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HINS Beam Optics Topics

Contents: A Broad Band Chopper for the CW linac
Optics optimization for energy spread measurement

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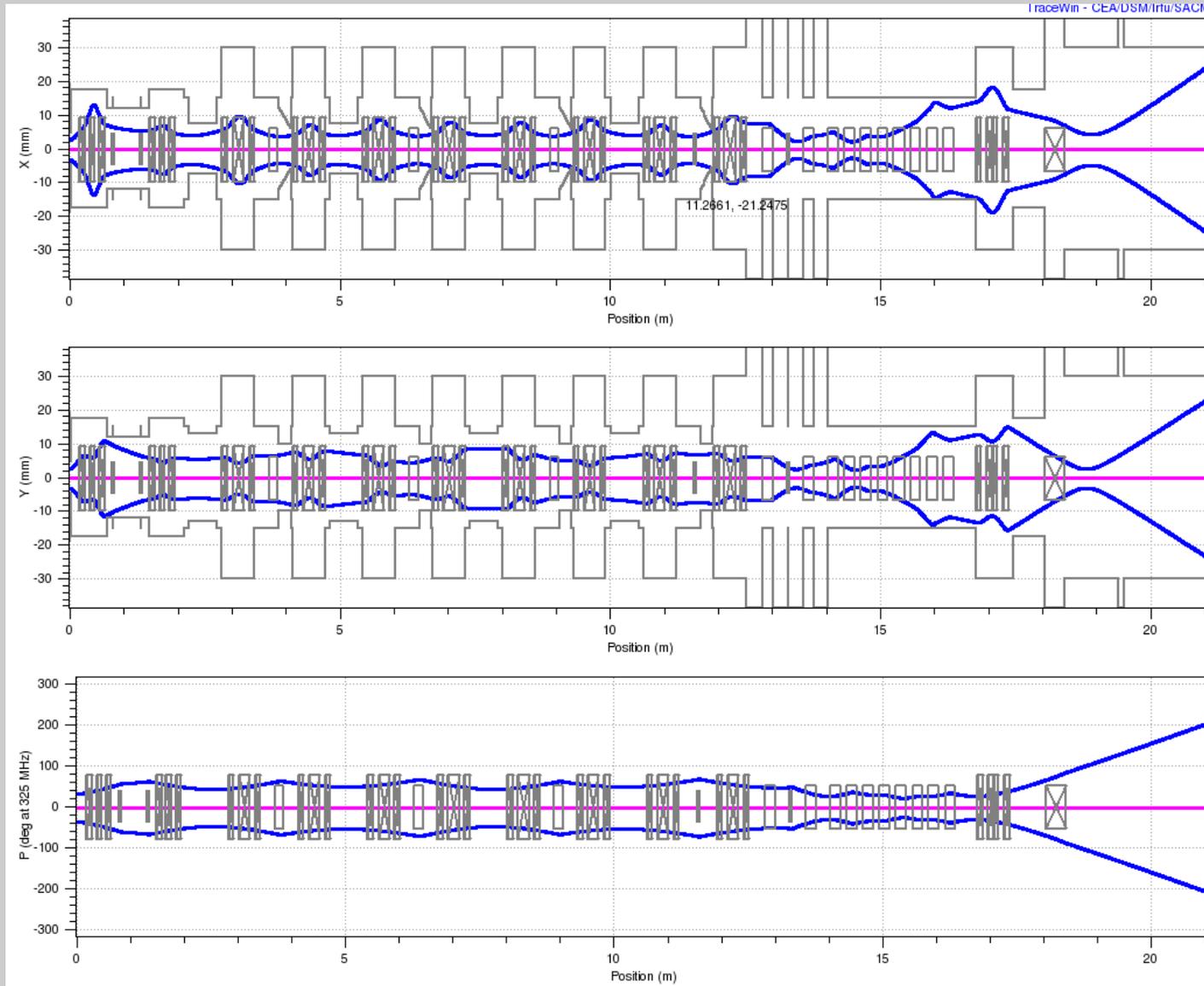
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Beam line

Optics (from RFQ):

- 2 triplets and two bunchers matching RFQ to chopper
- chopper
- 2RT solenoids and one gap matching chopper to the SSR0 section
- 4 SSR0 cavities and 4 RT solenoids
- a large aperture triplet and bending magnet have been added at the end of the beam line for energy spread measurement

Beam 3σ envelopes



Broad Band Chopper

The chopper optics (from V. Lebedev) consists of 8 triplets interleaved by 4 kickers and 4 bunchers.

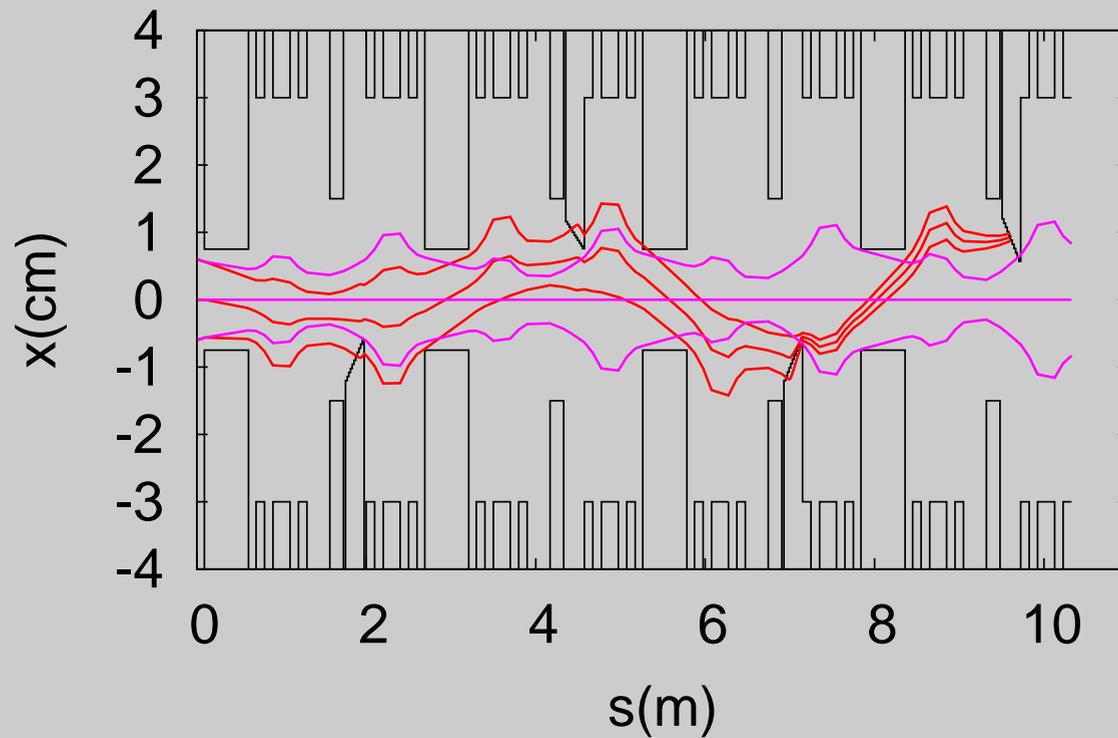
Chopper kickers:

- 4 Kickers each 0.5 m long with a 1.5 cm gap
- each provides 5 mrad kick, assuming $\simeq 748$ V (total voltage) feasible

With $\theta_1 = \theta_3 = -\theta_2 = -\theta_4 = 5$ mrad the kicked beam can be intercepted by 4 collimators.

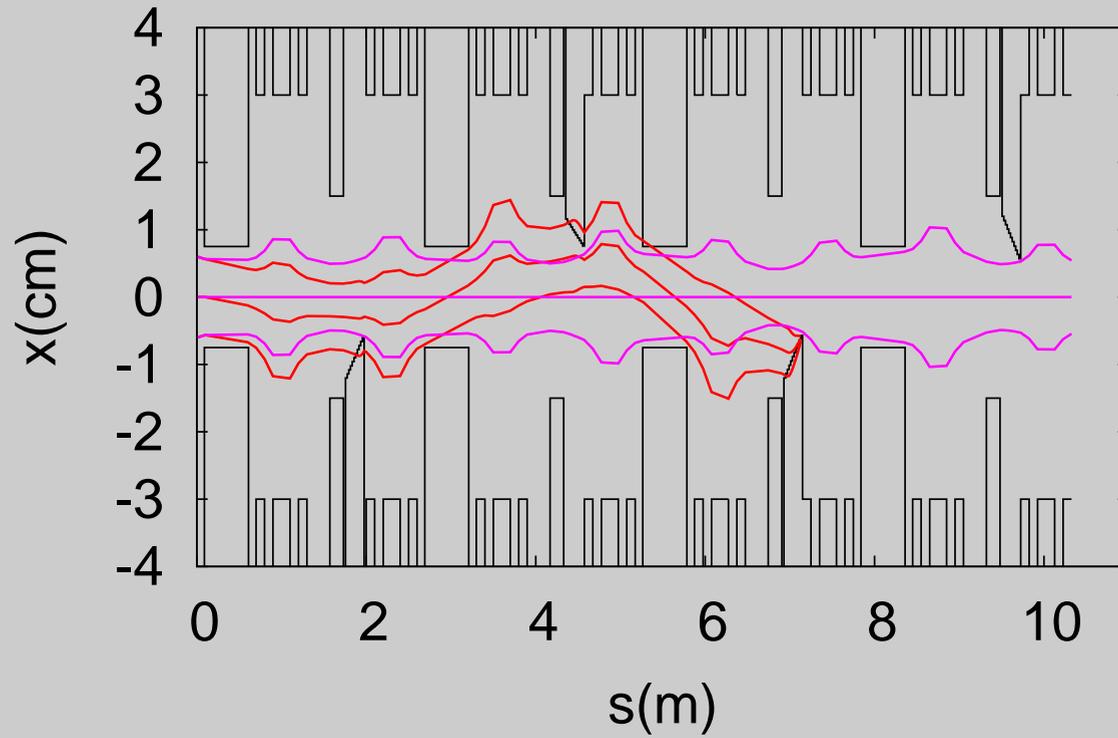
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4 Gaps I=0 mA 3σ Envelopes



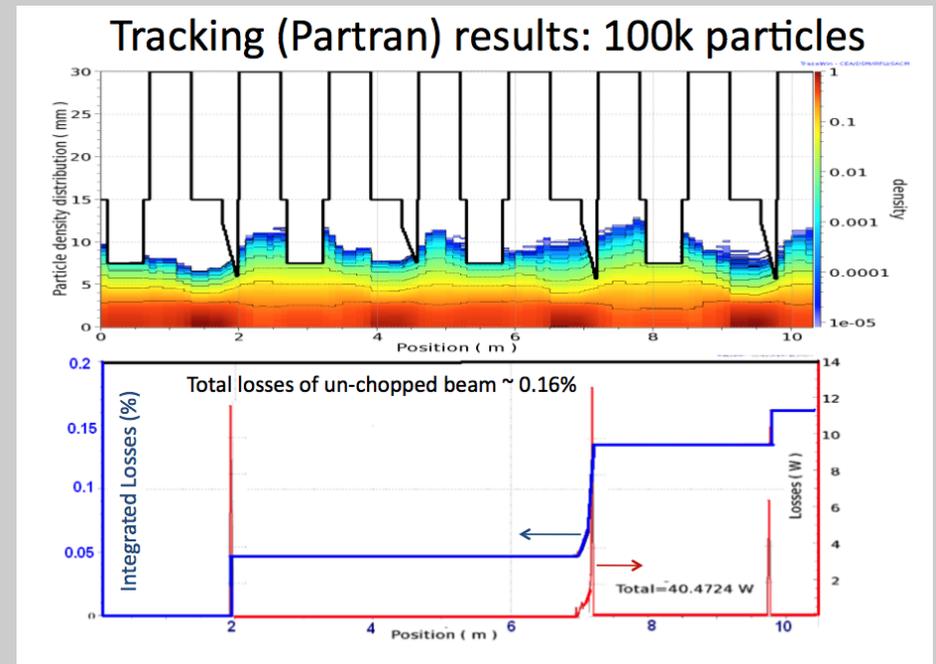
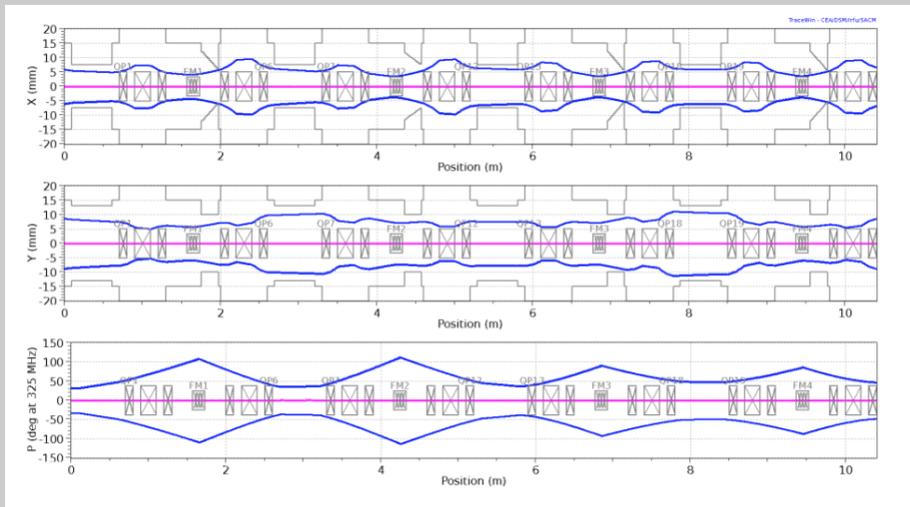
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4 Gaps I=10 mA 3σ Envelopes



Losses have been studied by N. Perunov in the “nominal” configuration.

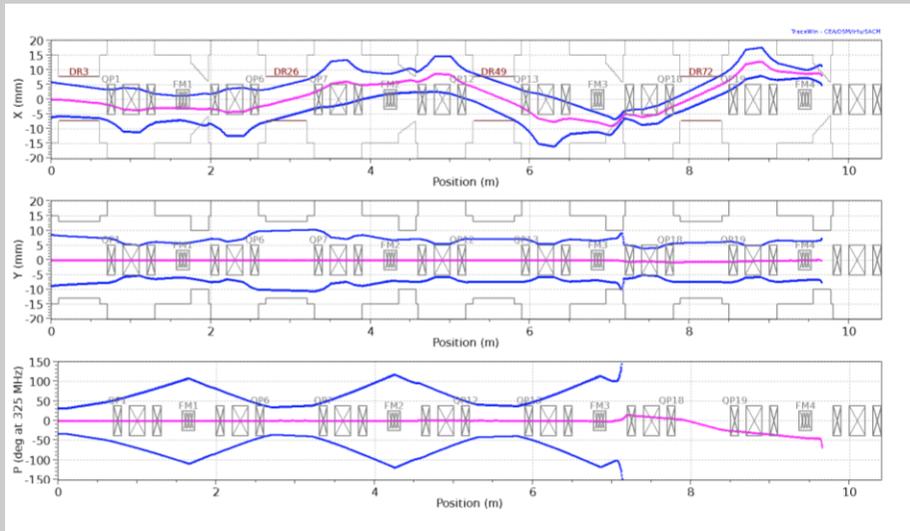
TraceWin - Chopper OFF - $I=10$ mA



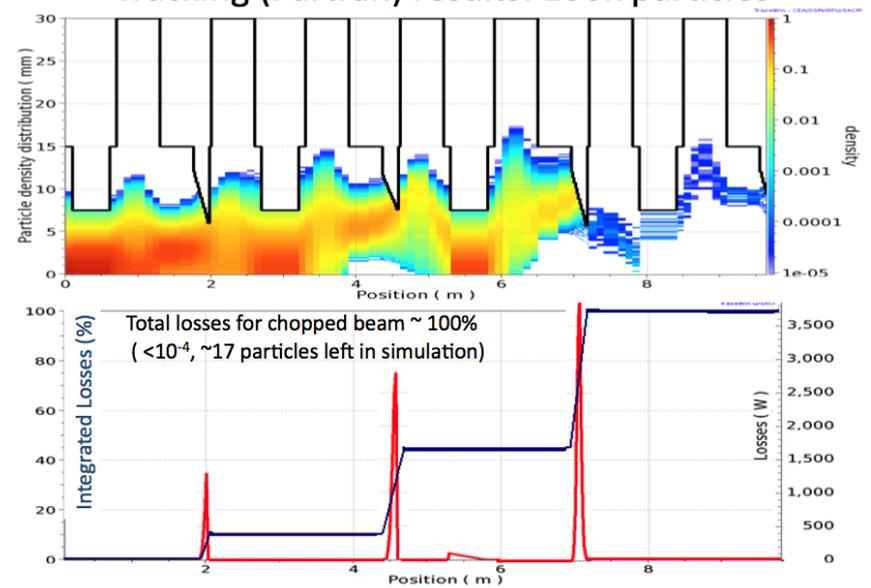
TraceWin - Chopper ON - $I=10$ mA

$I=10$ mA

$I=10$ mA



Tracking (Partran) results: 100k particles



Issues

- kicker strength
- losses in chopper #3 on the level of 4% (1 kW)
- effect of misalignments, not yet studied

Energy spread measurement

The beam size includes two terms

$$\sigma = \sqrt{\epsilon\beta + D^2 \left(\frac{\Delta p}{p}\right)^2}$$

If a horizontal dipole is introduced downstream the beam line for creating horizontal dispersion the energy spread may be measured from the beam size.

In general:

- *sector* magnet is more efficient than a rectangular one
- stronger the dipole, larger the dispersion

The best location for the Wire Scanner should be a location with maximum D_x^2/β_x : the optics should be designed so that β_x has a minimum no too close to the dipole allowing D_x to grow.

Problems encountered with TraceWin (in presence of dipoles)

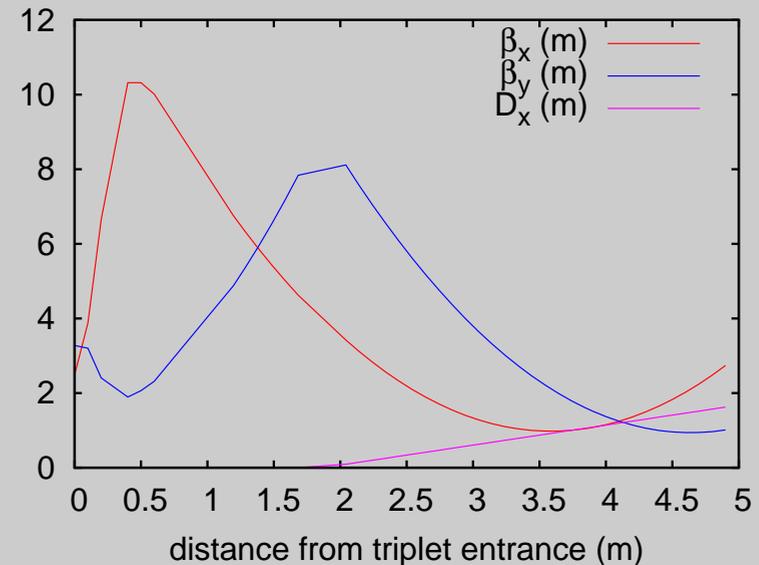
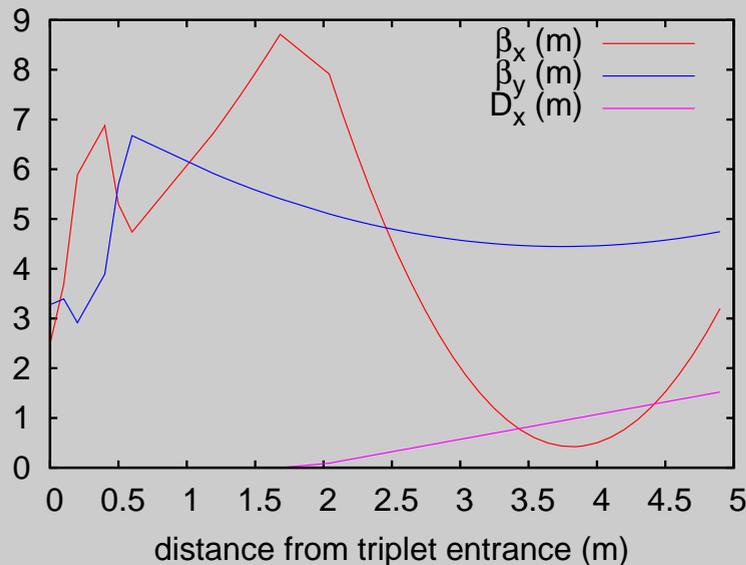
- TraceWin computes the “correct” β_x only if $\Delta p/p$ is made artificially small.
- Nevertheless, Twiss values for *rectangular* magnets disagree with MAD.

The strength of the last triplet is optimized (with MAD-X) so to maximize $\sigma_{x,p}^2/\sigma_{x,\beta}^2$ at the wire location while keeping $\hat{\beta}_x$ and $\hat{\beta}_y$ below a given value, $\hat{\beta}$.

For instance, we fix $\phi_b=30$ degrees and $B=0.340$ T ($\rho=0.684$ m, $\ell_{arc}=0.358$ m) and ask for $\hat{\beta}_x=\hat{\beta}_y < 9$ m.

Sector magnet: $\sigma_{x,p}^2/\sigma_{x,\beta}^2 \simeq 8$

Rectangular magnet: $\sigma_{x,p}^2/\sigma_{x,\beta}^2 \simeq 3$



Wire Scanner is at 3.9 m

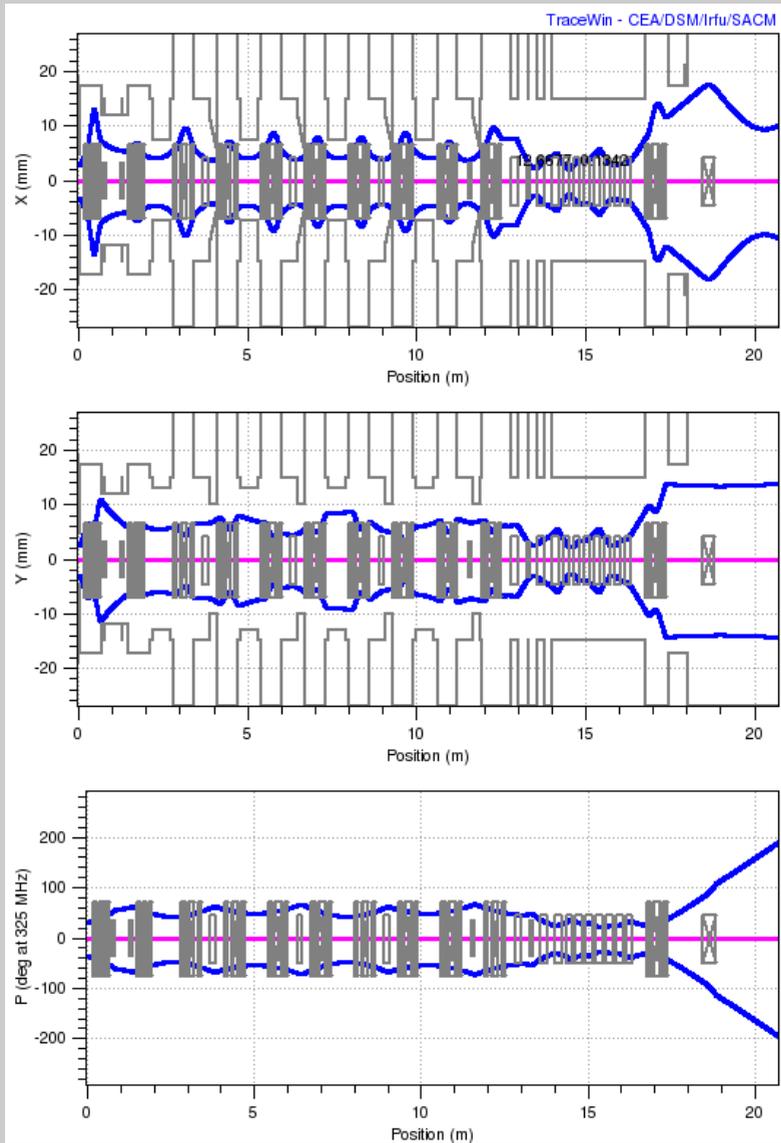
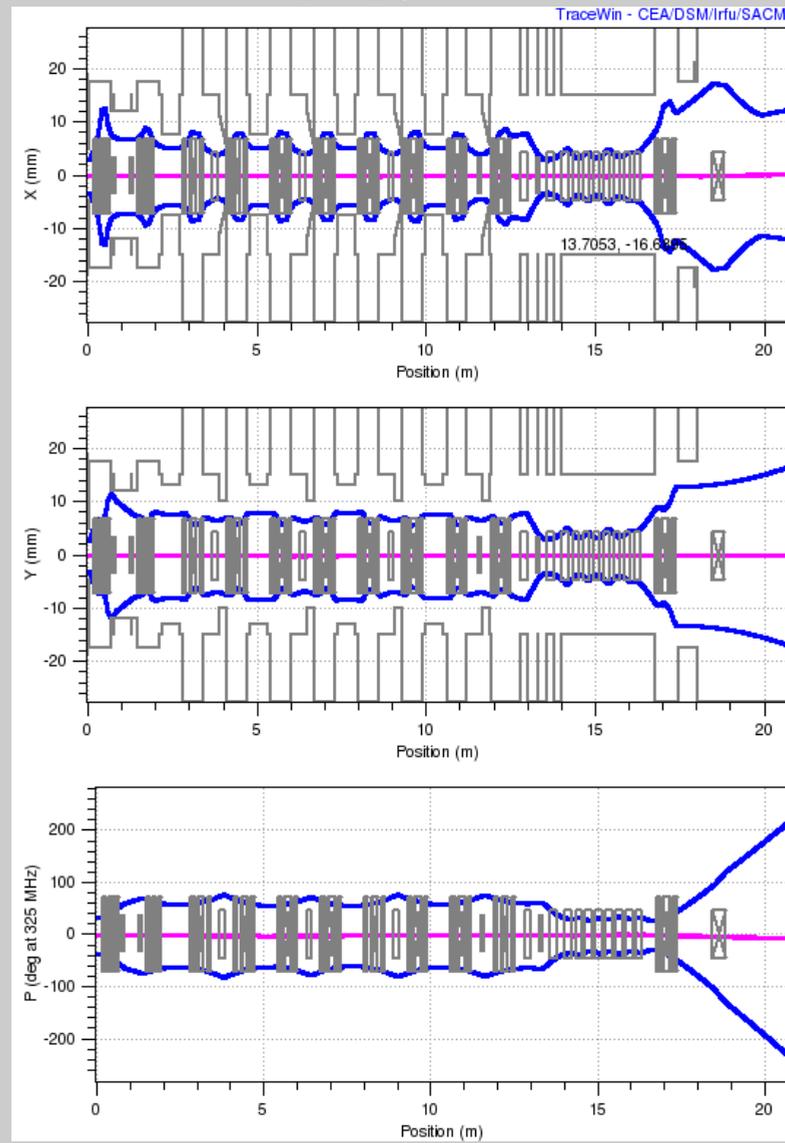
Without space charge, at the WS location is $(\Delta p/p)_{rms}=3.2 \times 10^{-3}$, $\beta_x = 0.437$ m and $D_x = 1.020$ m. Thus (with $\beta\gamma=0.079$)

$$\sigma_{x,\beta}^2 \equiv \beta_x \epsilon_x = 0.437 \times \frac{0.25}{0.079} \times 10^{-6} = 1.383 \times 10^{-6} \text{ m}^2$$

$$\sigma_{x,p}^2 \equiv \left[D_x \frac{\Delta p}{p} \right]^2 = [1.020 \times 3.2 \times 10^{-3}]^2 = 10.65 \times 10^{-6} \text{ m}^2$$

Ignoring the $\sigma_{x,\beta}$ contribution to the total beam size and computing $\Delta p/p = \sigma_x^{tot} / D_x$ we get 3.4×10^{-3} with an error of 6%.

We can insert a slit upstream the dipole to decrease the horizontal emittance and improve the precision.

$I=0$ mA $I=10$ mA

Extra slides

Starting conditions at RFQ exit (small spurious (?) offsets zeroed)

Input Beam parameters

Twiss parameters		Beam Center	
AlphaX	<input type="text" value="-1.2661473"/>	Dx	<input type="text" value="0"/> mm
BetaX	<input type="text" value="0.30146215"/> mm/pi.mrad	Dx'	<input type="text" value="0"/> mrad
AlphaY	<input type="text" value="-1.5730686"/>	Dy	<input type="text" value="0"/> mm
BetaY	<input type="text" value="0.27035219"/> mm/pi.mrad	Dy'	<input type="text" value="0"/> mrad
AlphaZ	<input type="text" value="-0.20011732"/>	Dz	<input type="text" value="0"/> mm
BetaZ	<input type="text" value="0.68573962"/> mm/pi.mrad	Dp	<input type="text" value="0"/> deg
BetaW	<input type="text" value="732.15644"/> deg/pi.MeV	Dz'	<input type="text" value="0"/> mm
Mismatchings (%)		Dw	<input type="text" value="0"/> MeV
X	<input type="text" value="0"/>	Dp/p	<input type="text" value="0"/> %
Y	<input type="text" value="0"/>		
Z	<input type="text" value="0"/>		

Ok Beam From file From calcul Cancel

TraceWin vs. MADX.

For instance, for $\phi_b=30$ degrees rectangular bend:

	ℓ_{arc}	β_x	α_x	β_y	α_y	D_x
MADX	0.358299	1.117067	-0.342150	0.867466	0.318003	0.092
TraceWin	0.3582986	0.9534	-0.1608	0.9398	-0.2161	0.092
TraceWin(*)	0.3582986	1.2272	-0.2427	1.0578	-0.5182	0.092

(*) Reducing longitudinal emittance by a factor 1e-3.

Estonishing the disagreement in the vertical plane.

It is convenient

- strong bend to get larger dispersion
- *sector* magnet for focusing downstream at the Wire Scanner

Dispersion downstream dipole

$$D = D_0 + D'_0 s$$

with (sector magnet)

$$D_0 = \rho(1 - \cos \phi_b) \quad \text{and} \quad D'_0 = \sin \phi_b$$

(D_0 and D'_0 being the values at the exit of the dipole).

It is convenient therefore a large ϕ_b and a large ρ .

But the focusing is $M_{21} = -\sin \phi_b / \rho$: the bending radius is determined by a balance between focusing and dispersion.

Error vs slit gap

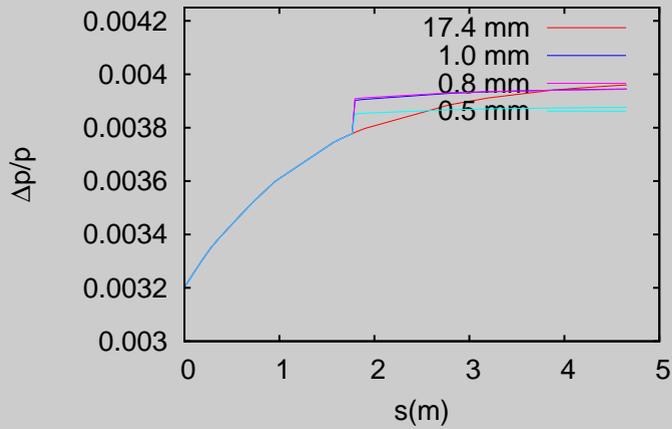
Check slit effect through tracking: 2×10^4 particles, starting conditions extracted from a 6D ellipsoid and tracked from RFQ to slit entrance with $I = 10$ mA. The new distribution is tracked through the slit to the wire scanner position. The slit is 1 cm long.^a

I (mA)	width (μm)	losses (%)	ϵ_x^N (mm mrad)	σ_x (mm)	$(\Delta p/p)_{rms}$ (%)	σ_x/D_x (%)	error (%)
10	17400×2	0	0.619	0.275	0.342	0.443	29
0	250×2	95	0.009	2.55	0.378	0.411	9
10	250×2	95	0.009	2.58	0.371	0.415	12
0	700×2	87	0.026	2.59	0.378	0.418	10
10	700×2	87	0.026	2.69	0.366	0.433	12

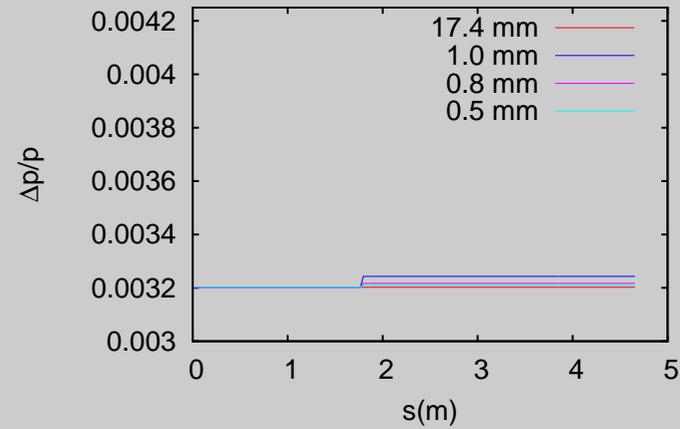
There is an *intrinsic* error which seems not strongly related to space charge.

^anb: results for a different optics!

1e4 particles, I=10 mA

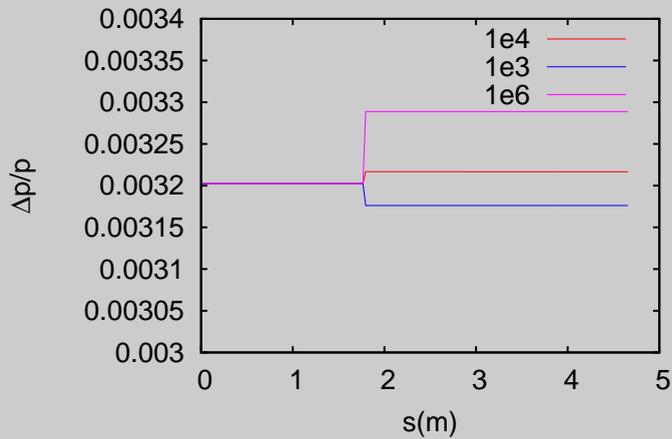


1e4 particles, I=0 mA



Slit aperture changes $\Delta p/p$ (?). It happens only by tracking. Statistics?

gap=0.8 mm, I=0 mA



It does not seem the case...