Baseline BDS Design Updates

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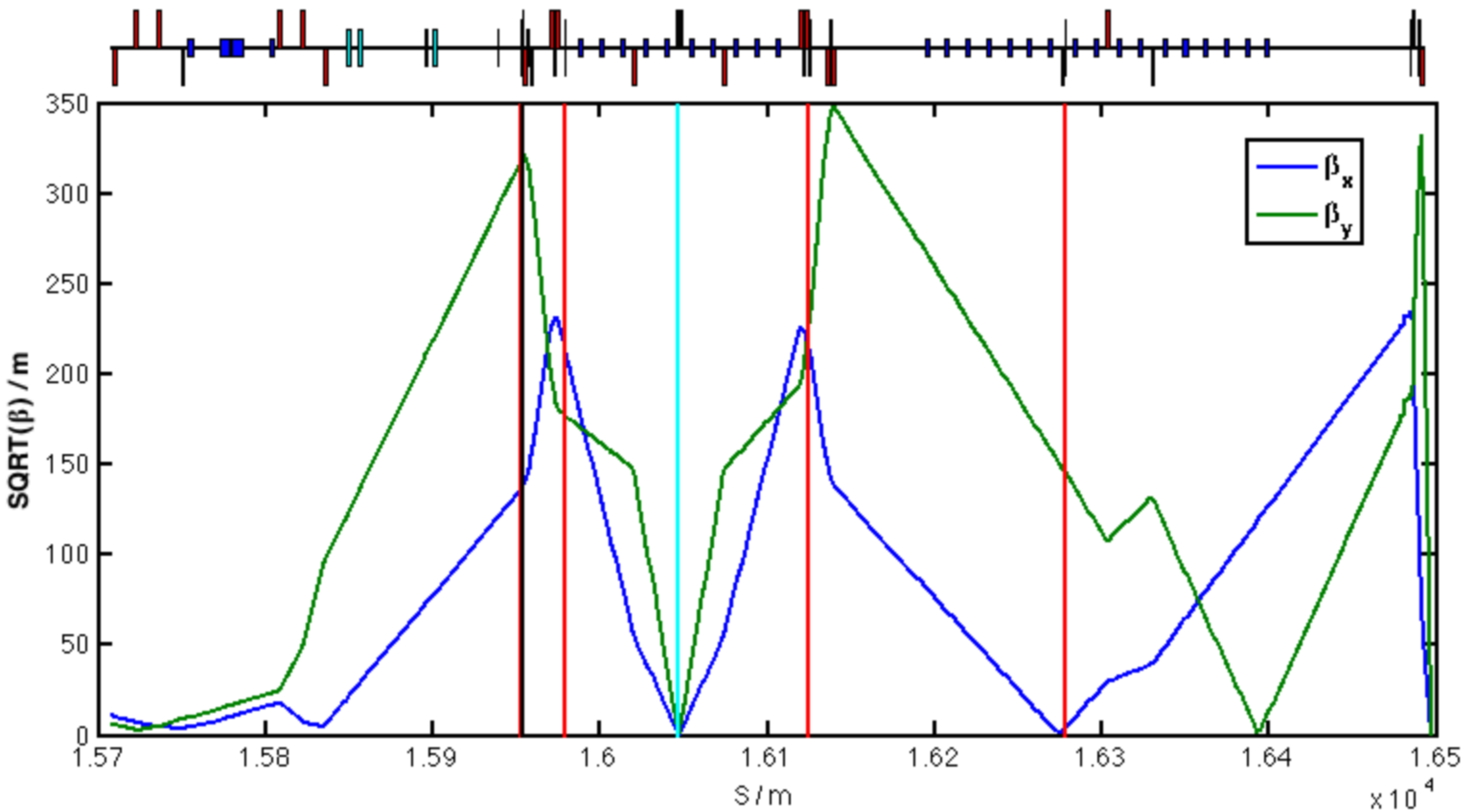
Ichinoseki, MDI/CFS Meeting

Update of Design Work @ SLAC

- Lattices
  - Some changes to existing BDS decks
    - Split QF7 for beam profile diagnostics
    - SQFF added u/s SF6
    - Add 4 skew-sextupoles
    - Move FFB correctors d/s QD0 to between QD0/QF1 to match TDR description
  - Lattice admin tasks
    - Tidy decks & remove re-definition errors
  - Lattice description issues
    - LW chicane too long by ~35m? (See MDW talk)
    - Length of BDS used for matching incorrect (historical QF1 position move related)
    - Tune-up dump e- vs. e+ - need DC or pulsed extraction? Length of system…
      - e+ system needs to match e-
- BDS optics
  - Optics matching for baseline L*=3.5 & 4.5m
  - Collimation design work started for baseline
- Beam dynamics
  - Beam losses calculated for baseline & 1TeV optics
  - Work ongoing for BDS tuning simulations

Lattice Modifications



- 4 Skew-sextupoles (red)
- QF7 split (cyan)
- SQFF (black)

Lattice Design Process[§]

- Starting from IP to Collimation section (reverse sense of beam)
  - Set α at the exit of FD by adjusting QD0 and QF1
  - Adjust magnets from QD2 to QF7 to impose
    - $\alpha=0$ at MIP
    - $\Delta\mu = n\pi$ between MIP and IP
    - $\Delta\mu = n\pi$ between Feedback and IP
    - $R_{ii}^{SF} = 1$
    - $R_{ii}^{SD} = -1$
  - Adjust QMs to constraint
    - $\Delta\mu = n\pi/2$ between SP4 to IP
    - $\Delta\mu = n\pi/2$ between SPEX to IP
- Starting from Collimation section to IP (beam sense)
  - Optimize Sexts and OCTs against IP spot size
  - Further optimization by adding magnets from QD2 to QF7 for compensating 3-order aberrations: U1222, U3224, U3444...

[§]*Following partially the recipe described at SLAC-PUB-9895*

$L^* = 3.51$ m

$\beta^*_x = 0.011$ m

$\beta^*_y = 0.00048$ m

$\alpha^*_{x,y} = -0.00 , 0.05$

$\alpha^{MIP}_{x,y} = 0.07 , -0.02$

$\eta^*_x = 0.5\ \mu m$

$\sigma^*_x = 492$ nm

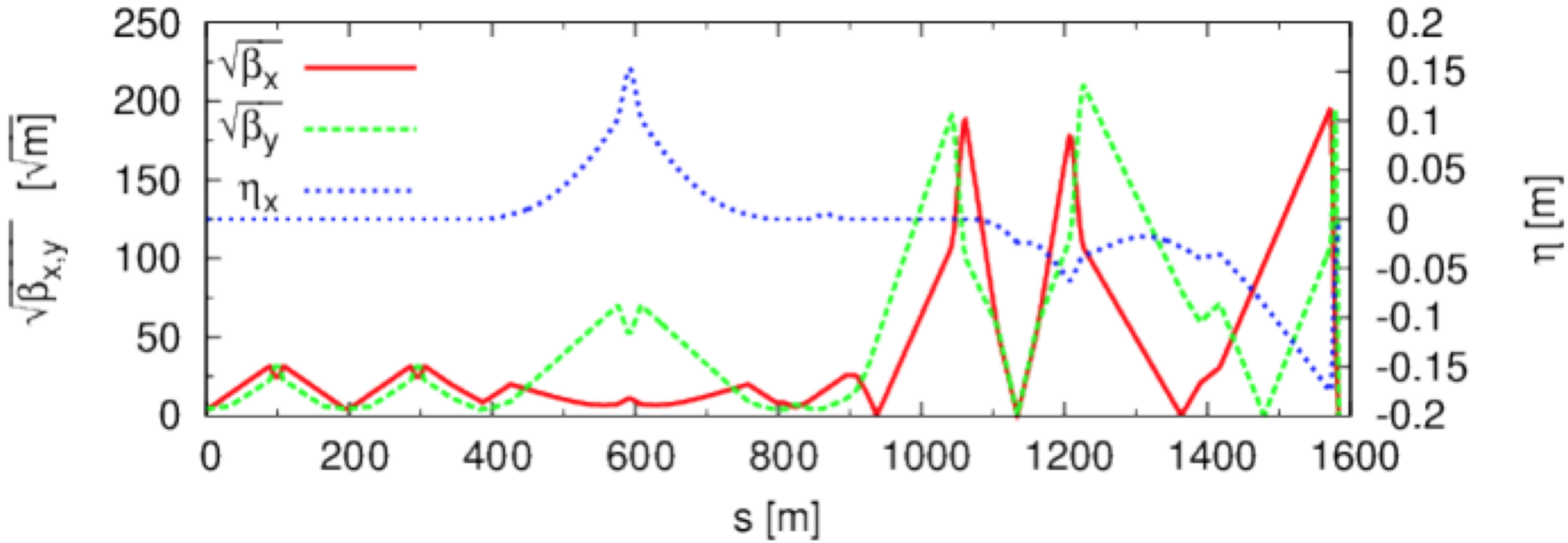
$\sigma^*_y = 5.95$ nm

L = — cm^2s^{-1}

$\Delta\mu^{MIP}_{x,y}\ [2\pi] = 1.0 , 1.0$

$\Delta\mu^{SP4}_{x,y}\ [2\pi] = 2.30 , 2.15$

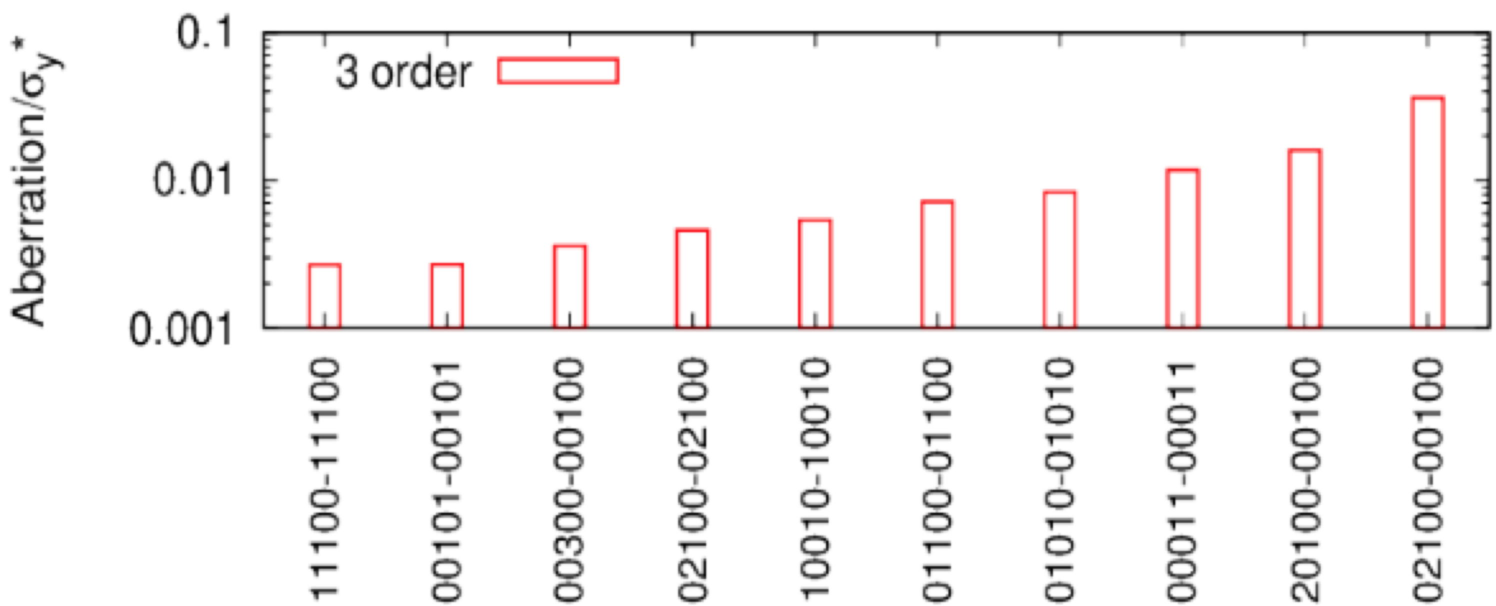
$\Delta\mu^{SPEX}_{x,y}\ [2\pi] = 2.70 , 2.74$



$L^* = 3.51$ m

IP spot size (2 order) is: 480 nm and 5.80 nm

(3 order) is: 492 nm and 5.95 nm



$L^* = 4.5$ m

$\beta^*_x = 0.011$ m

$\beta^*_y = 0.00048$ m

$\alpha^*_{x,y} = -0.01 , 0.01$

$\alpha^{MIP}_{x,y} = 0.08 , 0.02$

$\eta^*_x = 0.2\ \mu$m

$\sigma^*_x = 486$ nm

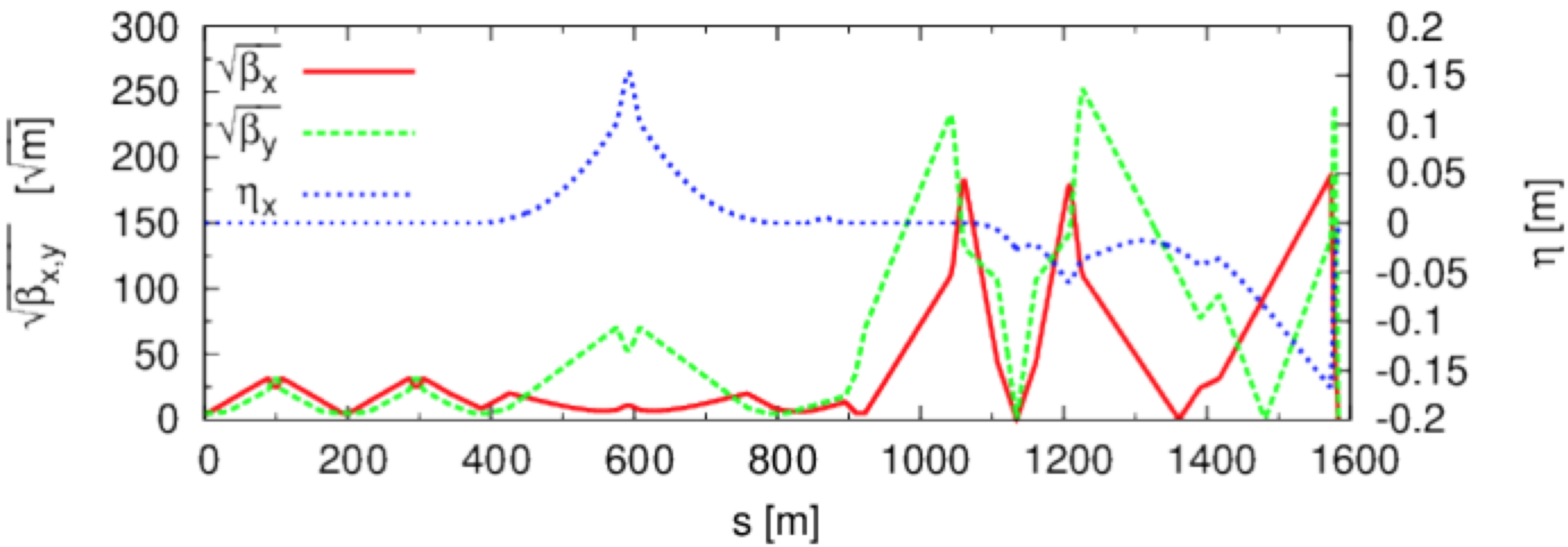
$\sigma^*_y = 5.8$ m

$L = 1.4 \cdot 10^{34}\ cm^2 s^{-1}$

$\Delta\mu^{MIP}_{x,y}\,[2\pi] = 1 , 1$

$\Delta\mu^{SP4}_{x,y}\,[2\pi] = 2.7 , 2.3$

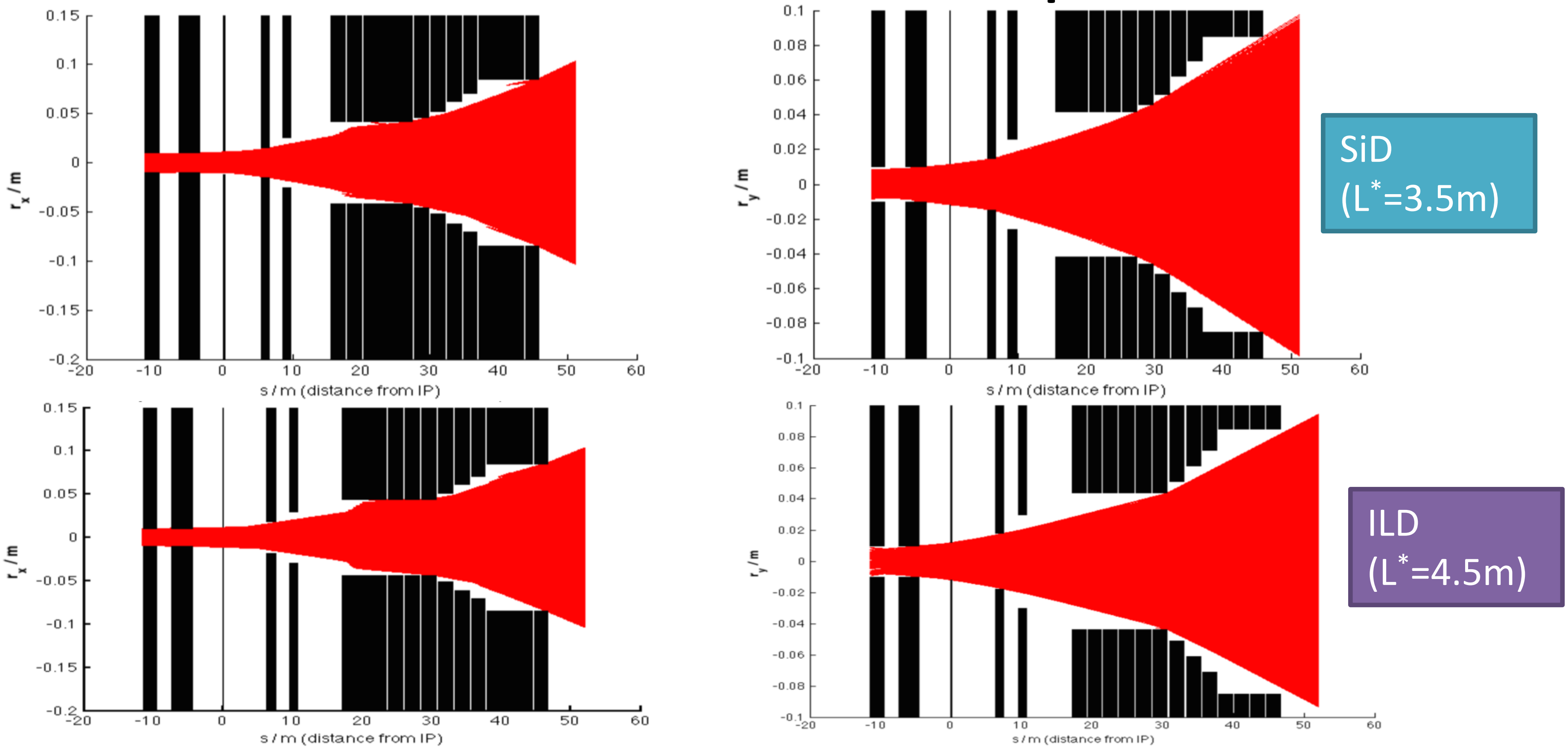
$\Delta\mu^{SPEX}_{x,y}\,[2\pi] = 2.3 , 1.7$



Comments on Optics Matching

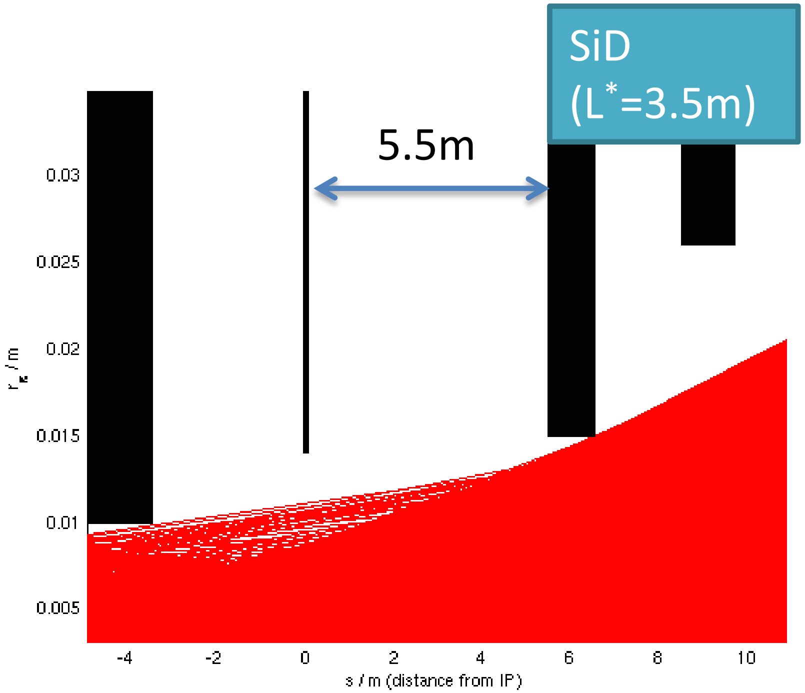
- Bandwidth/tolerances also calculated (see separate talk).
- Need to fix 1.69m length mismatch to TDR lattice & re-do lattice
  - QF1 moved in lattice but u/s space not reduced
- Alternate single-L* optics?

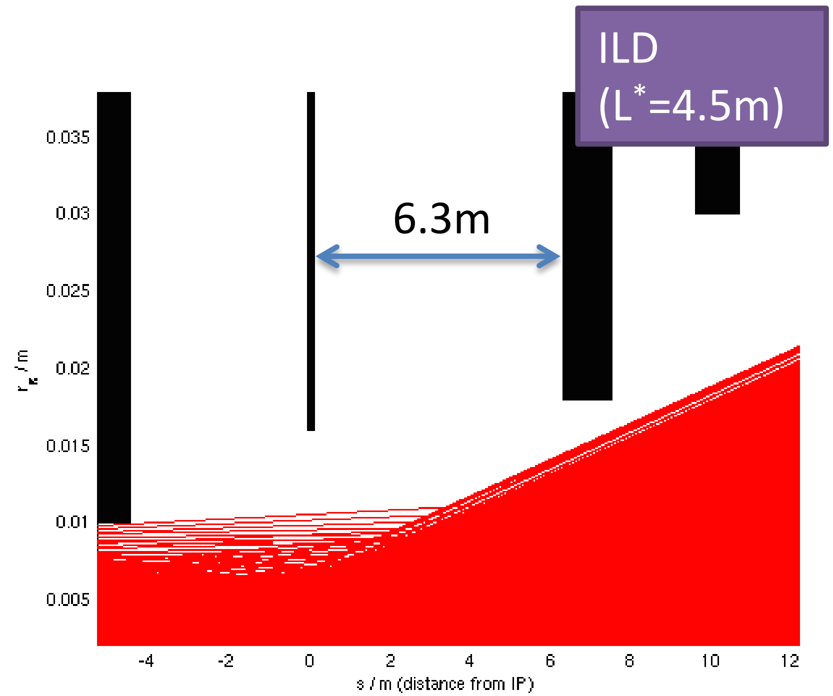
Calculate Collimation Depth to Set Betatron Collimator Apertures



- SR from particles covering all QF1 phase-space
  - Rays not hitting apertures shown
- Aperture @ IP = 14mm (SiD), 16mm (ILD) radius inner vertex detector layer (L=125mm)

3.5m vs. 4.5m L* IR Geometry





- Difference in detector and extraction system design for 2 IR's
  - No simple scaling for collimation depth

Betatron Spoiler Apertures

Name	L^*=3.5m		L^*=4.5m		Existing Lattice	
	X / mm ($N\sigma_x$)	Y / mm ($N\sigma_y$)	X / mm ($N\sigma_x$)	Y / mm ($N\sigma_x$)	X / mm ($N\sigma_x$)	Y / mm ($N\sigma_y$)
SP1	-	-	-	-	0.3 (15)	0.25 (250)
SP2	-	-	1.24 (11)	0.2 (24)	0.3 (2.7)	0.2 (24)
SP3	-	-	0.5 (25)	0.22 (219)	0.3 (15)	0.25 (250)
SP4	-	-	0.59 (5.4)	0.22 (26)	0.3 (2.7)	0.2 (24)
SP5	-	-	-	-	0.42 (11)	0.25 (250)

- "-" = no collimation needed at this location to prevent IR SR hits.
  - (L*=3.5m optics completely shielded by magnet apertures)
- Tightest aperture: SP2/SP4 (X)
  - *2.7σ = 0.7% Beam loss = 36kW for existing lattice*
- TDR calls for 1-2E-5 main beam loss => 4.3σ tightest collimation aperture. (Max with all muon spoiler space filled = 1E-3 beam loss => 3.3σ)
  - **Tightest L*=4.5m aperture = SP4 = 5.4σ**

Summary of extraction loss (baseline 500 GeV Optics) L*=4.5m

	Magnets		Detectors		Collimators				
	SC	Warm (max)	Synch-rotron	Cheren-kov	Energy	Cheren-kov	Dump-1	Dump-2	Dump-3
TDR 2013	**0**	**12 W/m**	**30 W**	**130 W**	**22 W**	**0.3 kW**	**2.8 kW**	**1.9 kW**	**3.0 kW**
Nominal	0	0.6 W/m	4 W	26 W	2 W	37 W	0.3 kW	0.2 kW	0.2 kW
Low-P	0	130 W/m	0.5 kW	0.6 kW	0.4 kW	2.2 kW	14.8 kW	9.0 kW	10.3 kW

- Extraction losses with the TDR 2013 IP parameters are a factor of 10 higher than in the RDR 2007 nominal option, but a factor of 5 lower than in the low-P option.
- The TDR losses on magnets and collimators look acceptable. Losses on the Synchrotron and Cherenkov detectors may need an expert opinion to evaluate the impact of background.
- The TDR beamstrahlung photon losses are small.

<u>Note</u>: The calculations were done assuming ideal collision conditions. Non-ideal conditions, such as large vertical beam-to-beam separation at IP, will increase the disruption and the extraction beam loss. Evaluation of this effect requires a special study.

Summary of beam loss (1 TeV) L*=4.5m

Parameter option	Magnets		Detectors		Collimators				
	SC	Warm (max per magnet)	Synch-rotron	Cheren-kov	Energy	Cheren-kov	Dump-1	Dump-2	Dump-3
A1	0	85 W	0.28 kW	0.64 kW	88 W	1.8 kW	5.9 kW	2.5 kW	1.5 kW
A1 y-offset	0	294 W	0.56 kW	6.3 kW	0.9 kW	4.0 kW	42 kW	17 kW	11 kW
B1b	0	1.6 kW	4.0 kW	4.6 kW	3.5 kW	17 kW	43 kW	18 kW	15 kW
B1b y-offset	0	1.9 kW	3.0 kW	37 kW	9.8 kW	17 kW	184 kW	56 kW	35 kW

- Beam loss in option A1 may be manageable (expert opinion is needed). The much higher losses with the y-offset are expected to be only for short periods of time. The IP offsets are expected to be continuously corrected in operation.
- Beam losses in option B1b are rather high due to the longer beam energy tail and larger angular spread at IP. Of particular concern are the losses on magnets and diagnostic.
- A better collimation may reduce the losses on magnets and diagnostic.
- Losses of photons generated in the collision are negligible (compared to electron losses) and limited to two dump collimators.

Future Work Plan

- Decision on 1 vs. 2 L*
  - Decision on L* if single L*
- Fix lattice irregularities
- Fine-tune matching
- Set collimator gaps, calculate beam losses , backgrounds & muon flux
- Demonstrate BDS tuning and calculate expected luminosities