Decay Losses in RCS, PS and SPS

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Outline

- Aim
- Definitions
  - Particle decay
  - Power loss
- Accumulation & accelerator cycle
- Decay distributions in the accelerator chain
- Power losses
- Comparison with CNGS operation
- Conclusions

Aim

- Calculate ion distributions over machines
- In order to compare power deposition with known high intensity operation
- Only particle losses due to decay considered
- without MC simulations, no cascade studies

- Based on version 2
  - Version 2: Not reaching design rate for ^{18}Ne yet

    $\leftrightarrow$ missing factor 25

Definitions

- Decay of ^{6}He to ^{6}Li and ^{18}Ne to ^{18}F according

$$\dot{N}(t) = \frac{\ln(2)}{t_{1/2} * \gamma(t)} N(t)$$

$$B\rho = \frac{A}{Q} p$$

- Decay products ^{6}Li and ^{18}F with a changed A/Q by 50% and 10%
- Losses equally distributed over machine circumference
- The energy loss for activation of the surrounding machine components is calculated as

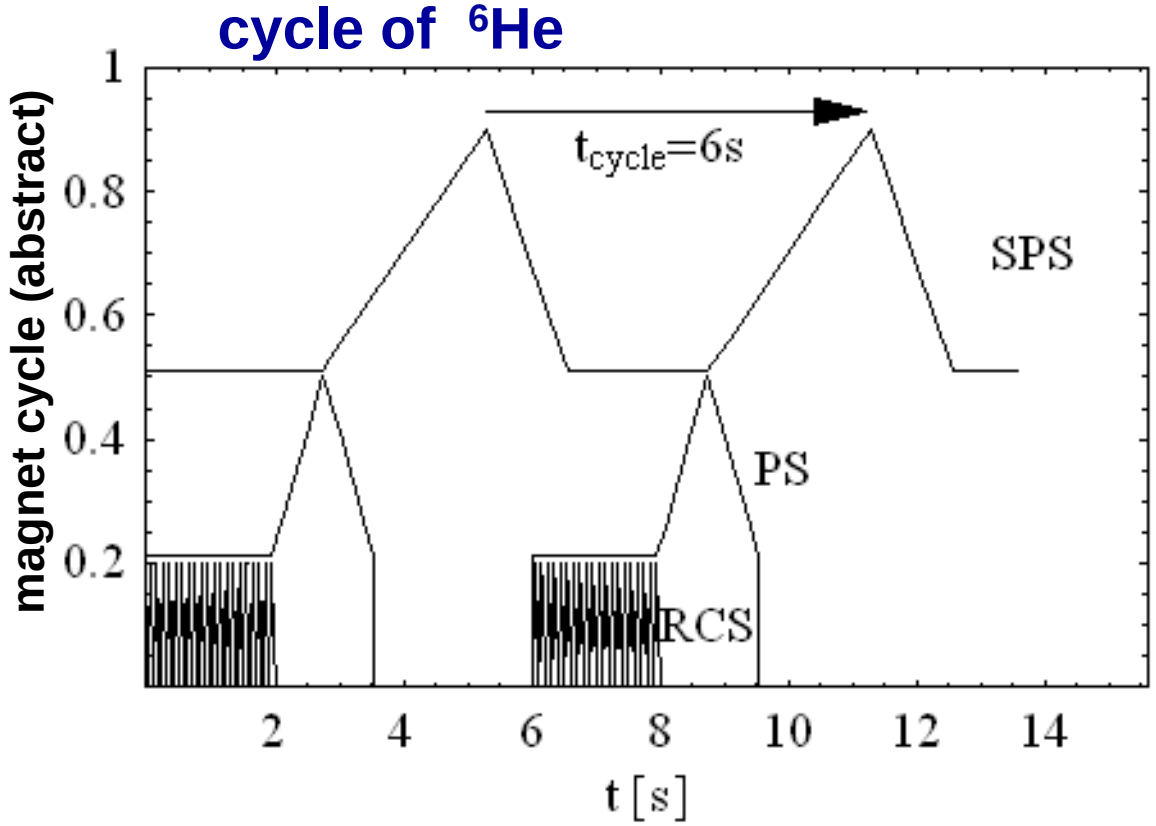
$$E_{loss} / cycle = \int^{t_{cycle}} \frac{dI}{dt} T(t) dt$$

- Kinetic energy T taken as relevant

$$P_{loss} / l = \frac{E_{loss} / cycle}{t_{cycle} * circumference_{machine}}$$

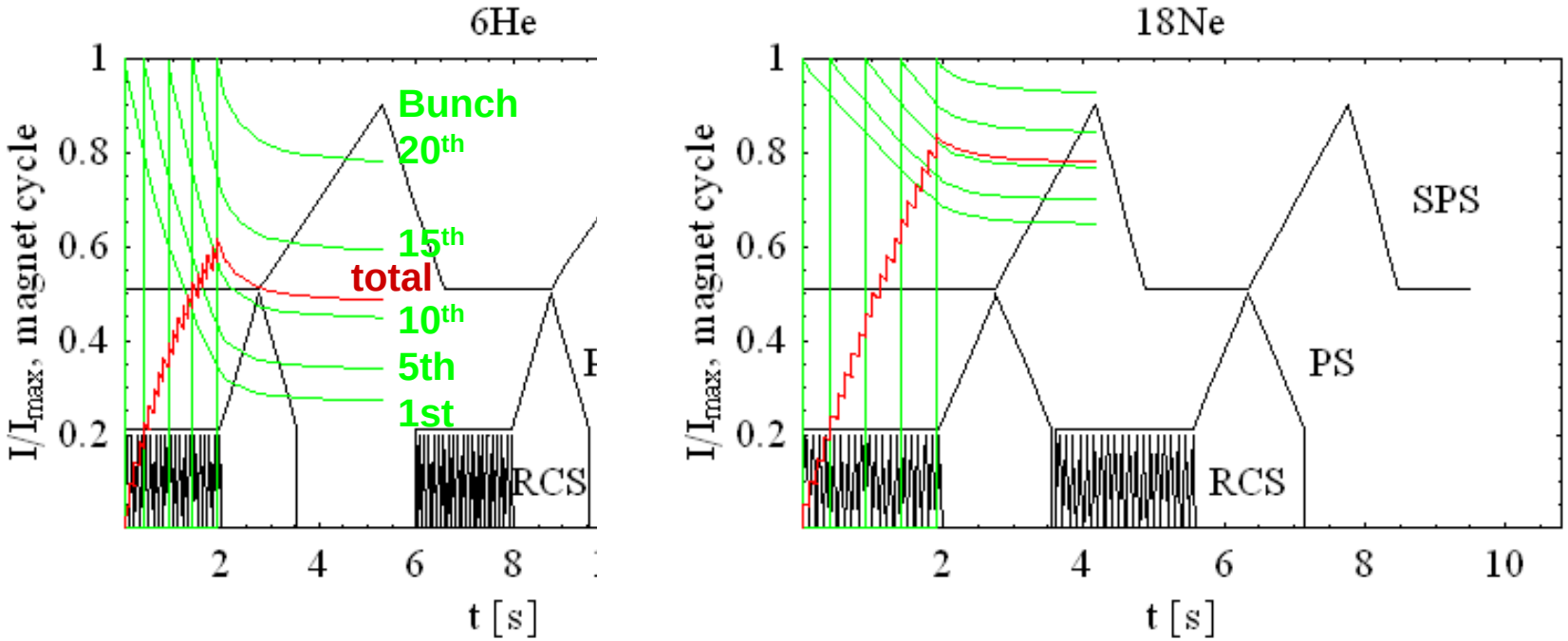
- Power loss P/l can be compared with other HIP cases
- Looked into decay from RCS accumulation to SPS ejection

Cycle of the Beta-beam complex



- Mix of intensities in RCS, PS

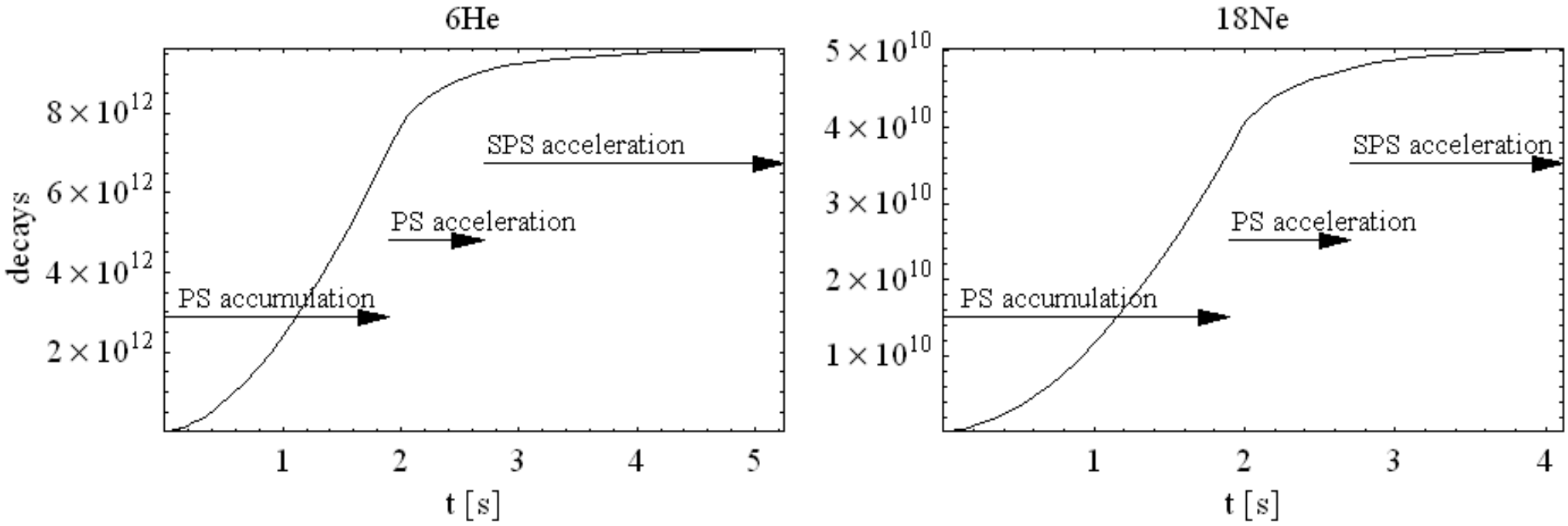
Decay distribution



- 70% of first ^{6}He bunch are lost before reaching decay ring
- Overall only 50% (^{6}He) and 80% (^{18}Ne) reach decay ring

- Normalization
  - Single bunch intensity to maximum/bunch
  - Total intensity to total number accumulated in RCS

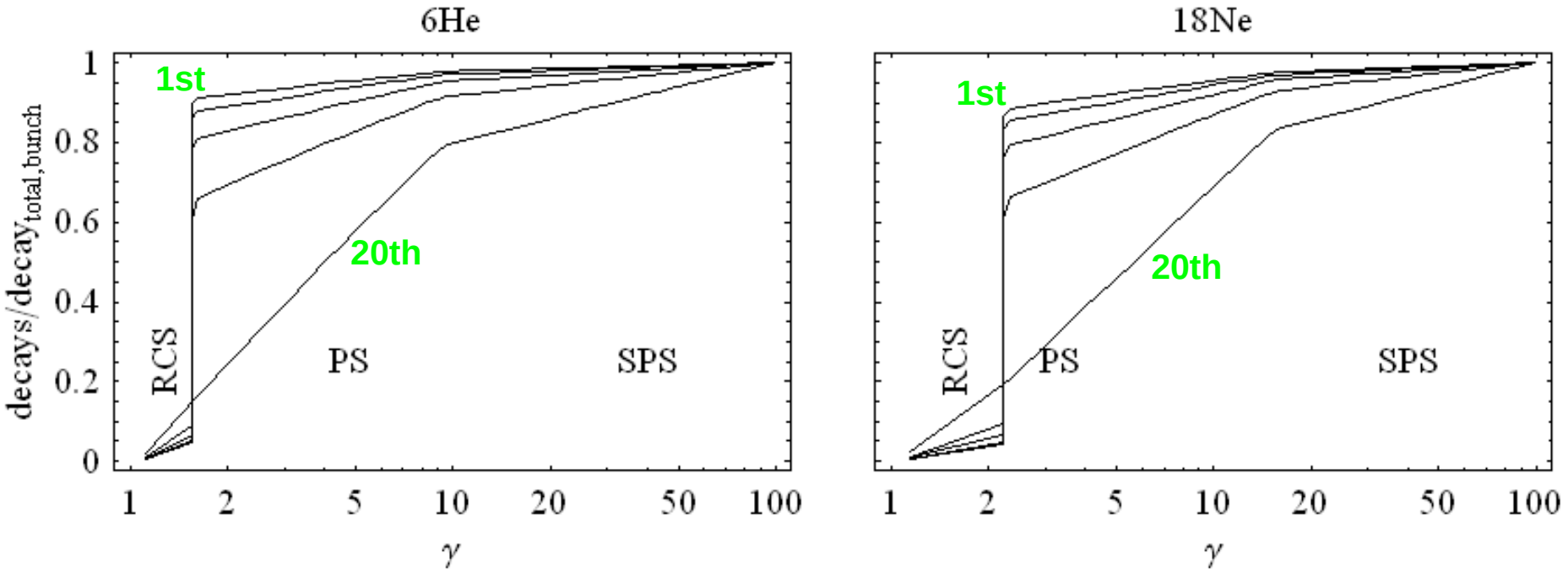
Decay losses (1)



- Relative decay distribution similar for both isotopes
- Absolute 20 time more losses for ^{6}He
- ~90% of all decays occur in the PS

Decay losses (2)

- In the PS most losses occur at low energy



Loss/cycle [ions]	RCS	PS	SPS	Total
^{6}He	$0.64*10^{12}$	$8.48*10^{12}$	$0.53*10^{12}$	$9.7*10^{12}$
^{18}Ne	$0.3*10^{10}$	$4.5*10^{10}$	$0.2*10^{10}$	$5*10^{10}$

CNGS numbers

Source: report of HIP working group

- Extrapolated from passed SFTPRO program to WA

Machine / process	Intensity/cycle [protons]	Transmission	Losses/cycle [protons]
target T40 to target (fast extraction)	$4.40 * 10^{13}$	 ≈ 100 %	
SPS at 400 GeV SPS transition (21GeV) SPS injection (13GeV)	$4.40 * 10^{13}$	 92% 96%	 $1.9 * 10^{12}$ $1.9 * 10^{12}$
TT2/TT10 PS extraction (13 GeV)	$4.78 * 10^{13}$	 90%	 $5.3 * 10^{12}$
PS 13 GeV PS transition (6.1 GeV) PS injection (1.4 GeV)	$5.31 * 10^{13}$	 92% 94%	 $1.15 * 10^{12}$ $1.15 * 10^{12}$
PSB extraction/recombination PSB 1.4 GeV	 $5.78 * 10^{13}$	96%	$2.3 * 10^{12}$

- Proton losses typically at injection, ejection and transition

Annual losses

machine		CNGS [5]	Beta-beam		ratio
			^{6}He	^{18}Ne	
RCS	nucleon loss	-	$6.4 * 10^{18}$	$1.5 * 10^{17}$	-
	ion loss	-	$1.1 * 10^{18}$	$8.3 * 10^{15}$	-
PS	nucleon loss		$8.5 * 10^{19}$	$2.25 * 10^{18}$	11 (0.3)
	ion loss	$7.8 * 10^{18}$	$1.49 * 10^{19}$	$1.25 * 10^{17}$	1.9 (0.02)
SPS	nucleon loss		$5.3 * 10^{18}$	$1.0 * 10^{17}$	1.4 (0.03)
	ion loss	$3.9 * 10^{18}$	$8.8 * 10^{17}$	$5.6 * 10^{15}$	0.2 (0.001)
Total	nucleon loss		$1.14 * 10^{20}$	$2.5 * 10^{18}$	13.3 (0.3)
	ion loss	$8.6 * 10^{18}$	$1.9 * 10^{19}$	$1.4 * 10^{17}$	2.2 (0.02)
	nucleon @ γ_{top}		$9.05 * 10^{19}$	$8.95 * 10^{18}$	2.0 (0.2)
	ions @ γ_{top}	$4.5 * 10^{19}$	$1.51 * 10^{19}$	$5 * 10^{17}$	0.34 (0.01)

ratio=beta-beam / CNGS

Power losses

machine		CNGS [5]	Beta-beam	
			^{6}He	^{18}Ne
RCS	loss/cycle [ions]	-	$6.4 * 10^{11}$	$0.3 * 10^{10}$
	loss/cycle/l [ions/m]	-	$1.1 * 10^{10}$	$5 * 10^{7}$
	E_{loss}/cycle[kJ]	-	0.184	0.005
	$P_{loss,average}$[1][W/m]	-	0.5	0.
PS	loss/cycle [ions]	$7.6 * 10^{12}$	$8.48 * 10^{12}$	$4.5 * 10^{10}$
	loss/cycle/l [ions/m]	$1.2 * 10^{10}$	$1.4 * 10^{10}$	$7.2 * 10^{7}$
	E_{loss}/cycle[kJ]	12.4	8	0.25
	$P_{loss,average}$[W/m]	3.3	2.2	0.12
SPS	loss/cycle [ions]	$3.8 * 10^{12}$	$0.53 * 10^{12}$	$0.2 * 10^{10}$
	loss/cycle/l [ions/m]	$5..4 * 10^{8}$	$7.6 * 10^{7}$	$3 * 10^{5}$
	E_{lost}/cycle[kJ]	10.3	16.9	0.27
	$P_{loss,average}$[W/m]	0.25	0.4	0.01
Total	loss/cycle [ions]	$11.4 * 10^{12}$	$9.7 * 10^{12}$	$5 * 10^{10}$
	E_{lost}/cycle [kJ]	22.7	25.0	0.52

- PS and SPS comparable for CNGS and bb operation at design values
- PS exposed to highest power losses

Conclusions

- Average power losses are comparable to CNGS case (which is accepted)
- PS has to stand the most demanding losses
  - About 3 W/m
- Losses due to transfer operations, space charge, intra-beam scattering have to be added