10^{34} Luminosity ideas

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Two betas

When discussing beam intersections where there is a significant pinch effect, as in EIC electron IRs, it is important to distinguish two βs

1. The local β_1^*s at the IP, including any pinching by the oncoming beam.

$$\sigma(IP) = \sqrt{\beta_1^* \, \epsilon}$$

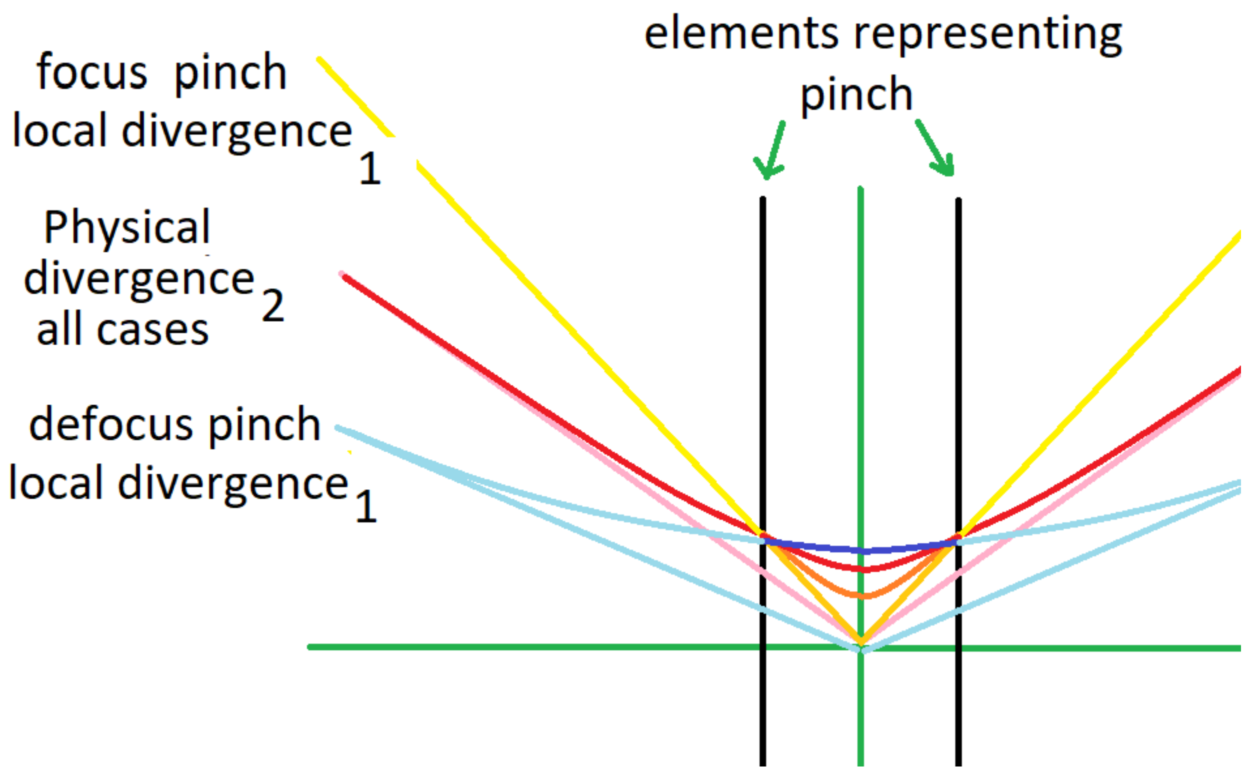
$$\sigma'(IP) = \sqrt{\frac{\epsilon}{\beta_1^*}}$$

2. The β_2^*s are what will appear in an IR latice, and which are the value at the IP without any pinch effect. i.e. with no significant focusing or defocusing by interactions with the oncoming beam.

$$\sigma_2'(\text{lattice}) \approx \sqrt{\frac{\epsilon}{\beta_2^*}} \qquad \text{for L}^* \gg \beta^*$$

$$\text{Aperture} \approx L^* \, \sigma_2'(\text{lattice}) \qquad \text{for L}^* \gg \beta^*$$

The two σ'



Local focusing (or defocusing) will change the local $\sigma(IP)$ and also the divergence $\sigma'(\mathrm{Lattice})$, increasing it with focus and decreasing it with defocus.

Think of the phase space: if the spot gets smaller, the angular spread must rise. If the spot gets larger, the spread will be less.

Examples

Normal pinch: reducing σ(IP) and increasing divergence $\sigma'(\mathrm{lattice})$

From DXU may 26 page 4/5 Vadim's case:
$\beta_y = 10.9$ cm and $\epsilon_y = 1.7$ nm
giving calculated $\sigma_{2y} = 13.6\ \mu$m.

$\sigma_{1y} = 12.5\mu$m, from simulation at IP

i.e. the pinch is reducing the σ_y by 8%,

and expected to increase $\sigma'_y(lattice)$ by the same 8%

Inverted pinch: increasing σ(IP) and decreasing divergence $\sigma'(\mathrm{lattice})$

From Derong May 23, page 1/13 note:

β_{2x} cm	ϵ_x nm	σ_y μm	$\mathrm{calc}\sigma_y$ μm
49	20	11.5	9.9
59	20	13	10.8

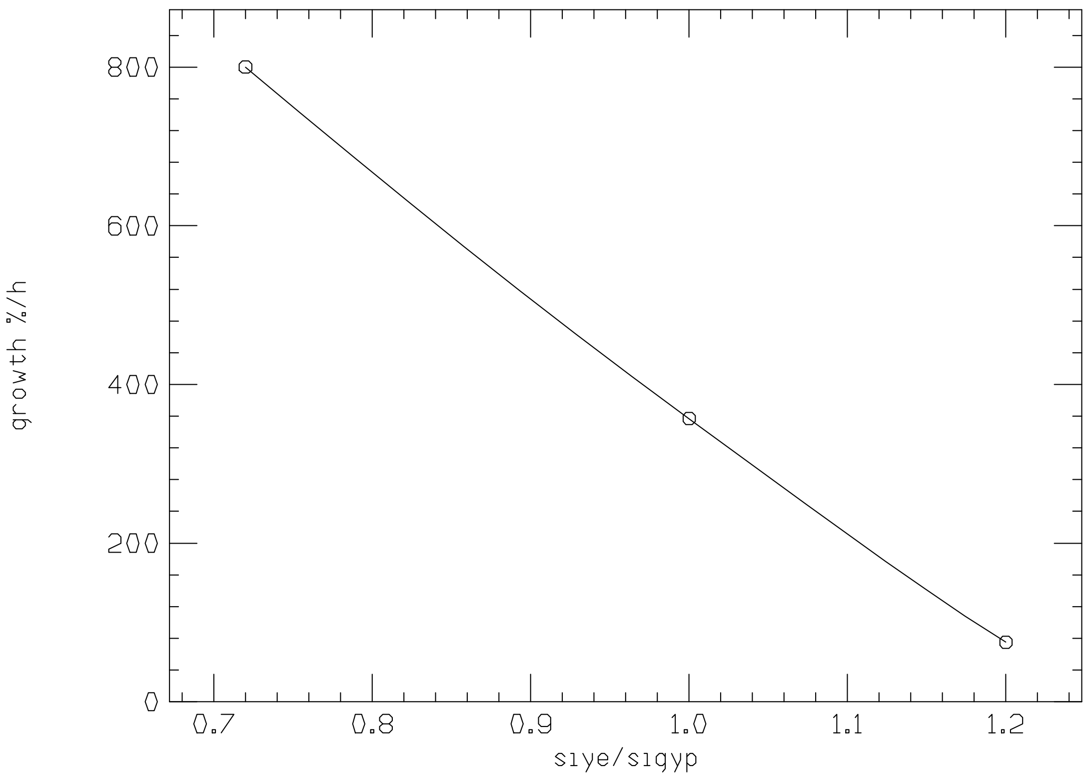
In all cases σ(IP) is LARGER than a non-pinched calculation.

If the beams are very asymmetric, as they are, the "pinch" can be asymmetric too, like a quadrupole electron lens.

Growth vs. e-p σ_y match

Approximate numbers from Derong:

Case	σ_{ye} μm	σ_{ye}/σ_{yp}	Growth %/hour
A	9	0.7	800
B	12.5	1.0	357
C	15	1.2	75



As expected: protons see a more uniform part of the e lens

Design steps

1. Start from Vadim's $L = 6.8\ 10^{33}$ K=.12 equal divergencies (see example 5)
2. Scale all betas down by factor 0.6, to get $L > 10^{34}$ (see example 6)
   - Electron x divergence now $> 220\mu$rad
   - But pinch modified (in parentheses) divergence $\sigma' \leq 220\mu$rad
   - Pinch modified (in parentheses) electron bunch sigmas larger x, smaller y
   - So pinch modified (in parentheses) sigmas no longer match hadron's
3. Modify hadron betas to match electrons: larger x, smaller y (see example 10). 9
   - $L = 10.2\ 10^{33}$ and $K = \sigma_y/\sigma_x = .09$, but the flattening came from asymmetric pinch
4. This study has not studied Vadim's ideas including reductions of electron x emittance that could allow re-adjusting the flatness without generating electron divergencies $\sigma' > 220\ \mu$m.

Parameters

Parentheses give parameters modified by pinch effects.
In red based, to some extent on b-b simulations
In blue guesses of effects not yet simulated

5) Vadim's current reference

6) My scale down all betas by factor 0.6

10)modifying hadron betas to match electrons with pinch

11)Reduced both hadron betas to improve growth

$$N_b = 1160,\ E = 275,\ E_e = 10\ GeV,\ n_p = 6.9,\ n_e = 17.2\ 10^{10}$$

		ϵ_x nm	ϵ_y nm	$\beta_{1x}(\beta_{2x})$ cm	$\beta_{1y}(\beta_{2y})$ cm	$\sigma_{1x}(\sigma_{2x})$ μm	$\sigma_{1y}(\sigma_{2y})$ μm	$K_{y/x}$	$\sigma'_{1x}(\sigma'_{2x})$ μrad	$\sigma'_{1y}(\sigma'_{2y})$ μrad	ξ_x	ξ_y	ΔQ	σ_s cm	I A	HG %	lum 10^{33}
5																	
	p	10.9	1.3	90.0	10.9	99	11.9	.12	110	109	.012	.012	.007	6.0	1.00	94	6.78
	e	20.0	1.70	49.0 (60)	8.4(7)	99(109)	11.9(10.9)	0.12(0.1)	202(184)	142(155)	.070	.100	.000	2.0	2.50		
6																	
	p	10.9	1.3	54.0	6.5	77	9.2	0.12	142	141	.012	.012	.007	6.0	1.00	88	10.60
	e	20.0	1.7	29.4(40)	5.0(4)	89(77)	8.4(9.2)	0.12(.09)	261(220)	184(215)	.070	.100	.000	2.0	2.50		
10																	
	p	10.9	1.3	72	5.2	89	8.2	0.09	123	159	.012	.009	.007	6.0	1.00	87	10.10
	e	20.0	1.7	29.4(40)	5.0(4)	89(77)	8.4(9.2)	0.12(.09)	261(220)	184(215)	.072	.079	.000	2.0	2.50		
11																	
	p	10.9	1.3	57.6	4.2	80.1	8.0	0.09	135	175	.012	.009	.007	6.0	1.00	87	11.1
	e	20.0	1.7	29.4(40)	5.0(4)	89(77)	8.4(9.2)	0.12(.09)	261(220)	184(215)	.072	.079	.000	2.0	2.50		

Remember the βs to be used in a lattice and for input to a simulation code are those β_2s that are in parentheses. The ones before are those β1s inside the interstctions.
All detailed numbers are only approximations. Development should follow simulations of above steps.

Luminosity vs. divergences