ILC BDS COLLIMATION

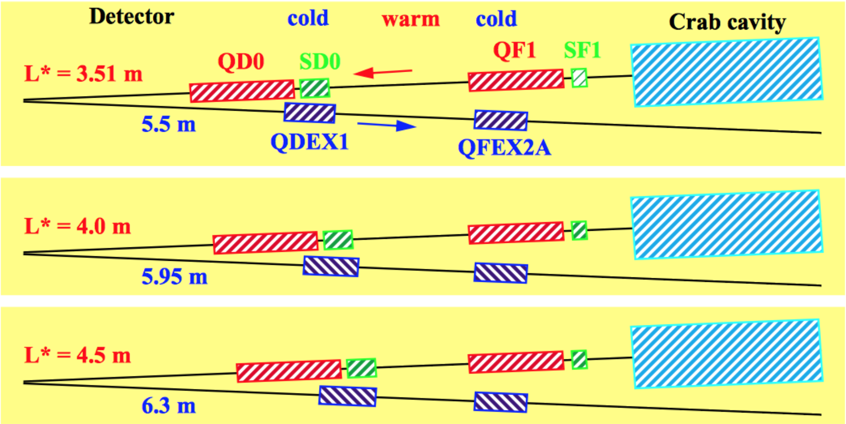
Glen White, SLAC

Oct 7, 2014

LCWS, Belgrade

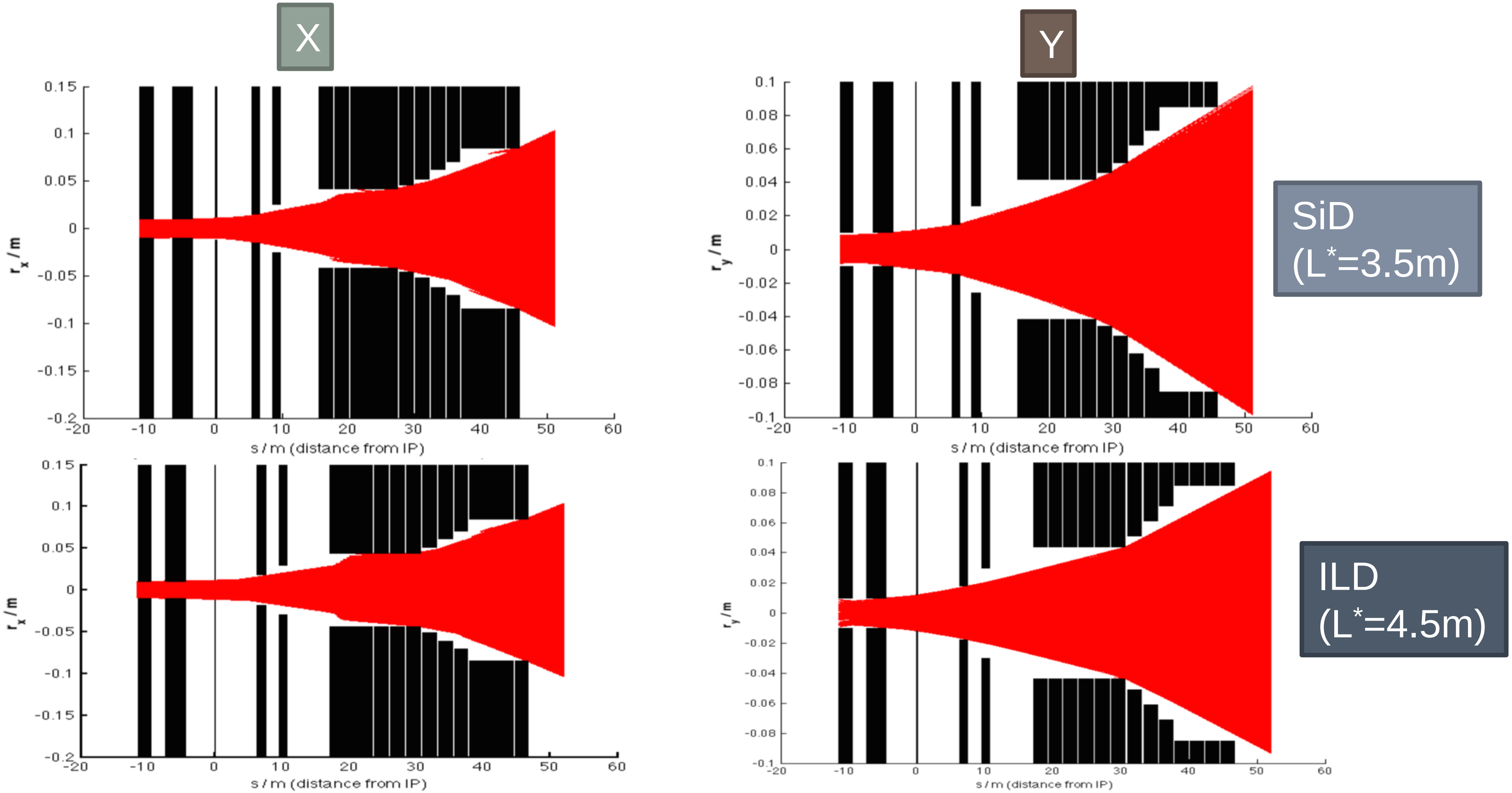
Overview

- Calculate collimation apertures based on criterion of no SR photons hitting IR region (QF1 -> IP+50m)
  - 3.5m (5.5m EXT) L^*
  - 4.0m (5.95m EXT) L^*
  - 4.5m (6.3m EXT) L^*
  - TDR Baseline (E_{CM} = 500 GeV)
  - MP tracking-based calculations including non-linear field elements



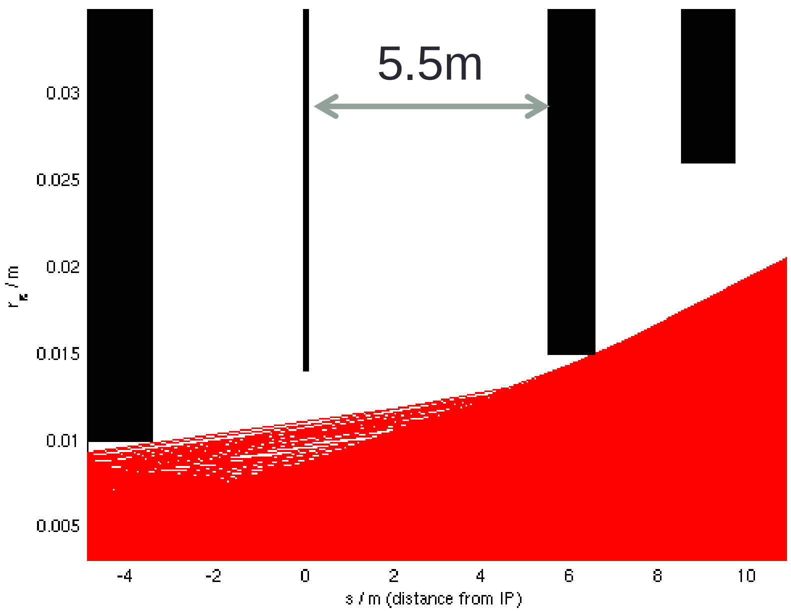
- Calculation of beam loss rates from halo particles.
- Aperture hits stop particles in simulation, no material interaction modeled here

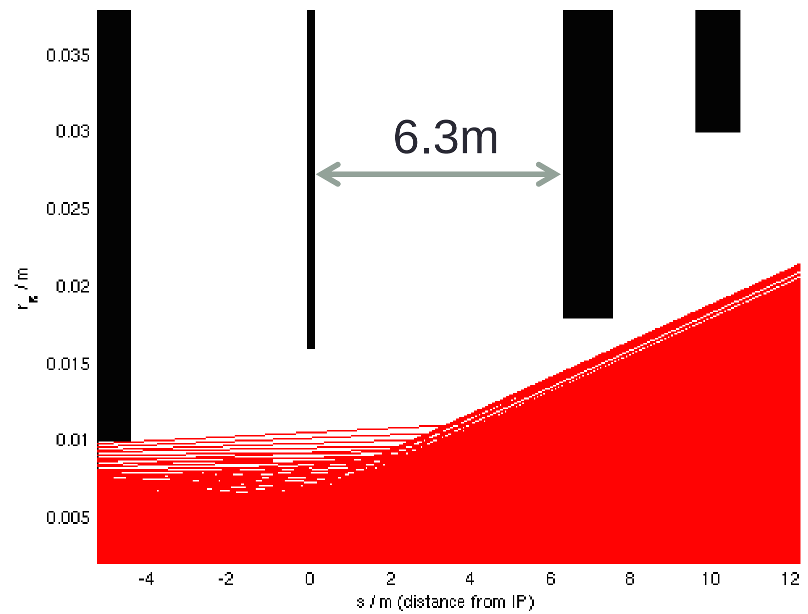
SR in IR Region



- 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)

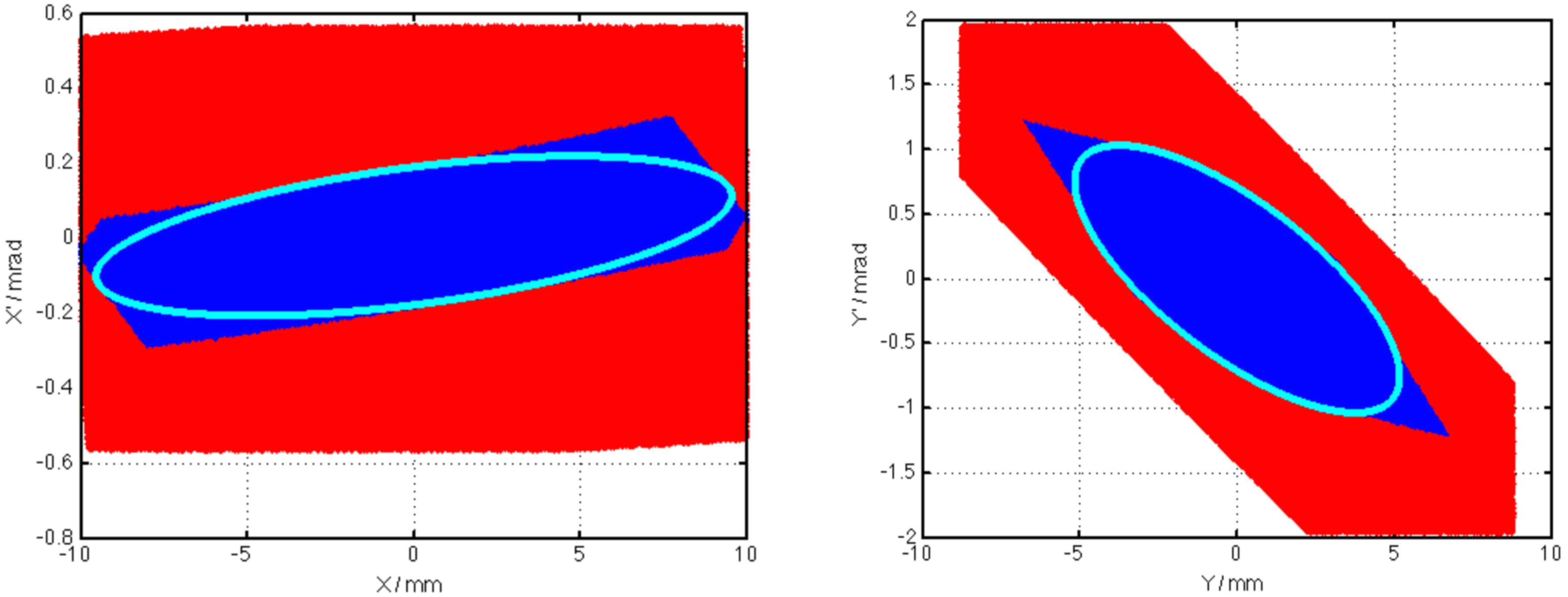
IR Geometry





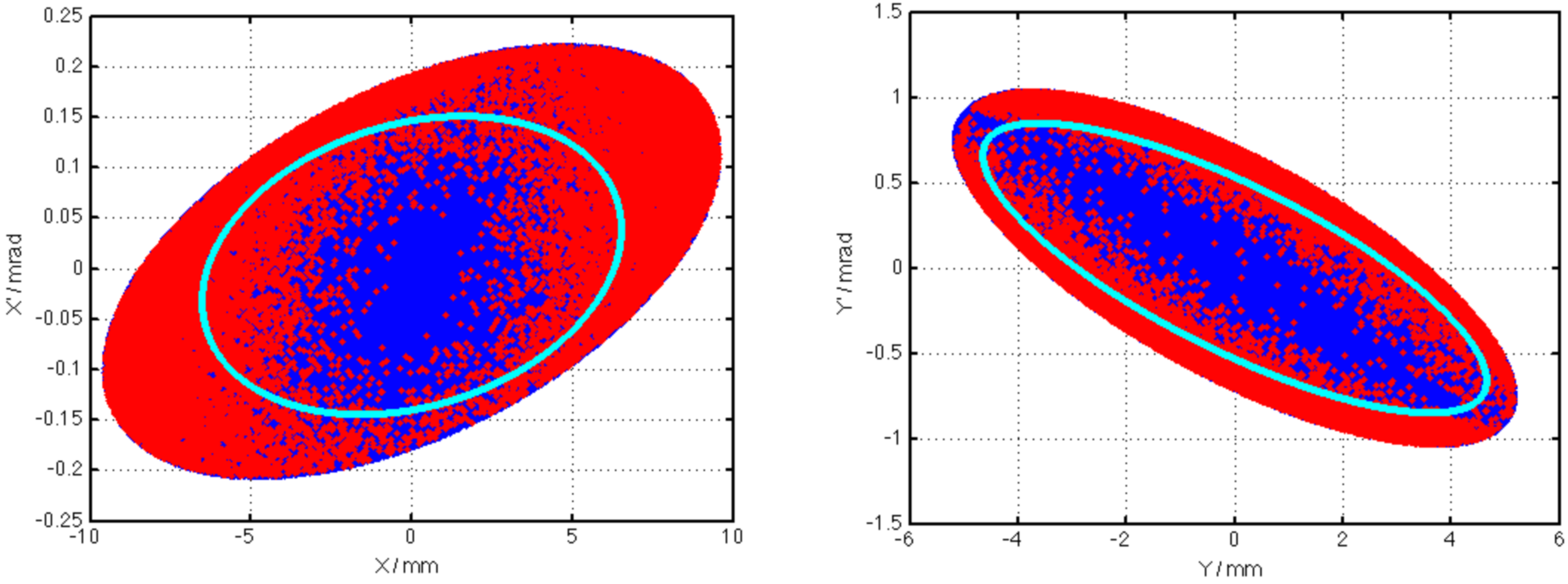
- Difference in detector and extraction system design for different BDS L^* options
  - No simple scaling for collimation depth

2D Particle Phase Space @ QF1 Entrance



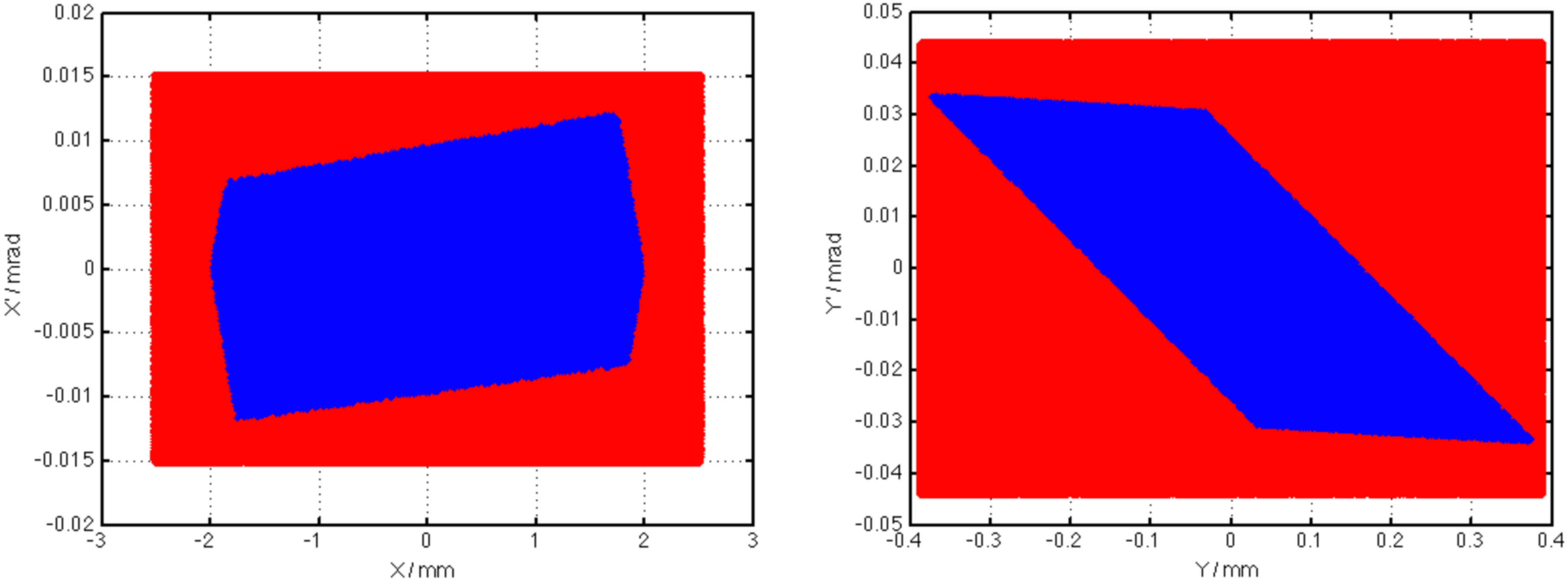
- 1e6 Macro-particles, uniform random distribution in 2D phase-space.
- Red tags particles generating SR photon hits in IR. Blue OK. Ellipse fit to define SR aperture.
  - Missing particles in above plots = collimated by IR magnet apertures.

4D Particle Phase Space @ QF1 Entrance



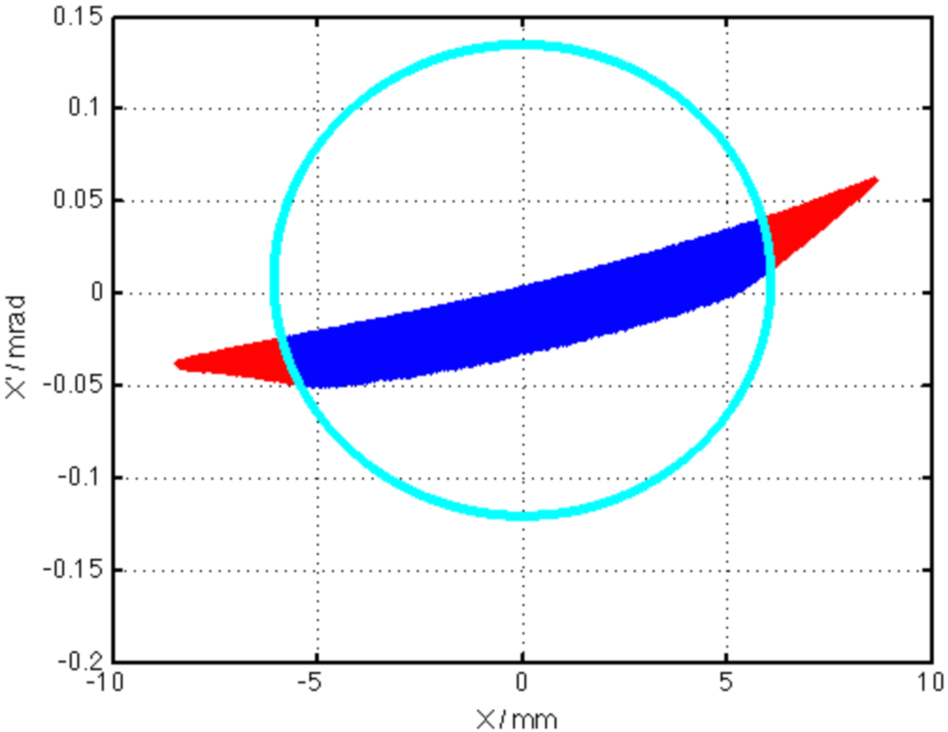
- Generate initial phase-space from previous plots.
- Additional hit particles present due to x-y correlations.
- Use minimizer to find simultaneous x and y phase space ellipse apertures which ensure no IR SR photon hits (cyan ellipses).

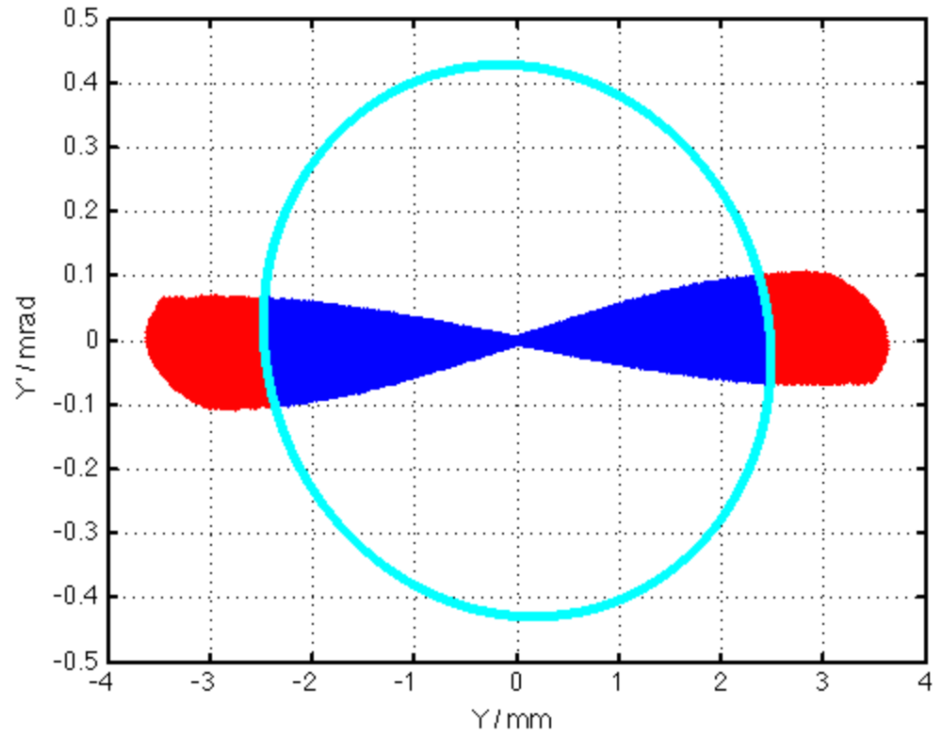
Phase Space Tracking SP1 -> QF1



- Track 4D phase space from entrance SP1 spoiler to QF1 magnet entrance.
  - Blue shows particles with clear transmission to QF1
  - Red shows particles collimated by magnet apertures (all spoiler apertures deactivated)

Phase Space @ QF1 Entrance





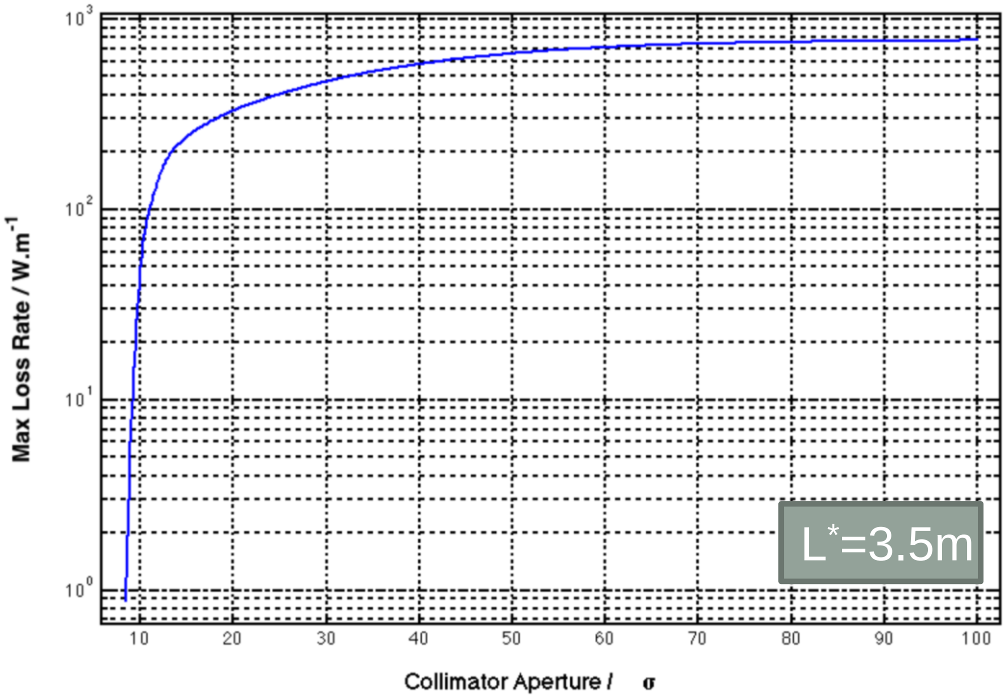
- Particles tracked from SP1 and not hitting magnet aperture
  - Blue = No SR hits in IR
  - Red = SR hits aperture in IR
  - Cyan ellipse = SR aperture @ QF1 from previous calculation
- Generate high-statistics particle distributions from red points
- Calculate collimator apertures required to collimate red particles which cause SR radiation to hit somewhere in IR.

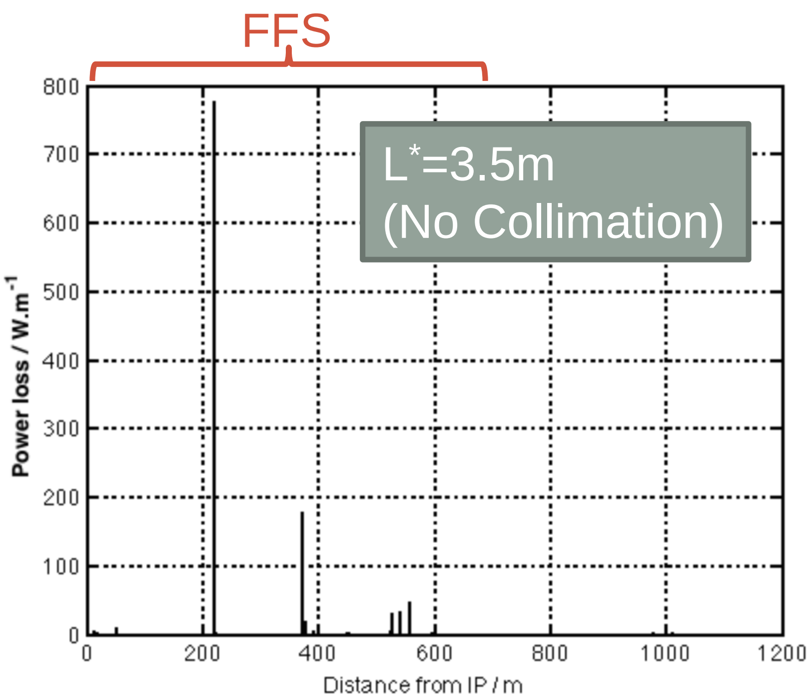
Required Collimator Spoiler Apertures

Name	L^*=3.5m		L^*=4.0m		L^*=4.5m	
	X	Y	X / mm ($N\sigma_x$)	Y / mm ($N\sigma_x$)	X / mm ($N\sigma_x$)	Y / mm ($N\sigma_x$)
SP1	-	-	-	-	-	-
SP2	-	-	0.43 (3.9)	0.2 (24)	0.48 (4.3)	0.2 (24)
SP3	-	-	0.6 (30)	0.2 (200)	0.4 (21)	0.21 (203)
SP4	-	-	0.43 (3.9)	0.2 (24)	0.48 (4.3)	0.2 (24)
SP5	-	-	-	-	-	-

- Requirement: collimators should be set to allow NO POSSIBLE SR HITS IN IR
- "-" = no collimation needed at this location to prevent IR SR hits.
  - (L*=3.5m optics completely shielded by magnet apertures)
- TDR calls for 1-2E-5 main beam loss (>4.25σ)
  - (Max with all muon spoiler space filled = 1E-3 beam loss => 3.3σ)
- **Tightest L^*=4.0m aperture = SP2/SP4 = 3.9σ = 9.6E-5**
  - *Need to refine collimation phase-advances & design EXT optics*
- **Tightest L*=4.5m aperture = SP2/SP4 = 4.3σ = 1.7E-5**

Halo Loss Rate in Magnets

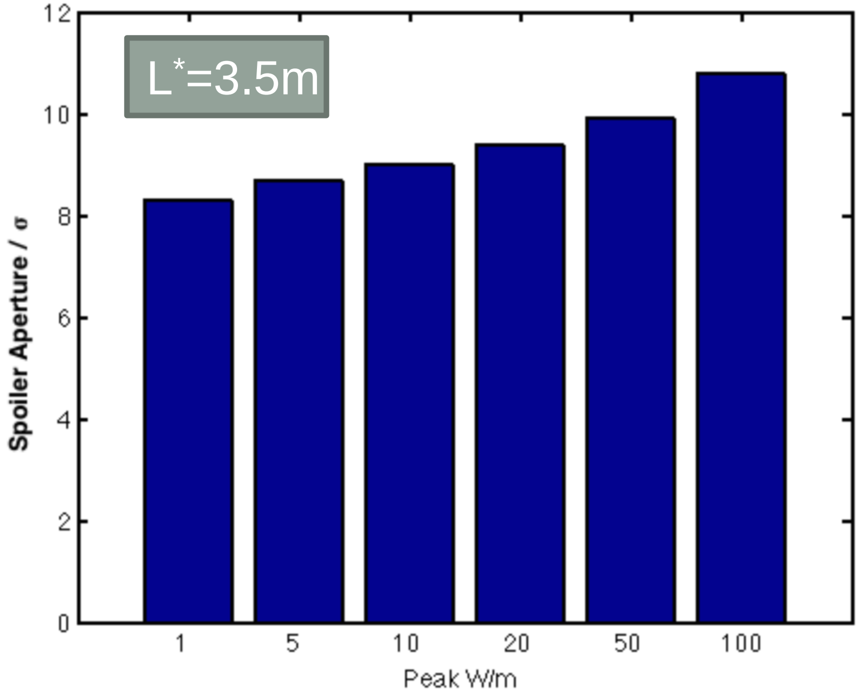




- Represent beam halo as 0.1% main beam charge with 1/r profile in transverse dimensions and 1% dP/P (Gaussian distribution).
  - Calculate max loss rate in magnets from tracking simulation (10^7 MP)
- Calculate max loss for any magnet as a function of horizontal collimator aperture
  - Fix vertical @ 24 σ

Collimation Settings For Magnet Protection

P_{loss}	Spoiler Aperture (x) / σ [σ_y = 24]
(W/m)	L^* = 3.5m
1	8.4
5	8.8
10	9.1
20	9.4
50	10.0
100	10.9



- L*=4.5m settings for SR protection <<1W/m power loss on any magnet.
- For L*=3.5m & 4.0m, required settings shown in table.
  - Small (0.1σ-level) differences between L* optics variants.
- SPEX set to 1.6mm = 1% dP/P (8 σ_E) collimation.

Summary (1)

- Tightest required collimation apertures for IR SR protection or BSD magnet protection
  - 3.5m L* = 8.4 σ
  - 4.0m L^* = 3.9 σ
  - 4.5m L* = 4.3 σ
- 4.0m optics requires further optimisation
  - Improve collimator systems phase relations
- 4.5m (and 4.0m after further optimisation?) fulfills TDR muon shielding requirements (acceptable fractional main beam loss).
  - Compatible with TDR muon shielding philosophy: 5m magnetized spoiler with space to extend to cope with up to 1E-3 main beam loss
  - Tail-folding octupoles supply additional overhead
- 3.5m could potentially allow considerable relaxing of muon collimation requirements.

Summary (2)

- Refinements to EXT/FFS magnet design & positioning?
  - E.g. 5.5m EXT L* design for 4.0 & 4.5m BDS L* reduces to 3.5m situation.
  - Can more compact QD0 design allow for 4.0m BDS L* with 5.5m EXT L* design option?
  - Influence of QF1 positioning?
- Possible refinements for SR / background calculations:
  - Tail-folding octupoles
  - Include perturbation effects from colliding beam
  - IR solenoid field
  - GEANT models of spoiler + absorber including scattering & secondary particles
  - Include "tuned beamline configuration", multipole errors in magnets, alignment, main field errors etc.
  - Systematic error study of simulation parameters
- Obvious sensitivity to phase advances from beta collimators to IP
  - Need to consider commissioning-> how to experimentally ensure phases correct