Introduction to the longitudinal phase space tomography at PITZ, part II

1. Tomography reconstruction algorithm
2. Example
3. First experimental results
4. Conclusion

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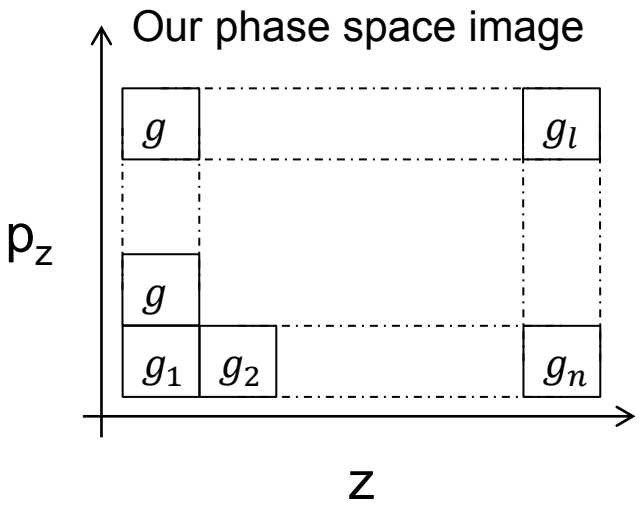
DESY

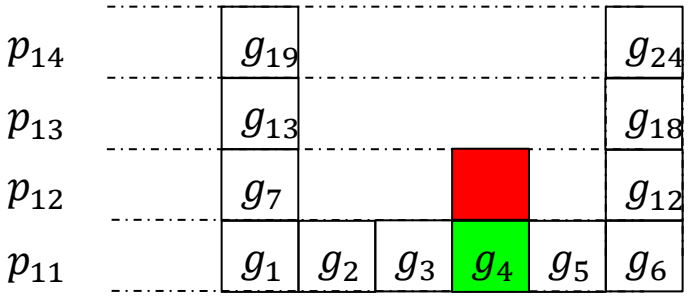
Reconstruction algorithm



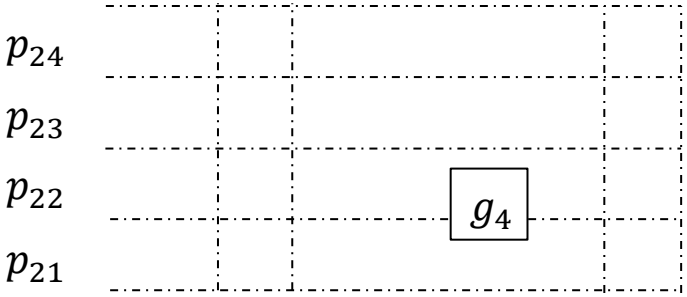
$$p_z(z) = p_z(z) + k(\varphi) \cdot z$$

$$p_{ij} = a_{ijl} \cdot g_l$$

Reconstruction algorithm, filling "a_{ijl}" array



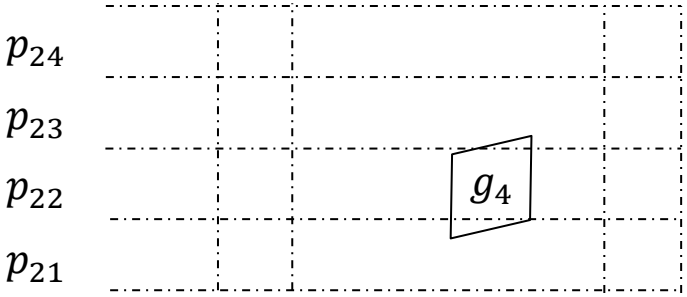
If φ_1 mean no rotation applied then $a_{1,1,4} = 1$, $a_{1,2,4} = 0$



$$p_z(z) = p_z(z) + k(\varphi) \cdot z$$

If φ_2 mean rotation applied then $a_{2,1,4} = 0.3$, $a_{2,2,4} = 0.7$

Reconstruction algorithm, filling "a_{ijl}" array



$$p_z(z) = p_z(z) + k(\varphi) \cdot z$$

$$a_{2,1,4} = ???,\ a_{2,2,4} = ???,\ a_{2,3,4} = ???$$

Reconstruction algorithm, iterations

$$g_q^{(k+1)} = g_q^{(k)} + \sum_{ij} \frac{a_{ijq}(p_{ij} - \sum_l a_{ijl} \cdot g_l^{(k)})}{\sum_{nm} a^2{}_{inm}}$$

i – phase (Nphase)

j – momentum (Npz)

– z coordinate (Nz)

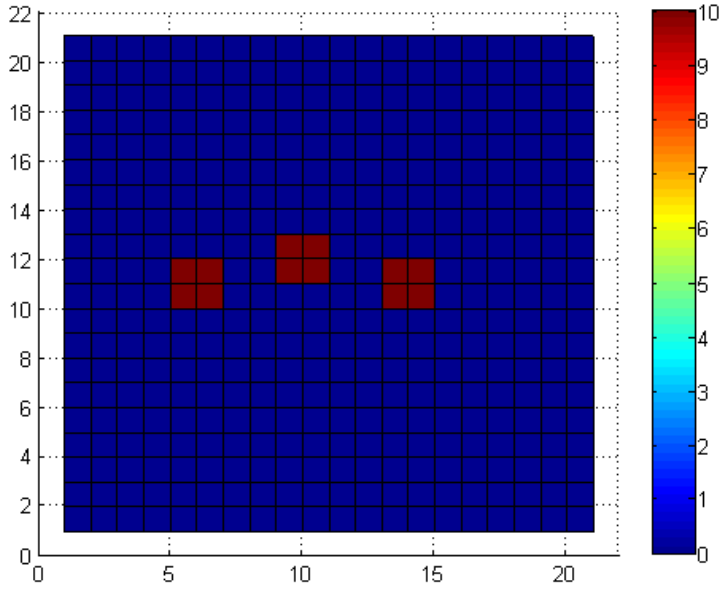
l – image index (Nl = Npz*Nz)

Total time is ~ Npz*Nz*Nphase*Npz*(Npz*Nz + Npz*Npz*Nz) =

$Npz^3Nz^2Nphase(1 + Npz)$ =

$Npz^4Nz^2Nphase$

Example


22
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
10
9
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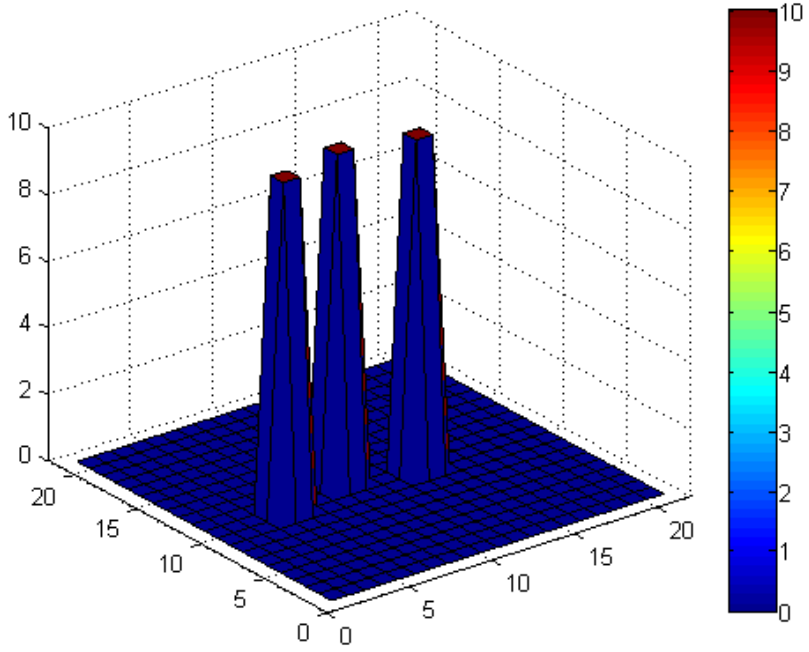
5
4
3
2
1
0


10
8
6
4
2
0
20
15
10
5
0
0
5
10
15
20
10
9
8
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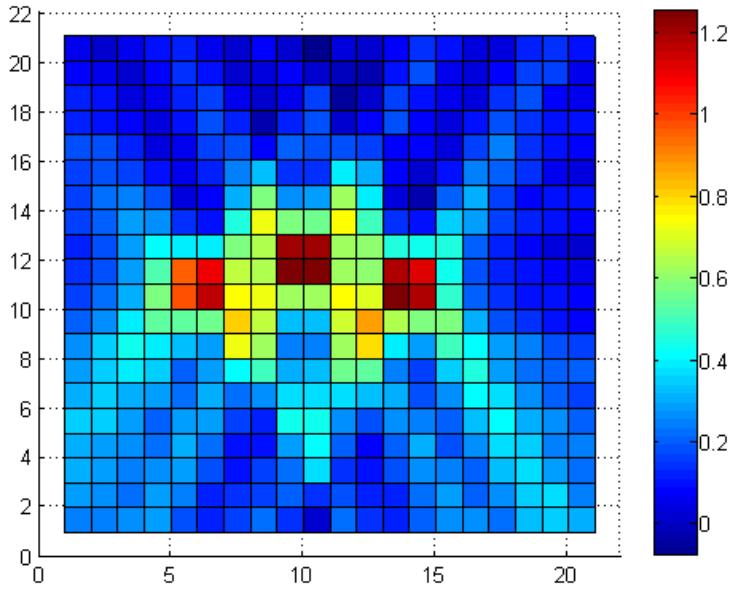
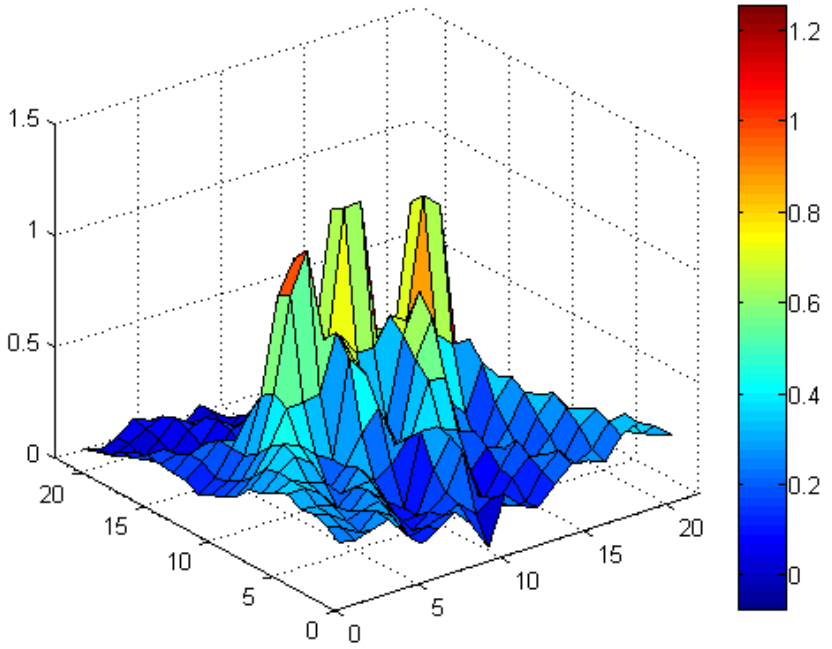
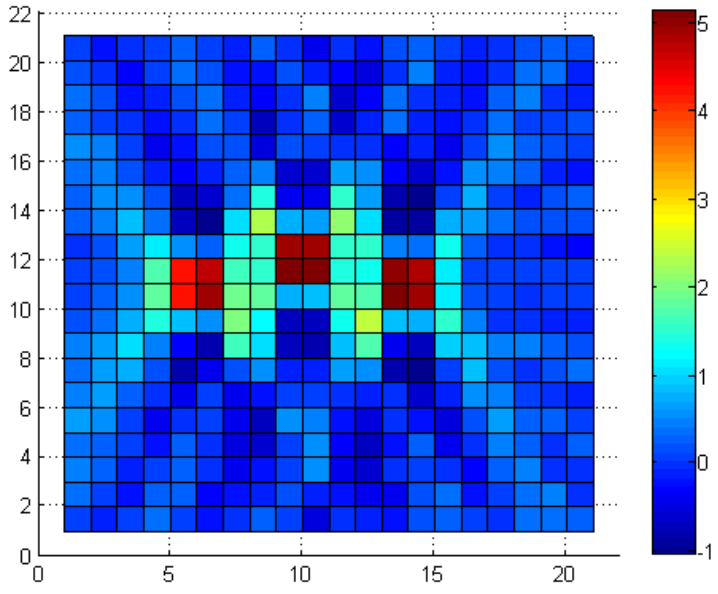
6
5
4
3
2
1
0

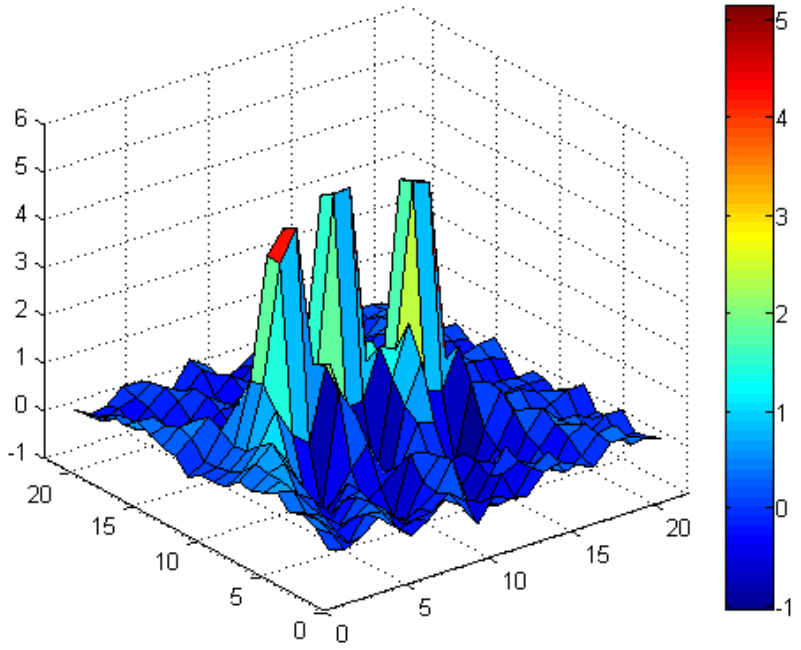
Example, 1 iteration





Example, 10 iteration

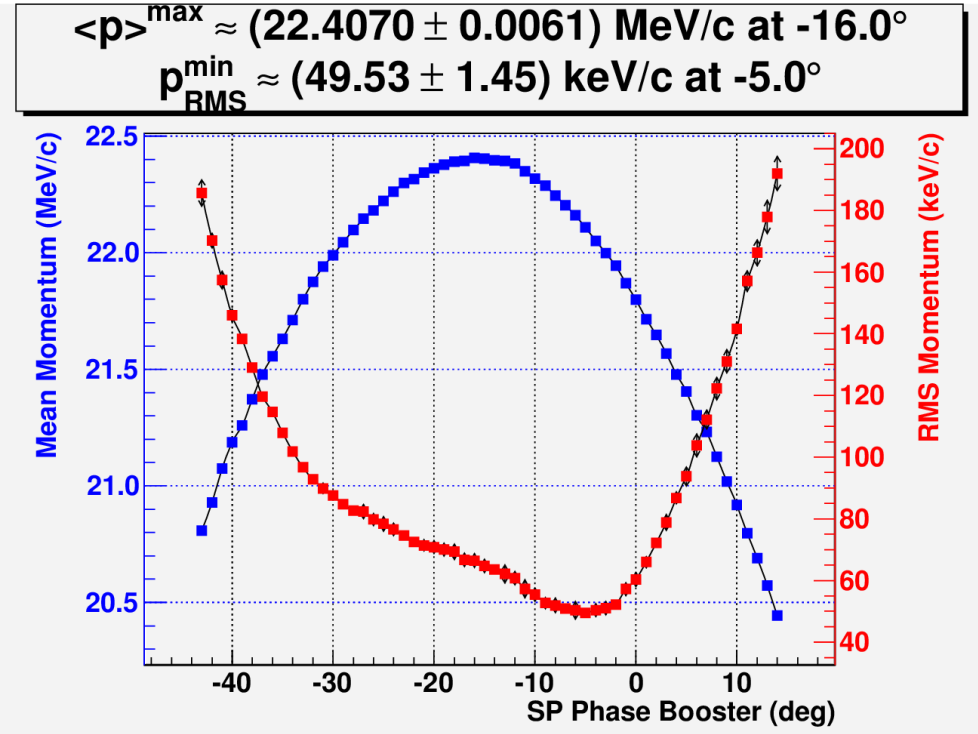




Experimental results, 2013.02.07 M 10:04

High1.Dipole = -79 A
Imain = 377 A
LT= 1.5 %
NoP = 30
Gun RF power = 6.71 MW
Booster RF power = 3.27 MW
Gun FB ON
Booster FB OFF
Statistics = 10
High1.Q4 = 1.8

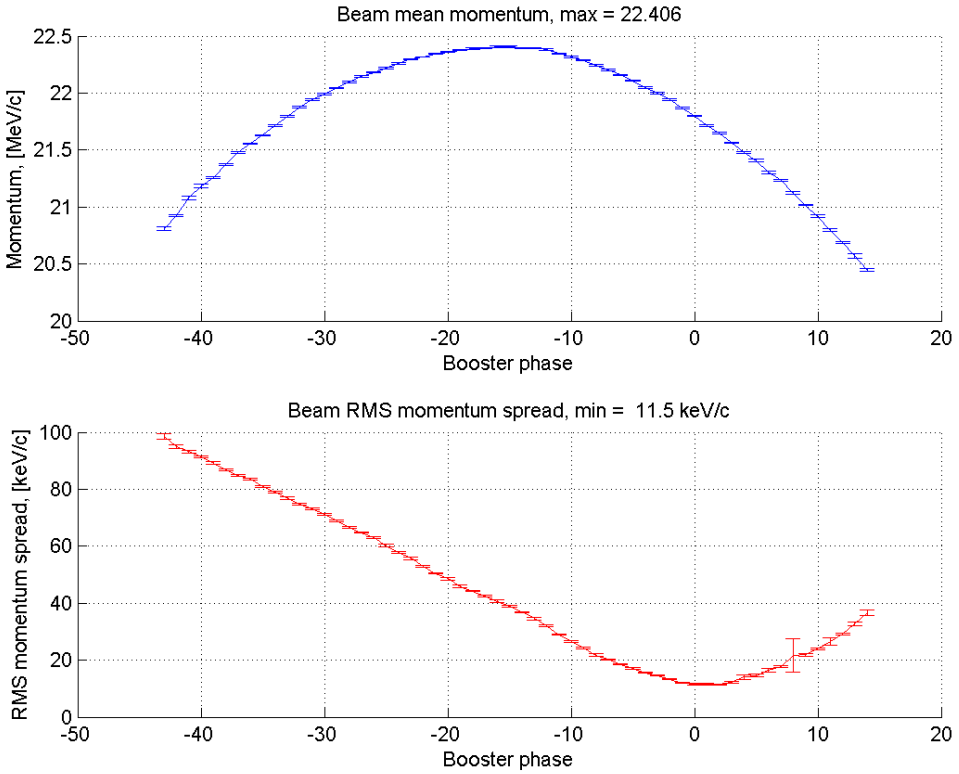
HEDA1 scan, 20 pC, Gauss, 2.8 ps FWHM, gun on-crest.



HEDA1 resolution expected: yRMS = 70 um → 3 keV/c
(see part I)

Experimental results, 2013.02.07 M 10:04

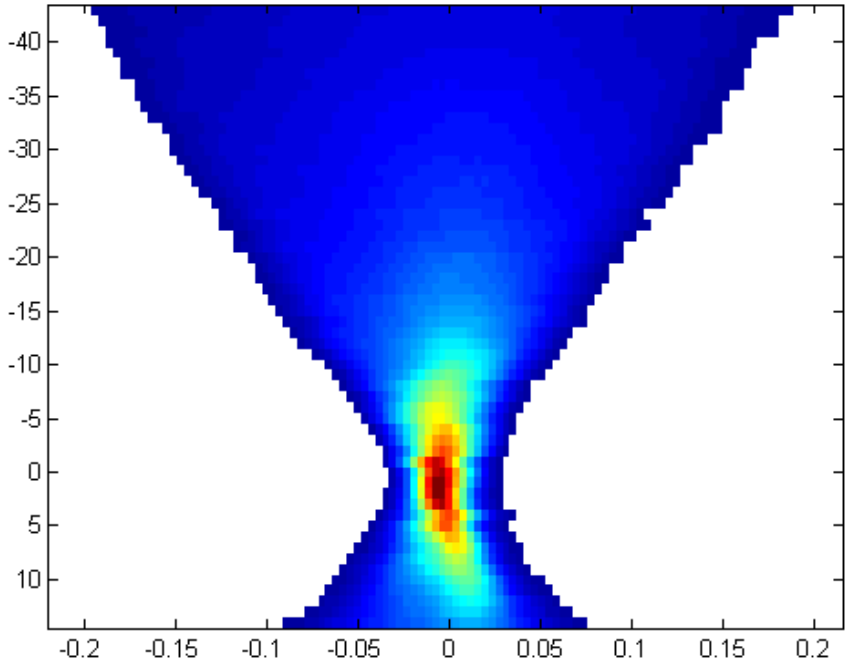
HEDA1 scan, 20 pC, Gauss, 2.8 ps FWHM, gun on-crest.



Momentum projections, initial data

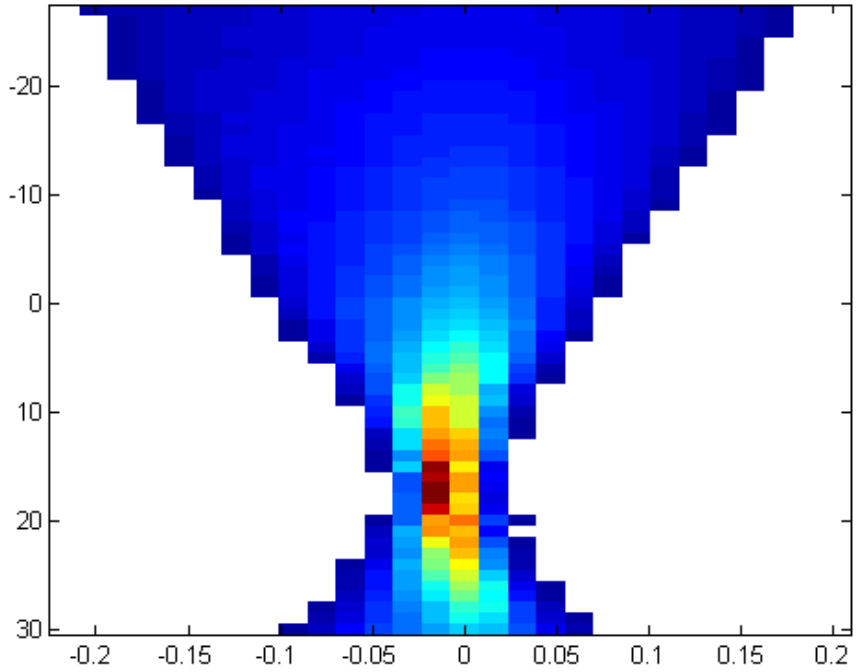
Booster phase

58 bins



Momentum, MeV/c

112 bins



Momentum, MeV/c

28 bins

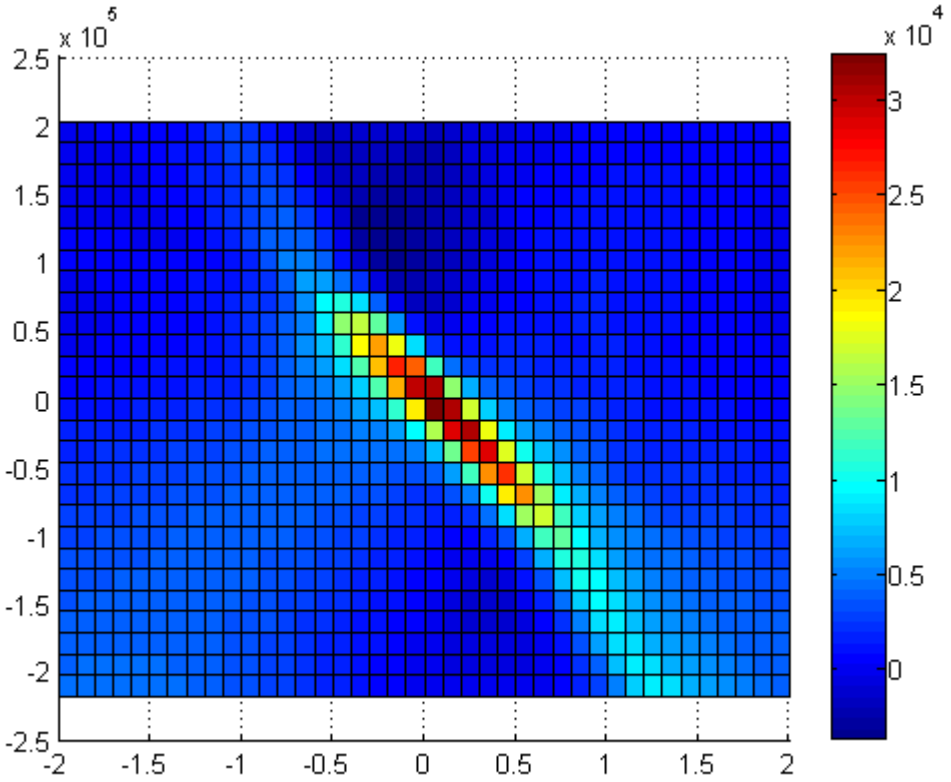
z = [-2.0 2.0] 41 bins

Reconstructed phase space, 1 iteration

Momentum, eV/c

28 bins

15 keV/c



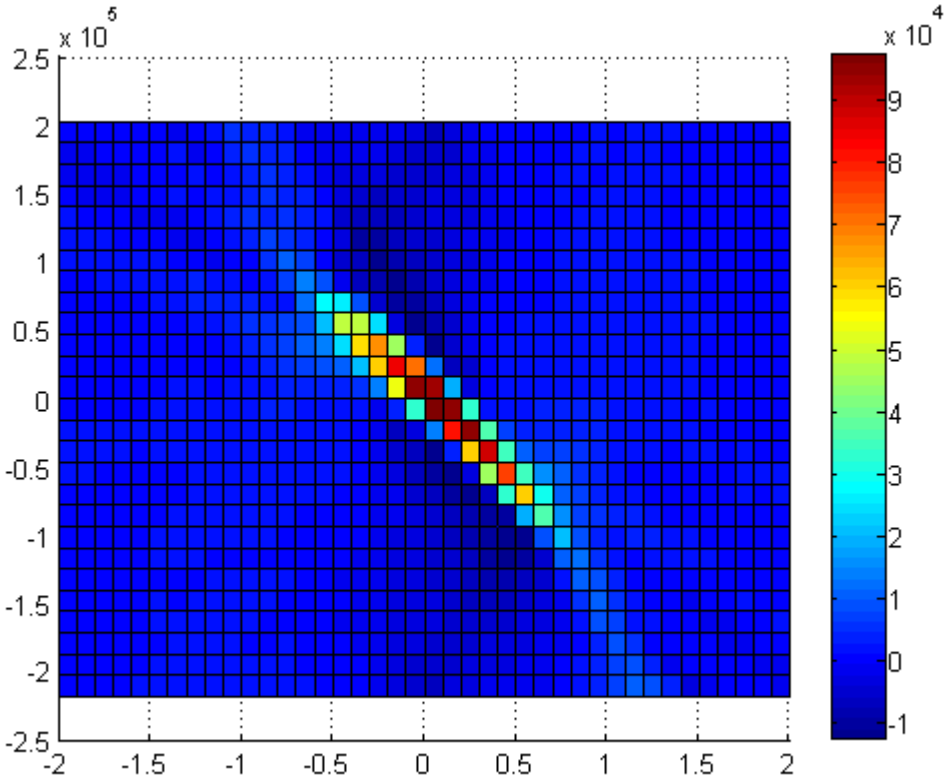
z, mm 41 bins 0.1 mm

Reconstructed phase space, 10 iterations

Momentum, eV/c

28 bins

15 keV/c



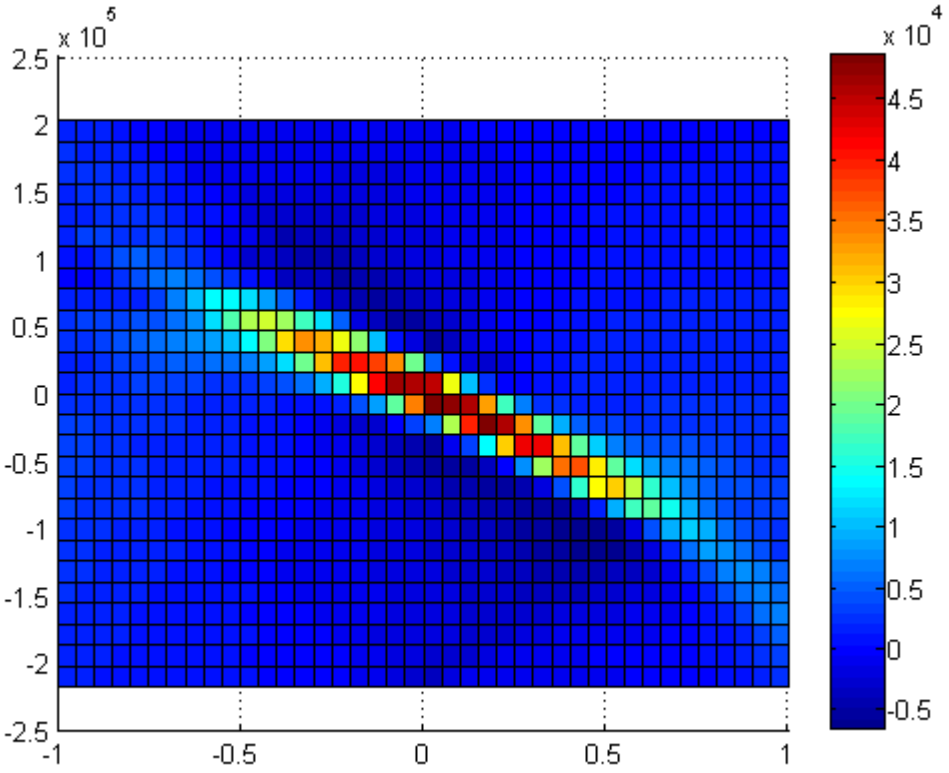
z, mm 41 bins 0.1 mm

Reconstructed phase space, 5 iterations, z more detailed

Momentum, eV/c

28 bins

15 keV/c



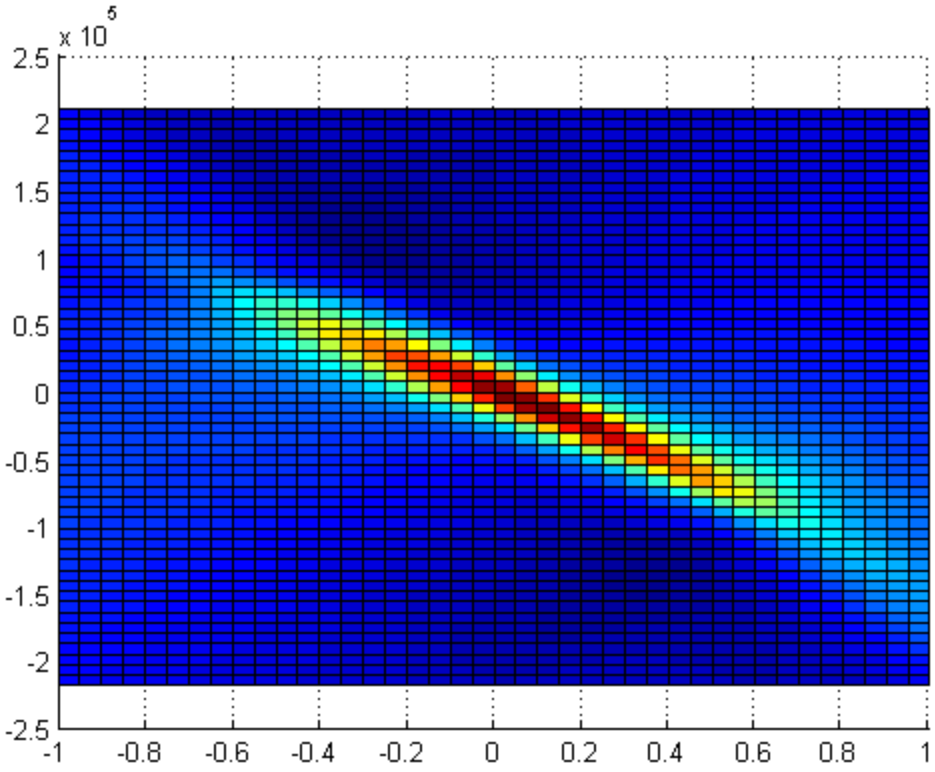
z, mm 41 bins 0.05 mm

Reconstructed phase space, 2 iterations

Momentum, eV/c

56 bins

7 keV/c



z, mm 41 bins 0.05 mm

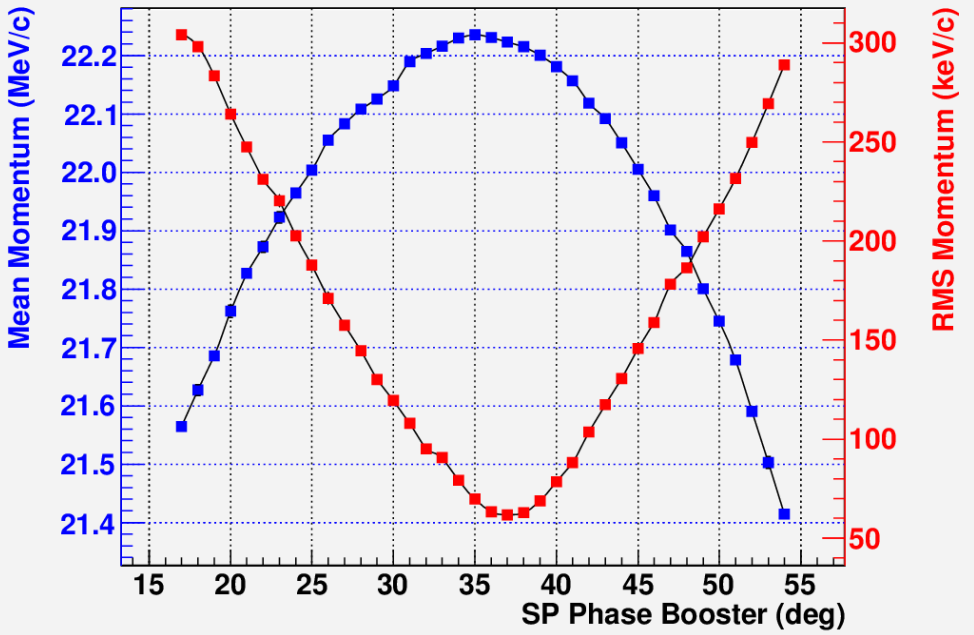
about 16 hours

Experimental results, 2013.02.14 A 19:35

HEDA1 scan, 1 nC, flat top, 17.5 ps FWHM, gun on-crest.

$\langle p \rangle^{max} \approx (22.2357 \pm 0.0040)$ MeV/c at 35.0°

$p^{min}_{RMS} \approx (61.74 \pm 1.15)$ keV/c at 37.0°

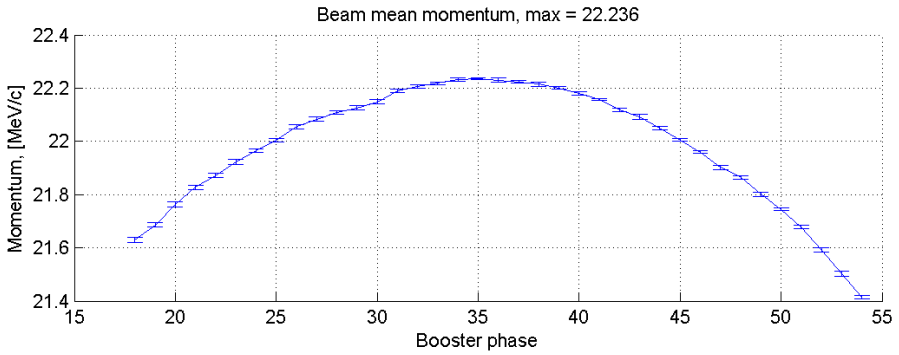


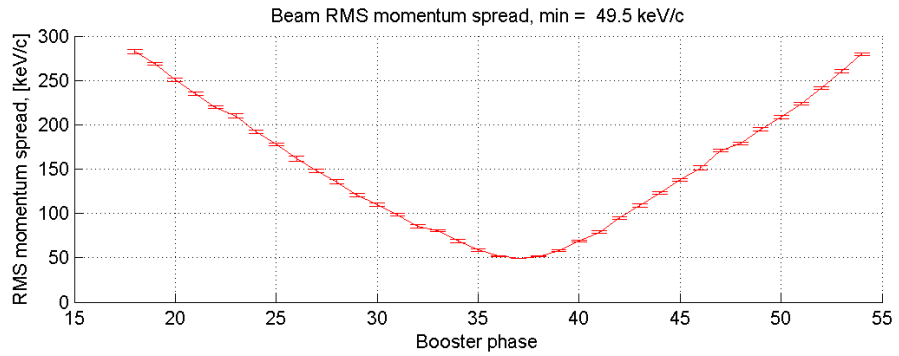
High1.Dipole = -81.6 A (rdb -81.59891 A)
Imain = 377 A
LT= 100 %
NoP = 1
Gun RF power = 6.8 MW
MMMG Gun phase
Booster RF power = 3.2 MW
Gun FB ON
Booster FB OFF
Statistics = 20
High1.Q4 = 2.1 A

HEDA1 resolution expected: yRMS = 0.6 mm → 25 keV/c
(see part I)

Experimental results, 2013.02.14 A 19:35

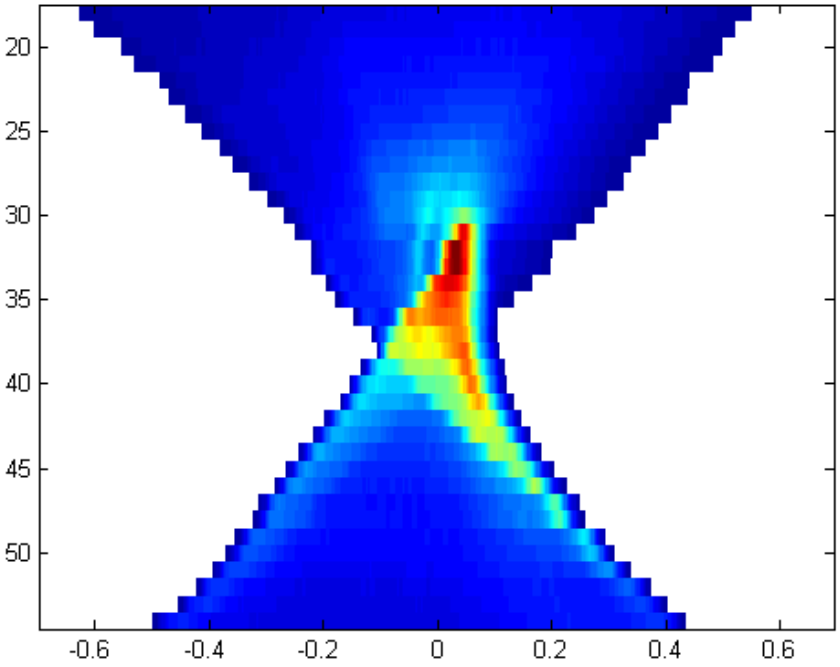
HEDA1 scan, 1 nC, flat top, 17.5 ps FWHM, gun on-crest.





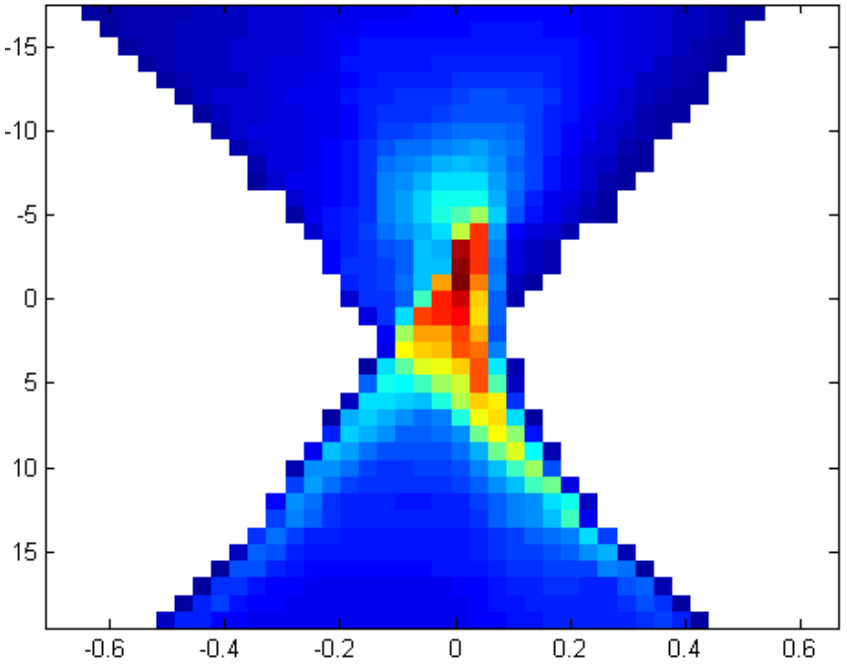
Momentum projections, initial data

Booster phase 37 bins



Momentum, MeV/c

348 bins



Momentum, MeV/c

43 bins

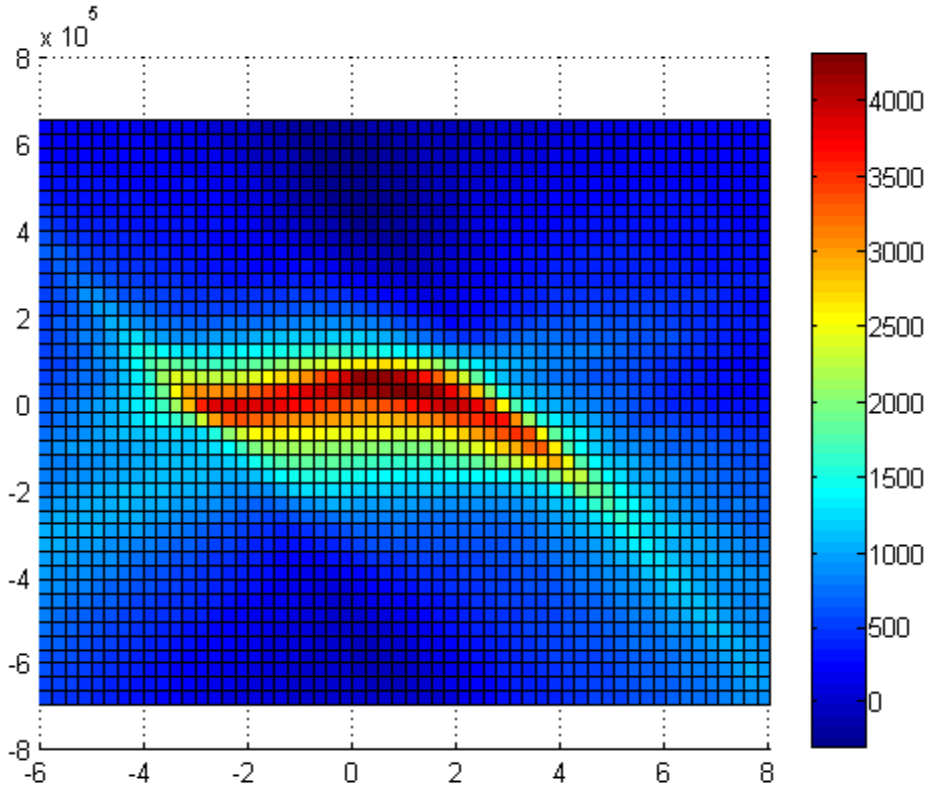
z = [-6.0 8.0] 57 bins

Reconstructed phase space, 1 iteration

Momentum, eV/c

43 bins

30 keV/c



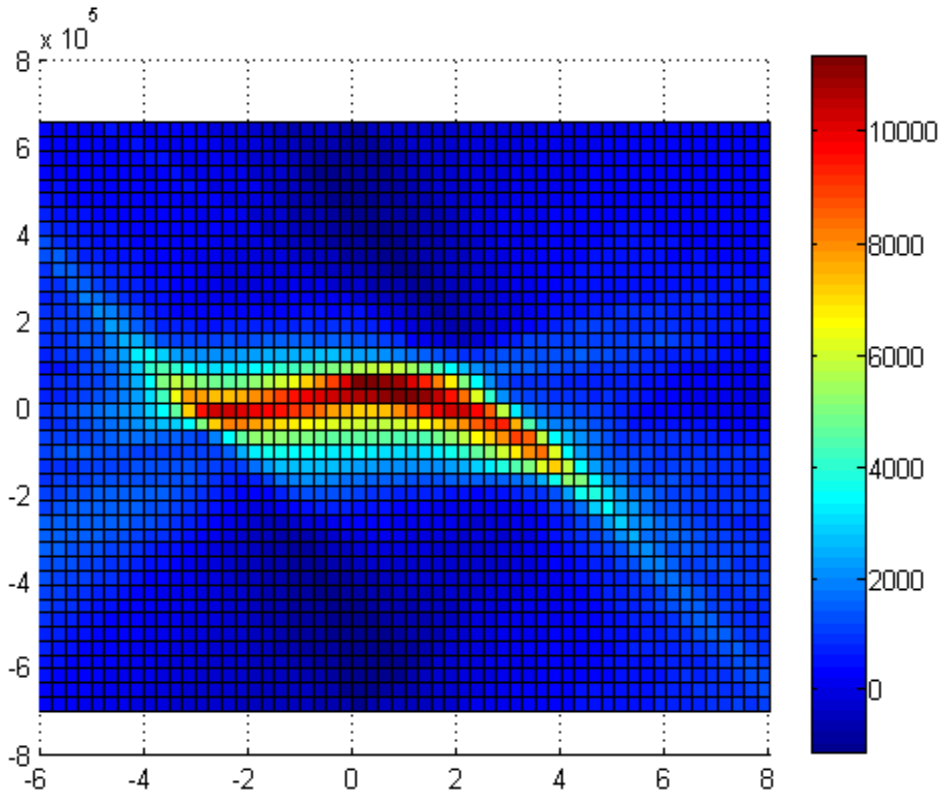
z, mm 57 bins 0.25 mm

Reconstructed phase space, 4 iterations

Momentum, eV/c

43 bins

30 keV/c



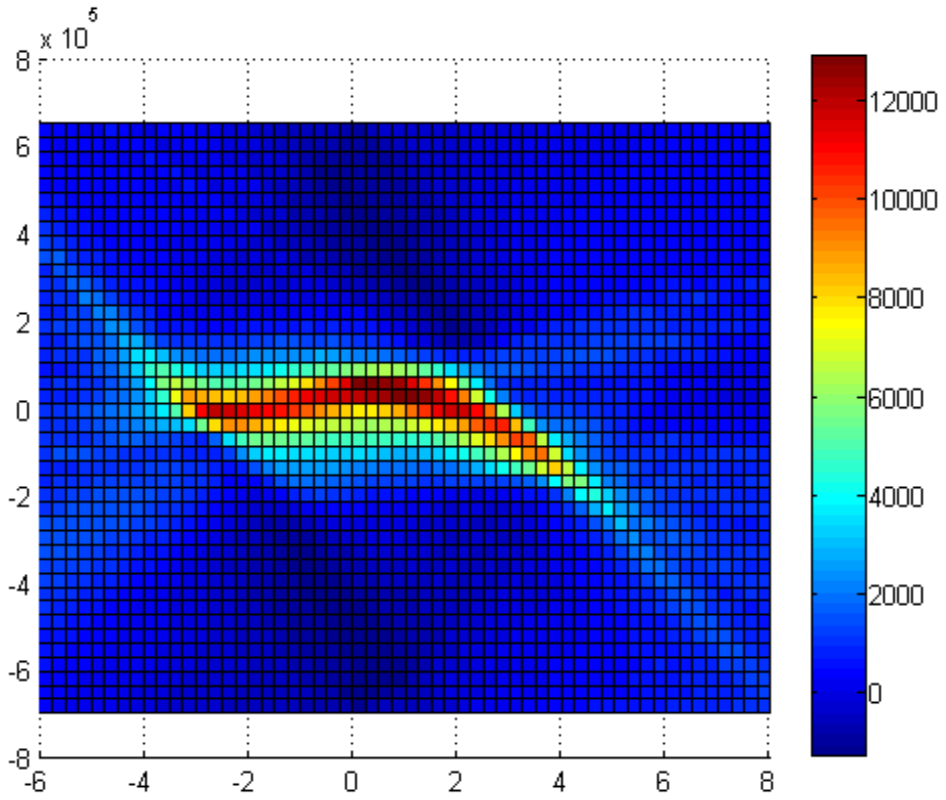
z, mm 57 bins 0.25 mm

Reconstructed phase space, 5 iterations

Momentum, eV/c

43 bins

30 keV/c



z, mm 57 bins 0.25 mm

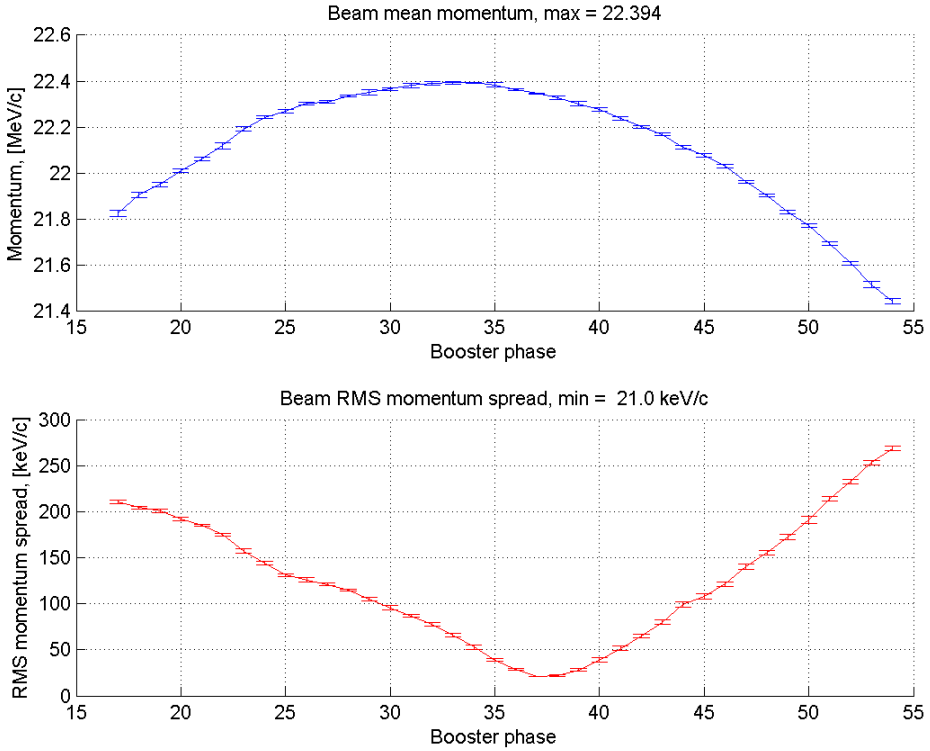
Experimental results, 2013.02.14 A 21:03

Disp3.D1 = 8.9 A (rbk = 8.97271 A)
Imain = 377A
High2.Q1 = 1.7 A
NoP = 1
LT = 100%

Gun:
6.8 MW in the gun

Booster:
3.2 MW in booster

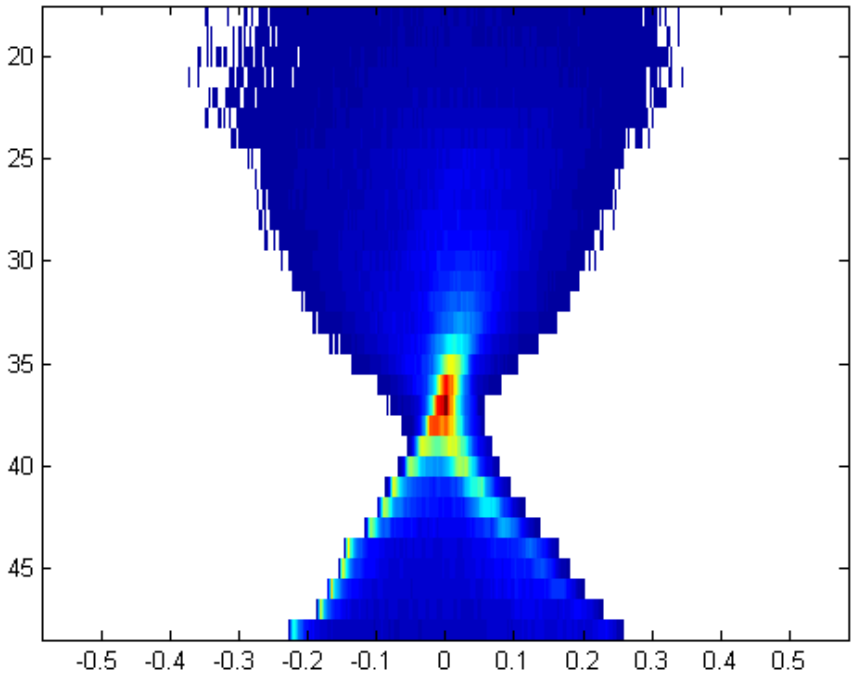
HEDA2 scan, 1 nC, flat top, 17.5 ps FWHM, gun on-crest.



Momentum projections, initial data

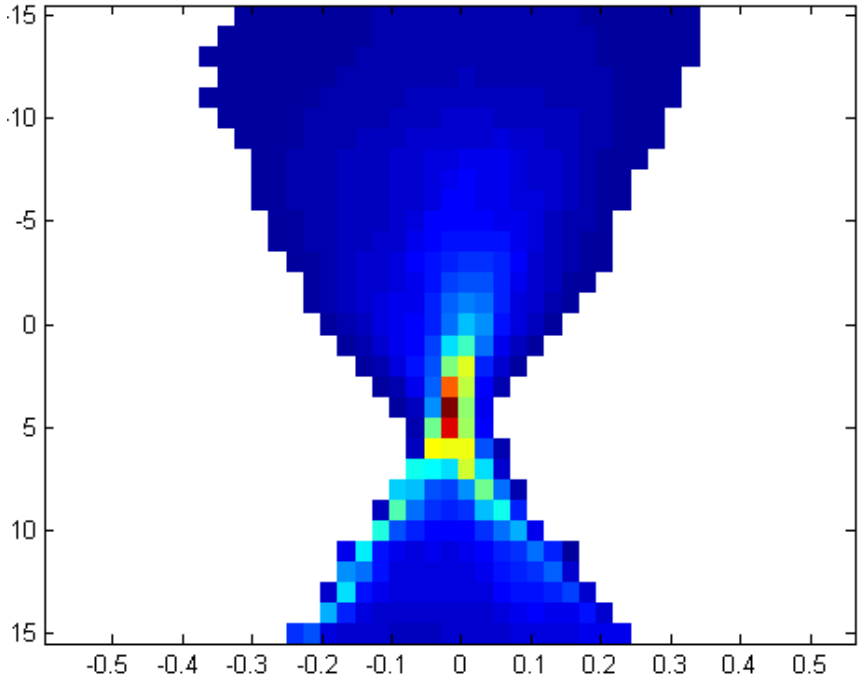
Booster phase

31 bins



Momentum, MeV/c

758 bins



Momentum, MeV/c

47 bins

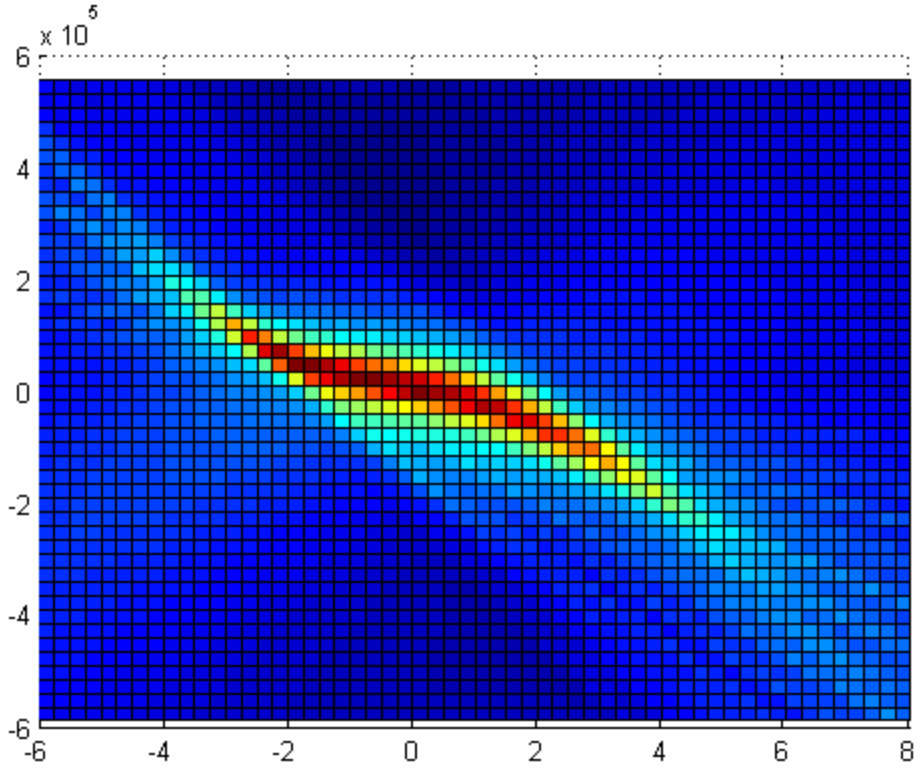
z = [-6.0 8.0] 57 bins

Reconstructed phase space, 1 iteration

Momentum, eV/c

47 bins

25 keV/c



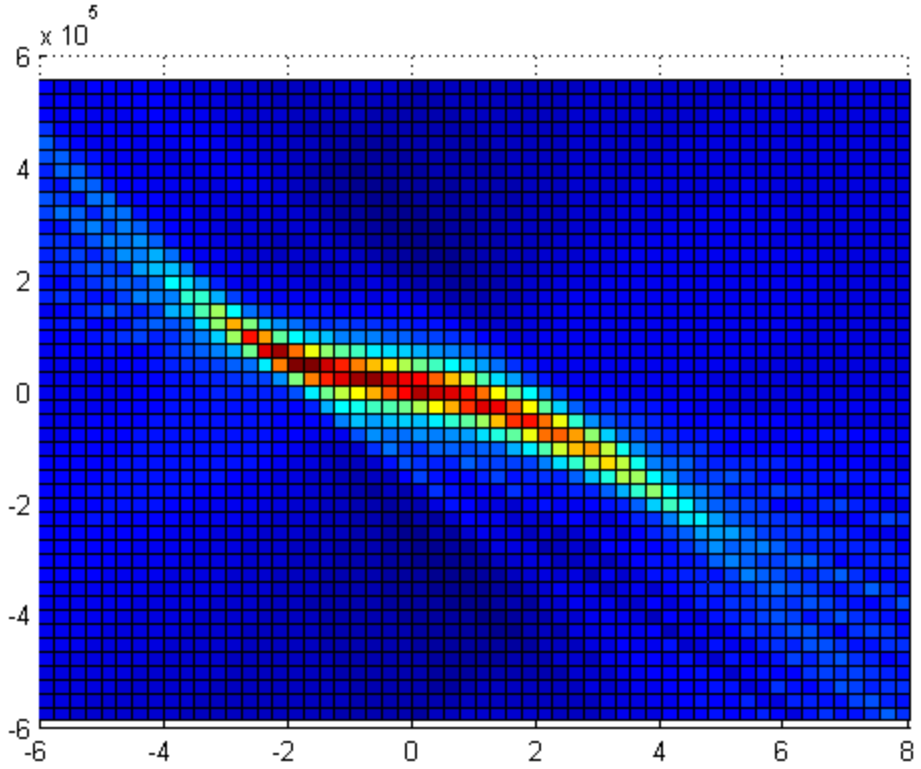
z, mm 57 bins 0.25 mm

Reconstructed phase space, 5 iteration

Momentum, eV/c

47 bins

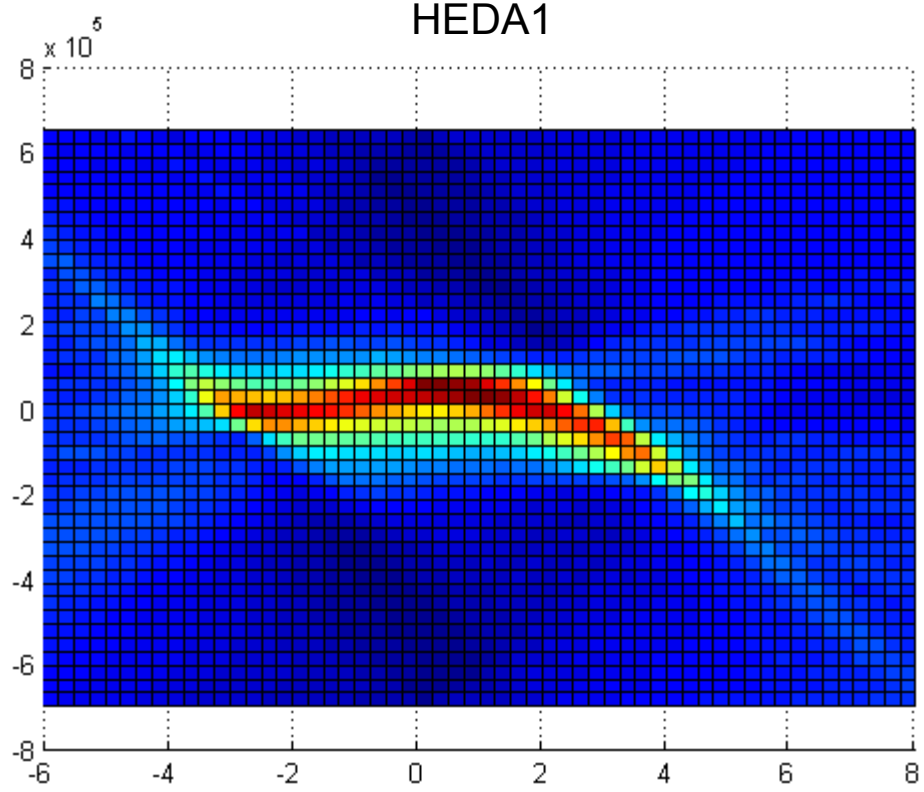
25 keV/c



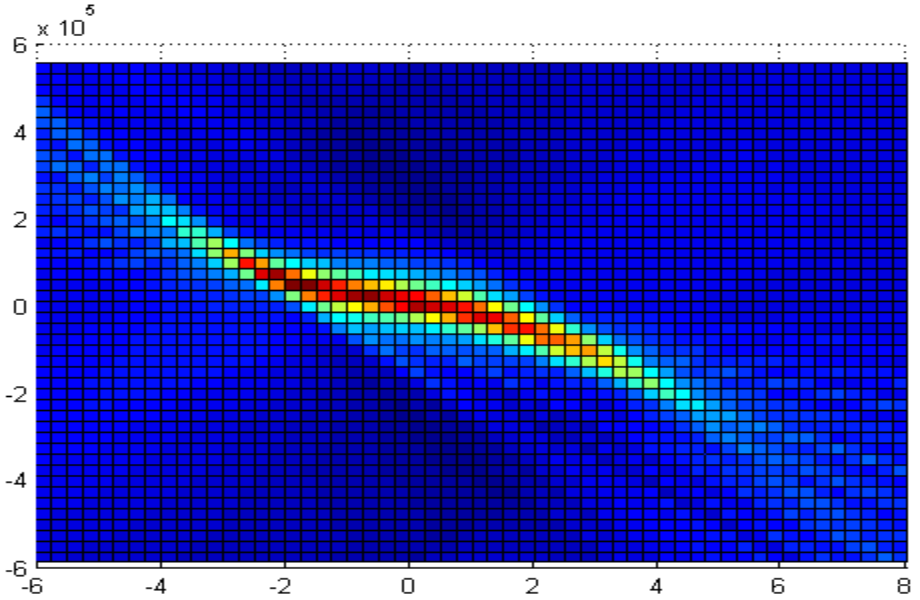
z, mm 57 bins 0.25 mm

Reconstructed phase space, HEDA1 and HEDA2

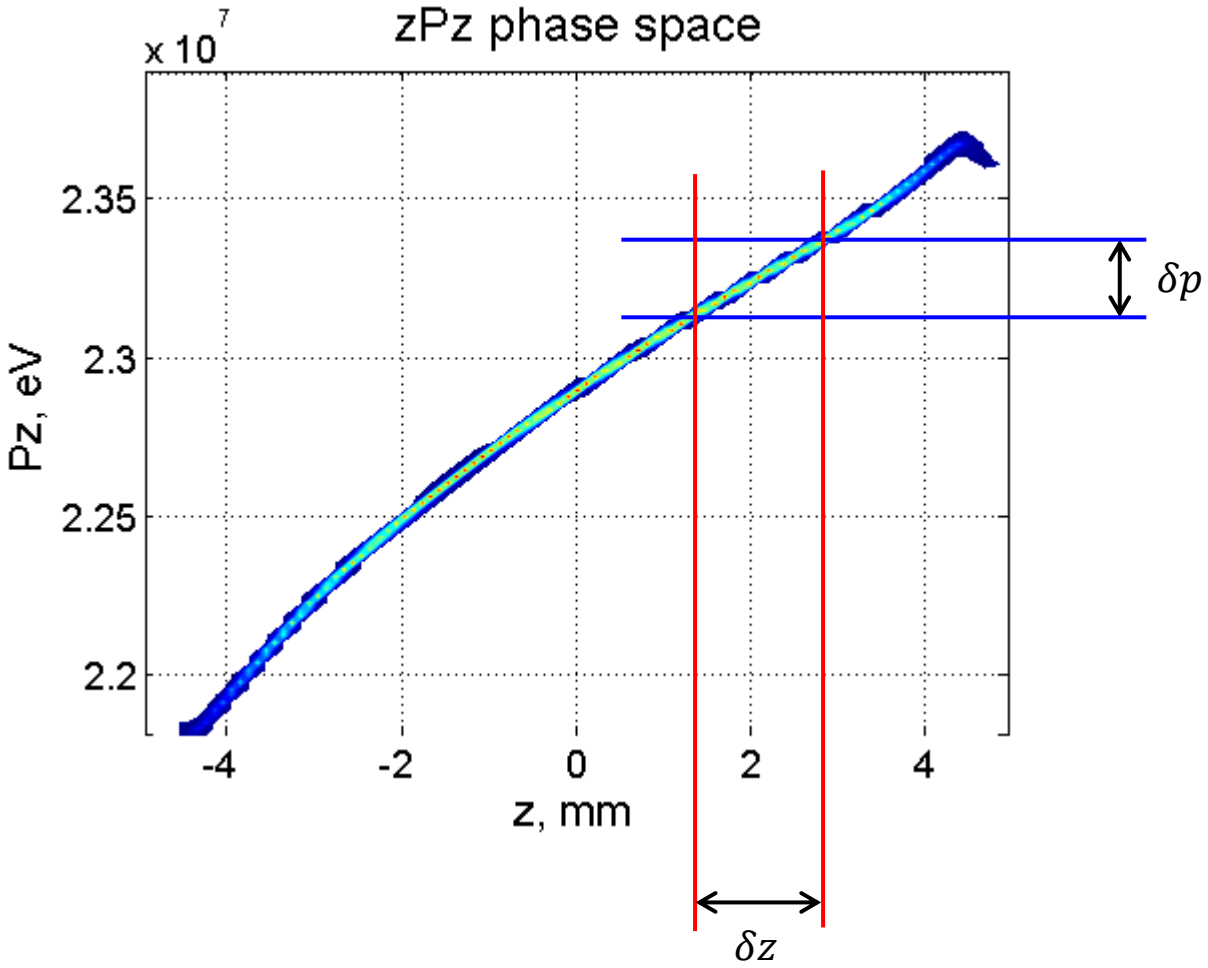
HEDA1



HEDA2



Longitudinal resolution



$$\delta z = \frac{\delta p}{k}$$

Longitudinal resolution (see part I)

$$\frac{dp}{dt} = -18 \cdot 2\pi f \cdot \sin(\varphi) = -147 \frac{keV/c}{ps} \cdot \sin(\varphi)$$

$k = 20 \frac{keV/c}{ps}$ (for 8° phase offset) → 0.05 ps resolution??? (1 keV energy spread)

→ 1.5 ps resolution??? (30 keV/c resolution)

$$\delta z = \frac{\delta p}{k} \quad \overset{???}{\Longrightarrow} \quad f_{res} = \frac{k_{max}}{2\pi\delta p} \quad \Longrightarrow \quad \delta z = \frac{2\pi\delta p}{k}$$