FACET-II Sector 20 Optics Design

Configuration Options for Different Experiments

FACET-II Science Workshop, October 29, 2019

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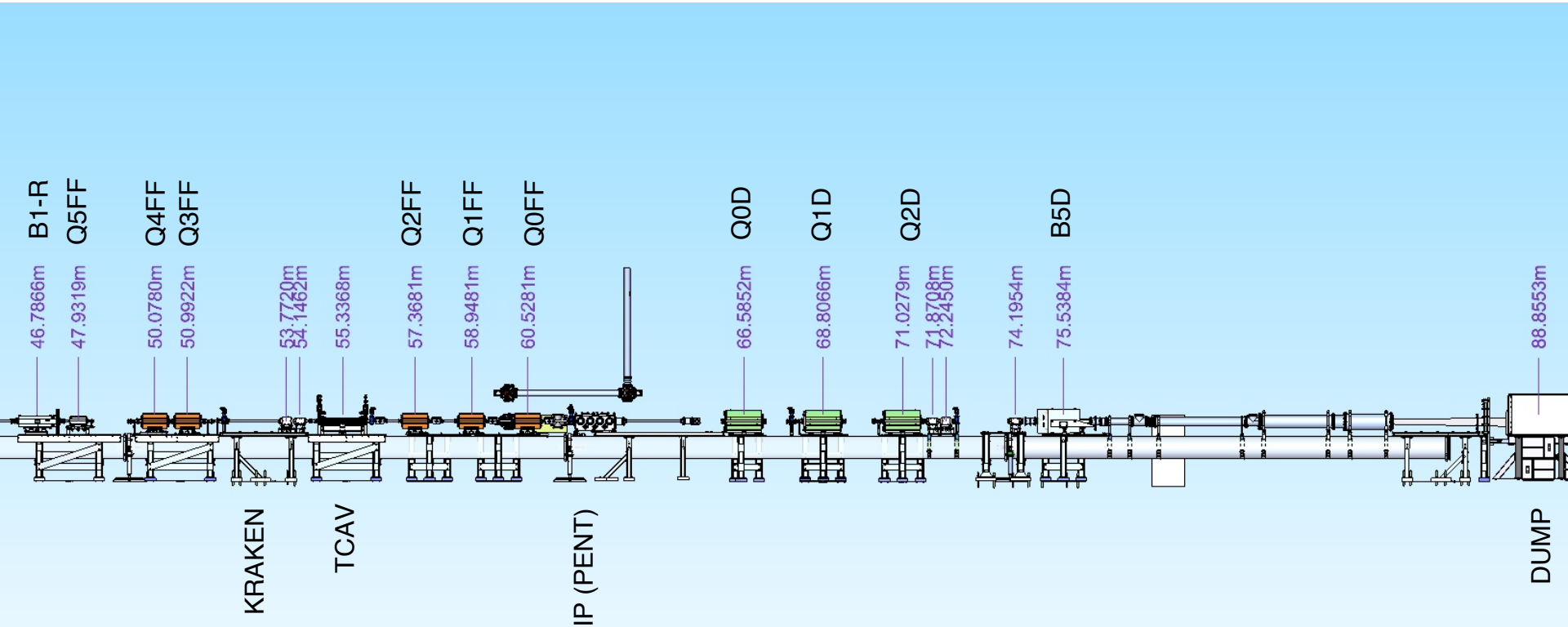
Design Requirements & FFS Layout

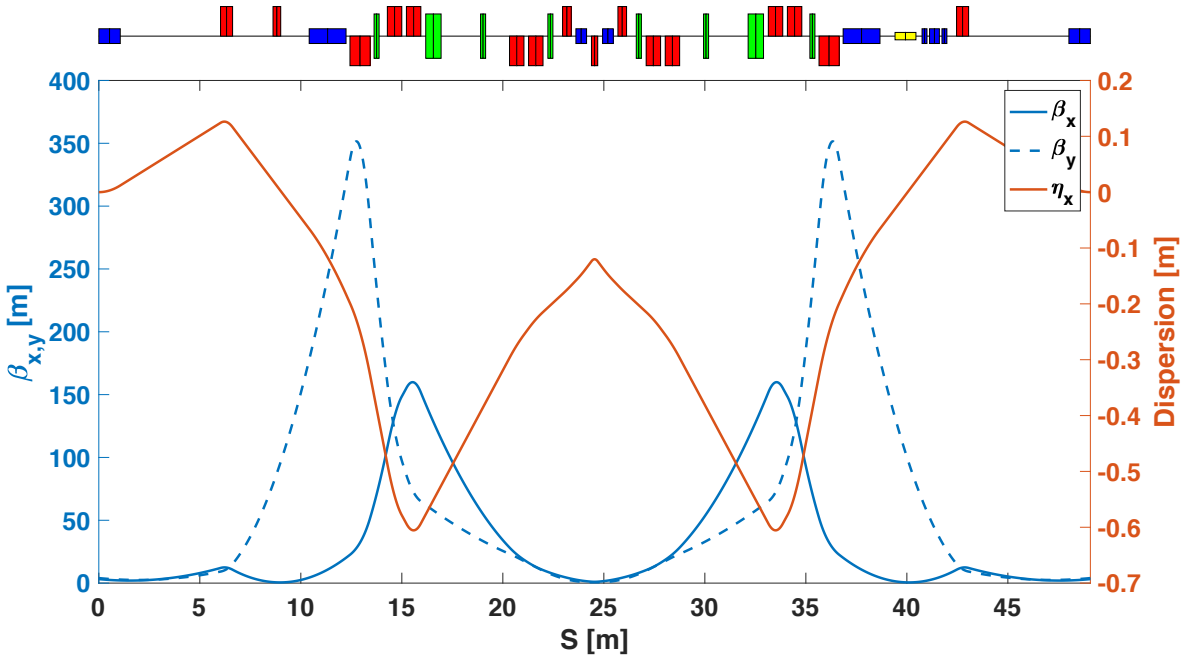
- 3 configurations to serve top 7 priority experiments:
  - 2-bunch: 1.5/0.5 nC, 30/15 | 20/10 kA, dz=150 μm, $\beta^*_{x,y}$=5-50cm
  - Single Bunch, high I_{pk}: I_{pk} 50-300kA , $\beta^*_{x,y}$=0.1-1m
  - Single Bunch, high E, low δ_E, low aberrations: E=13GeV, σ_z=100μm, $\beta^*_{x,y}$=10m
- Consider waists at:
  - Kraken (round and 100:1 beta functions)
    - *Center Q3FF -> KRK dz = 1.574m*
  - PENT for PWFA experiments
    - *Center Q0FF -> IP (PENT) dz = 3.057m*
  - Entrance to “picnic basket” for filamentation experiments
    - *Center Q0FF -> IP dz = 2.257m*
  - PDUMP (point-point imaging IP>PDUMP) *(PDUMP->DUMP dz=1.673m)*
    - Default: $r_{12}=r_{34}=0$
    - SFQED: r_{11}=0, beta_y min

S20 Final Focus and Dump Layout



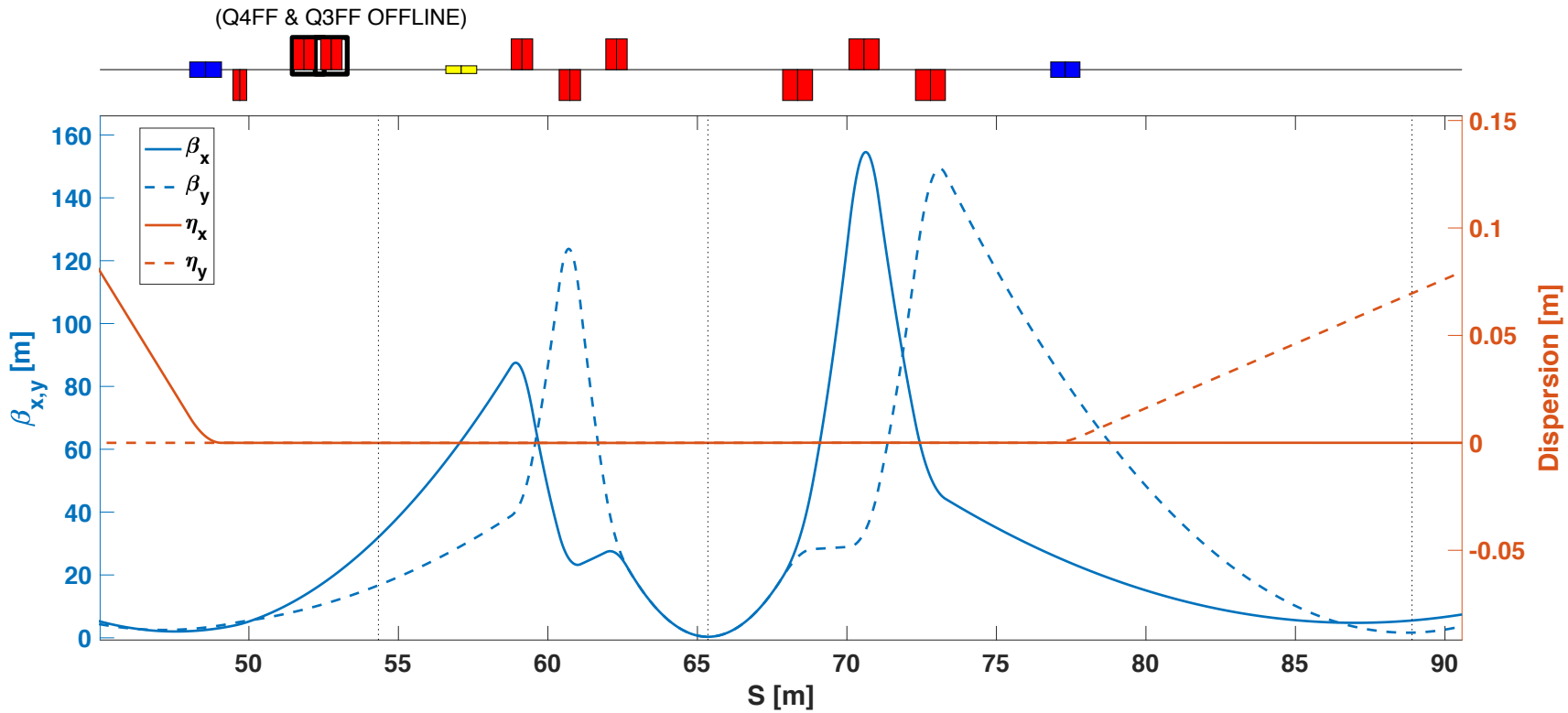
BC20 W-Chicane – Existing Configuration for Commissioning Only

In/Out Twiss Parameter	Value
β_x	3.173 m
α_x	±0.7578
β_y	4.002 m
α_y	±0.7710



- Existing FACET W-chicane with 2 Q4E quads removed
- Use FACET-II S19 optics (same in/out Twiss parameters as double dogleg)
- Following slides use this BC20 layout as input

Minimum KPP Demonstration Optics



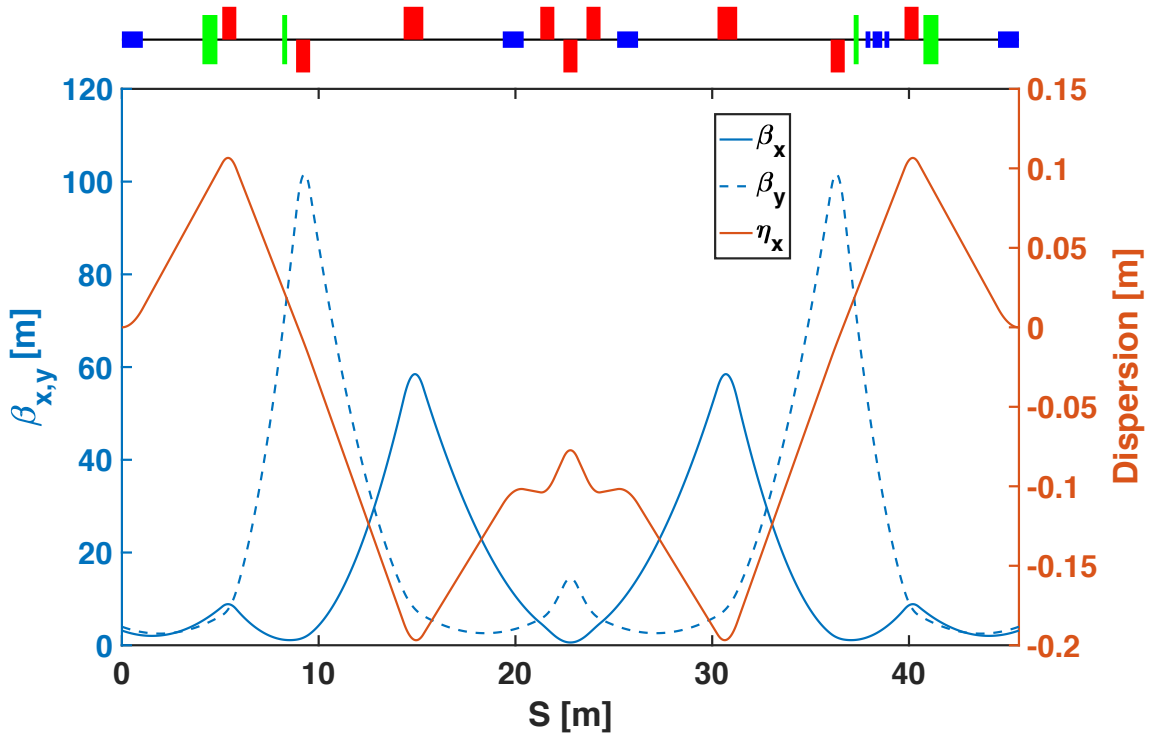
IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	32.0	16.7	70.0	50.6
PENT	0.33	0.33	7.1	7.1
PDUMP	5.5	1.6	29.1	15.9

*** (γε=3.0 μm-rad)**

Minimize # Power Supplies Required for testing of KPP's

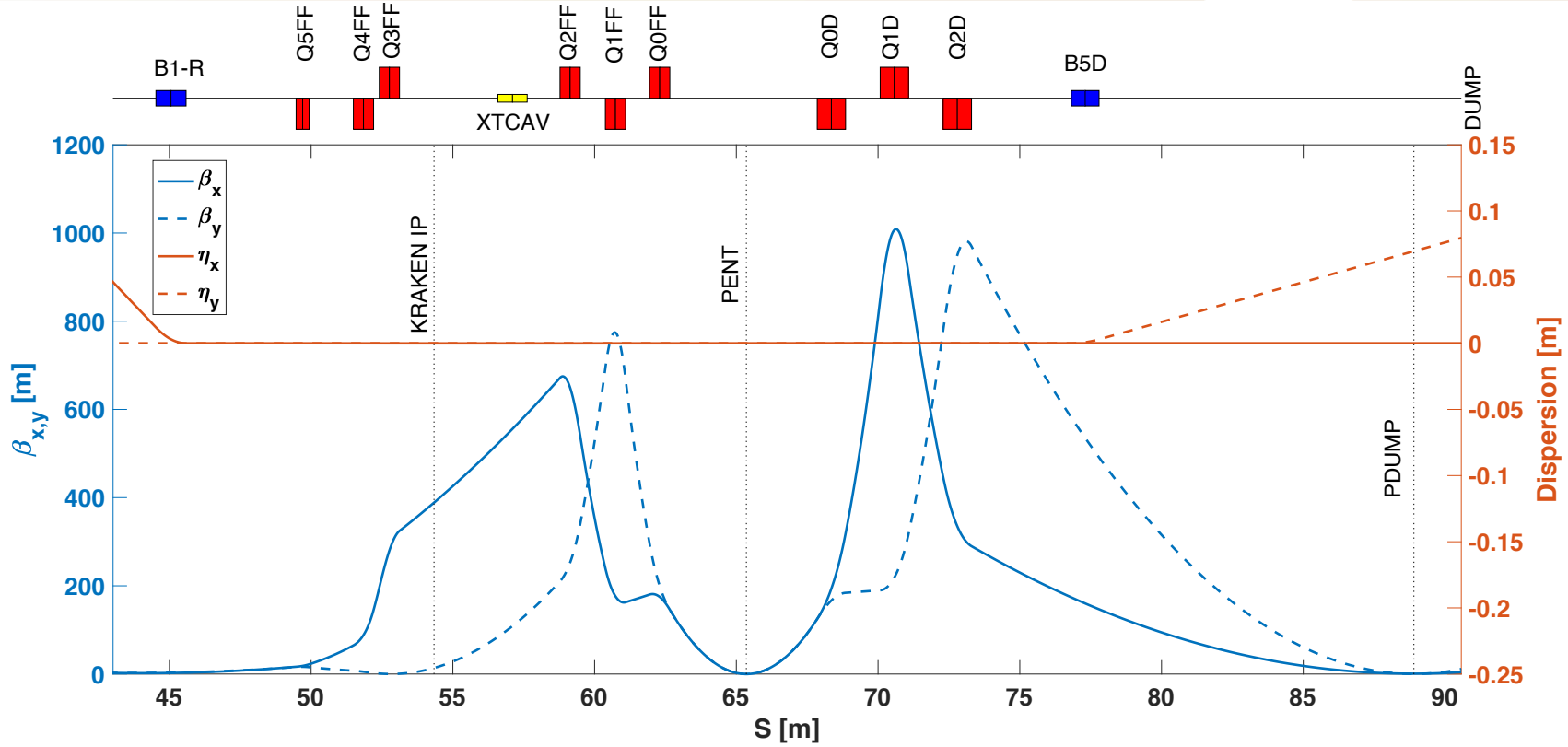
BC20 – New "Double Dogleg Configuration"

In/Out Twiss Parameter	Value
β_x	3.173 m
α_x	±0.7578
β_y	4.002 m
α_y	±0.7710



- Double-dogleg design with R56=5mm at start of S20 common to all FFS optics following

IP=PENT β^* = 5 cm (2-bunch PWFA, min β^*)

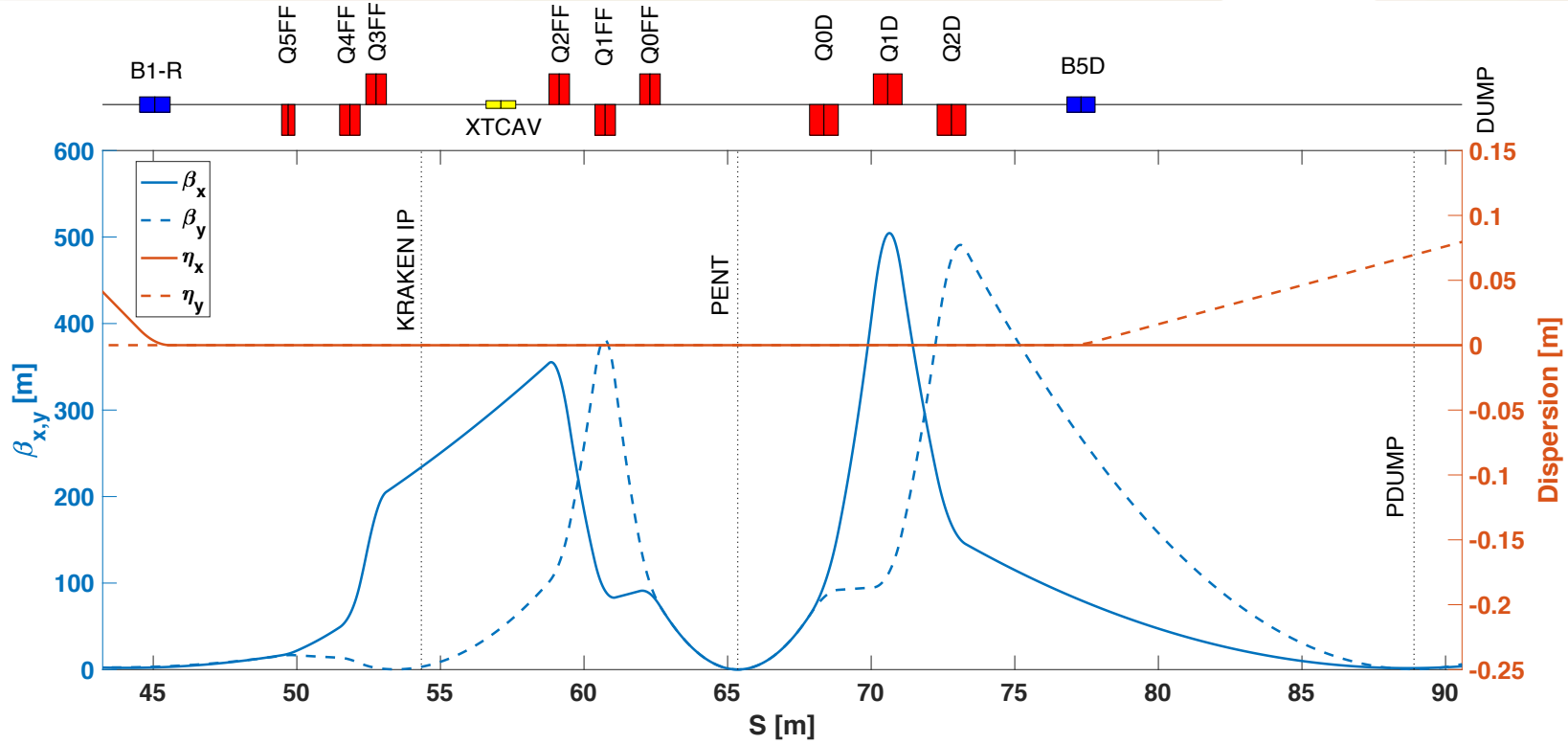


IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	389	13.8	244	46.0
PENT	0.05	0.05	2.8	2.8
PDUMP	0.84	0.25	11.3	6.2

*** (γε=3.0 μm-rad)**

Optics for 2-bunch PWFA experiments with smallest requested β^*

IP=PENT β^* = 10 cm (single bunch, high I_{pk}, min requested β^*)

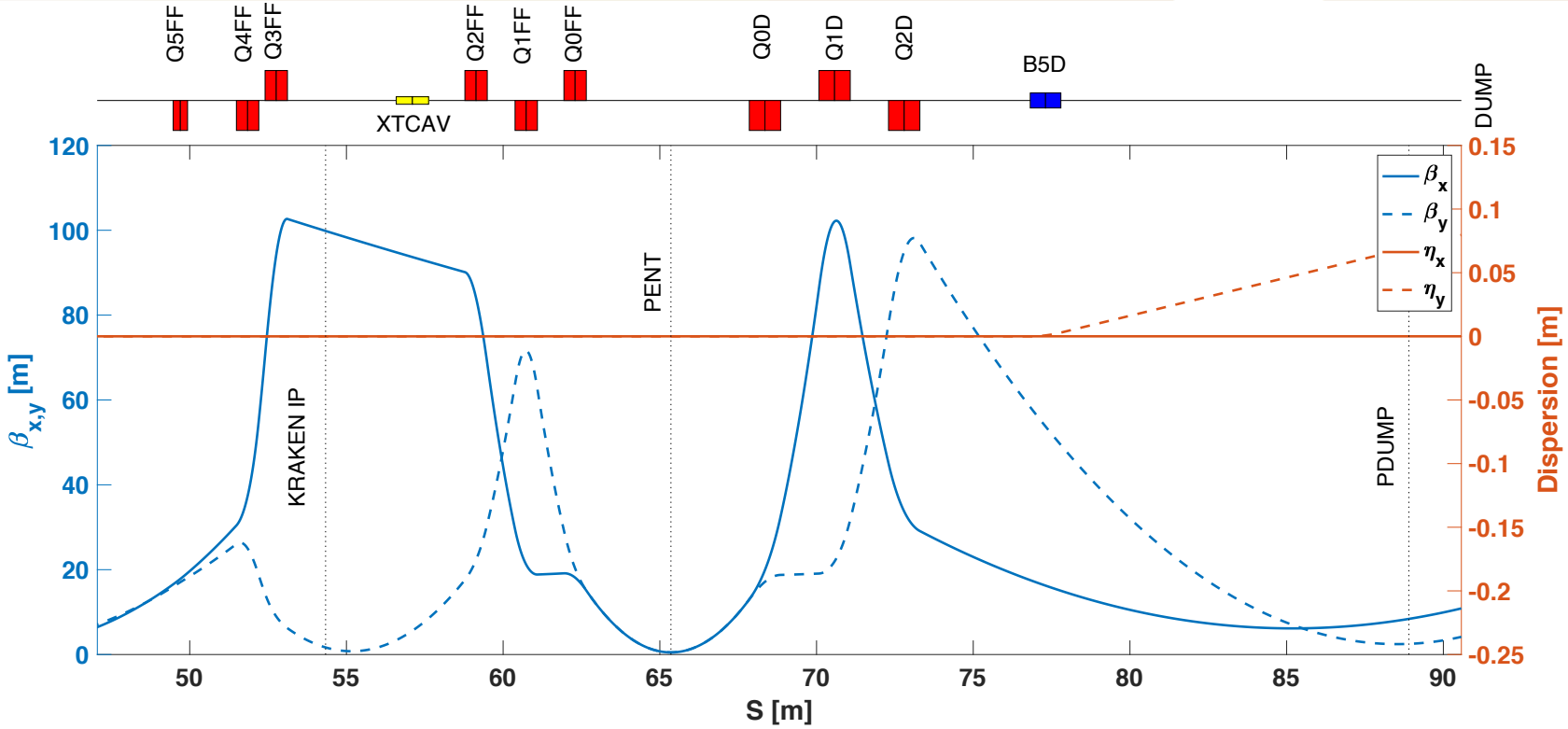


IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	234	3.2	189	22.1
PENT	0.1	0.1	3.9	3.9
PDUMP	1.7	0.5	16.0	8.8

* (γε=3.0 μm-rad)

Single bunch, high peak current option, low β^*

IP=PENT β* = 50 cm (2-bunch PWFA, max requested β*)

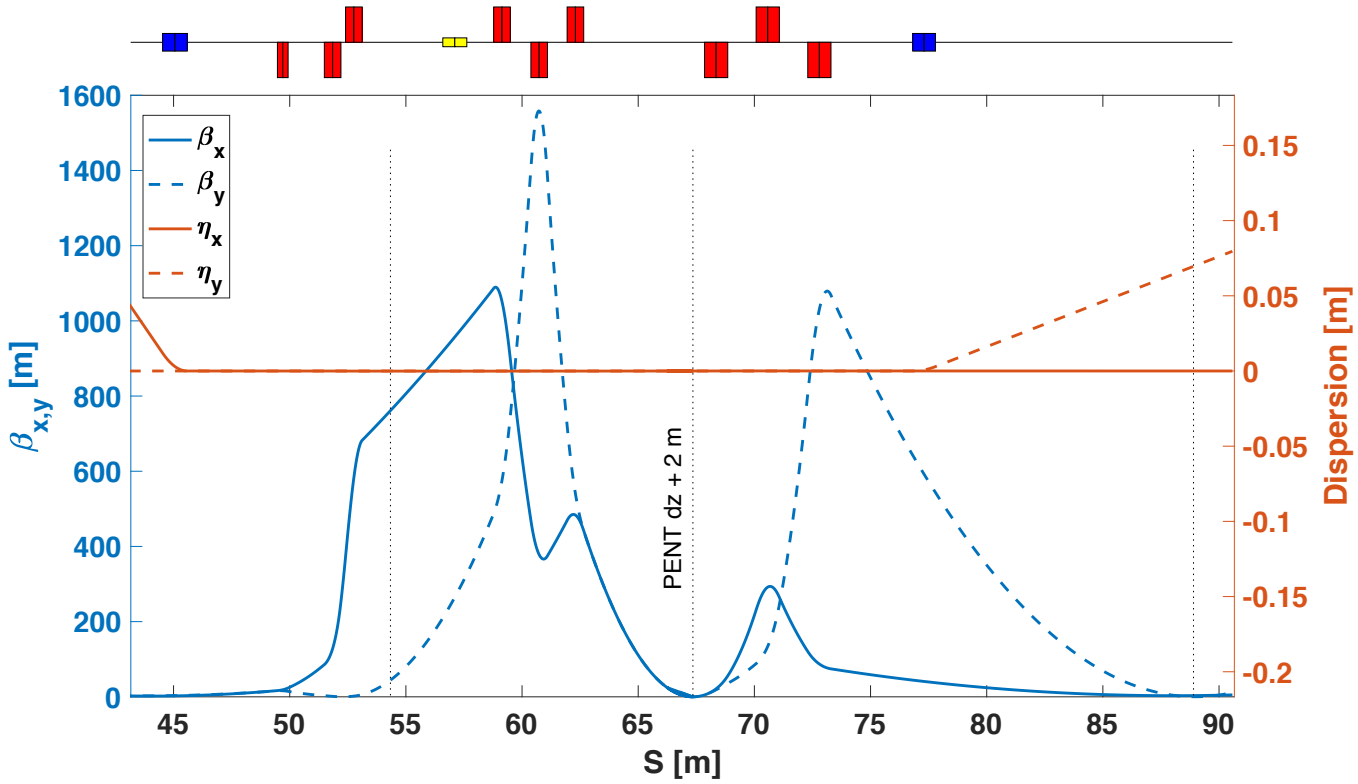


IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	99.8	1.7	124	16.0
PENT	0.5	0.5	8.8	8.8
PDUMP	8.4	2.5	35.9	19.6

*** (γε=3.0 μm-rad)**

Optics for 2-bunch PWFA experiments with largest requested β*

TCAV Measurement Resolution Optimized



IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	761	44.4	342	82.5
PENT	0.05	0.05	2.8	2.8
PDUMP	3.3	0.26	22.5	6.3

$$\sigma_{z,res} = \frac{\sqrt{\sigma_{YAG}^2 + \beta_S \epsilon\{1 + (\xi_x \delta_E)^2\}}}{S} = 1.0\mu m$$

$$\frac{\sigma_{E,res}}{E} = \frac{\sqrt{\sigma_{YAG}^2 + \beta_S \epsilon\{1 + (\xi_y \delta_E)^2\}}}{\eta_y} = 1.3\times10^{-4}$$

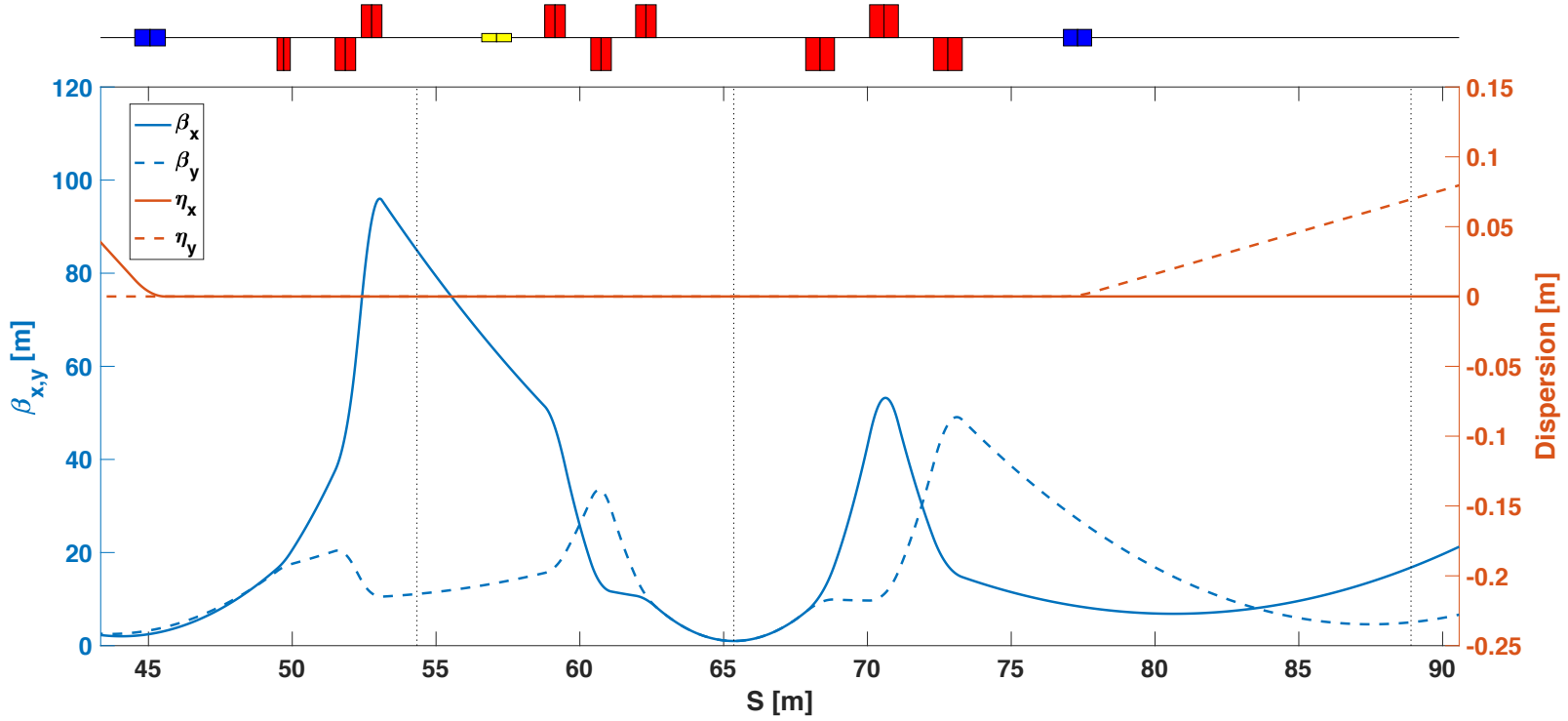
$$S = \sqrt{\beta_T \beta_s} k_{rf} \frac{eV_{rf}}{pc} \sin\Delta\psi$$

- V_{rf}=20 MV
- σ_{YAG}=3.5 μm
- θ_{B5D}=6 mrad
- η_y (PDUMP)=7 cm

*** (γε=3.0 μm-rad)**

Beta functions and IP waist location optimized to minimize TCAV resolution

IP=PENT β^* = 100 cm (single bunch, high I_{pk}, max requested β^*)

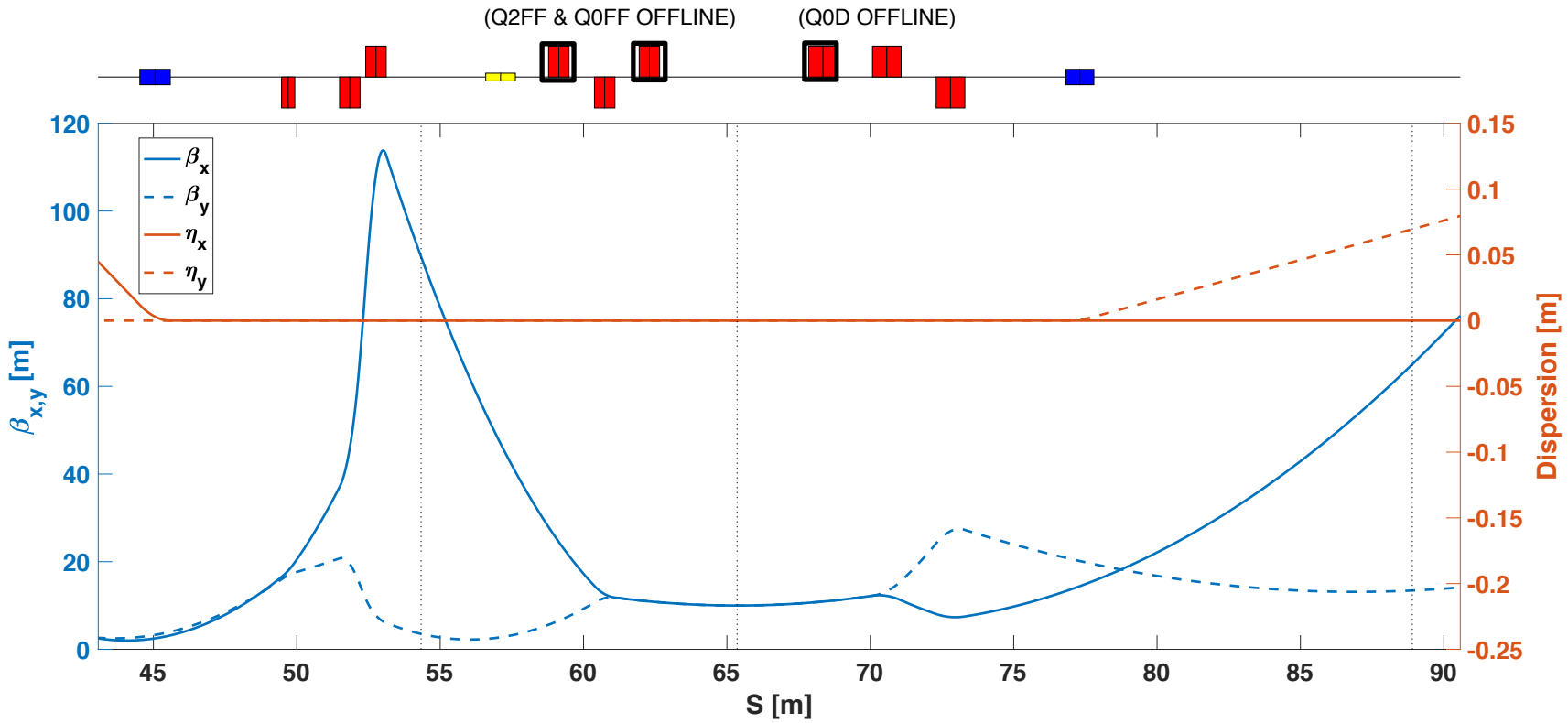


IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	84.9	11.1	114	41.2
PENT	1.0	1.0	12.4	12.4
PDUMP	16.8	5.0	50.7	27.7

*** (γε=3.0 μm-rad)**

Single bunch, high peak current option, high β^*

IP=PENT β^* = 10 m E=13GeV (SFQED Configuration)

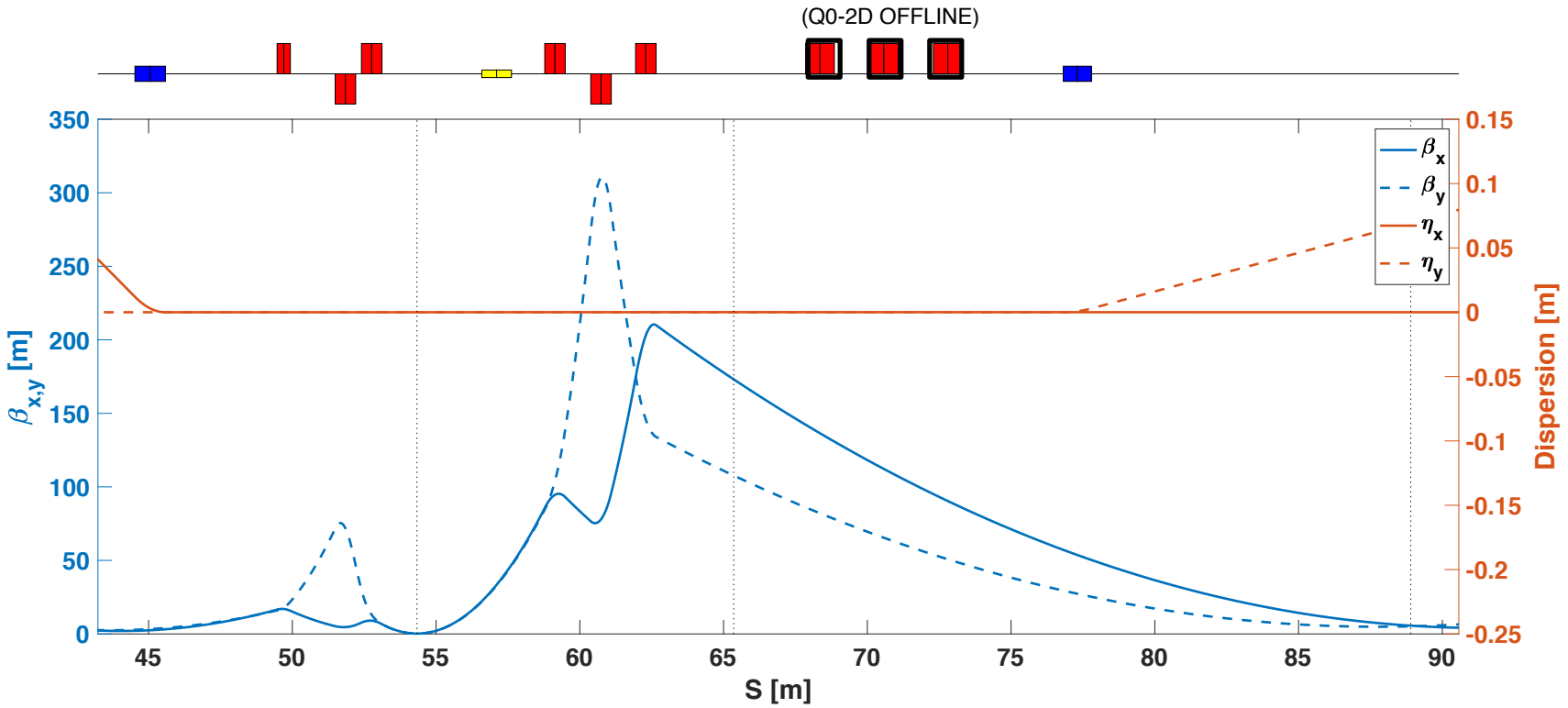


IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	89.6	3.5	103	20.4
PENT	10.0	10.0	34.3	34.3
PDUMP	65.0	13.4	87.6	39.8

*** (γε=3.0 μm-rad)**

Low Aberration, Low Energy Spread Beam for Initial SFQED Experiments
Spectrometer configured for high resolution detection of IP x angle and dE kicks

IP=KRAKEN (Round β Config)

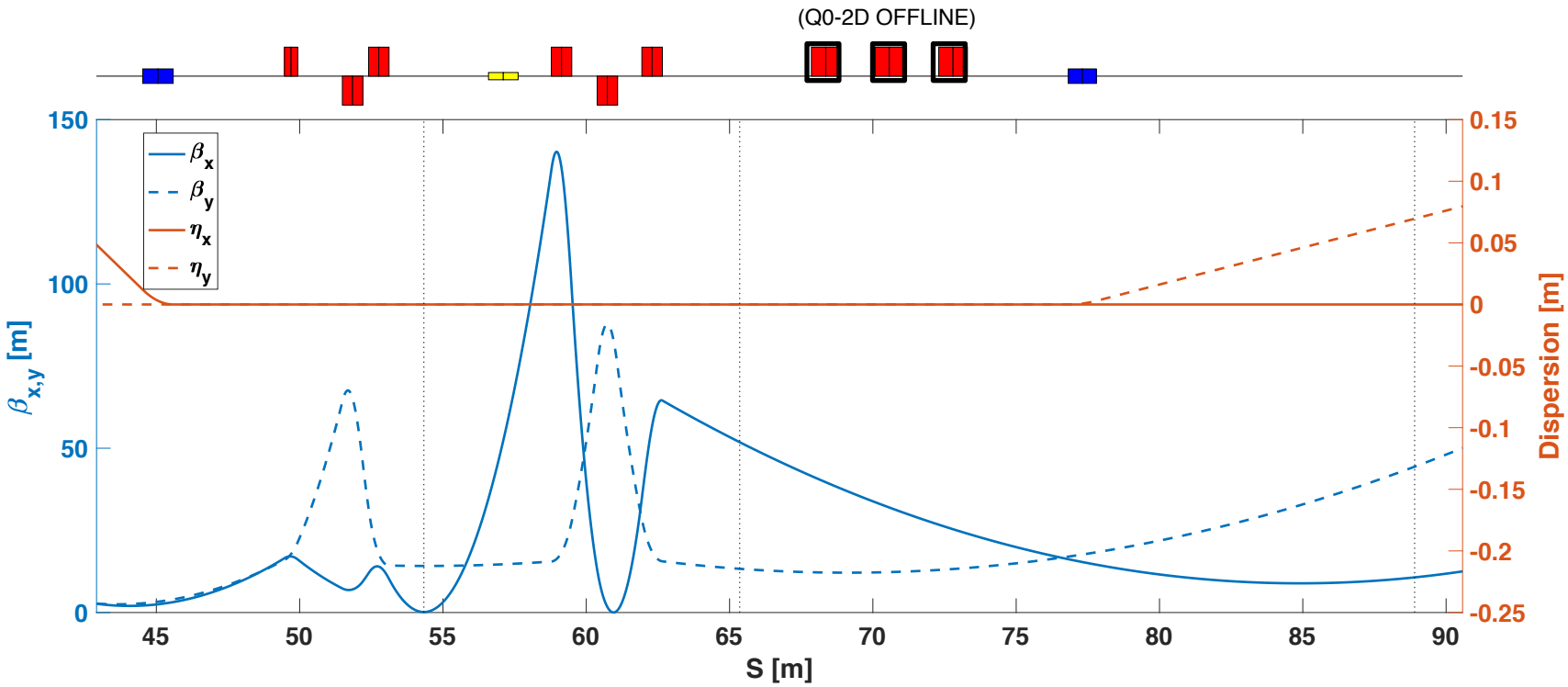


IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	0.23	0.23	5.2	5.2
PENT	173	108	162	129
PDUMP	5.6	5.1	29.4	28.1

*** (γε=3.0 μm-rad)**

Waist at KRAKEN IP with round beams

IP=KRAKEN (100:1 β Config)

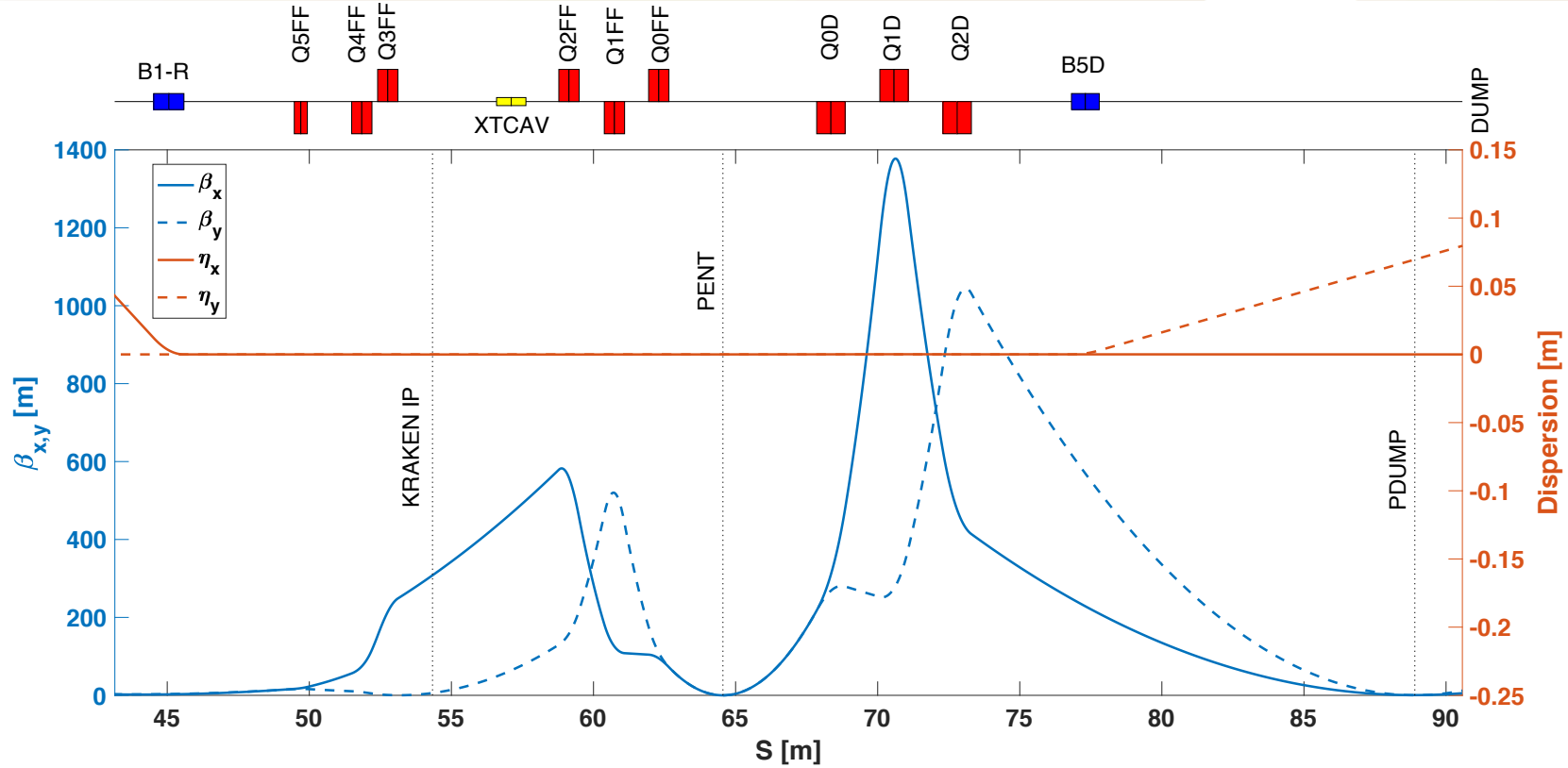


IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	0.147	14.17	4.7	46.6
PENT	51.8	13.3	89.1	45.2
PDUMP	10.7	44.4	40.5	82.5

*** (γε=3.0 μm-rad)**

Waist at KRAKEN IP with 100:1 β-ratio

Filamentation Experiment (Solid Target)



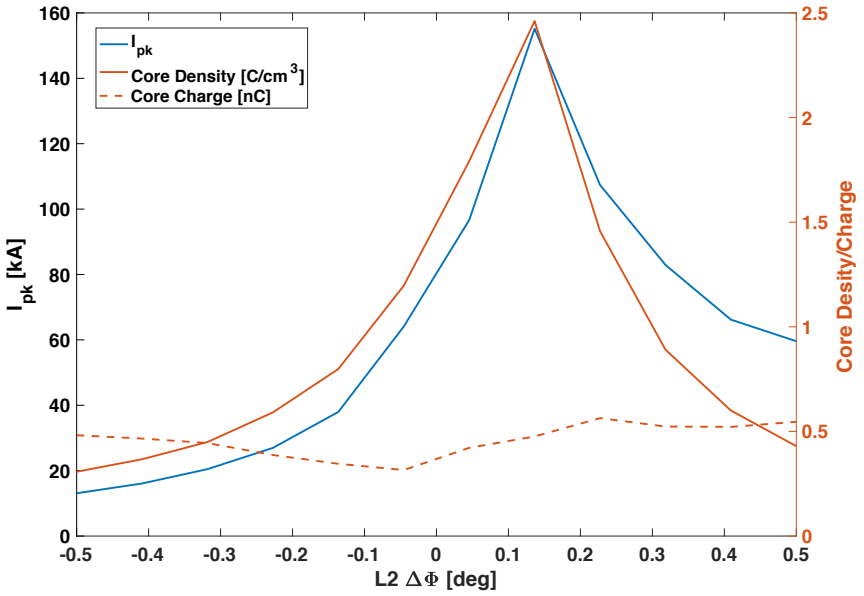
IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	308	5.9	217	30.1
PENT	0.05	0.05	2.8	2.8
PDUMP	0.6	0.2	9.5	6.0

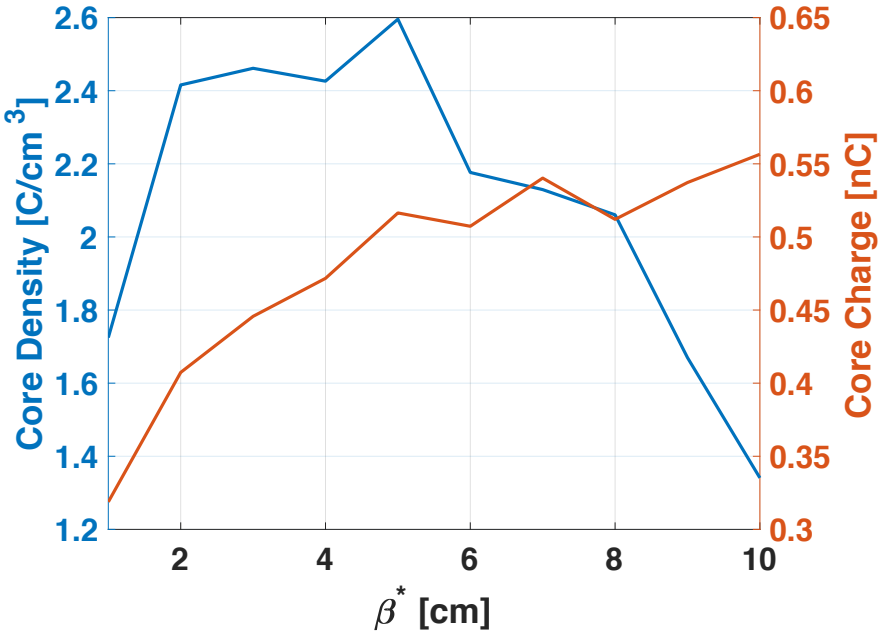
*** (γε=3.0 μm-rad)**

Waist at 119cm from Q0FF, max core density, Q_{bunch} = 2.0 nC

Filamentation Experiment Options (Solid Target)

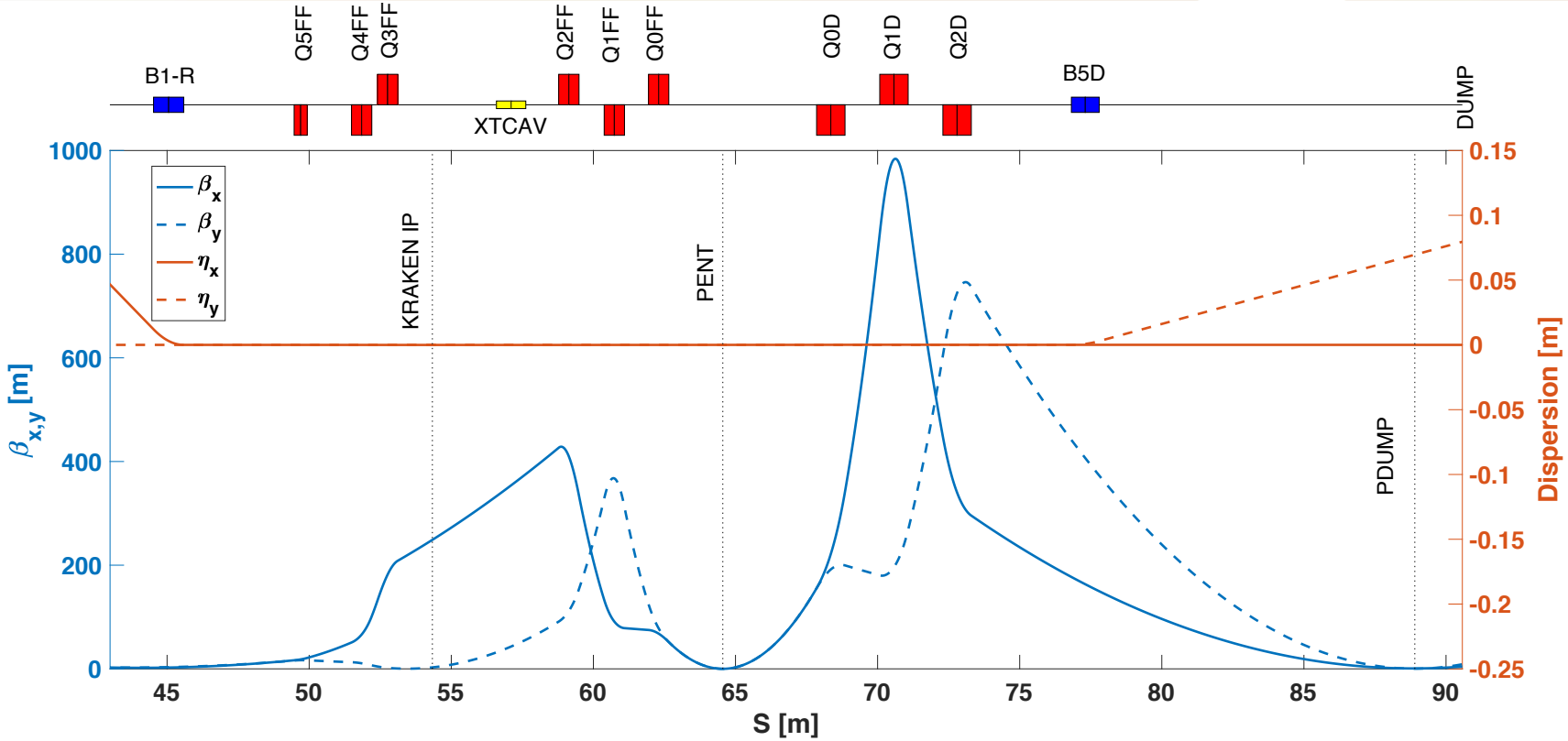
- Define core as charged contained within FWHM in x, y & z





- Q_{bunch} = 2.0 nC
  - Max core density ~ 2.5 C/cm^3 with β^* = 5 cm
  - 500 pC in core (25% of bunch)

Filamentation Experiment (Gas Target)



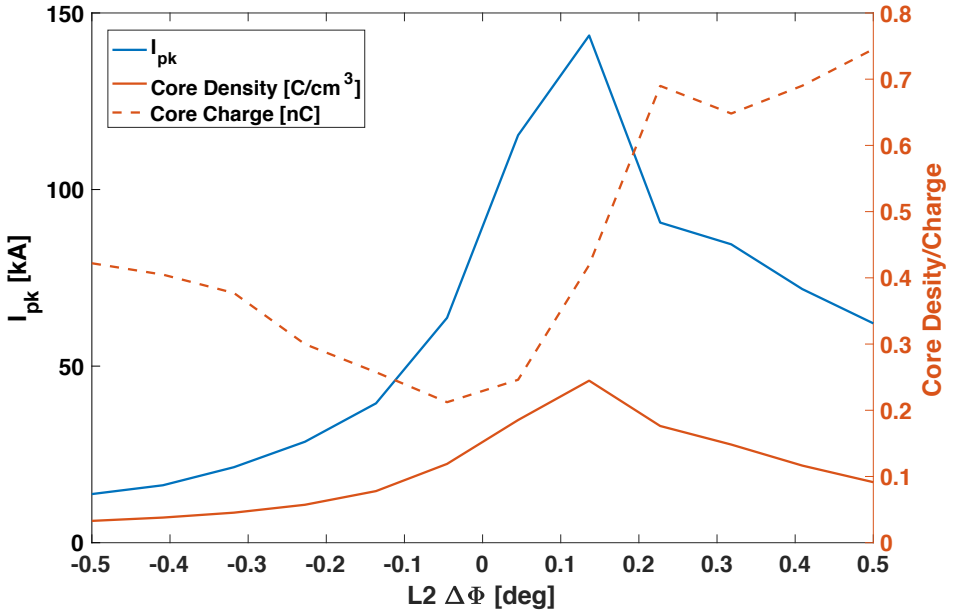
IP	β_x [m]	β_y [m]	√βε (X) [μm] *	√βε (Y) [μm] *
KRAKEN	2492.8	2.8	195	20.8
PENT	0.7	0.7	10.4	10.4
PDUMP	0.8	0.3	11.2	7.1

*** (γε=3.0 μm-rad)**

Waist at 119cm from Q0FF, $\sigma_{x,y}$ = 10 μm, I_{pk}=100kA

Filamentation Experiment (Gas Target)

- Define core as charged contained within FWHM in x, y & z projections



- Q_{bunch} = 2.0 nC
  - β^* = 0.7 m ($\sigma_{x,y}$ = 10 μm at γε=3μm-rad)
  - 700 pC in core for I_{pk}=100kA (35% of bunch)

Summary

- Sector 20 final focus + spectrometer beamline designed from ground up to provide required flexibility for proposed FACET-II experiments
- See talk later today for tracking studies aimed at understanding expected performance
- Version of this talk available together with particle dristributions for different configurations:

http://www.slac.stanford.edu/~whitegr/F2_S2E