Low Beam Energy Spread for FLASHII HGHG Option

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S2E Meeting, DESY

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The plan for this month

1. Low energy spread for FLASHII HGHG option (100%)
2. particle distributions of FLASH for Johann Zemella for special purpose of plasma study. (100%)
3. The internal report for EXFEL simulations (~100%)

Achieved progress

1. Low energy spread for FLASHII HGHG option (100%)

Requirements:

1) The global slice length: ~15 um slice = 50 fs
   Maximal energy chirp (correlated energy spread) along the global slice ~150 keV

2) Min current along the global slice: Should exceed at least 0.5 kA

3) Maximal local slice emittance along the global slice?: 1.5 um

4) Maximal local (uncorrelated) energy spread: ~100 keV

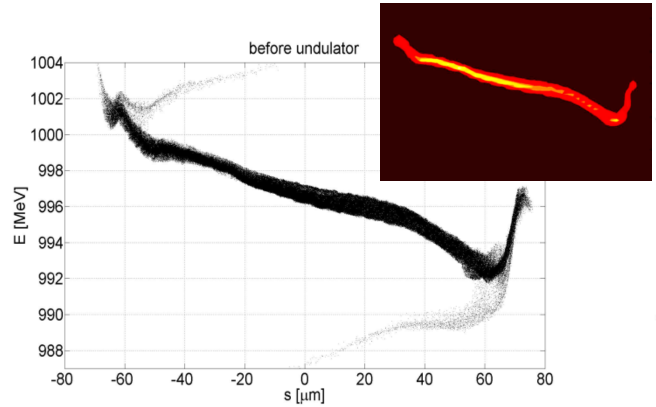
Low energy spread for FLASHII HGHG option

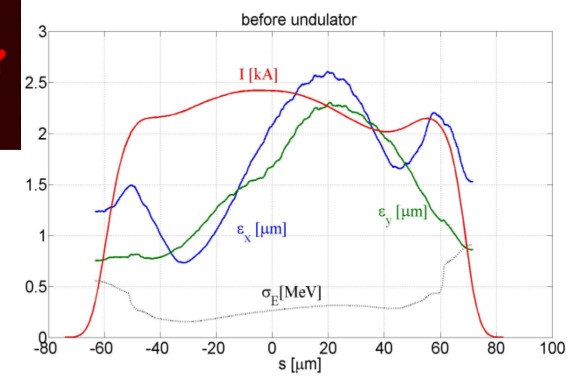
RF settings in accelerating modules for CASE1 (1.0nC)

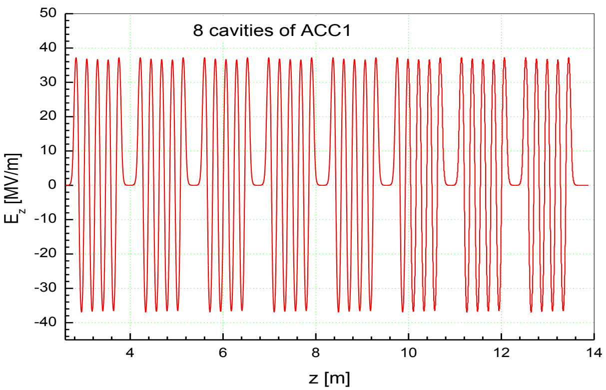
Charge nC	V_{acc1}* [MV]	φ_{acc1} [deg]	V_{acc39} [MV]	φ_{acc39} [deg]	$V_{acc2,3}$ [MV]	$\Phi_{acc2,3}$ [deg]	$V_{acc4,5,67}$ [MV]	$\Phi_{acc4,5,6,7}$ [deg]
1.0	160.4	-3.2	21.9	153.4	337.3	25.0	550.0	0.0

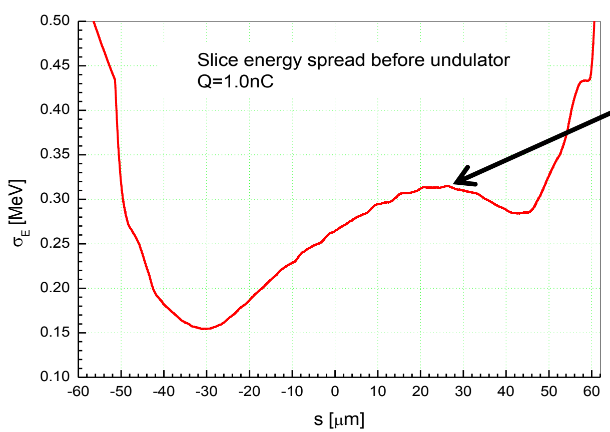
* Same voltage amplitude has been used for the first 4 cavities and the last 4 cavities of ACC1

$V_{1\text{-}4}=V_{5\text{-}8}$









σ_E >300keV

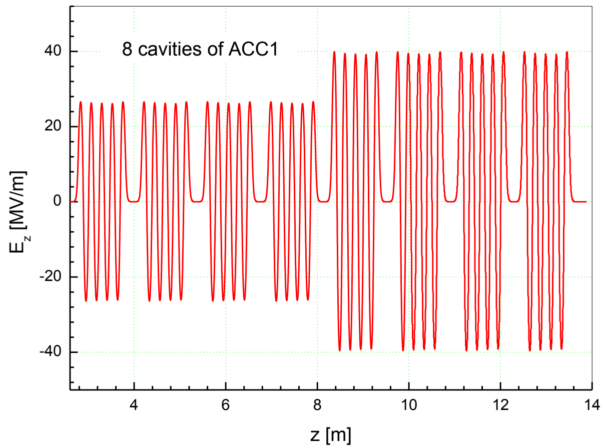
FLASH II HGHG option need beam bunch with low slice energy spread !!!

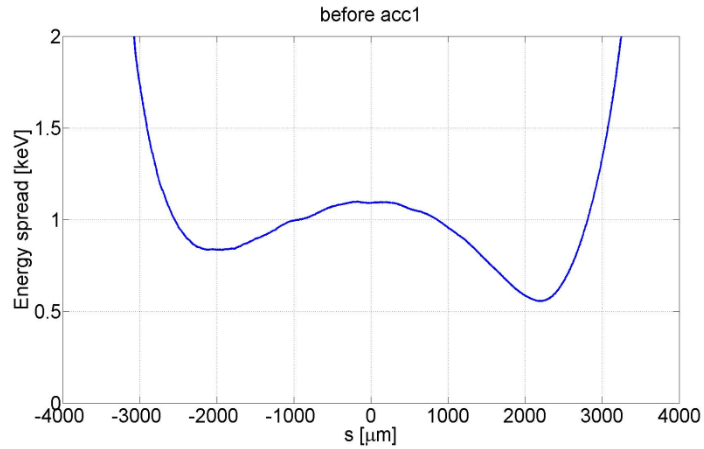
Low energy spread for FLASHII HGHG option

RF settings in accelerating modules for CASE2 (1.0nC)

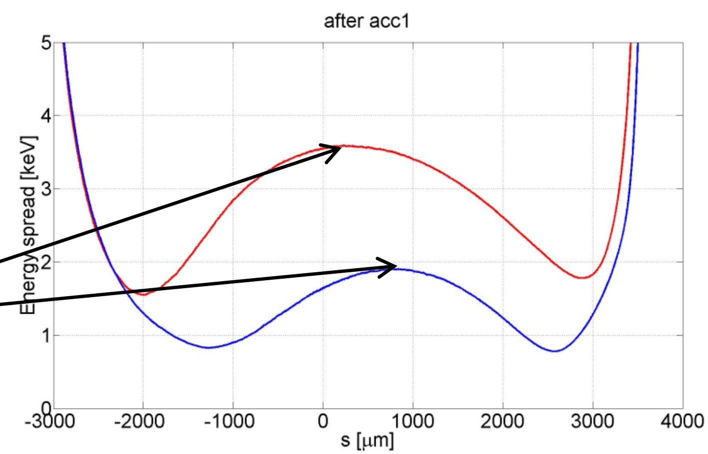
Charge nC	V_{acc1}* [MV]	φ_{acc1} [deg]	V_{acc39} [MV]	φ_{acc39} [deg]	$V_{acc2,3}$ [MV]	$\Phi_{acc2,3}$ [deg]	$V_{acc4,5,67}$ [MV]	$\Phi_{acc4,5,6,7}$ [deg]
1.0	143.33	-5.1	20.63	149.4	337.3	25.0	550.0	0.0

*** In ACC1, $V_{1\text{-}4}$:$V_{5\text{-}8}$=2:3**

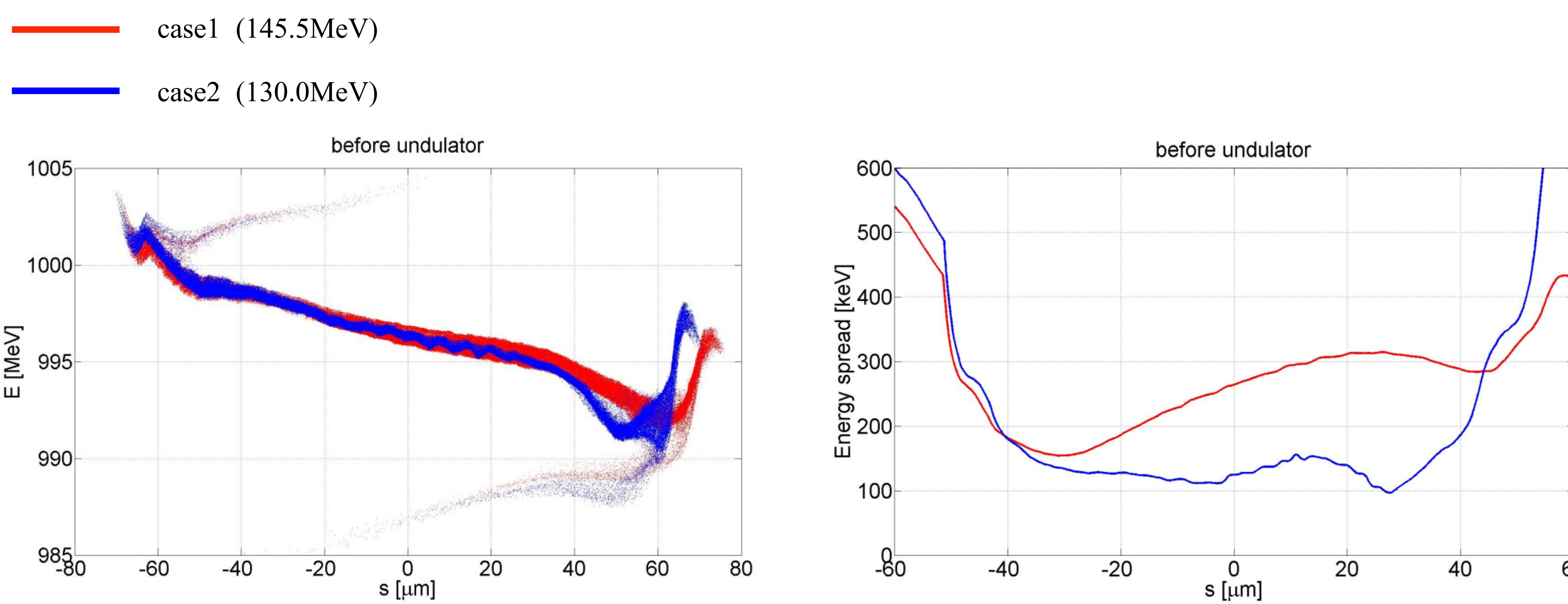




case1 (145.5MeV)
case2 (130.0MeV)



Significant difference can be found in ACC1



Conclusion:

1. Higher energy gradient in the first cavity of ACC1 may lead to a transverse over focusing on the beam bunch. The stronger space charge force will make the slice energy spread and transverse emittance become larger.

2. When keeping $V_{1-4}=V_{5-8}$ in ACC1, it is not easy to make a significant improvement to get the low slice energy spread by optimizing the RF parameters of ACC1 and ACC39 in a reasonable region.

3. A proper voltage distribution ($V_{1-4}:V_{5-8}$) in ACC1 may bring two advantages:

   (1) Lower energy gradient in the first cavity of ACC1 to avoid transverse over focusing.

   (2) High beam energy gain after ACC1 to reduce the space charge effects.

Low energy spread for FLASHII HGHG option

Conditions for new calculation:

1. Keeping the same accelerating gradient for each cavity of ACC1.
2. Low energy spread calculation with low longitudinal compression in BC3 (Low peak current)

Parameter settings for the bunch compressors

Charge Q, nC	Curvature radius in BC_2 r1 [m]	Momentum compaction factor in BC_2, $R_{56,2}$ [mm]	compr. In BC2	Curvature radius in BC_3 r2 [m]	Momentum compaction factor in BC_3, $R_{56,3}$ [mm]	Total compr. C
1.0	**1.618**	**180.7**	**2.7**	**5.55**	**90.5**	**15**
0.5	**1.618**	**180.7**	**4.7**	**6.25**	**71.2**	**47**
0.25	**1.618**	**180.7**	**6.4**	**6.85**	**59.2**	**77.5**
0.10	**1.618**	**180.7**	**11.7**	**8.55**	**37.9**	**120**

E_1=145.5MeV, E_2=450MeV

Curvature radius in BCs[#] $1.4 \le \frac{r_1}{m} \le 1.93$ $5.3 \le \frac{r_2}{m} \le 16.8$

Low energy spread for FLASHII HGHG option

RF settings in accelerating modules for different bunch charge cases

Charge nC	V_{acc1}* [MV]	φ_{acc1} [deg]	V_{acc39} [MV]	φ_{acc39} [deg]	$V_{acc2,3}$ [MV]	$\Phi_{acc2,3}$ [deg]	$V_{acc4,5,67}$ [MV]	$\Phi_{acc4,5,6,7}$ [deg]
1.0	160.4	-3.2	21.9	153.4	323.3	19.0	623.0	-28.0
0.50	159.5	2.4	19.8	162.6	323.3	19.0	623.0	-28.0
0.25	159.9	1.9	20.5	160.5	323.3	19.0	623.0	-28.0
0.10	160.0	-1.0	21.9	152.6	323.3	19.0	623.0	-28.0

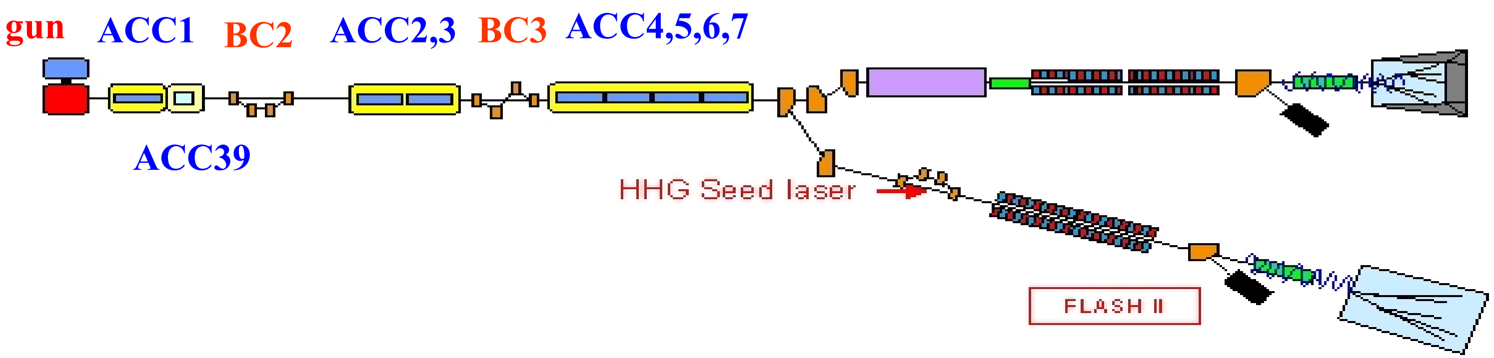
* Same voltage amplitude has been used for each cavity of ACC1

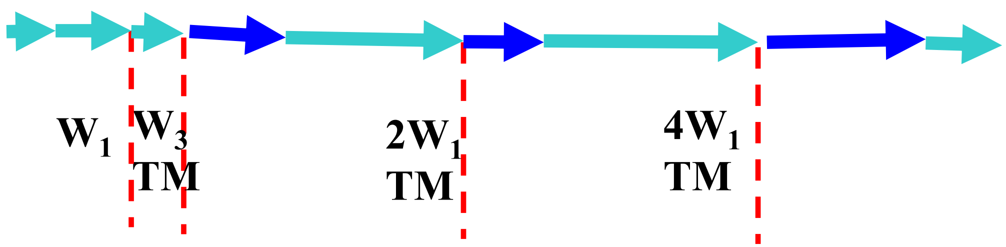
RF power restrictions:

Maximum energy gain for accelerating modules

ACC1	**165 MeV**
ACC39	**22 MeV**
ACC2/3	**345 MeV**
ACC4/5	**320 MeV**
ACC6/7	**430 MeV**

Low energy spread for FLASHII HGHG option





300000 particles

ASTRA (tracking with space charge effects, 3D calculation)

CSRtrack (tracking with CSR effects)

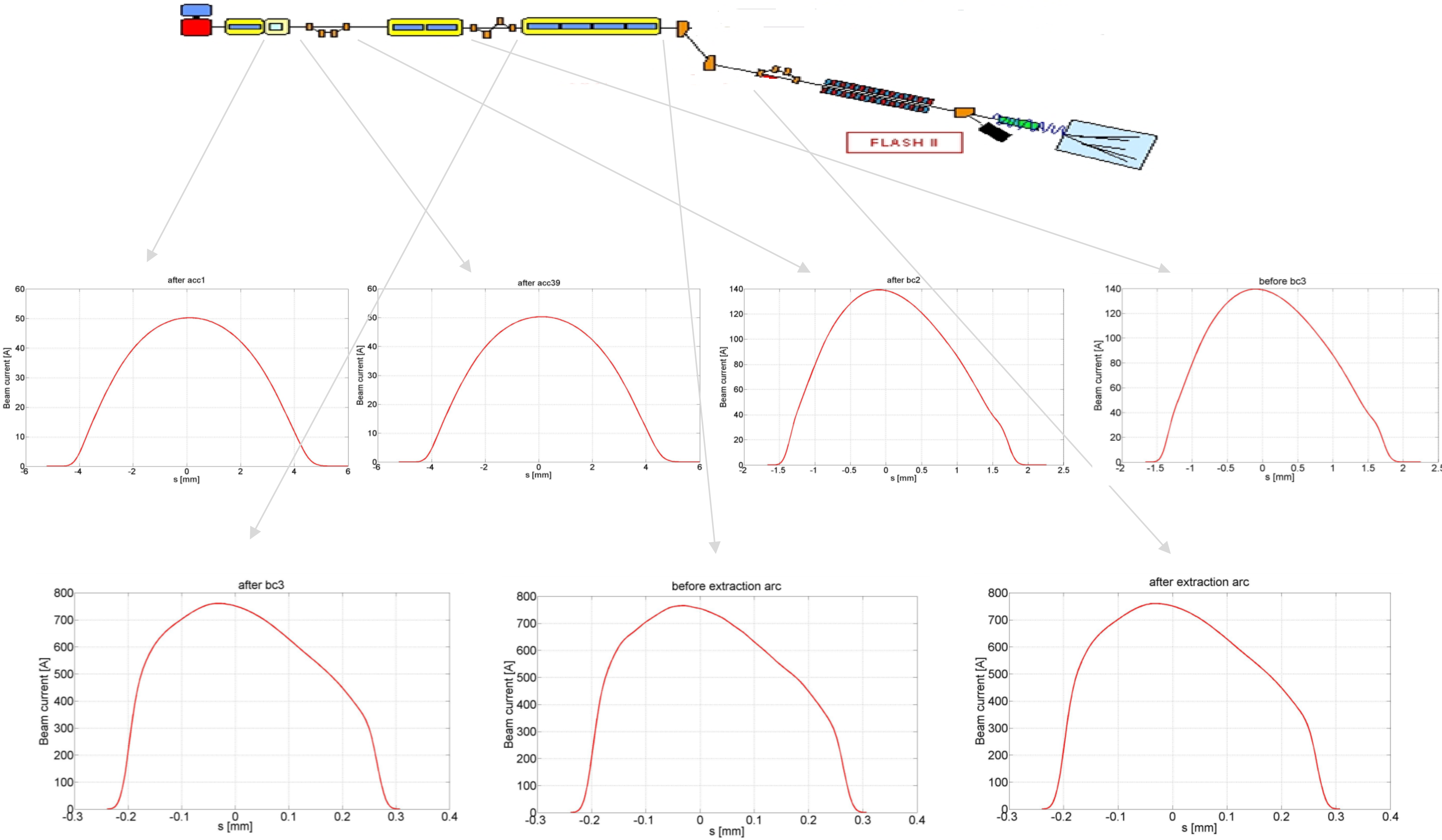
W1 -TESLA cryomodule wake (TESLA Report 2003-19, DESY, 2003)

W3 - ACC39 wake (TESLA Report 2004-01, DESY, 2004)

TM - transverse matching to the design optics

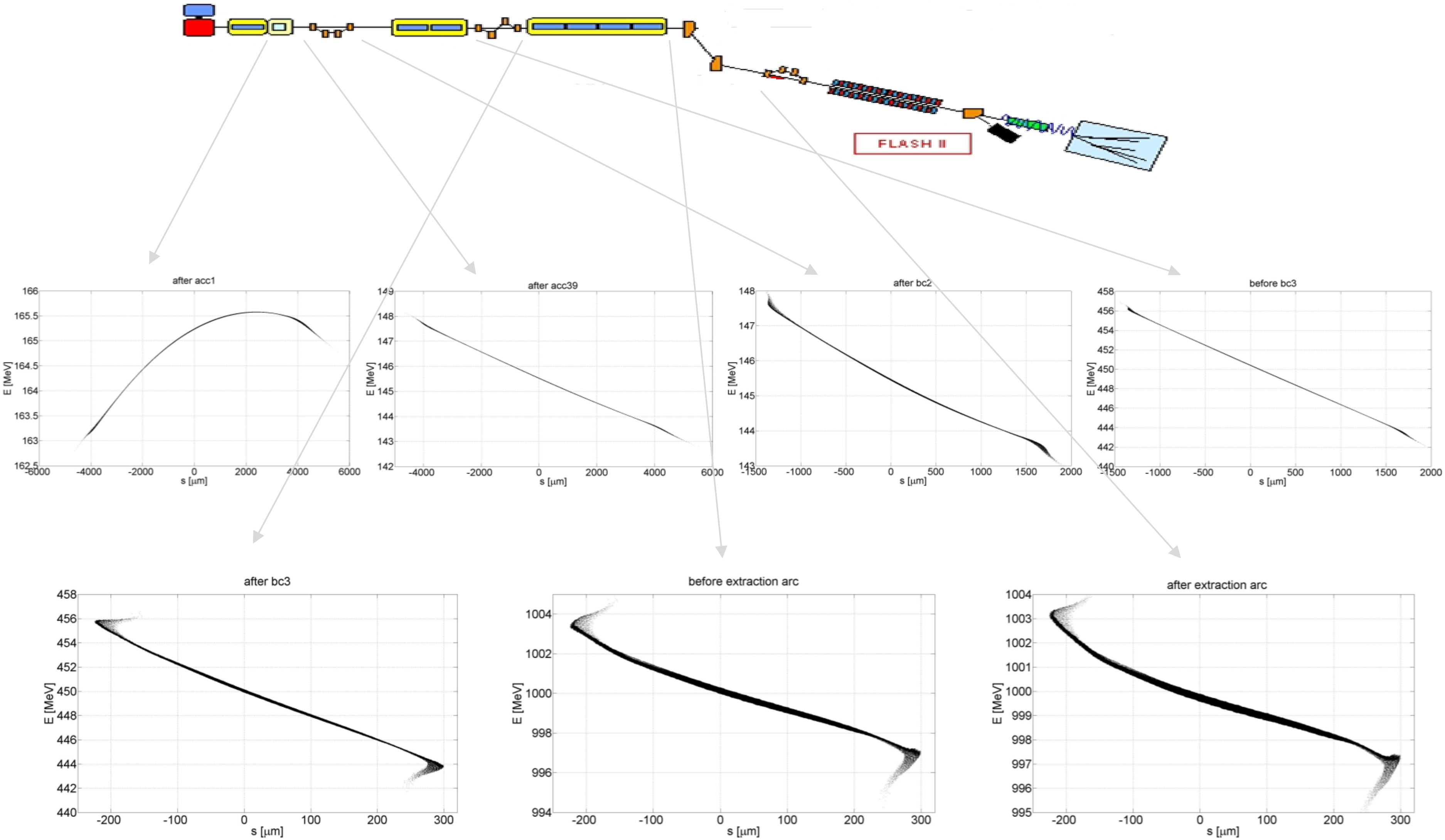
Low energy spread for FLASHII HGHG option (1.0nC)

Current profile along the beam line

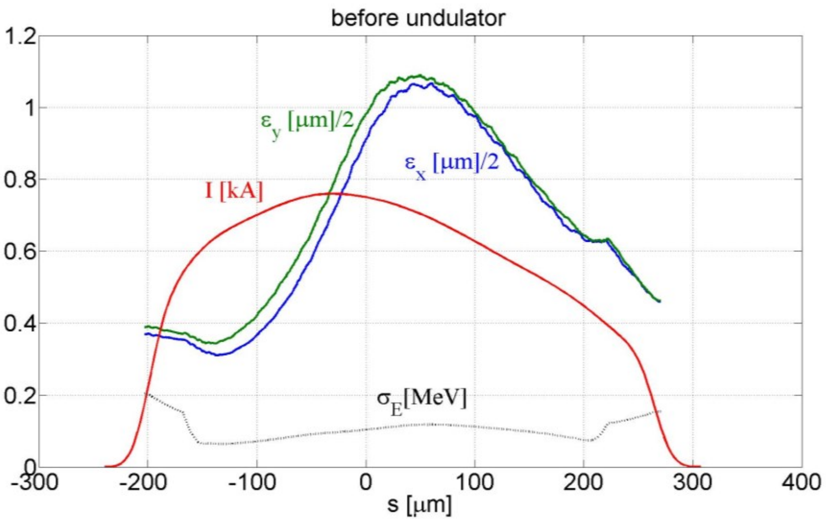


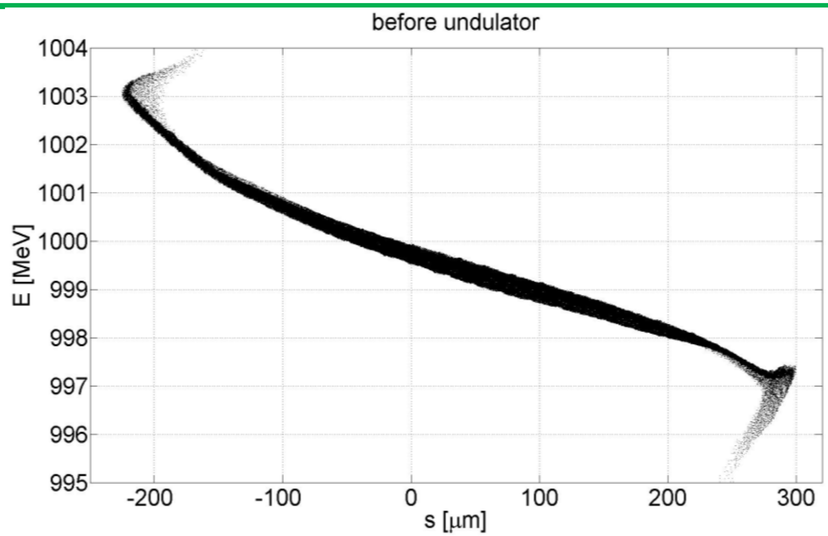
Low energy spread for FLASHII HGHG option (1.0nC)

Longitudinal phase space along the beam line



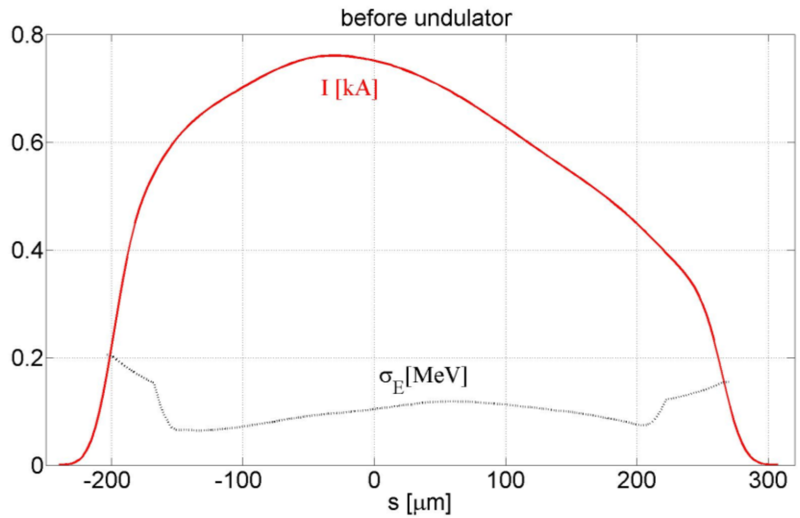
Low energy spread for FLASHII HGHG option (1.0nC)



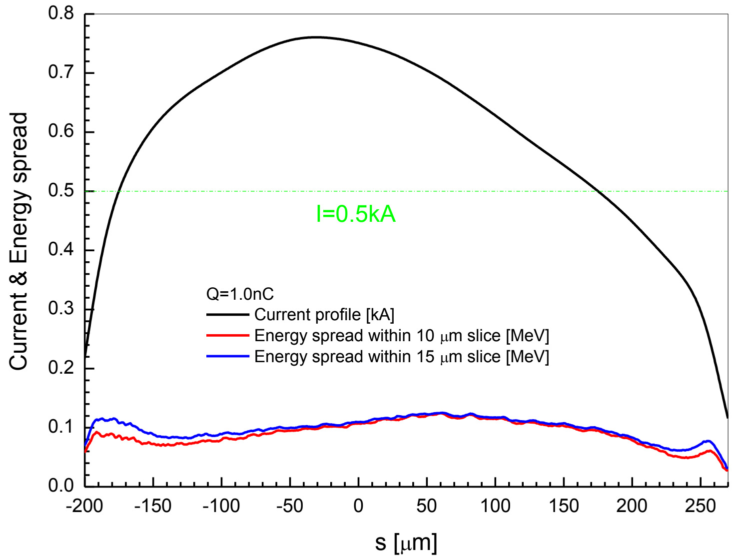


$\varepsilon_x{}^{proj} = 1.89\mu m \cdot rad, \varepsilon_y{}^{proj} = 1.90\mu m \cdot rad$

6% bad particles are removed



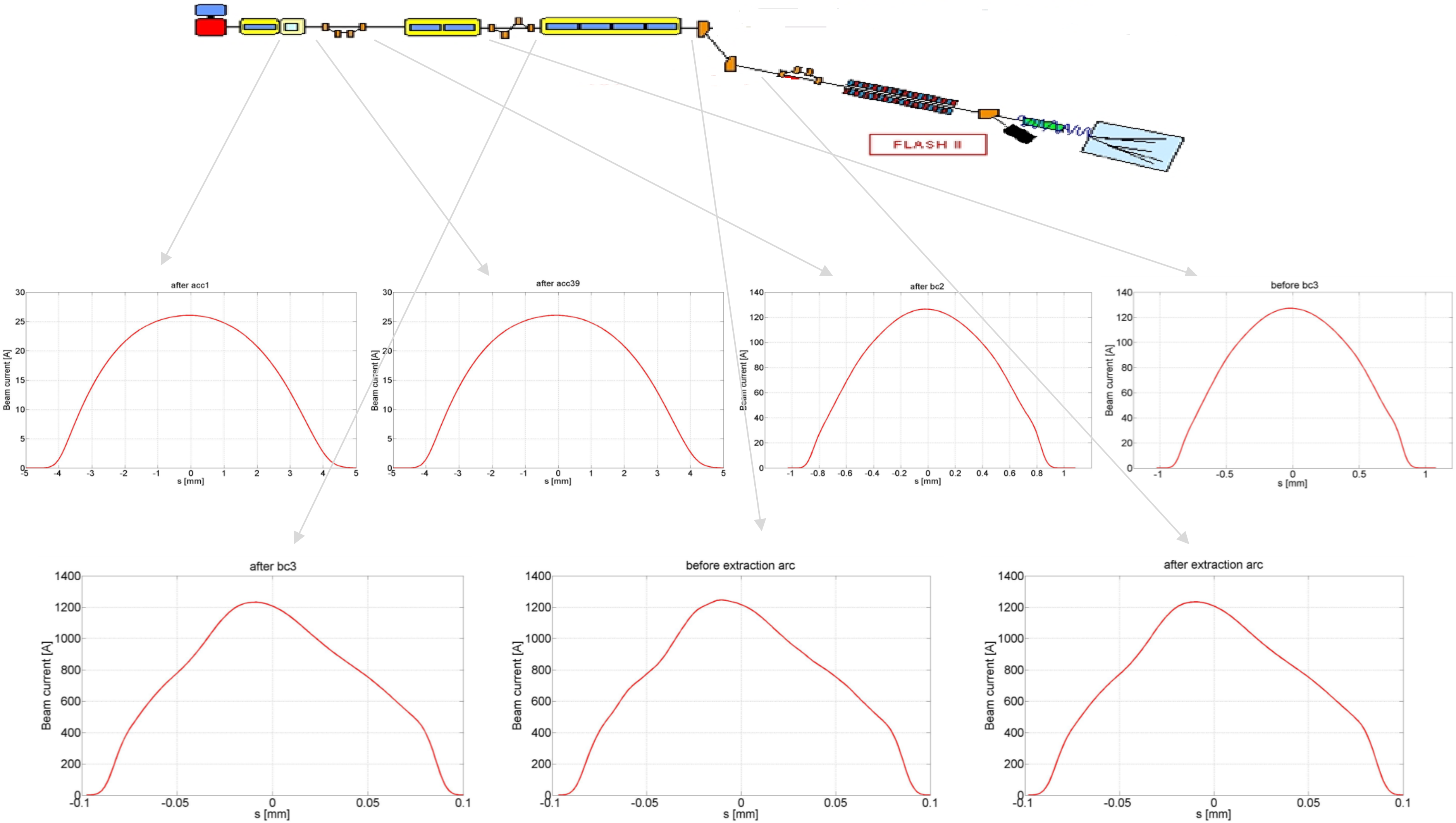
Slice energy spread distribution (uncorrelated)



Energy spread within 15μm and 10μm slice length

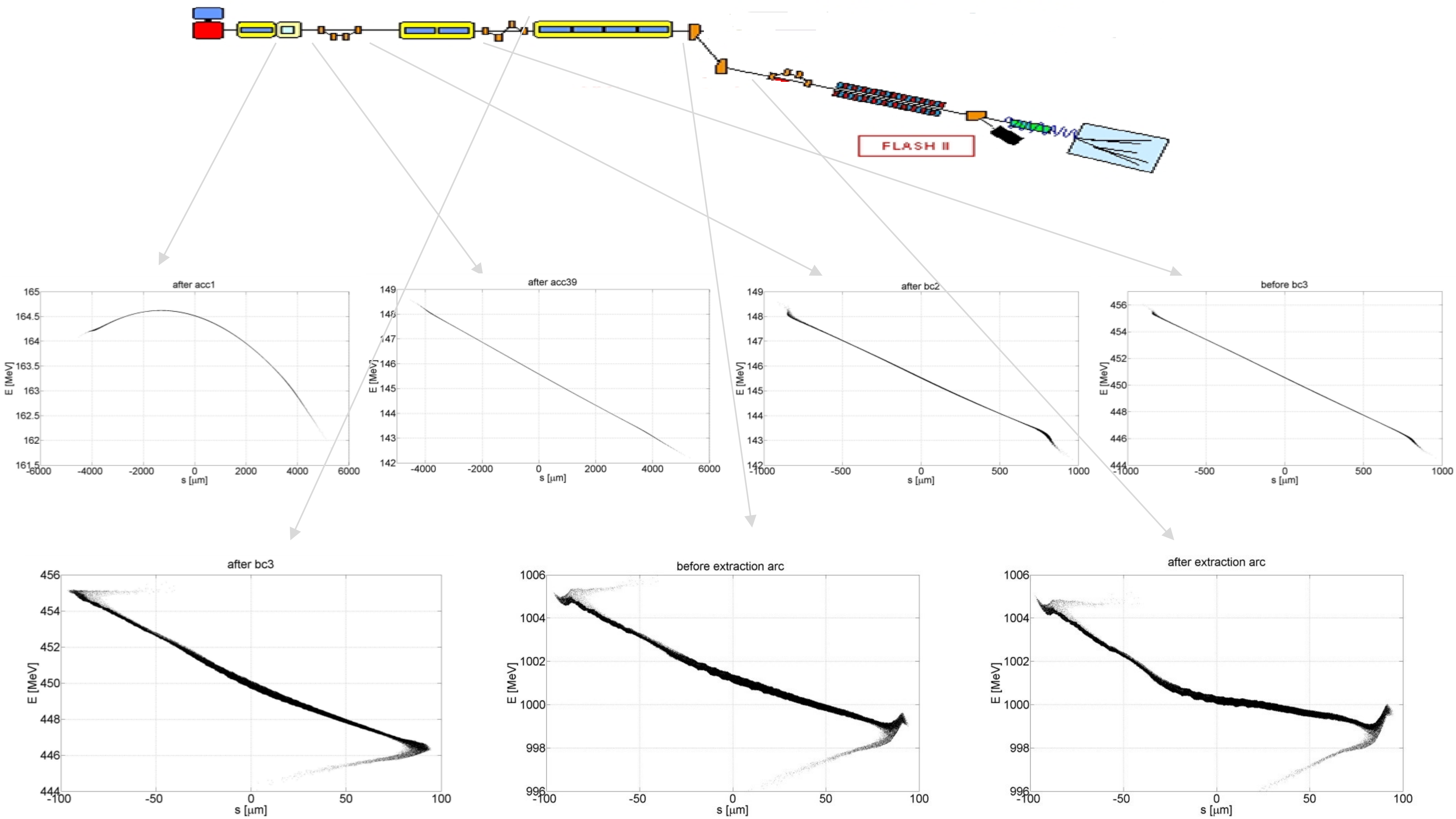
Low energy spread for FLASHII HGHG option (0.5nC)

Current profile along the beam line

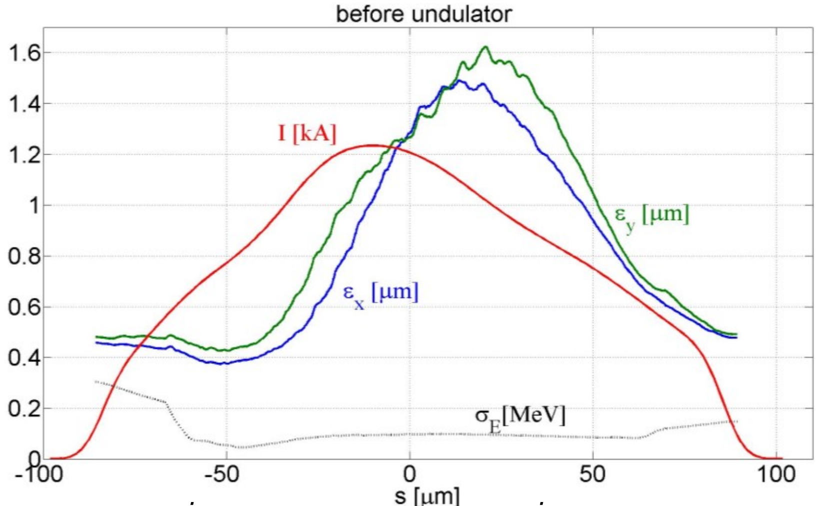


Low energy spread for FLASHII HGHG option (0.5nC)

Longitudinal phase space along the beam line

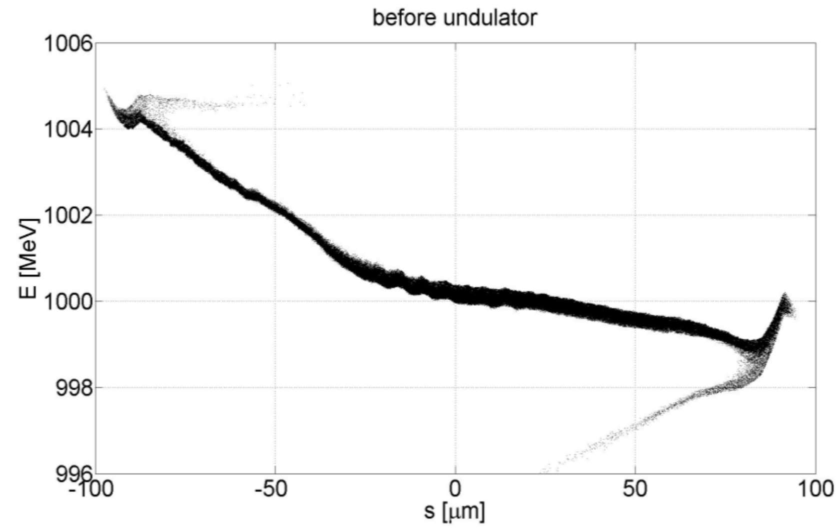


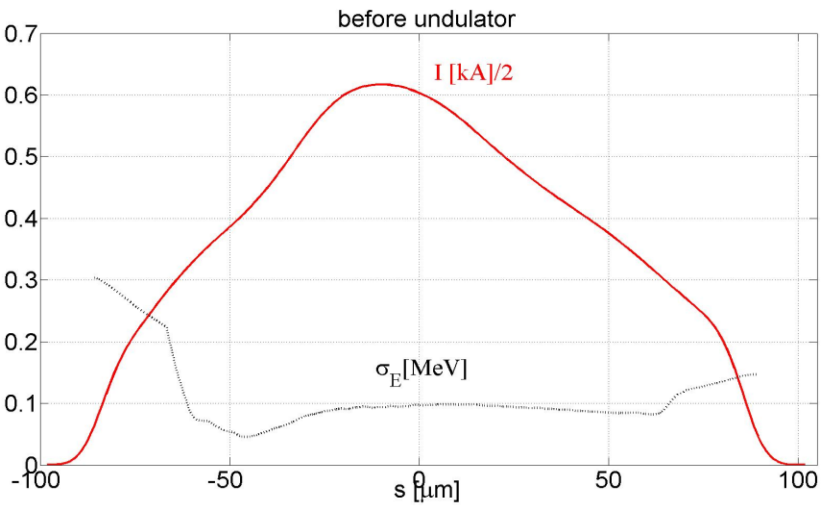
Low energy spread for FLASHII HGHG option (0.5nC)



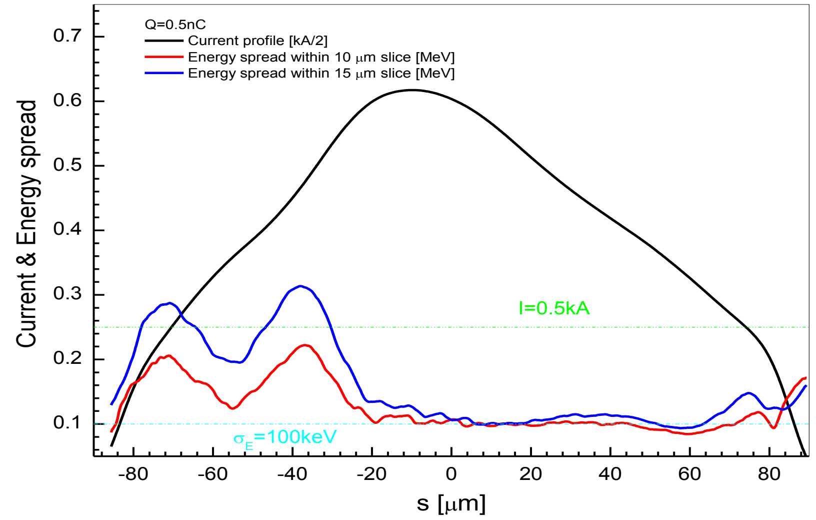
$\varepsilon_x{}^{proj} = 1.0\mu m \cdot rad, \varepsilon_y{}^{proj} = 0.98\mu m \cdot rad$

5% bad particles are removed





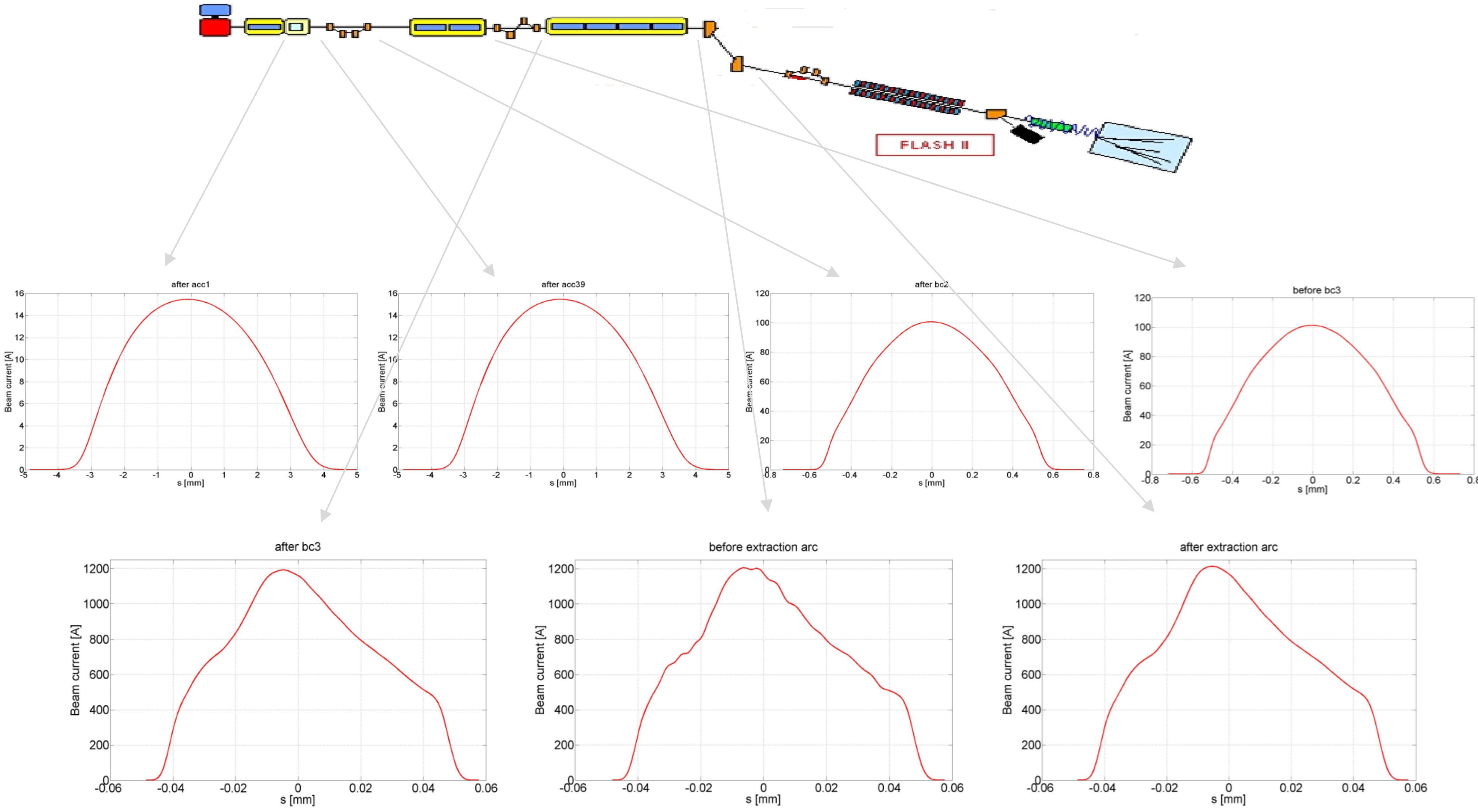
Slice energy spread distribution (uncorrelated)



Energy spread within 15μm and 10μm slice length

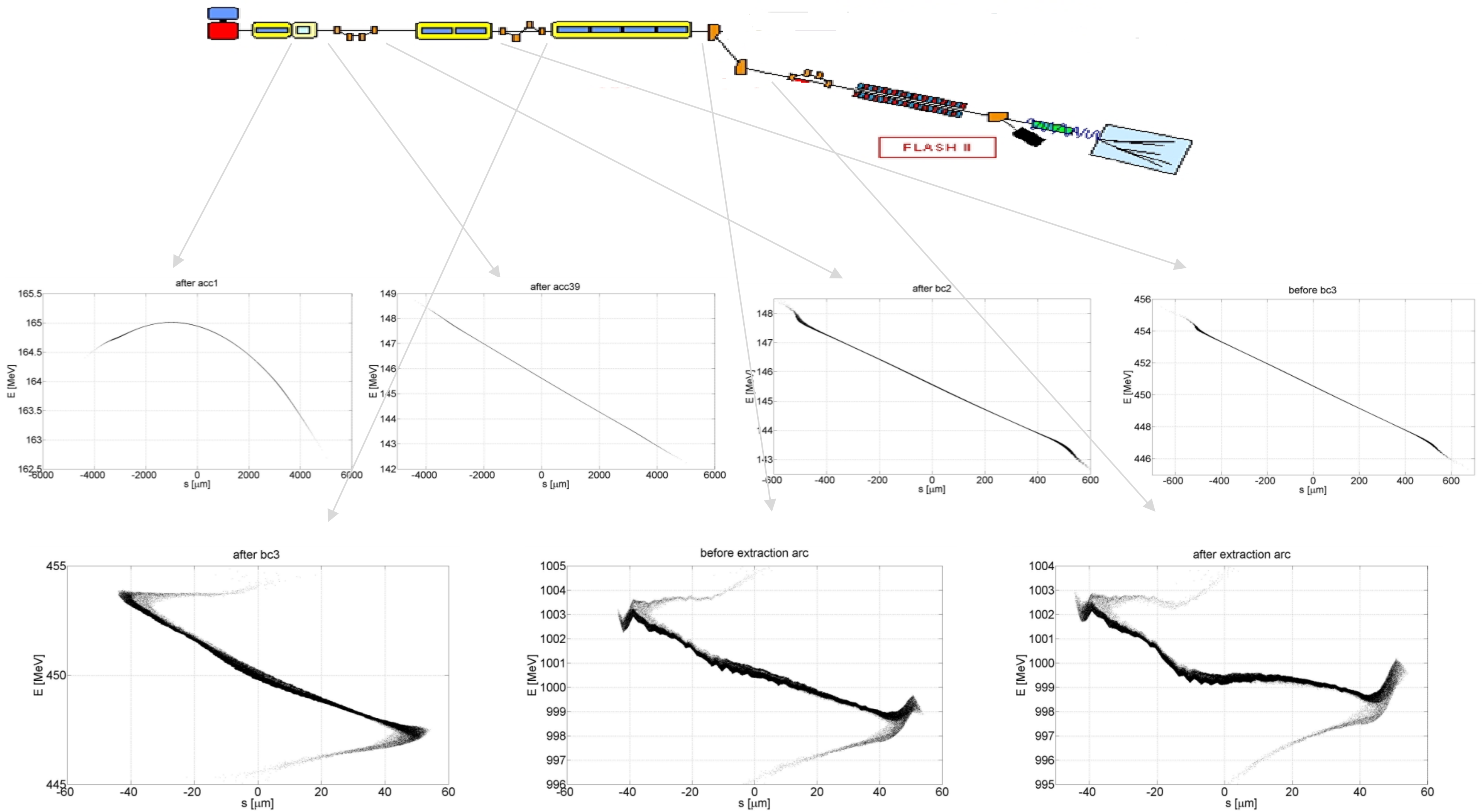
Low energy spread for FLASHII HGHG option (0.25nC)

Current profile along the beam line

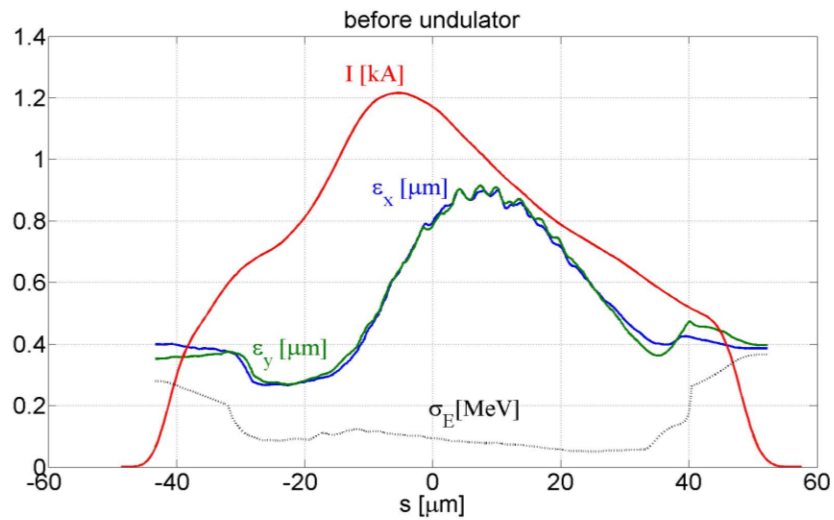


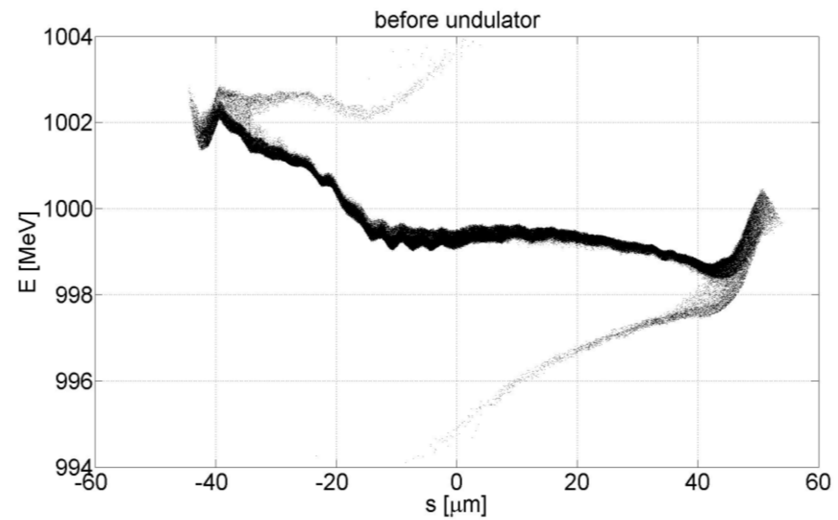
Low energy spread for FLASHII HGHG option (0.25nC)

Longitudinal phase space along the beam line



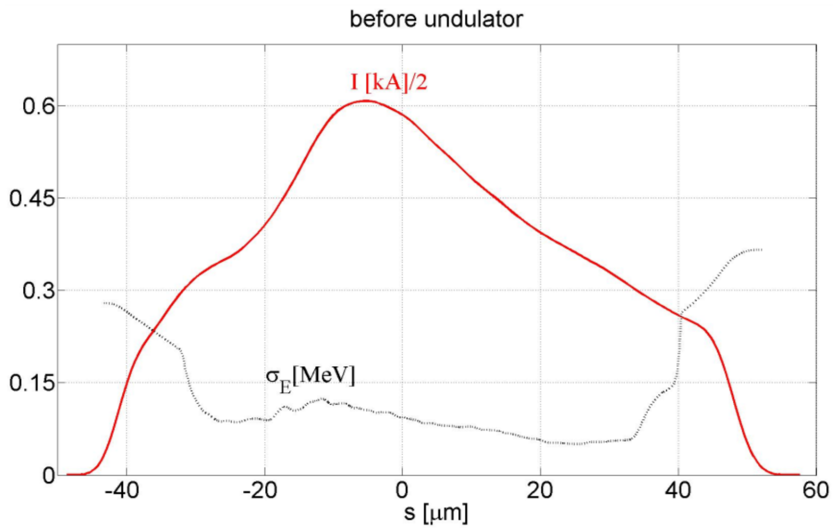
Low energy spread for FLASHII HGHG option (0.25nC)



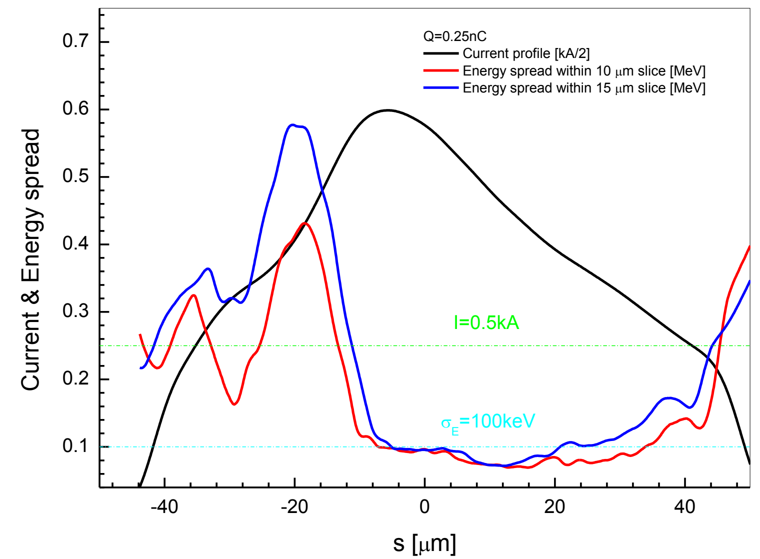


$$\varepsilon_x{}^{proj} = 0.63\mu m \cdot rad, \varepsilon_y{}^{proj} = 0.62\mu m \cdot rad$$

5% bad particles are removed



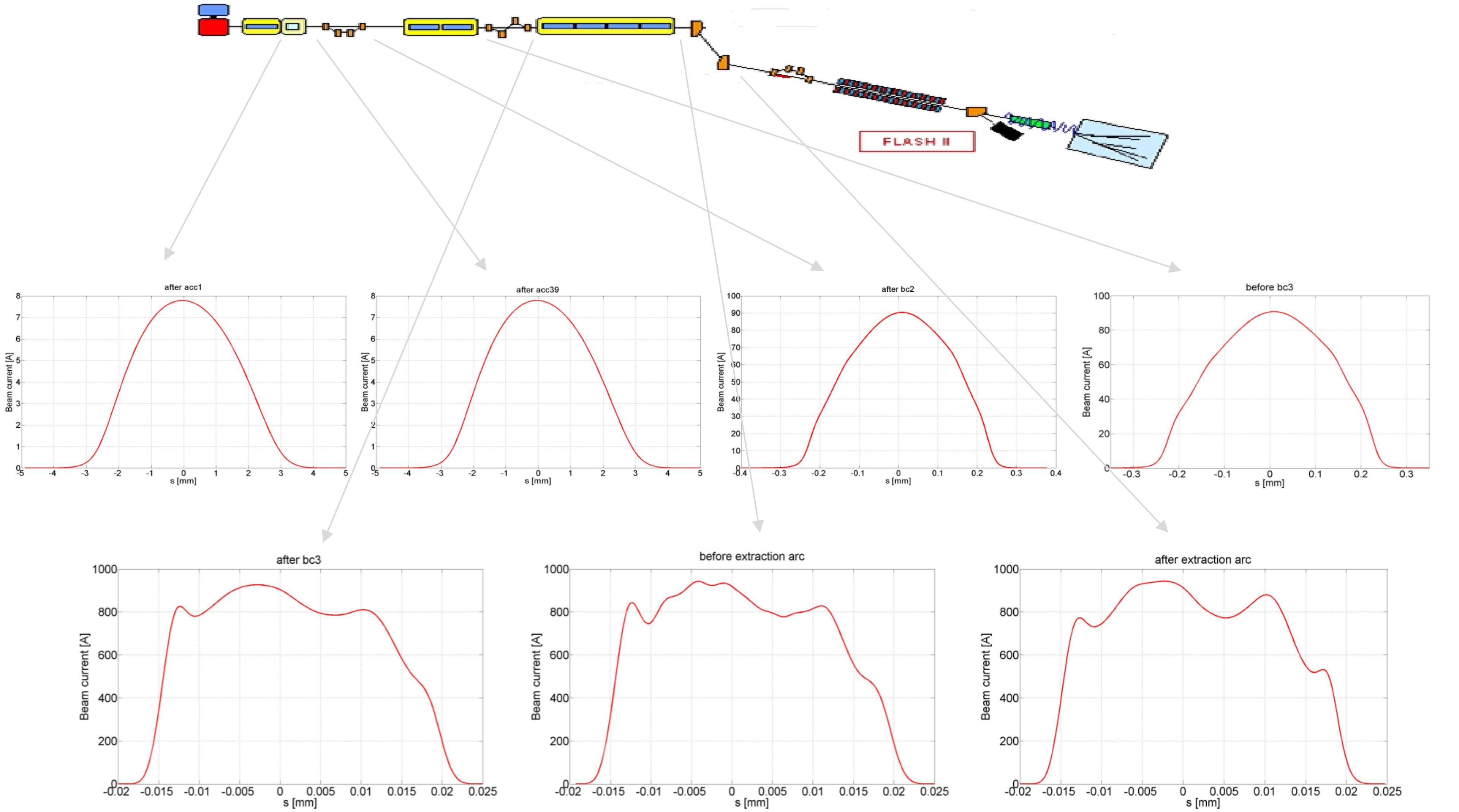
Slice energy spread distribution (uncorrelated)



Energy spread within 15μm and 10μm slice length

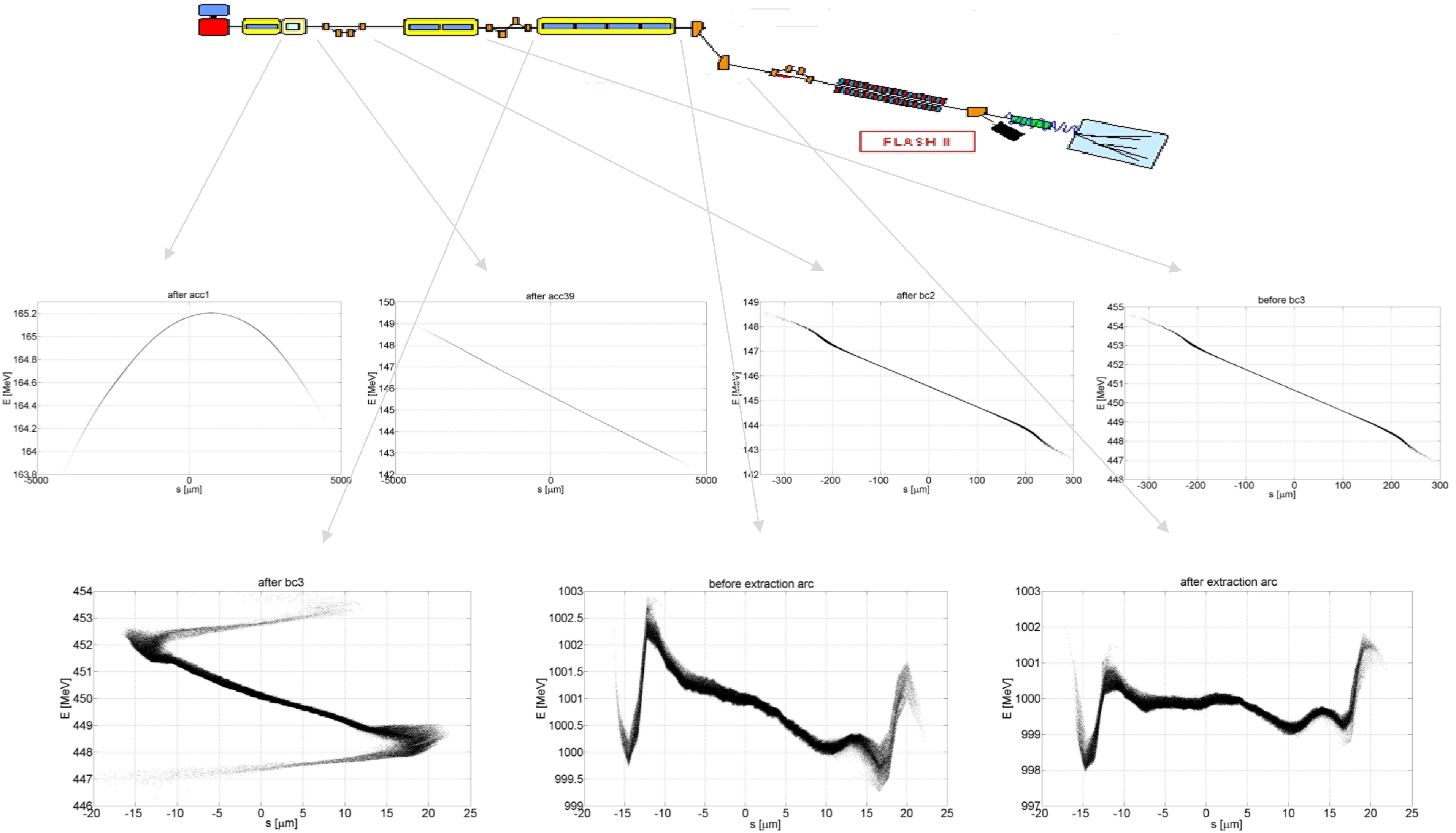
Low energy spread for FLASHII HGHG option (0.10nC)

Current profile along the beam line

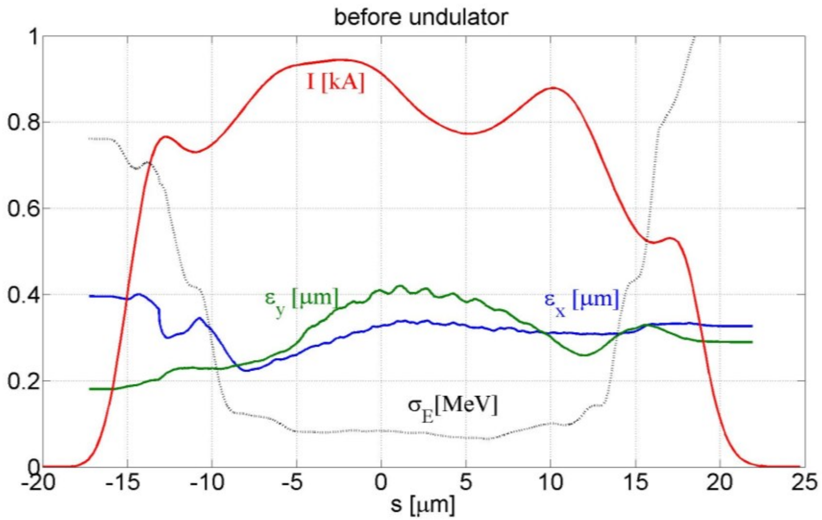


Low energy spread for FLASHII HGHG option (0.10nC)

Longitudinal phase space along the beam line

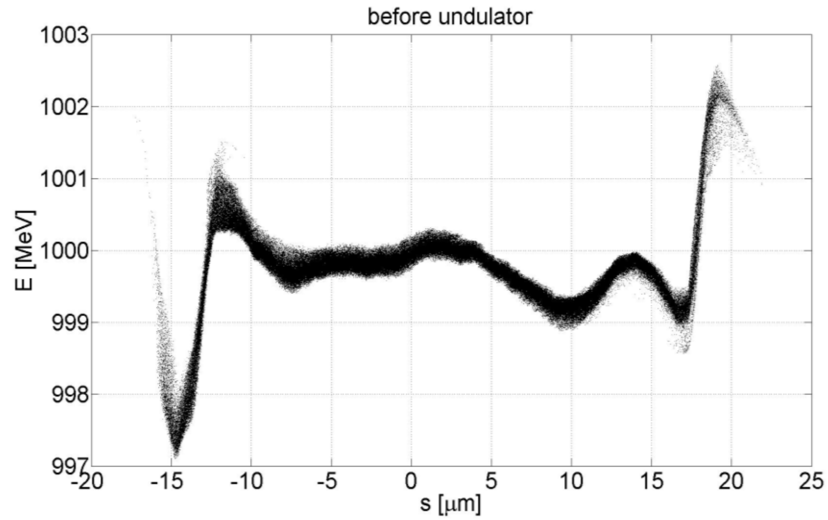


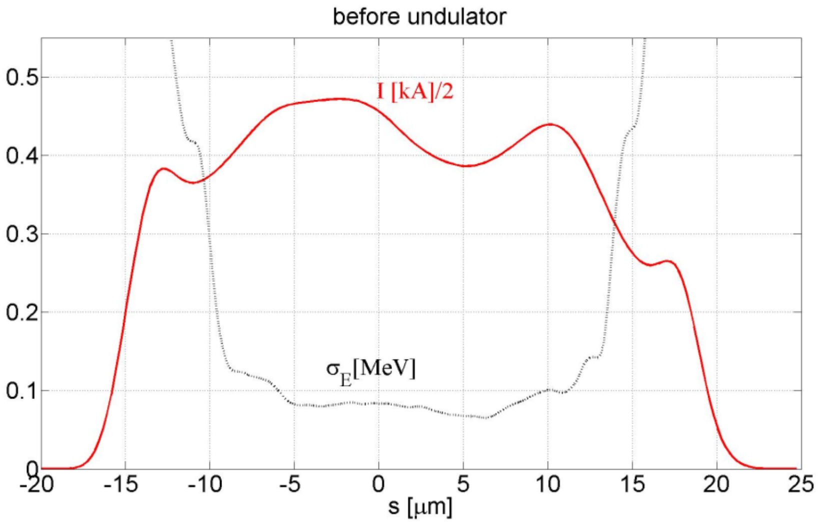
Low energy spread for FLASHII HGHG option (0.10nC)



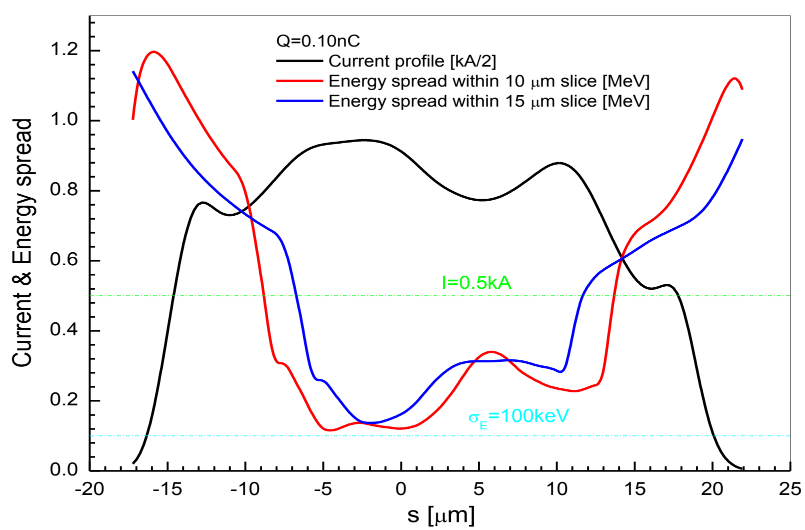
$\varepsilon_x{}^{proj} = 0.40\mu m \cdot rad, \varepsilon_y{}^{proj} = 0.39\mu m \cdot rad$

9.5% bad particles are removed





Slice energy spread distribution (uncorrelated)



Energy spread within 15µm and 10µm slice length