Acceptance and emittance studies at RHIC EBIS.

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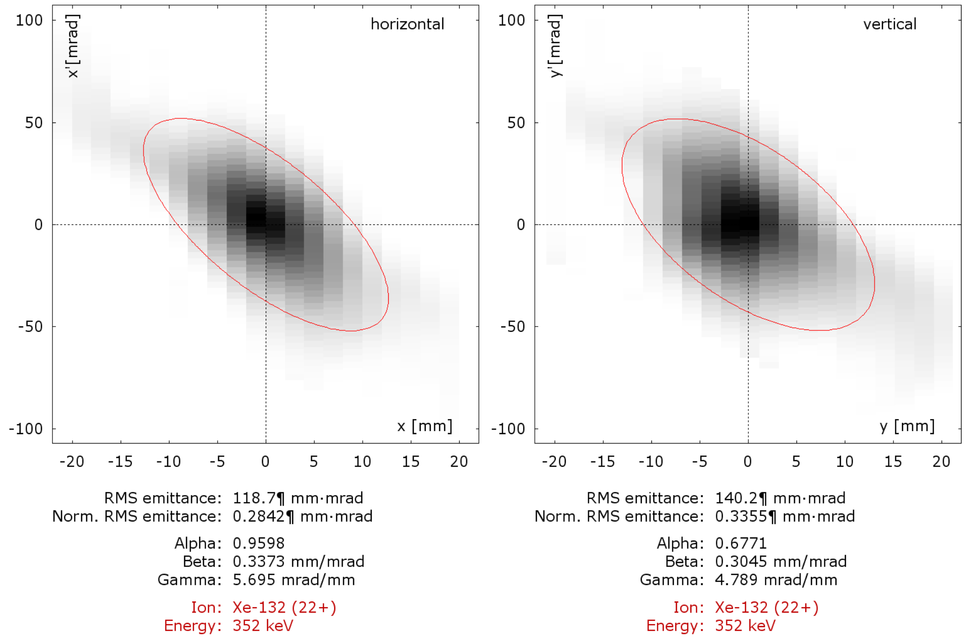
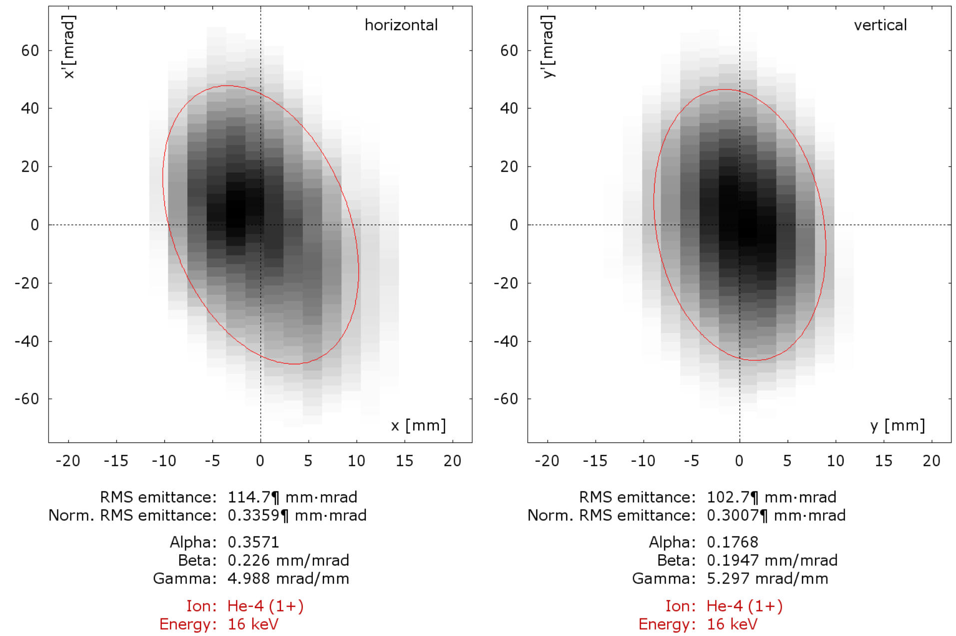
EBIS emittance at low energy (LEBT, 16 keVxq)

20060307_01_Xe_20nC_2mA_28ms_Average
Charge state+21_Negat lens_Y-Em_0_166.bmp



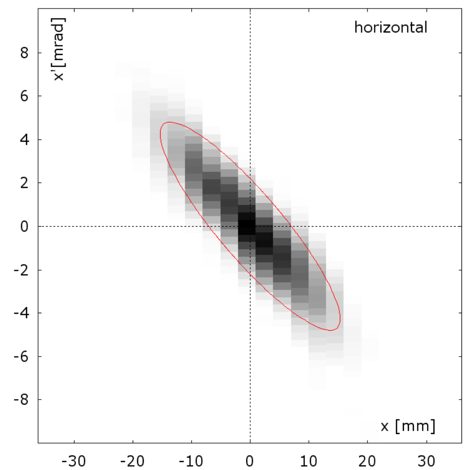
20060623_1_He_6_5A_3_6mA_14_3nC.bmp



After LINAC (2 MeV/n)

I_{el}=9.6 A, E_{el}≈20 keV, high neutralization

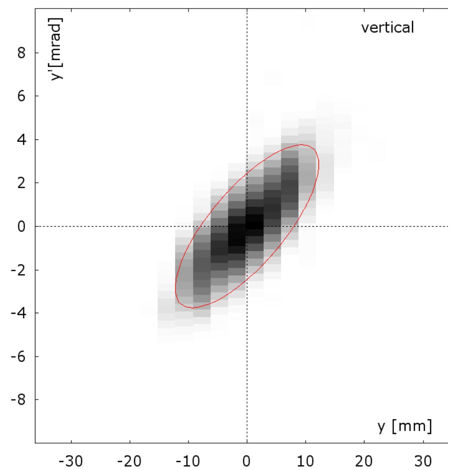
Fe20+ (τ_{conf} ≈ 220 ms)



RMS emittance: 8.432¶ mm·mrad
Norm. RMS emittance: 0.5529¶ mm·mrad

Alpha: 1.934
Beta: 6.96 mm/mrad
Gamma: 0.6809 mrad/mm

Ion: Fe-56 (20+)
Energy: 111870 keV

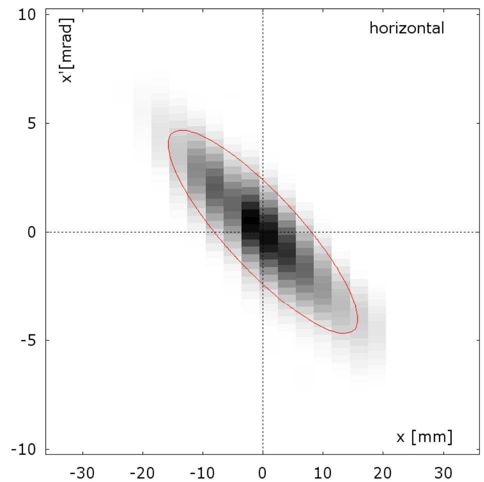


RMS emittance: 7.481¶ mm·mrad
Norm. RMS emittance: 0.4905¶ mm·mrad

Alpha: -1.164
Beta: 5.002 mm/mrad
Gamma: 0.4706 mrad/mm

Ion: Fe-56 (20+)
Energy: 111870 keV

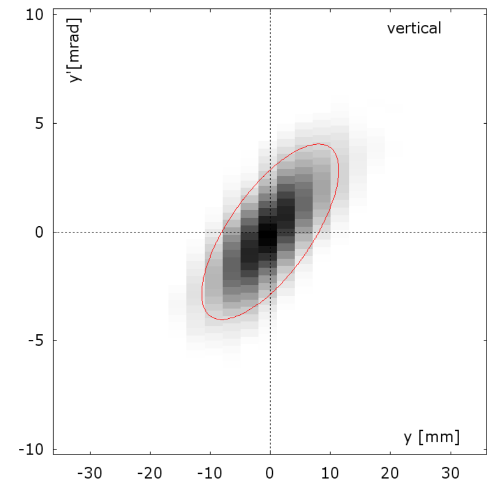
Au32+ (τ_{conf} ≈ 60 ms)



RMS emittance: 9.452¶ mm·mrad
Norm. RMS emittance: 0.6197¶ mm·mrad

Alpha: 1.676
Beta: 6.563 mm/mrad
Gamma: 0.5801 mrad/mm

Ion: Au-197 (32+)
Energy: 393934 keV



RMS emittance: 8.161¶ mm·mrad
Norm. RMS emittance: 0.5351¶ mm·mrad

Alpha: -0.9981
Beta: 3.983 mm/mrad
Gamma: 0.5012 mrad/mm

Ion: Au-197 (32+)
Energy: 393934 keV

Rod Keller's formula for ion source (no magnetic field):

$$\varepsilon = \pi r_i \sqrt{\frac{T_i}{E_i}}$$

EBIS application →

$$\varepsilon = \pi r_i \sqrt{\frac{K \Delta U_{beam}}{\Delta U_{accel}}}$$

r_i = radius of ion system (80% of intensity), T_i – ion temperature
K=0.1 (?)   (B. Penetrante, R. Marrs).
Good for small beam sizes, where effect of magnetic field is small.
Inclusion of the magnetic field effect:

$$\varepsilon = \pi \frac{r_{beam}}{\sqrt{2U_{extr}}} \left[B r_{beam} \sqrt{\frac{q_i}{m_i}} + \sqrt{\frac{q_i B^2 r_{beam}^2}{4m_i} + \frac{\rho_l}{2\pi\varepsilon_0}} \right]$$

Fredrik Wenander

$$\varepsilon_B = \varepsilon_{B=0} \left[1 + \frac{1}{2} \frac{r_i}{r_c} \right] \qquad r_c = 0.14 \frac{\sqrt{AT_i}}{r_c} \ (cm)$$

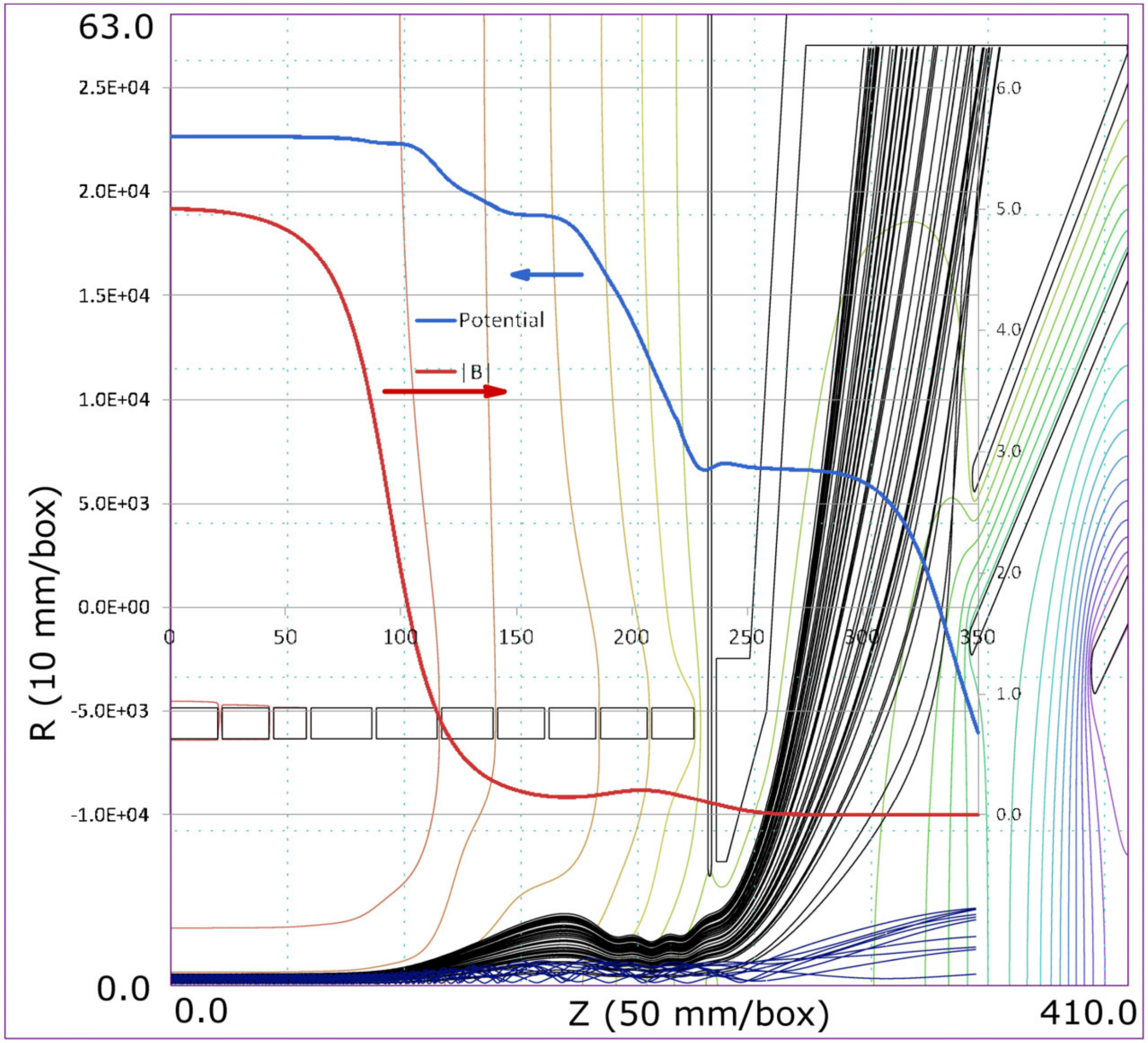
Ross Marrs

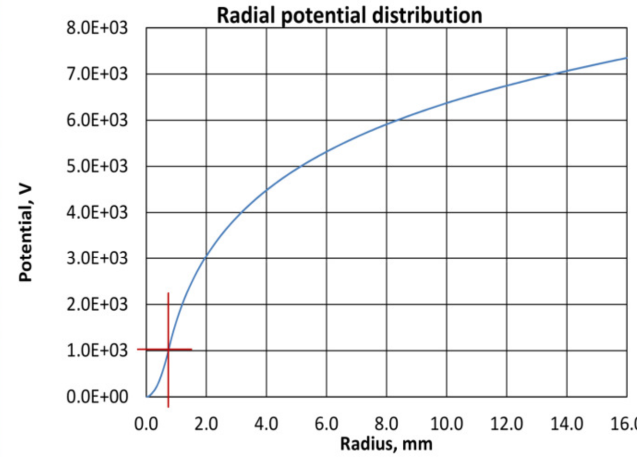
$$\varepsilon = \pi r_i \left[\sqrt{\frac{K \Delta U_{beam}}{\Delta U_{accel}}} + \frac{q_i B r_i}{p_i} \right]$$

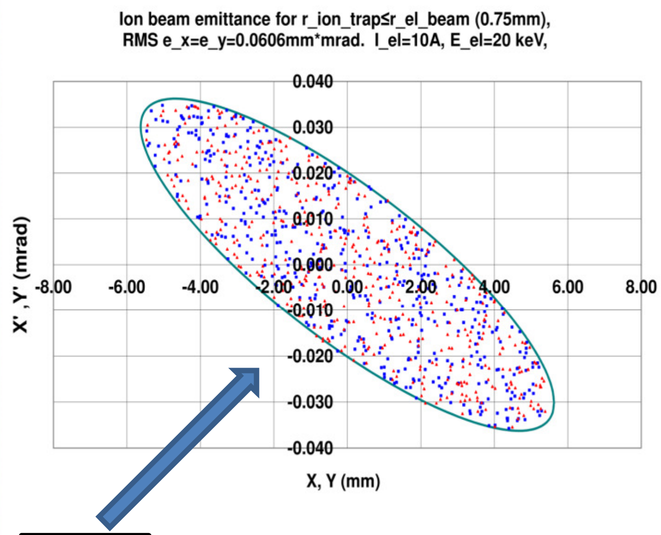
Formula with inclusion ion deflection in M-field

p_i-ion momentum at exit,
All units in SI

Ion injection simulation model

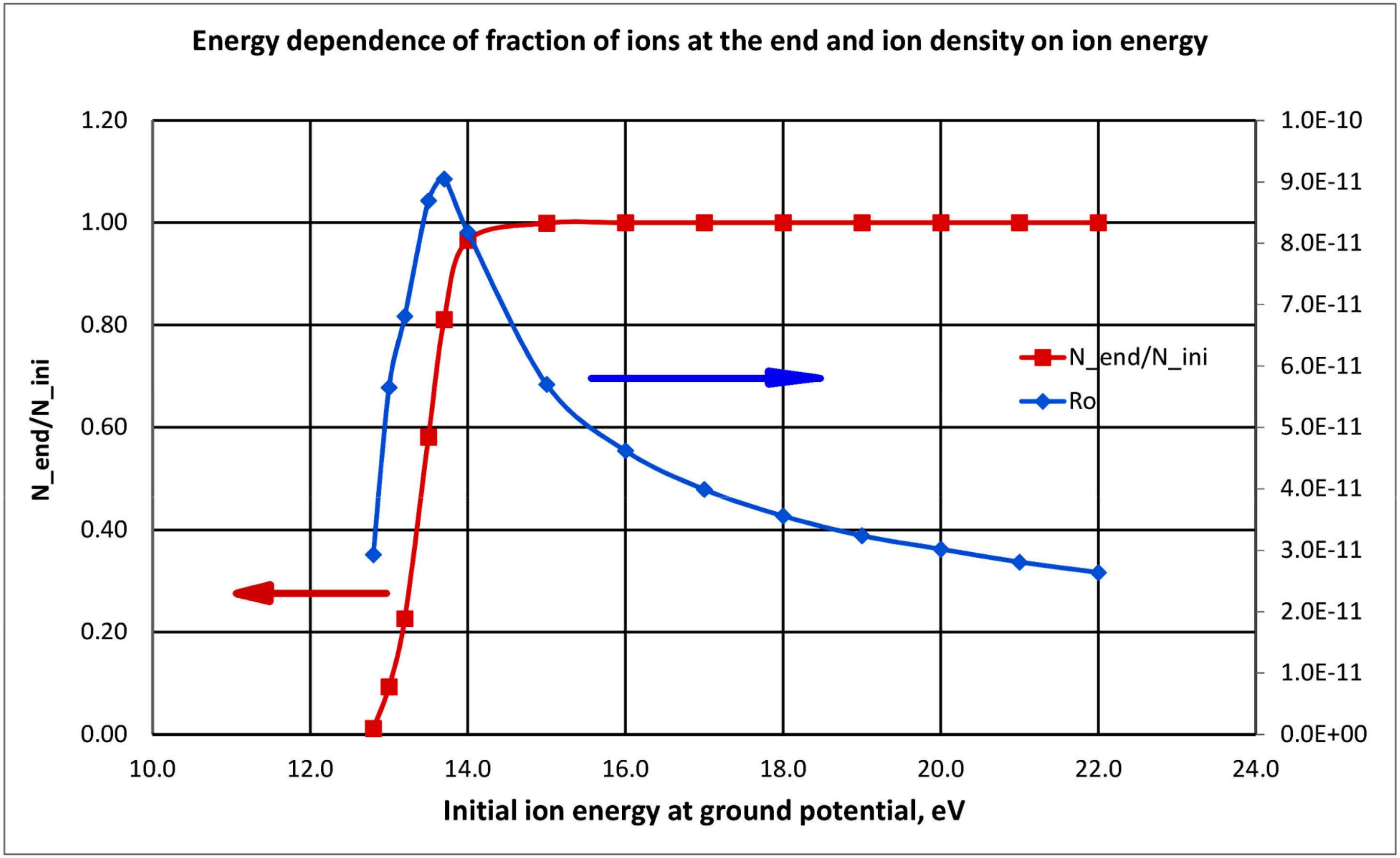




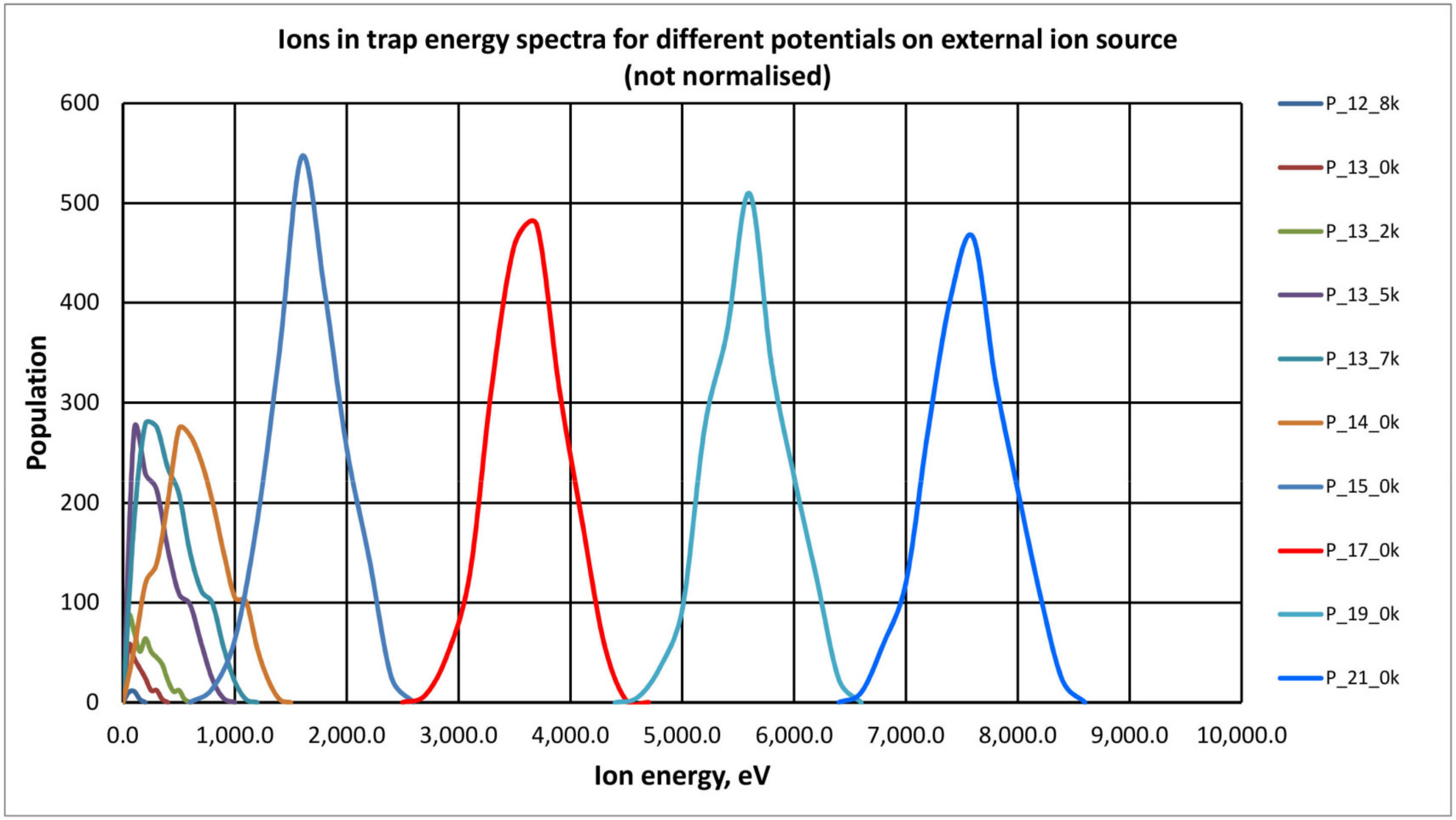


$r_i \leq r_{el}$

Effect of ion energy on efficiency and final ion density

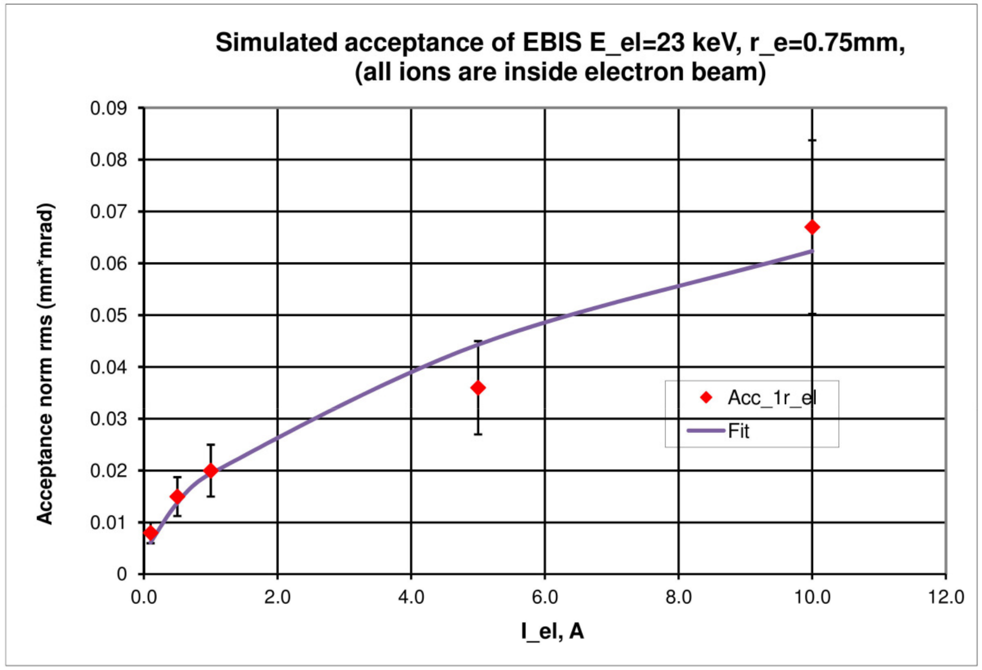


Energy spectra of injected ions (simulated)



Simulation result

No injected ion trajectories come out of electron beam boundary):



Fitting formula for emittance (normalized RMS):

$$\varepsilon(mm \cdot mrad) = 2.6 \cdot 10^{-3} \cdot r_b[mm] \cdot \sqrt{\Delta U_b(V)}$$

For RHIC EBIS, 10A, 22 keV, ε=0.062 mm*mrad

Test EBIS experiment with ANL

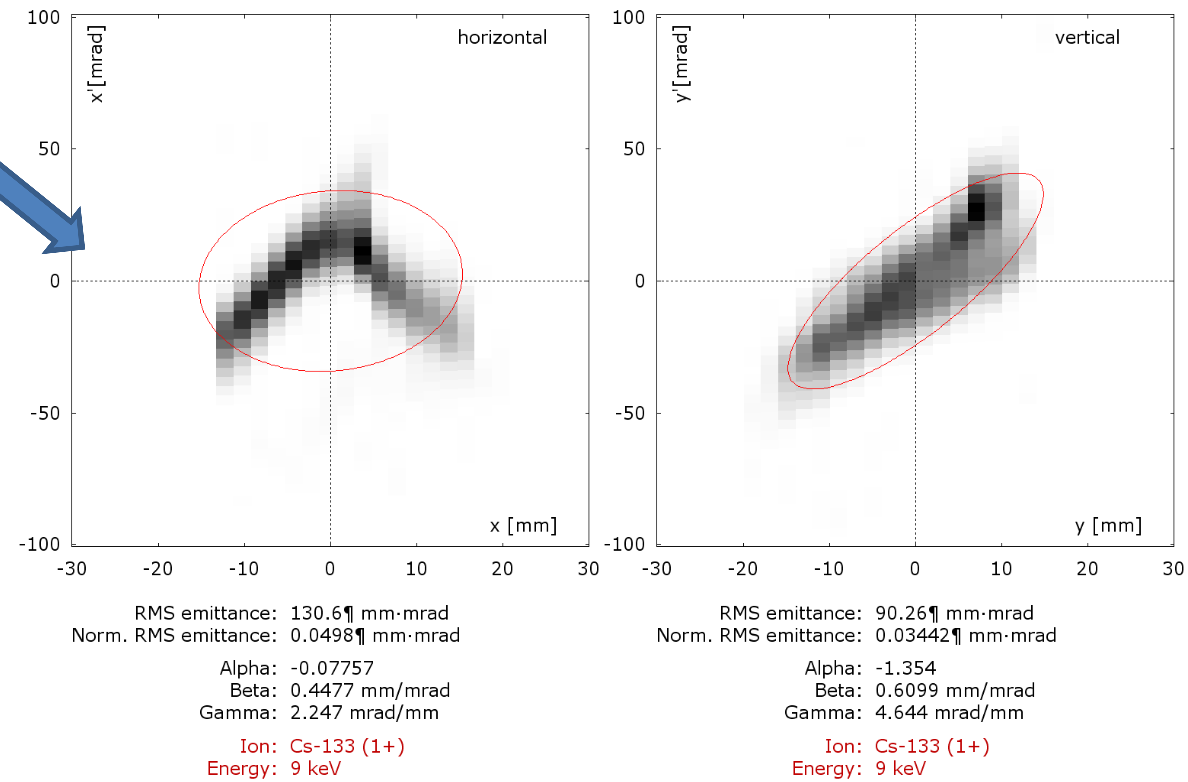
Distortion in horizontal benders:

Test EBIS parameters:
E_{el}=20 keV
I_{el}=1.0 and 1.5A

Possible reasons for differences with simulated acceptance:

1. Distortion of the ion beam emittance of the injected beam
2. 1.0 A: good tuning, actual acceptance is higher because of trapping some of out-of-beam ions (allowed for low neutralization)
3. 1.5A: not sufficient tuning

Emittance of Cz1+ ion beam



e-beam current, A	ε_{inj} (mm*mrad)	A_{sim} (mm*mrad)	Measured efficiency	Expected efficiency
1.0 A	0.04	0.027	0.75	0.68
1.5 A	0.04	0.033	0.71	0.82