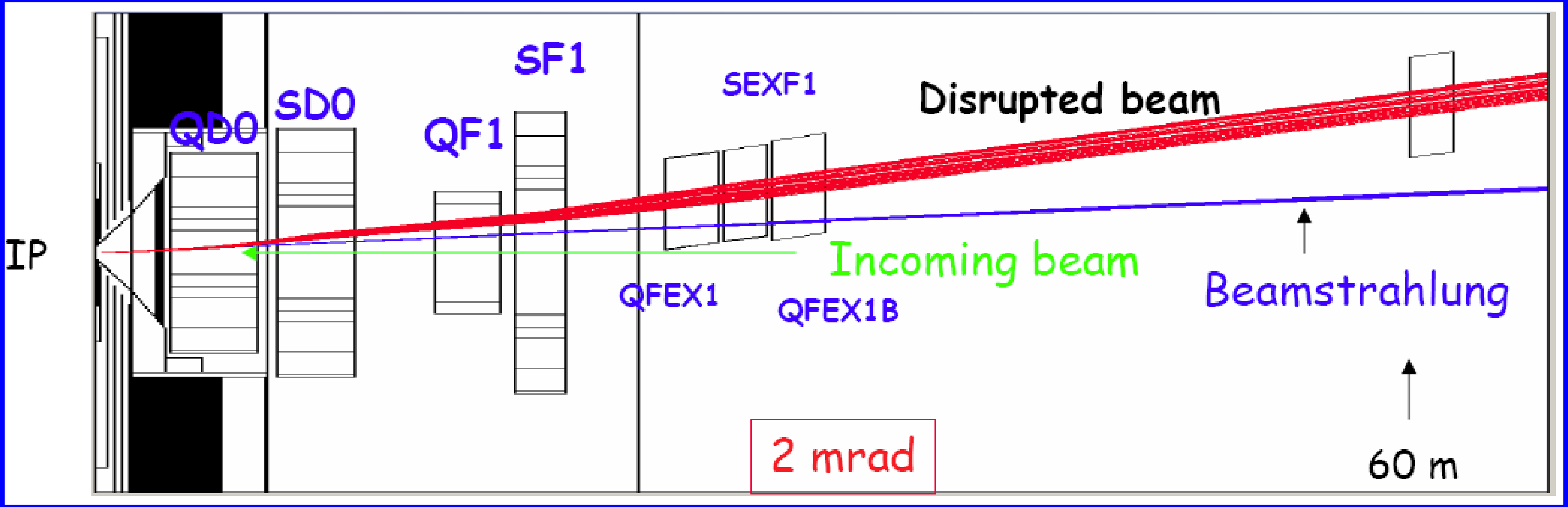
Polarimeter SF

  - downstream diagnostics
  - Collimators and optics for beam blow-up
- FD region: large-bore SC sextupoles, QD0 with g=160 T/m

Talks from yesterday's session

- Design challenges of the 2mrad scheme
  O. Napoly
- Extraction beam line design principles
  R. Appleby
- Collimation requirements
  F. Jacksson
- Final doublet optimisation
  R. Appleby
- Limits on SC final doublet magnets
  G.-L. Sabbi
- Limits of RF deflectors and availalability of other devices
  Y. Iwashita

Final Doublet optimisation



Magnet type	Bore radius, mm	Field at radius, T	Eff. length, m	type
Quad QD0	35	5.6	2.5	SC
Sextupole SD0	88	4.0	3.8	SC
Quad QF1	10	0.68	2.0	NC
Sextupole SF1	112	2.12	3.8	NC
SeptumQEX1A	113	1.33	3.0	NC

LC optimised luminosity → trade-off between:

- total power $P_{\text{electrical}}$
- beamstrahlung emission δ_{BS}
- vertical emittance ε_y
- (for given E_{CM} and power transfer efficiency η)

$$L \sim \frac{n_b N_e^2 f}{4\pi\sigma_x\sigma_y} H_D$$

$$\delta_{BS} \sim \frac{N_e^2 E_{cm}}{\sigma_z(\sigma_x+\sigma_y)^2}$$

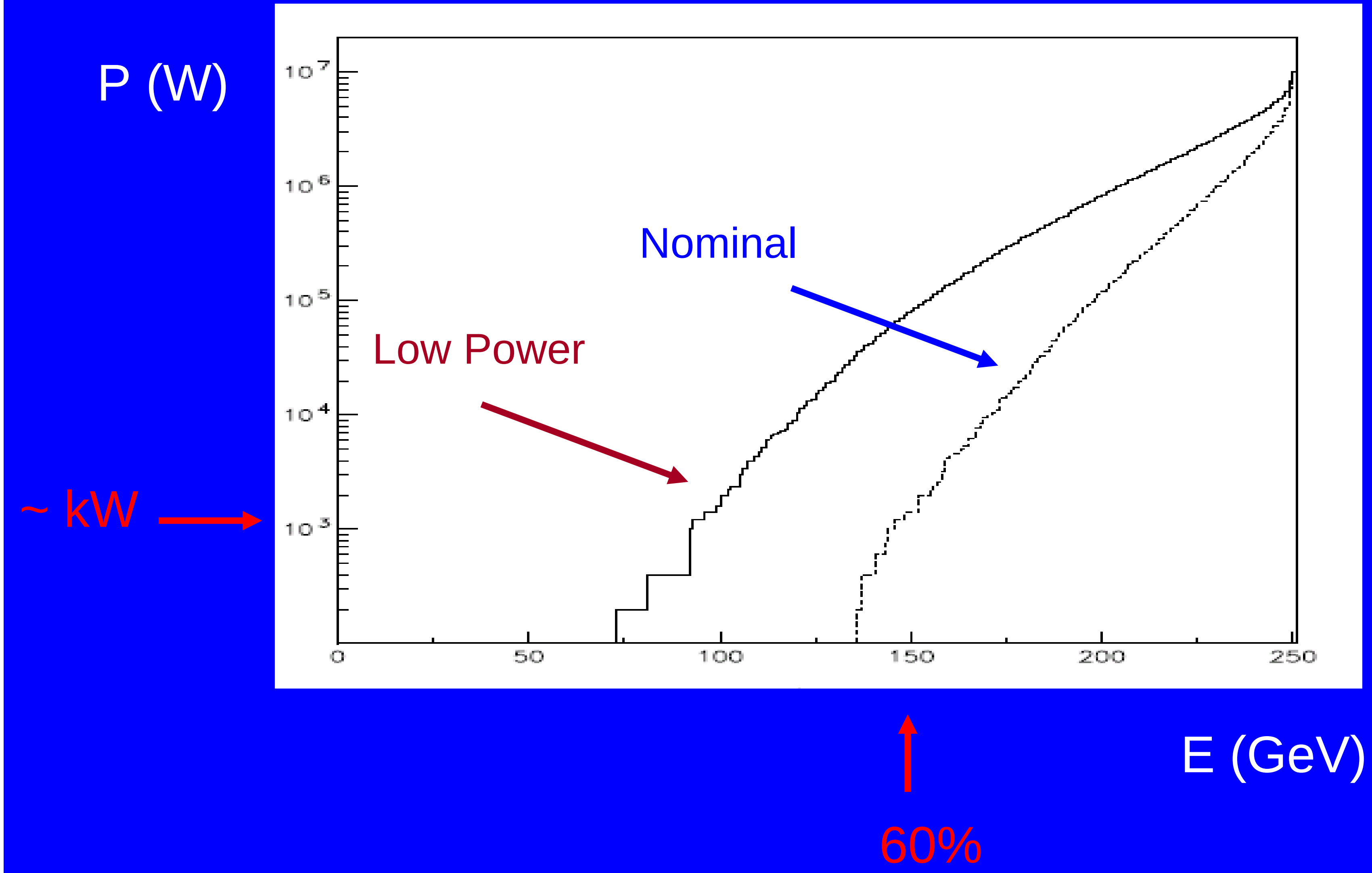
SET $\sigma_z \lesssim \beta_y$

$$\sigma^2 = \varepsilon_n \beta$$

$$\longrightarrow \qquad L \sim \eta \frac{P_{\text{electrical}}}{E_{CM}} \sqrt{\frac{\delta_{BS}}{\varepsilon_{n,y}}} H_D$$

Nominal ↔ Low Power ILC parameters

Post-IP transport needs large energy acceptance
0-2 mrad : bending & shared magnets → harder



Snowmass final doublet losses (All powers in W)

	Beam	QD0	SD0	QF1	SF1
500 GeV	Low P (cb)	7.6	0	0	470
	Low P (rb)	0.39	0	0	0.10
	High L (cb)	91.9	0	0	1400
	High L (rb)	0.97	0	0	0.25
1 TeV	Low P (cb)	756	0	7.6	95.4
	Low P (rb)	1.2	0	0	0.34
	High L (cb)	8431	0	190	878
	High L (rb)	3.6	0	0.1	0.92

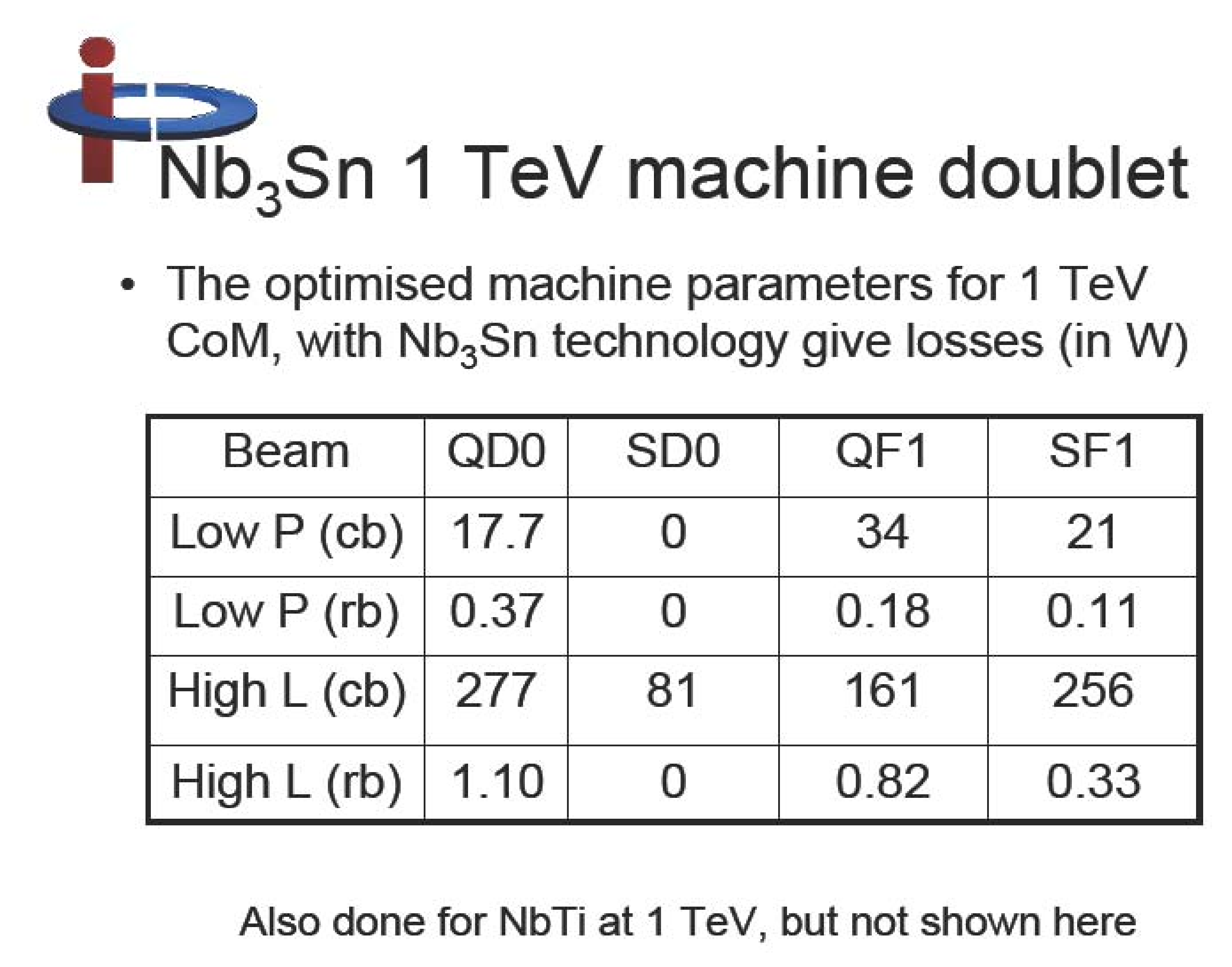
cb=charged beam losses rb=radiative bhabha losses

- Redesign of final doublet region of small crossing angle scheme using
  - NbTi SC magnets with g=180 T/m
  - Nb_3Sn SC magnets with g=250 T/m

NbTi 500 GeV machine doublet

- The optimised machine parameters for 500 GeV CoM give a much shorter QD0. The beam power losses are then (in W):

Beam	QD0	SD0	QF1	SF1
Low P (cb)	0	0	0	0
Low P (rb)	0.05	0.1	0	0
High L (cb)	0	4.1	11.6	0
High L (rb)	0.13	0.25	0.13	0



Nb_3Sn 1 TeV machine doublet

- The optimised machine parameters for 1 TeV CoM, with Nb_3Sn technology give losses (in W)

Beam	QD0	SD0	QF1	SF1
Low P (cb)	17.7	0	34	21
Low P (rb)	0.37	0	0.18	0.11
High L (cb)	277	81	161	256
High L (rb)	1.10	0	0.82	0.33

Also done for NbTi at 1 TeV, but not shown here

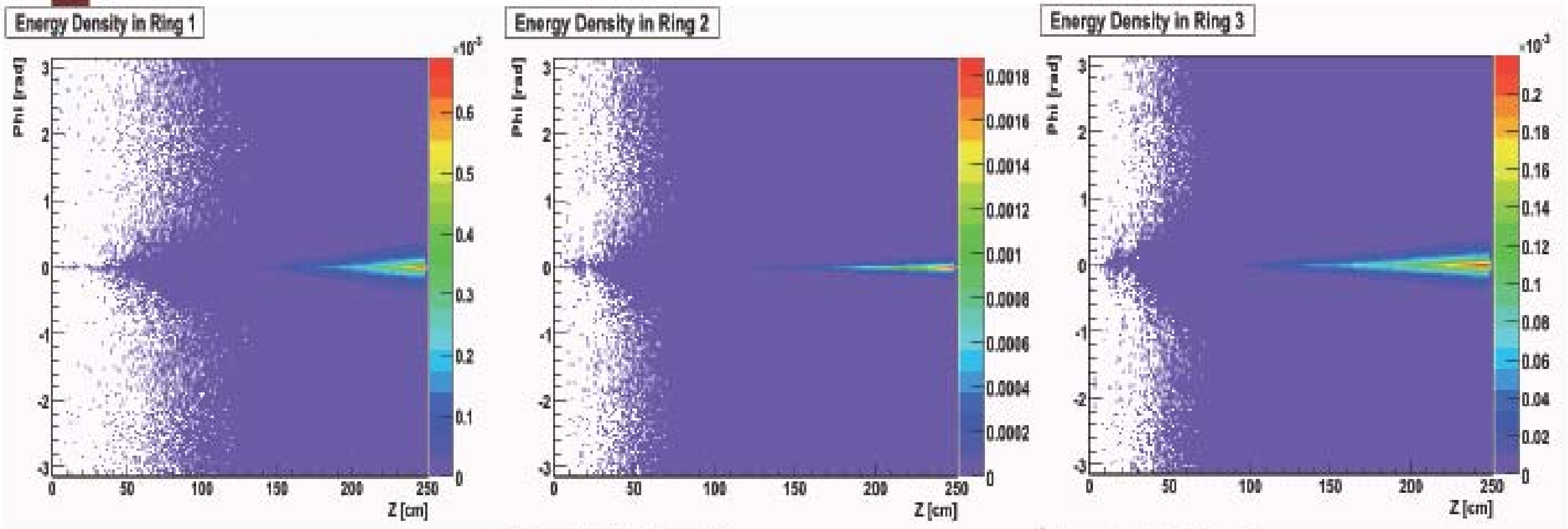
Max. pole-tip field assumed = 8.8 T

11 T ⇒ losses OK for Low Power ILC parameters

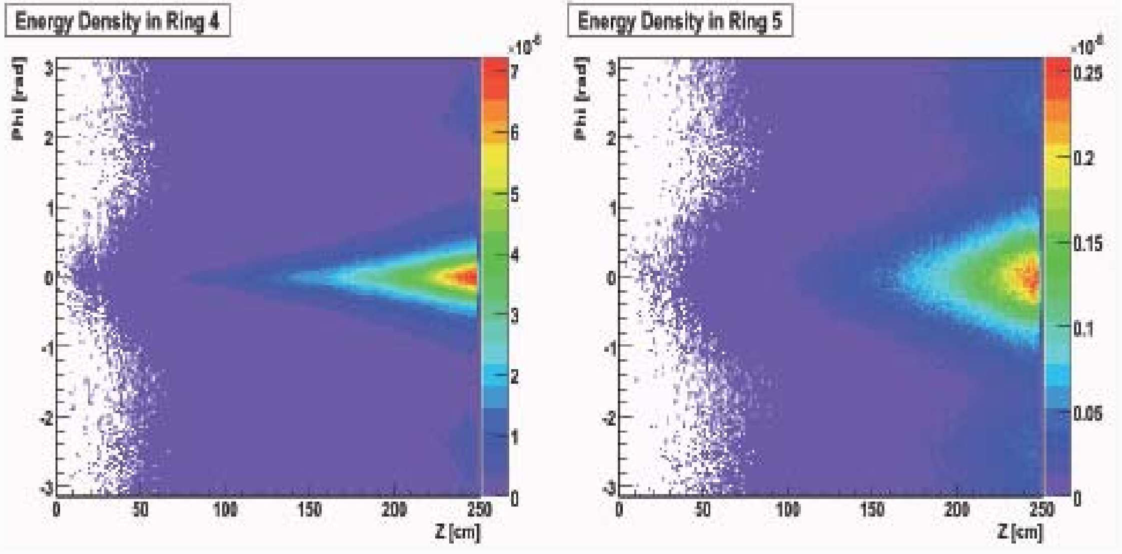
NbTi 500 GeV magnet parameters

Name	Length [m]	Strength	Radial aperture [mm]	Gradient [T/m]	Pole-tip field [T]
QD0	1.23	-0.1940 m^{-1}	39	162	6.3
SD0	2.5	1.1166 m^{-2}	76	-	2.69
QF1	1.0	0.0815 m^{-1}	15	70	1.02
SF1	2.5	-0.2731 m^{-2}	151	-	2.59

2mrad Losses - QD0 Power Density Maps for 250 GeV beam nominal parameters



- Power density maps for the first 5 rings (6th ring had no deposits)
- All density units in W/g

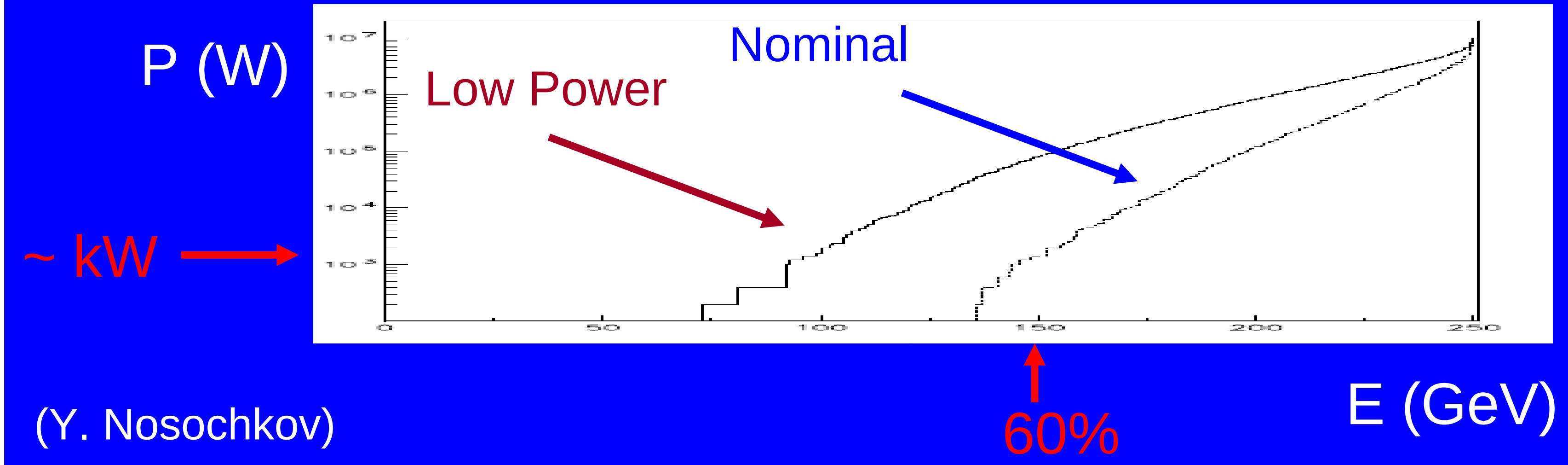


2mrad Losses - Radiative Bhabhas into QD0 (using SiD Solenoid Field)

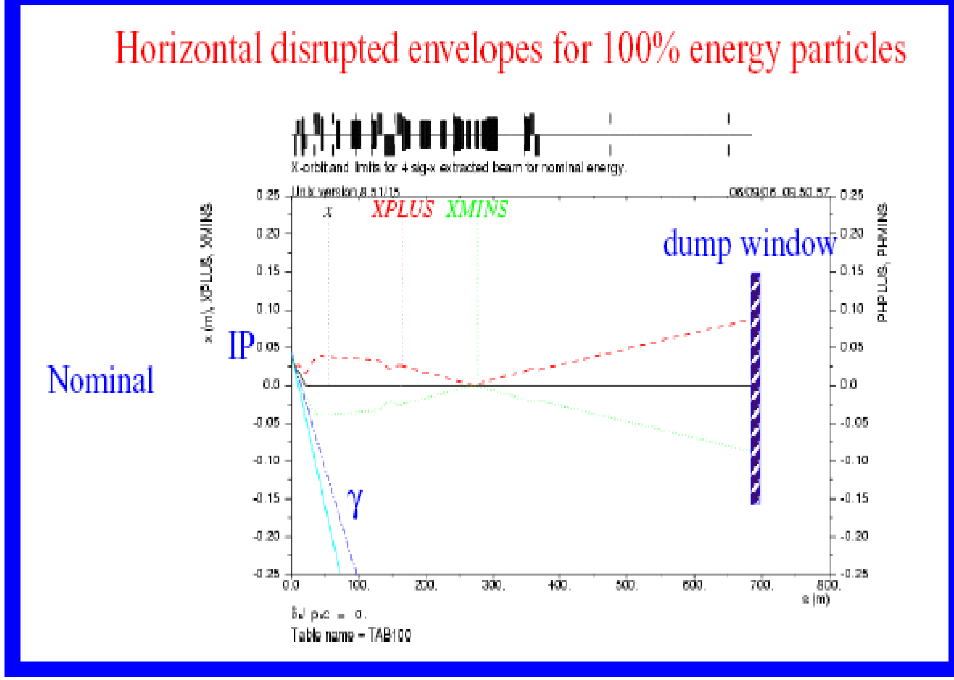
- Tracking in BDSIM with shower development to give energy deposition
- Assumed Coil is 100% NbTi with density 5.6g/cm^3 @ 4Kelvin from R=35mm to 200mm (i.e. no support structure or gaps between 4 coils, etc. accounted for).
- Using Tungsten liner with 3mm thickness (~1 radiation length), density = 19.3g/cm^3
- Total energy deposits recorded per segment with showers tracked down to 10KeV (charged and neutral)

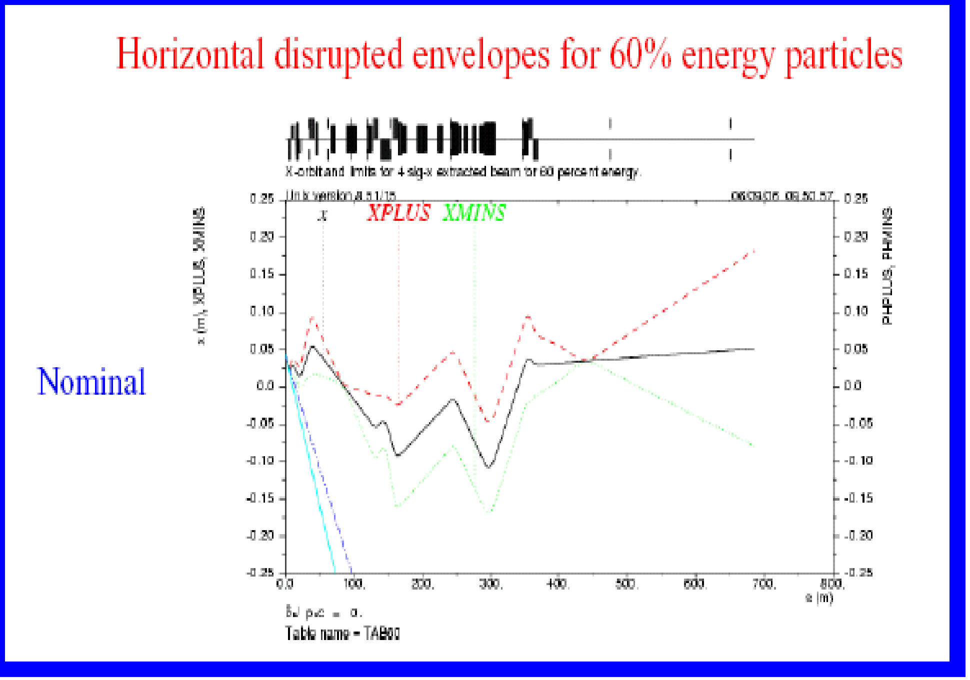
		Total Extracted Power [W]	Total Incident Power [W]	Total Power deposited in beampipe & Coils R<20cm [W]	Peak Power Density in Beampipe [mW/g]	Peak Power Density in NbTi Coils [mW/g]
cs11	No Liner	70.498	0.45 ± 0.01	0.27 ± 0.01	0.71 ± 0.03	1.90 ± 0.07
	Tungsten Liner		0.61 ± 0.02	0.13 ± 0.004	0.26 ± 0.01	0.11 ± 0.01
cs15	No Liner	161.37	1.07 ± 0.09	0.60 ± 0.05	1.60 ± 0.15	4.27 ± 0.41
	Tungsten Liner		1.44 ± 0.12	0.32 ± 0.03	0.61 ± 0.05	0.27 ± 0.02
cs21	No Liner	179.12	1.12 ± 0.07	0.65 ± 0.04	1.35 ± 0.08	4.11 ± 0.23
	Tungsten Liner		1.49 ± 0.09	0.34 ± 0.02	0.67 ± 0.04	0.30 ± 0.02
cs25	No Liner	483.03	3.61 ± 0.31	2.08 ± 0.18	4.41 ± 0.38	13.7 ± 1.2
	Tungsten Liner		4.95 ± 0.43	0.69 ± 0.07	1.40 ± 0.15	0.62 ± 0.07

Post-IP transport needs large energy acceptance
0-2 mrad : bending & shared magnets → harder

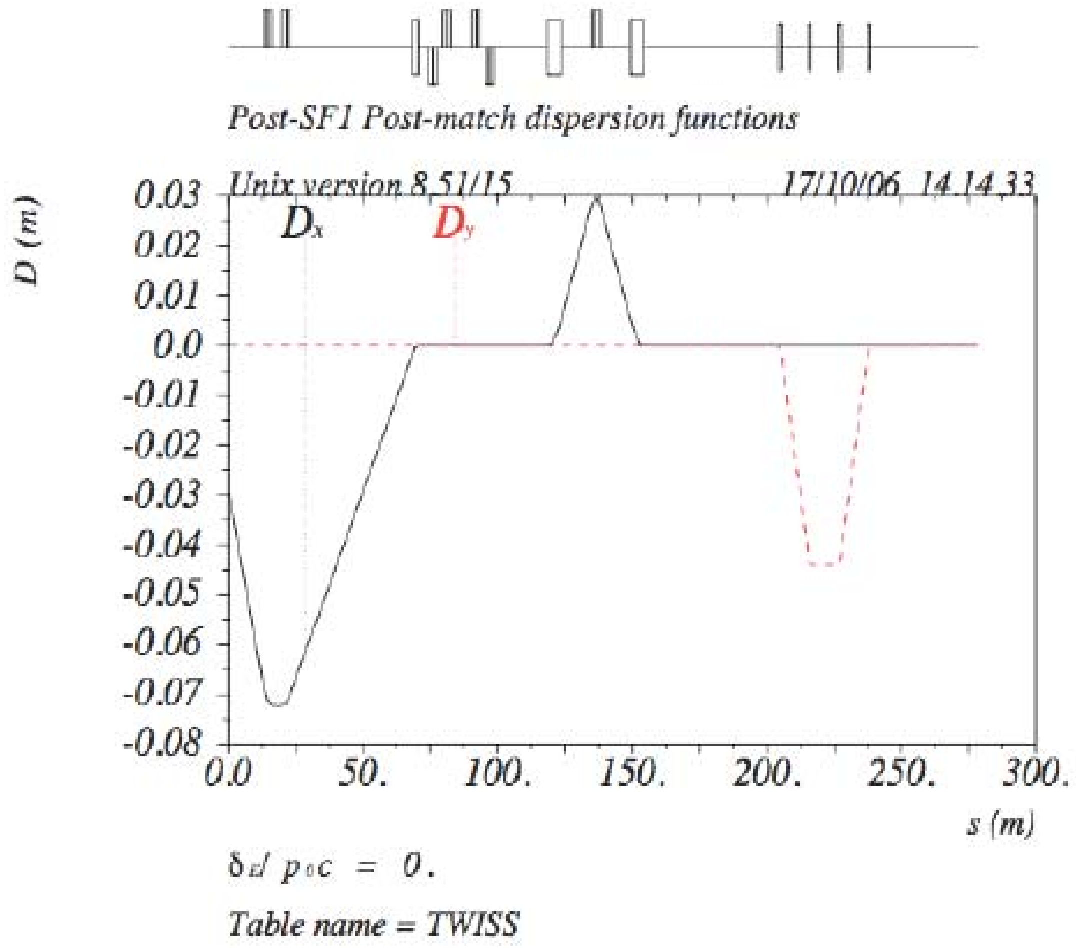


(Y. Nosochkov)

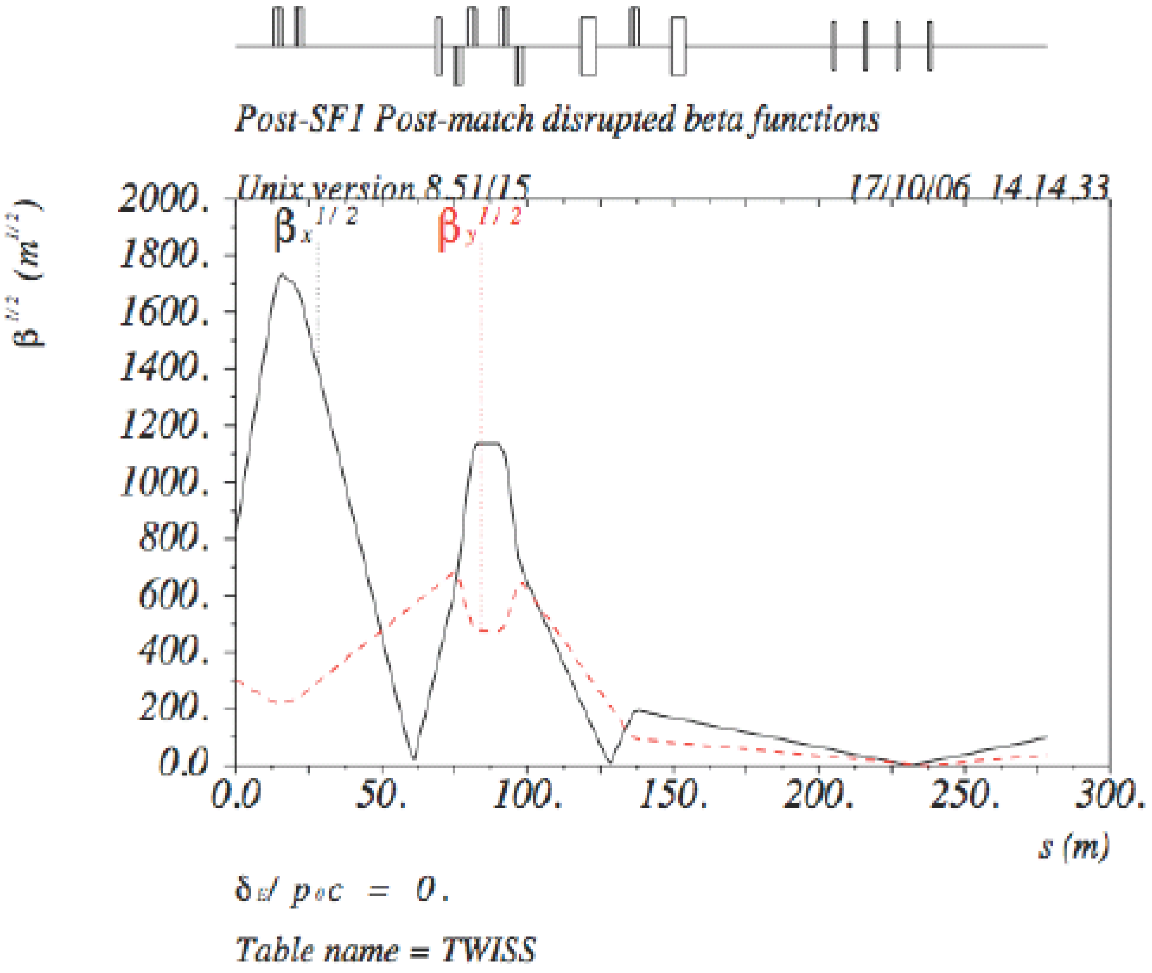

Horizontal disrupted envelopes for 100% energy particles


Horizontal disrupted envelopes for 60% energy particles

Baseline lattice Dispersion



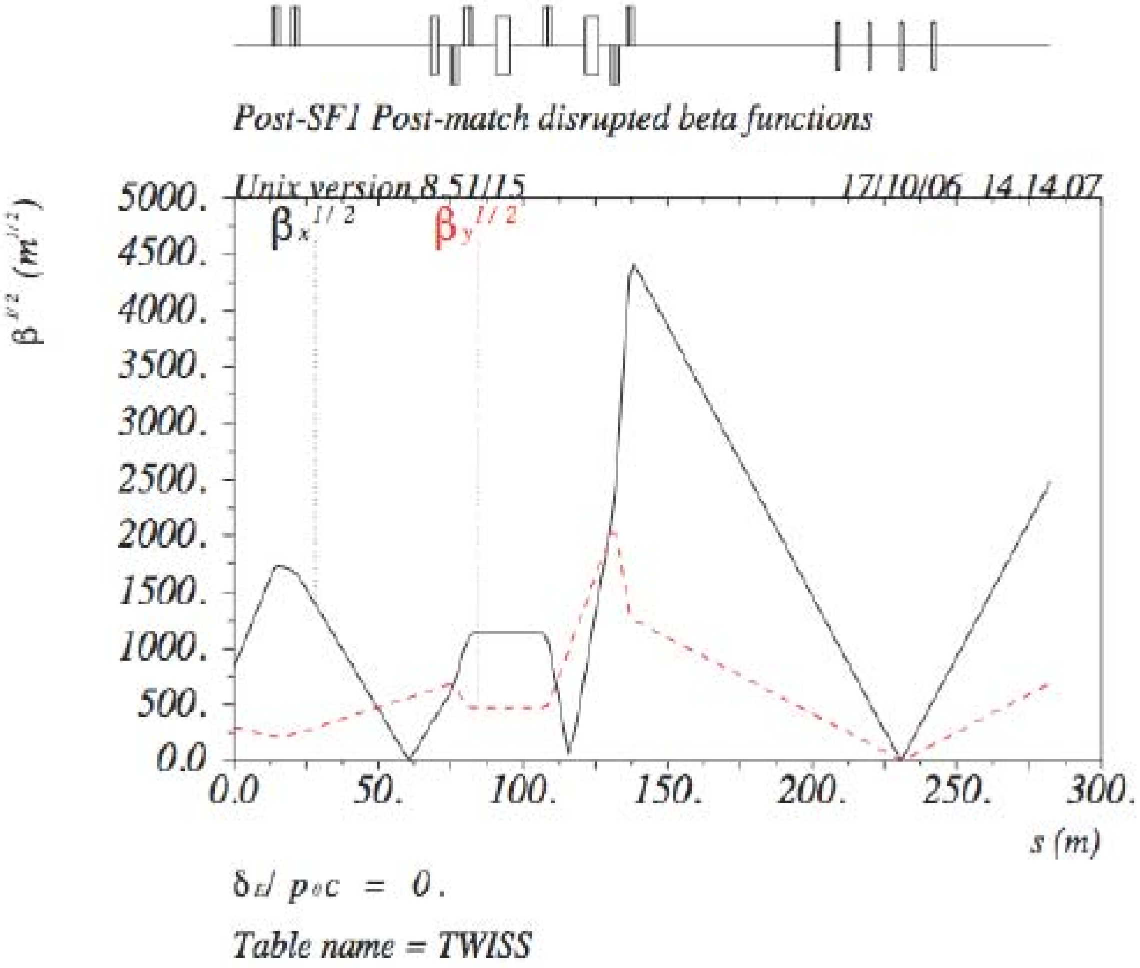
Baseline lattice
Beta functions


Post-SF1 Post-match disrupted beta functions

$\delta_E / p_0c = 0.$

Table name = TWISS

Reversed structure Beta functions



Focus

- finalise optimisation of FD sextupoles
  interact with SC magnet experts
- revisit extraction line optics design, combining modular approach and dedicated (and possibly more aggressive) collimation
  interact with warm magnet experts (non conventional ?)
- further W liner optimisation to ease SC power tolerance
- luminosity impact of not crabbing in “realistic conditions”
- minimal extraction line without post-IP diagnostics
- beamstrahlung cones and conservative clearance specs

Collider motivations

	very small 0 – 2 mrad	large 14 – 25 mrad
	Insufficient effort so far (design, hardware R&D)	Advanced developement
injection & extraction	• shared magnets ⇒ coupled design	• separate channels
challenges & remedies	• post-IP losses → careful optics & collimation → large magnet bores → electr. separators	• large $\mathcal{L}$ loss : $< x \; z >$ → crab-crossing (R&D) • non-axial in solenoid → DID / anti-DID & post / pre-IP bumps
approach & risks	• preserve pre-IP beam • reflected background	• emphasize post-IP beam • adds pre-IP constraints

Both are valid viewpoints which can work…