Intra-beam scattering

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http://cern.ch/beta-beam

Outline

- Definitions
- The beta-beam case: RCS, PS, SPS and decay ring
- Critical cases
- Summary

IBS definitions

- Emittance growth

$$\epsilon_{long,hor,ver}(t_0) = \epsilon_{long,hor,ver}(0)\; e^{\int_0^{t_0} \frac{1}{\tau_{long,hor,ver}(t)}\, dt}$$

- Growth time

$$\frac{1}{\tau_{long,hor,ver}} \propto A_0 \int e^{-Dz} \ln\left(1 + C^4 z^2\right) \begin{pmatrix} n_b\,(1-d^2)\,g_1 \\ a^2\,g_2 + \left(d^2 + \tilde{d}^2\right) g_1 \\ b^2\,g_3 \end{pmatrix} d\theta\, d\phi\, dz$$

- Always assumes Gaussian distributions in the three phase spaces.

$$A_0 \propto N \frac{Z^4}{A^2} \frac{1}{\epsilon_x^* \epsilon_y^* \sigma_p \sigma_s \beta\gamma^2}$$

- Injection and 18Ne operation is more demanding.

A. Piwinski, Intra-beam scattering, proc 9th Conf. on High Energy Accelerators, 1974, p. 405
J. Bjorken, S. Mtingwa, Intrabeam Scattering, Particle Accelerators 1983 13, pp 115-143
J. Wei, “Evolution of hadron beams under Intra-beam scattering”, PAC1993

Beta-beam cases

- Investigated machines:
  - RCS, PS, SPS, decay ring
    only at injection
- Ions: ^{6}He, ^{18}Ne

^{6}He

	RCS	PS	SPS	DECAY
N_b	9.264×10^{11}	8.981×10^{11}	7.667×10^{11}	4.829×10^{12}
$l_{full,bunch\,[m]}$	189.7	23.94	5.984	2.992
sigt [m]	63.	8.0	2.0	0.63
sigE/E [mrad]	0.13	0.30	0.36	1.3

^{18}Ne

	RCS	PS	SPS	DECAY
N_b	2.726×10^{11}	2.692×10^{11}	2.564×10^{11}	3.708×10^{12}
$l_{full,bunch\,[m]}$	189.7	23.94	5.984	2.992
sigt [m]	63.	8.0	2.0	0.55
sigE/E [mrad]	0.17	0.20	0.16	1.5

- IBS codes (and simplified models):
  - MAD8 and MAD-X (differ on the per-mille level)
  - Wei approximation (thanks to J. Jowett)

Growth times

Results obtained with Mad-8

- ^{6}He

	RCS	PS	SPS	DECAY
τ_{long}[s]	22	194	3289	263345
τ_{hor}[s]	-10361	-3157	-111774	44566
τ_{ver}[s]	-4840	-5082	-214853	5605307

- ^{18}Ne

	RCS	PS	SPS	DECAY
τ_{long}[s]	2	6	39	7309
τ_{hor}[s]	-595	-360	-63147	910
τ_{ver}[s]	-302	-341	-9145	74039

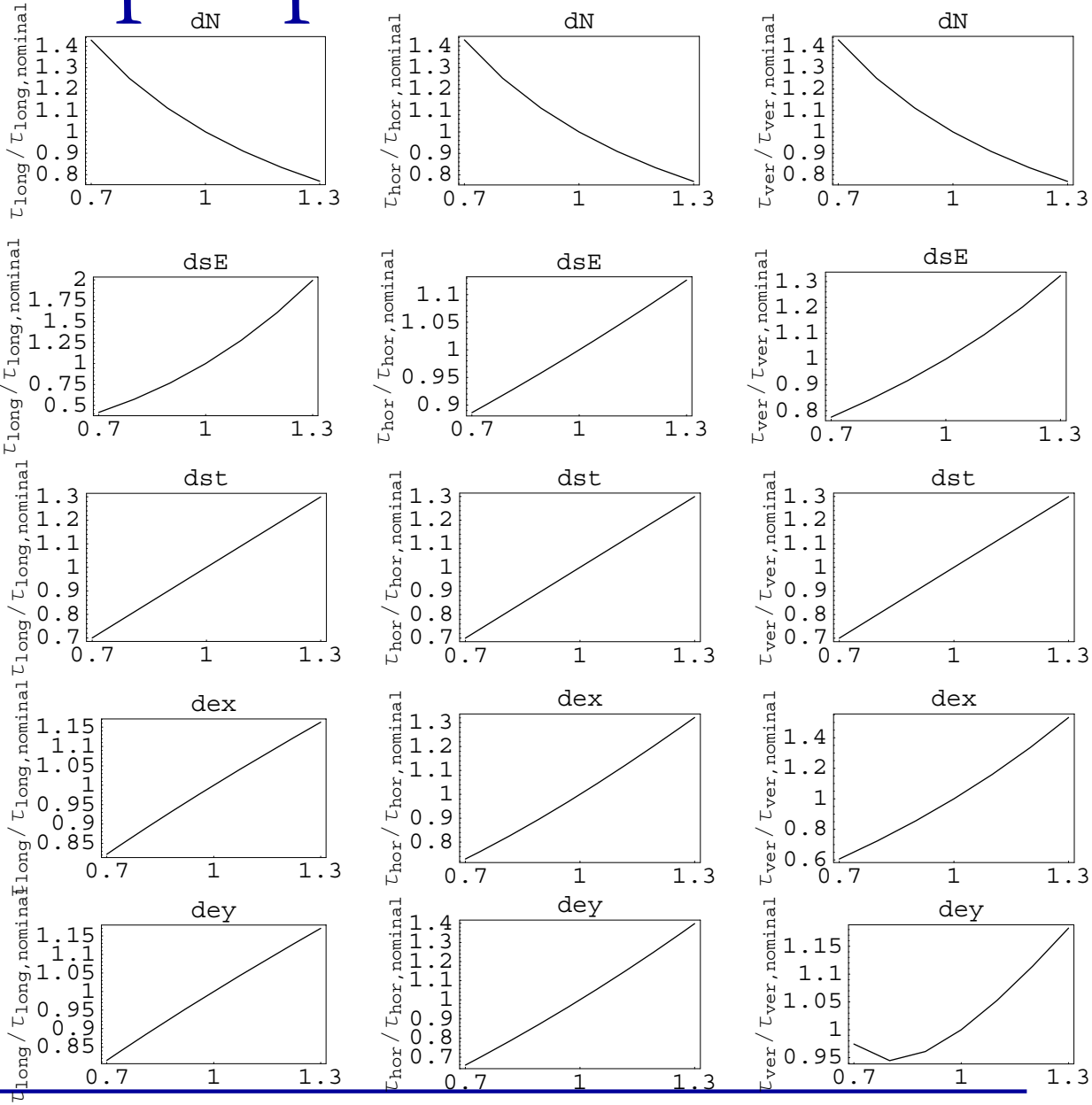
Growth times according to J. Wei

IBS growth time		RCS	PS	SPS	DECAY
6He	τ_{long} [s]	n.a.	745	$12*10^3$	$783*10^3$
	τ_{hor} [s]	n.a.	$-45*10^3$	$-1.2*10^6$	$*10^6$
	τ_{ver} [s]	n.a.	$-22*10^3$	$-534*10^3$	$1.3*10^7$
18Ne	τ_{long} [s]	n.a.	21	162	$19*10^3$
	τ_{hor} [s]	n.a.	$-5.1*10^3$	$-465*10^3$	$19.9*10^3$
	τ_{ver} [s]	n.a.	$-2.2*10^3$	$-60*10^3$	$-256*10^3$

- Same trends as for Mad-8.
- Longitudinal growth times about a factor 4 larger.
- Transverse growth times about an order of magnitude larger.

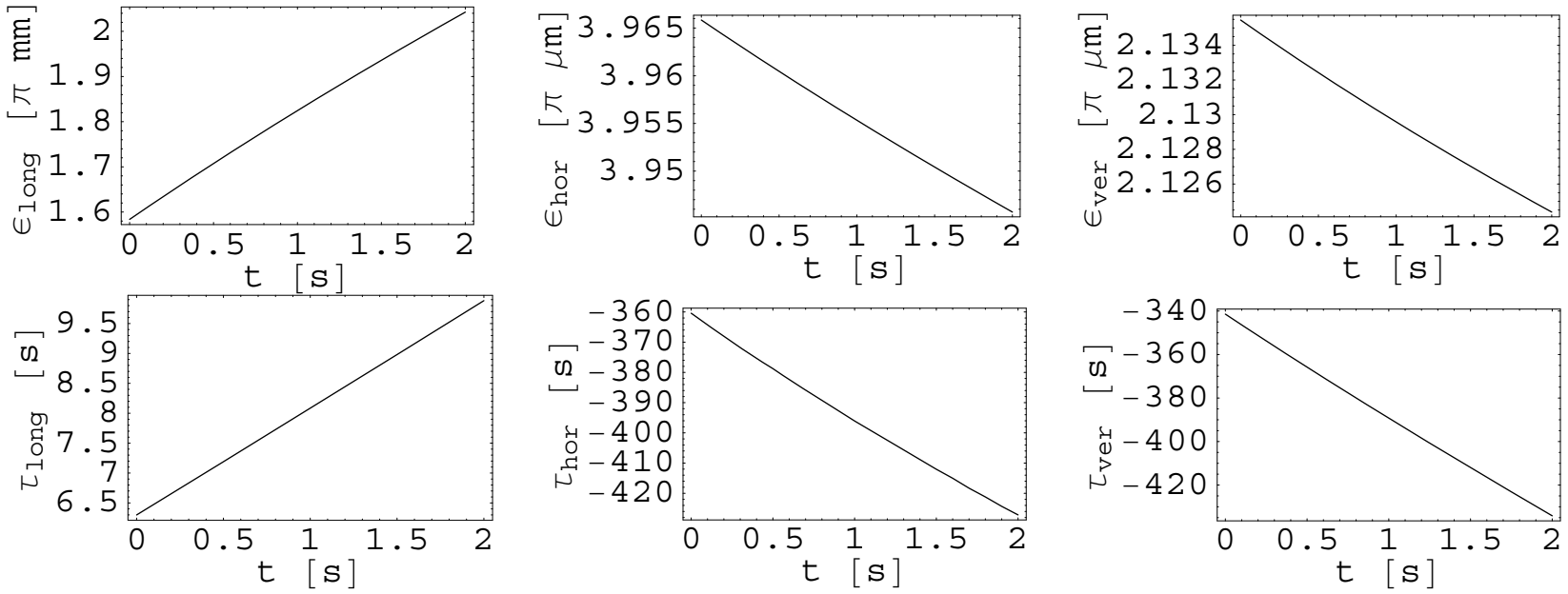
Sensitive on input parameters

- Bunch intensity
- Energy spread
- Bunch length
- Hor. Emittance
- Ver. Emittance

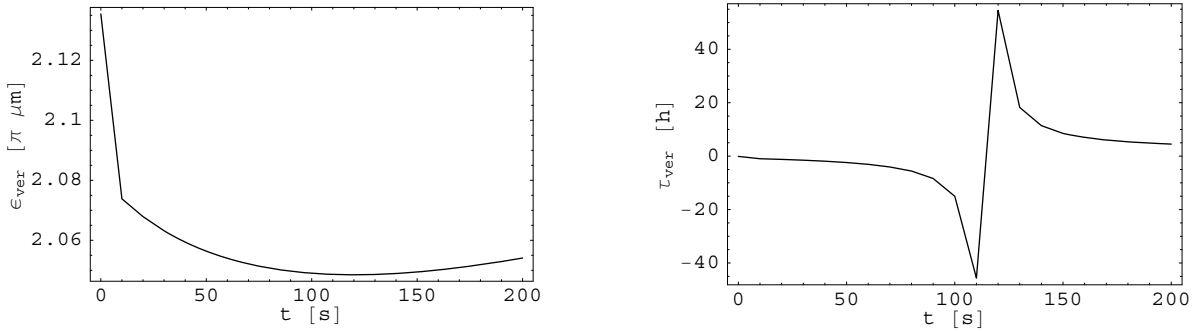


Accumulation of ^{18}Ne in the PS

- Time transient model with Mad-8.



- Sign change for growth time:



Summary

- ^{18}Ne in the PS at injection is the critical case.
- Still large difference using different codes. Needs to be investigated further.
- No surprise expected, but evolution during acceleration needs to be investigated as well. Requires definition of RF cycle.