Loss Analysis for Beta Beam Operation in existing CERN Synchrotrons

Proposal for a Replacement of PS with Optimized Loss Distribution

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Beta Beam Task Meeting
17th October 2005

Outline

Beta Beams in EURISOL

- Introduction to StrahlSim
- Loss analysis in existing CERN synchrotrons and the proposed decay ring – Distribution and Dynamic Vaccum
- Proposal for a Strong Focusing s.c. PS (G7) with Improved Loss Distribution

Tracking and Dynamic Vacuum: StrahlSim by C. Omet (GSI)

Implementations

- Initial systematic beam losses (e.g. multi turn injection losses, RF capture losses)
- Projectile and target ionization and capture cross sections and the resulting ionization and multiple ionization degree
- Collimation efficiency for each generated charge state
- Energy dependence of the collimation efficiency and of the cross sections
- Effective desorption rate of the collimation system (leakage rate)
- Initial residual gas composition
- Desorption coefficient and assumption for the composition of the desorped gases
- Desorption generated by target ionization
- Coulomb scattering with the residual gas
- Version 2: rewritten to be more efficient at computation
- Import sextupoles and combined function magnets
- Export to WINAGILE, MAD-X and MIRKO, import from WINAGILE and MIRKO

Lattice parameters (1)

	PS	SPS	PS G7
General lattice parameters			
Circumference	628.32 m	6911.5 m	628.32 m
Number of superperiods	10	6	6
Focusing structure	Comb. Func. (FDDF)	Singlet FODO	Doublet (DF)
Number of cells per arc	100 (one arc)	16	6
Number of cells per straight section	-	2	1
Number of cells per superperiod	10	18	7
Length of each cell	4.4 m	64 m	14.96 m
Distance between quadrupole multiplets	-	28.6 m	11.48 m
Total (usable) drift length per superperiod	12.8 m	251.7 m	11.48 m

Lattice parameters (2)

	PS	**SPS**	**PS G7**
Optics parameters			
Max. β (x / y)	22.52 m / 22.32 m	104.36m/103.57m	22.68 m / 23.06 m
Max D	3.04 m	5.64 m	5.72 m
mod Q	6.xx / 6.xx	26.xx / 26.xx	7.xx / 7.xx
γ_T	6.12	22.2	6.58
ξ_{nat} /Q (x / y)	-1.03 / -1.04	1.73 / -1.09	-1.07 / -1.09
Acceptance (x * y)	60 * 20 π mm mrad	28 * 4.5 π mm mrad	110 * 108 π mm mrad (chamber aperture)

Lattice parameters (3)

	PS	SPS	PS G7
Dipole Magnets			
Number of dipoles	200	744	108
Max. flux density	1.24 T	2.02 T	4 T
Bending angle	1.8 °	0.48 °	3 1/3 °
Radius of curvature	70 m	740 m	40 m
Effective field length	2200 mm	6260 mm	2327.1 mm
Chamber aperture	Elliptical H 146mm V 68mm	Elliptical H 284mm V 69mm	100 mm round

Synchrotron Parameters

Synchrotron Parameters	PS		SPS	PS G7
	Protons	Beta beams		
Synchrotron circumference *L*, m	628.32	628.32	6911.5	628.32
Magnetic rigidity at injection, Tm	7.13	11	86.7	11
Magnetic rigidity at extraction, Tm	86.7	86.7	1500	160
Ramping rate, T/s	1.35	1.35	0.45	4.5
Accumulation time, s		1.9	0	1.9
Collimation possible	No	No	No	Yes

Beam parameters

Beam Parameters	PS		PS G7	SPS (proton and beta beams)
	Protons	Beta beams		
Beam ions species, nuclear charge *Z*	1	He: 2 Ne: 10	He: 2 Ne: 10	He: 2 Ne: 10
Charge state of the ion beams *q*	1+	He 2+ Ne 10+	He 2+ Ne 10+	p +1 He 2+ Ne 10+
Injection energy *E*, GeV/u	1.4	He 0.5 Ne 1.1	He 0.5 Ne 1.1	P 25 He 15 Ne 26
Extraction energy *E*, GeV/u	25	He 7.8 Ne 13.539	He 15 Ne 26	P 450 He 92 Ne 92
Horizontal emittance e_h, mm mrad	5.2	He 26 Ne 16	He 26 Ne 16	P 0.5 He 3.2 Ne 1.6
Vertical emittance e_v, mm mrad		He 14 Ne 8	He 14 Ne 8	He 2 Ne 1.2
Initial number of particles in the beam	8.4×10^{12}	He 1.12×10^{13} Ne 1.9×10^{11}	He 1.12×10^{13} Ne 1.9×10^{11}	p 8.1×10^{12} He 9.05×10^{12} Ne 1.79×10^{11}

UHV System Parameters

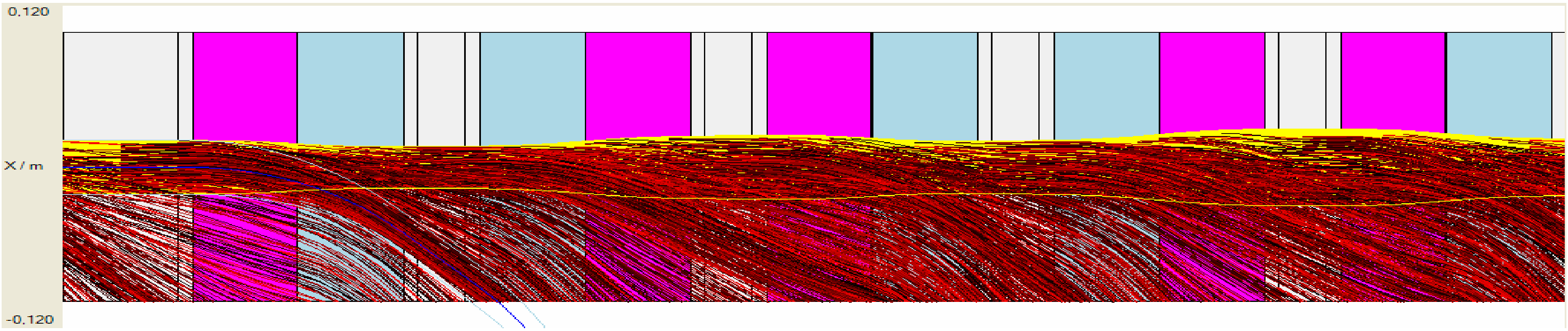
Beta Beams in EURISOL

UHV System Parameter	PS	SPS	PS G7 (Beta Beams)	SPS (Beta Beams)
Beam tube volume V, m^3	6	50	4.93	50
Pumping speed S, l/s	7600	2280	1400000[1]	2280
Base residual gas pressure P, mbar	10^{-9}	10^{-9}	10^{-12}	10^{-9}
Vacuum composition, %	H_2 (35%) N_2 (7%) H_2O (50%)	H_2 (35%) N_2 (7%) H_2O (50%)	H_2 (35%) N_2 (7%) H_2O (50%)	H_2 (35%) N_2 (7%) H_2O (50%)
Desorption coefficient for beam particles η_b, 1/ion	2.8×10^4	2.2×10^4	2.8×10^4	2.2×10^4
Desorption coefficient for ionized gas molecules η_b, 1/mol	10	10	10	10

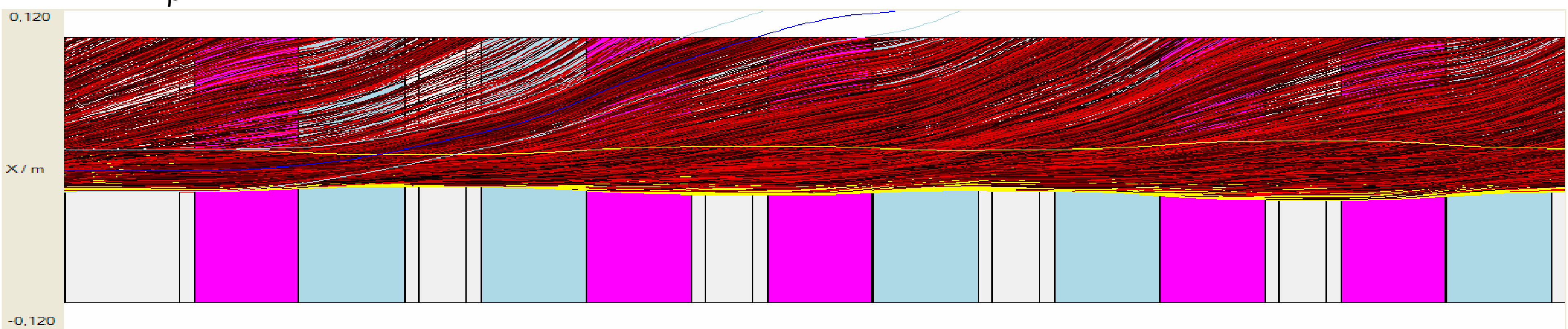
[1] Scaled from SIS90 with machine circumference, which has an effective pumping rate of 2.6×10^6 l/s.

Beam Loss in existing PS

He_{β} beam

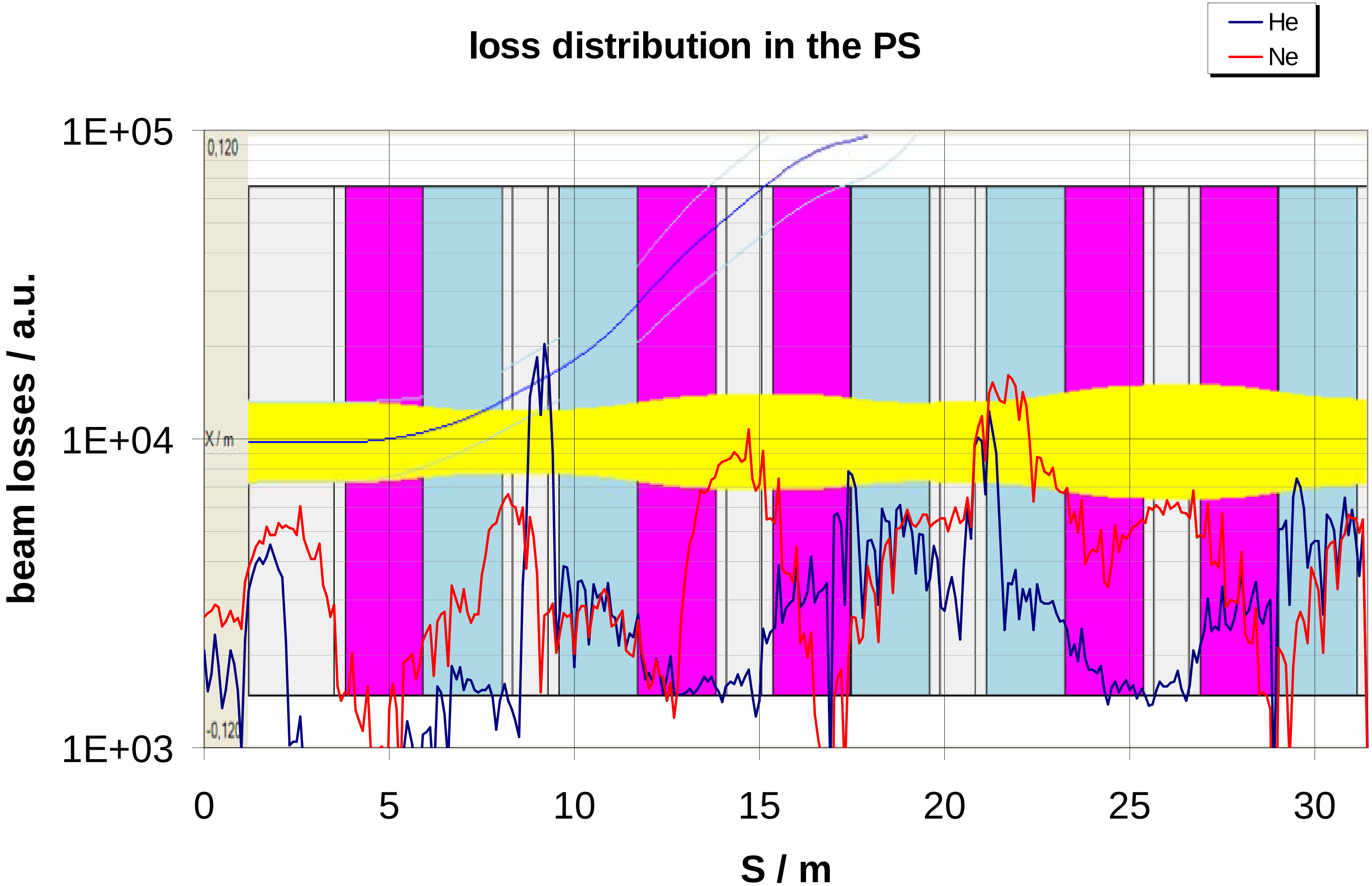


Ne_{β} beam



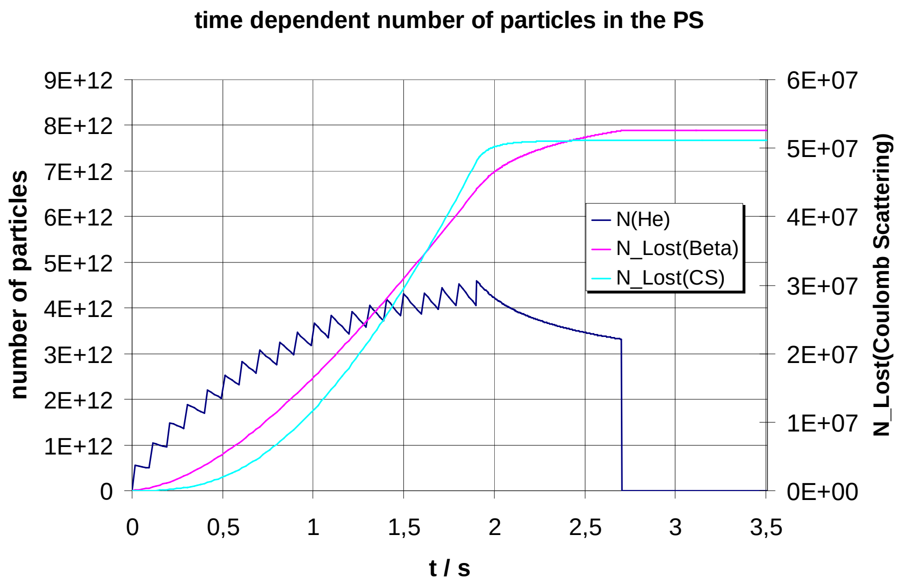
Loss Distribution in PS

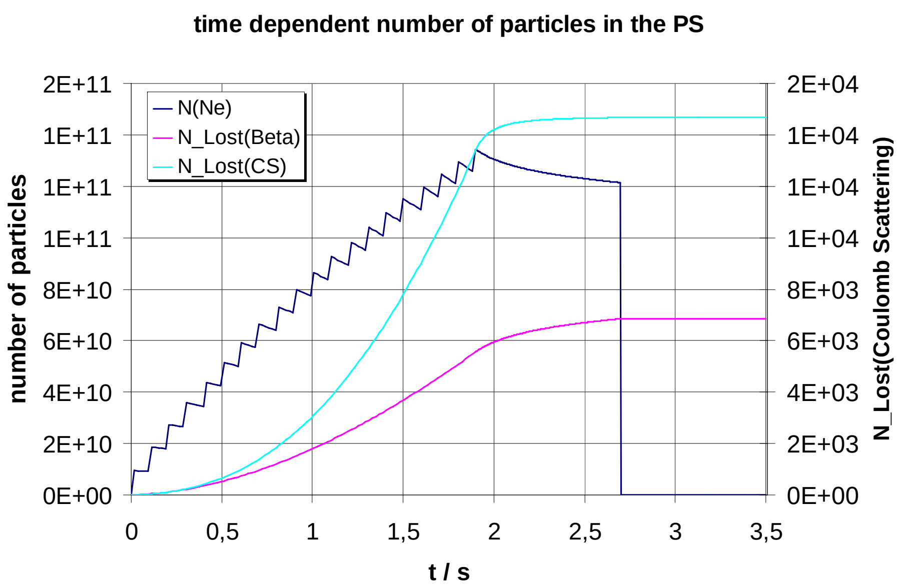
Beta Beams in EURISOL

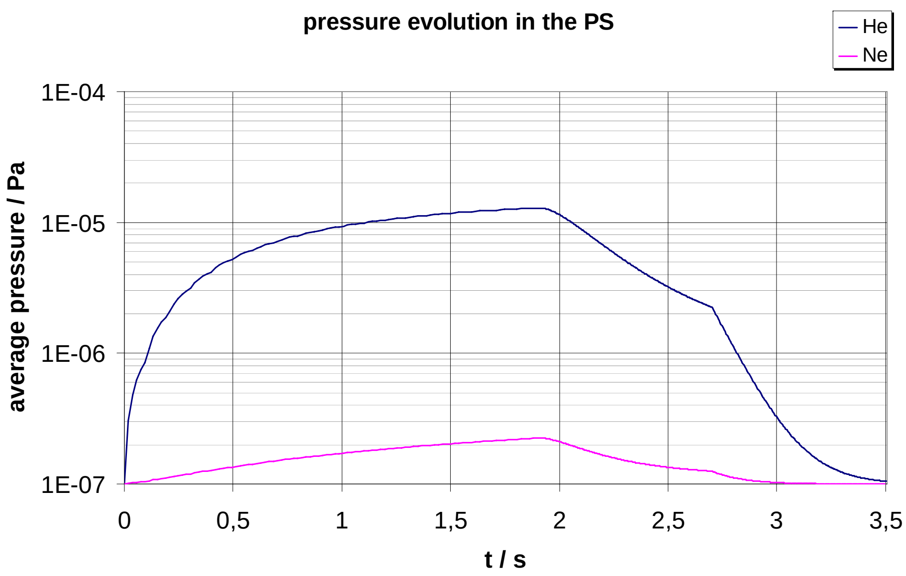


Beam Loss / Pressure in PS

Beta Beams in EURISOL

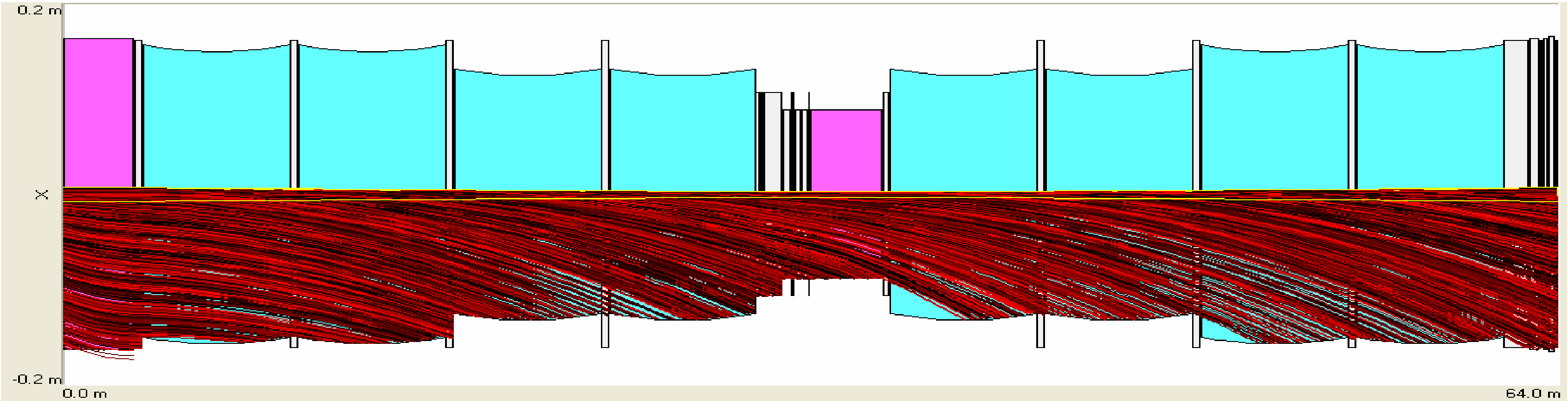




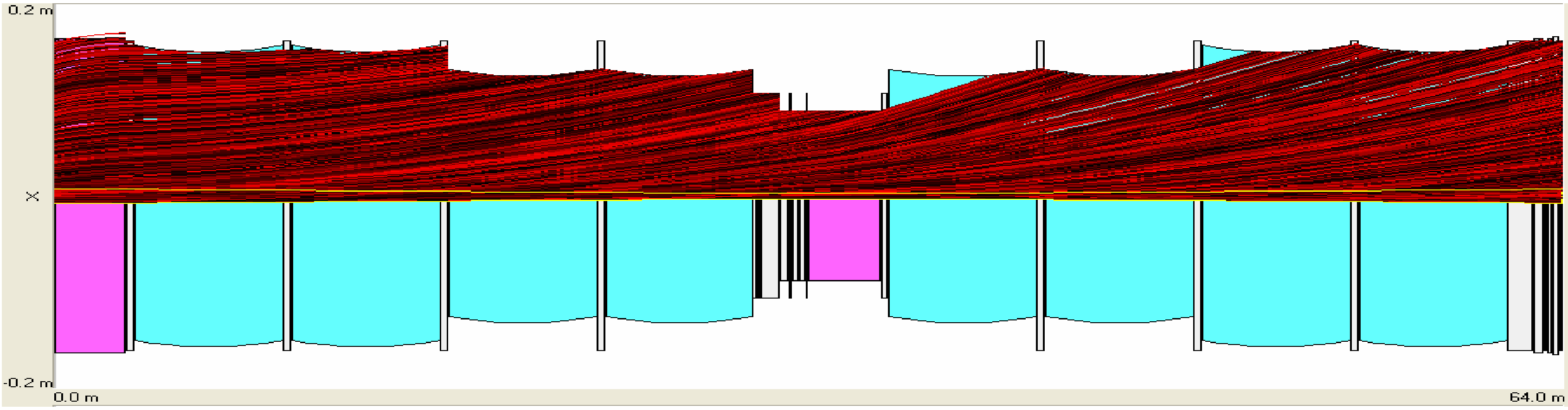


Beam Loss in existing SPS

He$_\beta$ beam

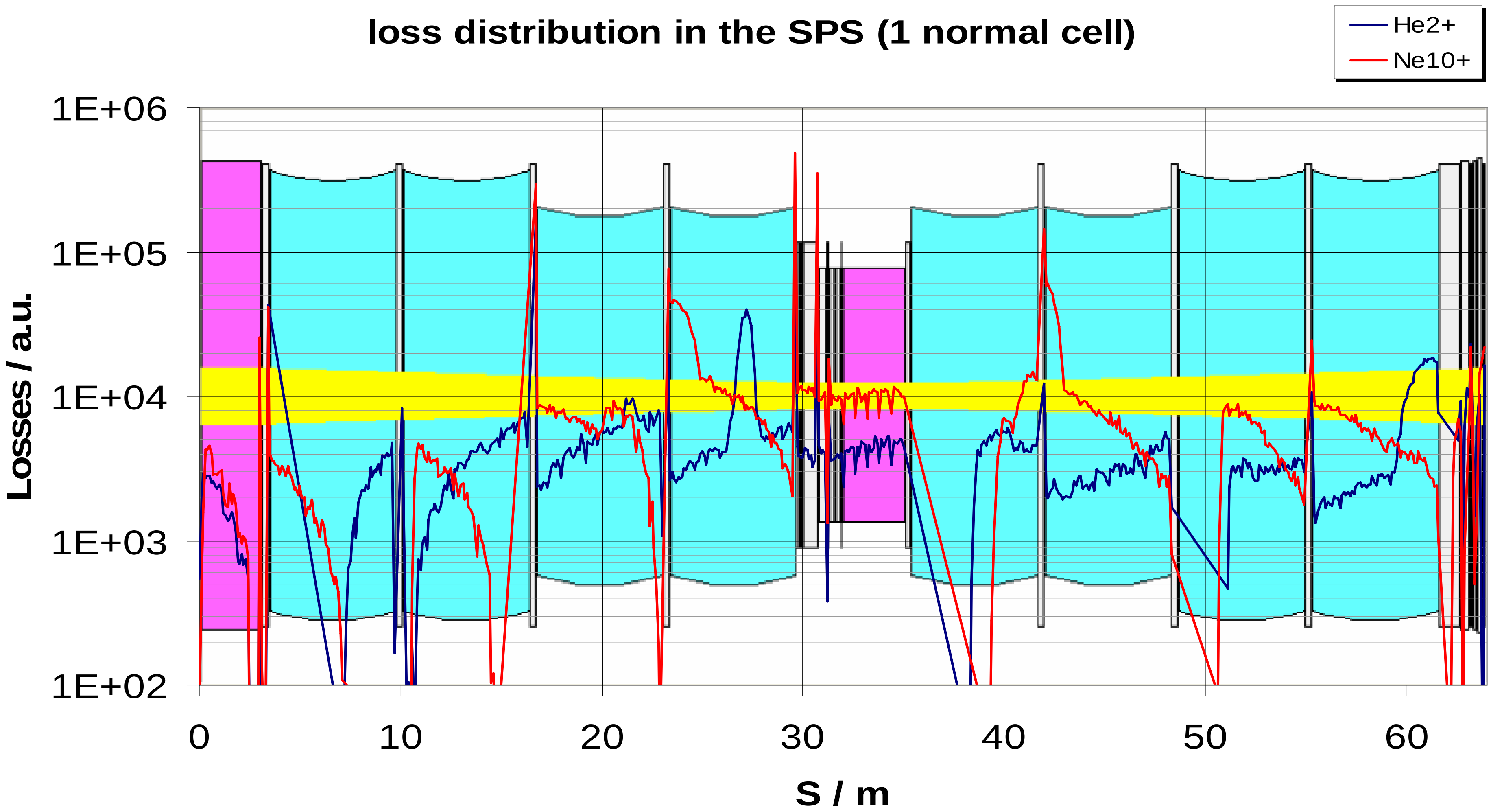


Ne$_\beta$ beam

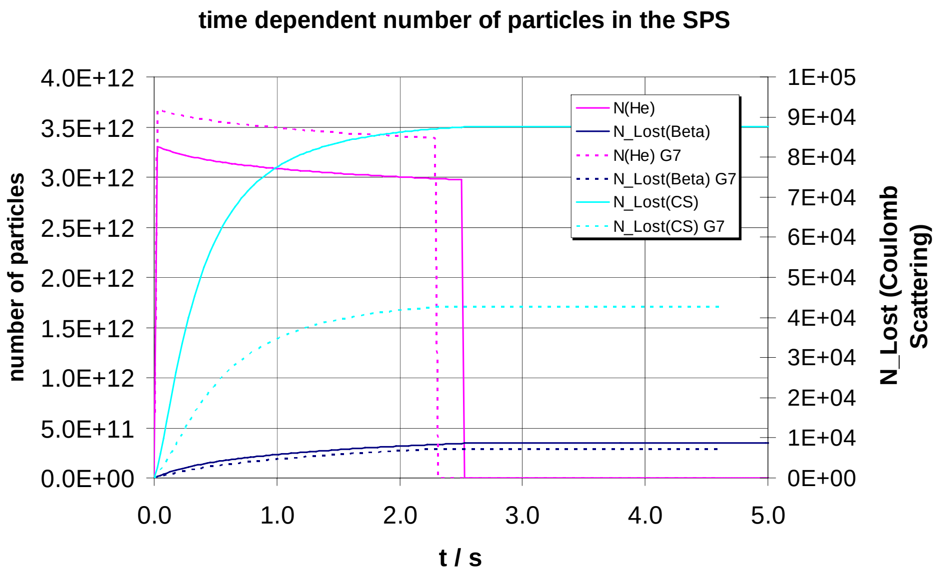


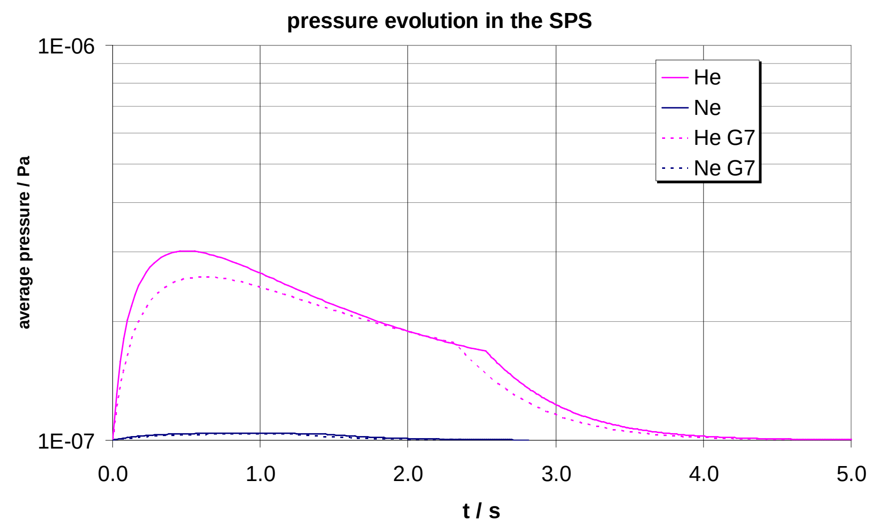
Loss Distribution in SPS

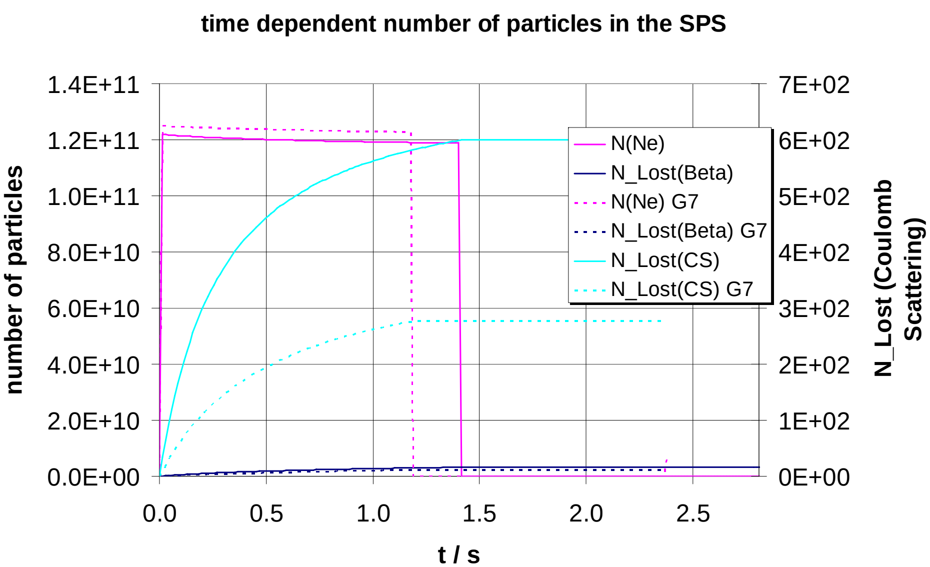
Beta Beams in EURISOL



Beam Loss / Pressure in SPS

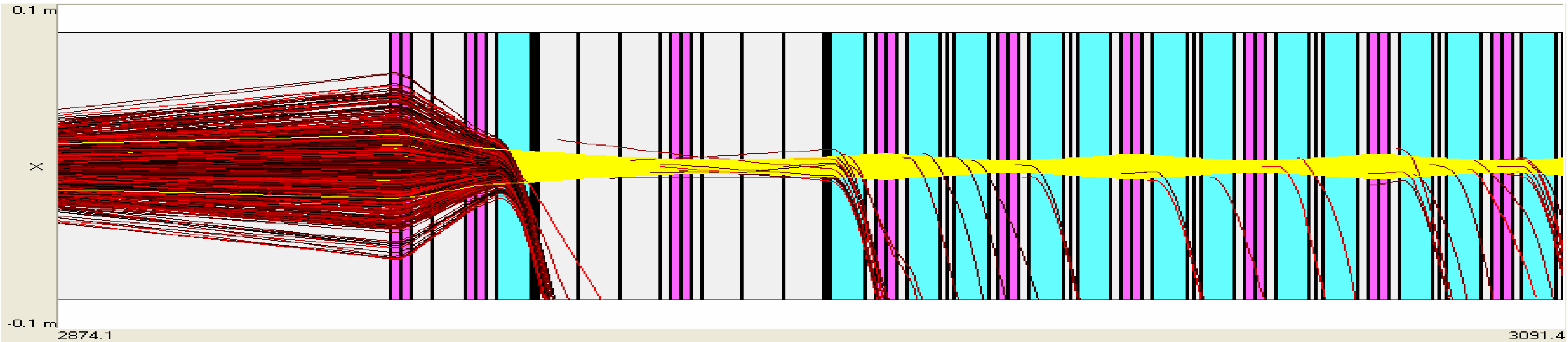




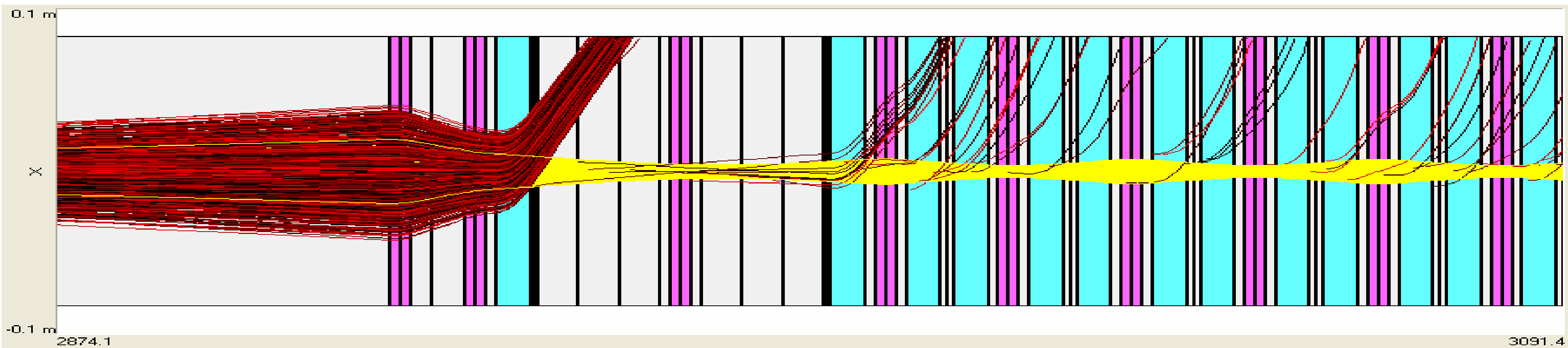


Beam Loss in Decay Ring

He_{β} beam

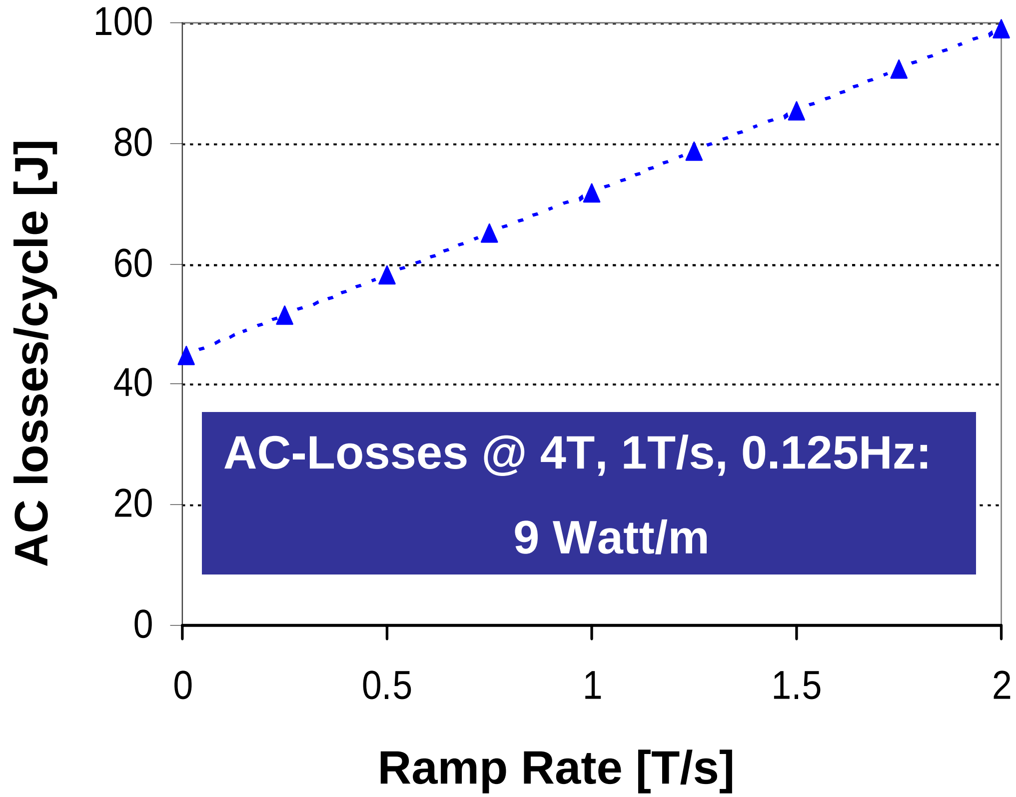


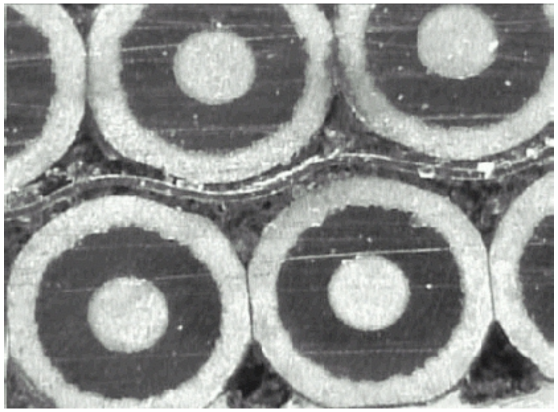
Ne_{β} beam



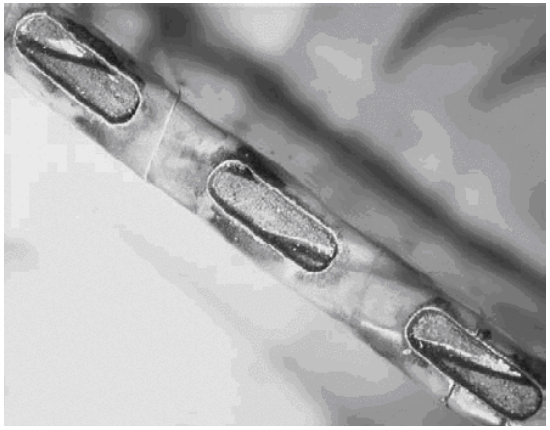
FAIR: SIS 300 Magnet R&D

Results of testing the advanced G001coil: 4.38 T @ 2 T/s





Cored rutherford cable



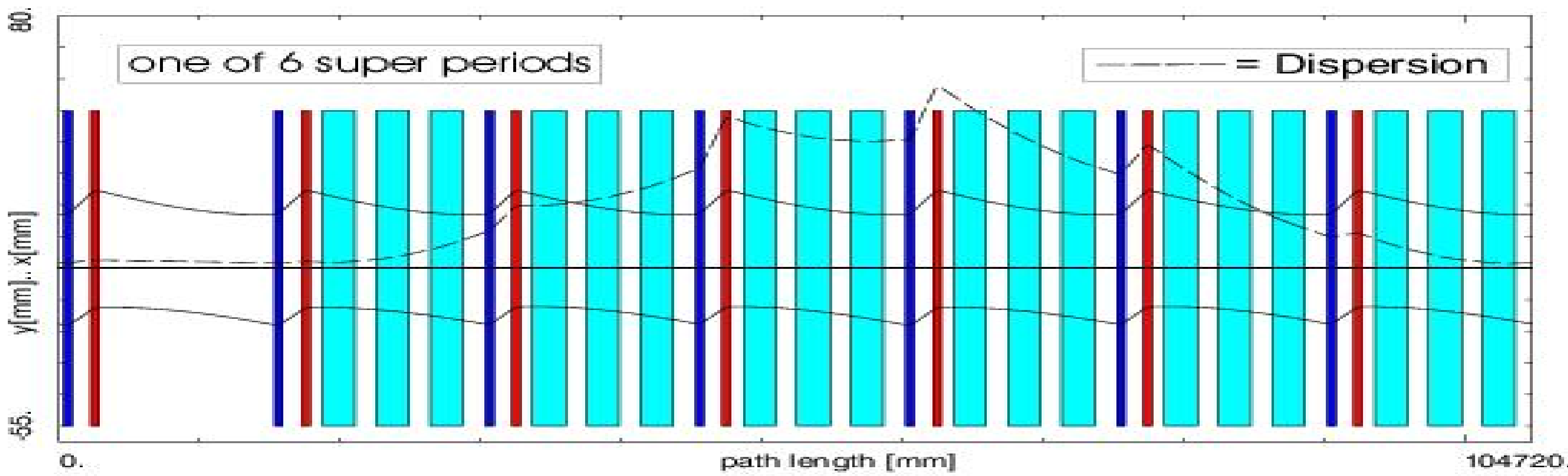
Laser cutted cooling slots

Major Improvements :

Reduced filament twist pitch, strand coating (stabrite), stainless steel core

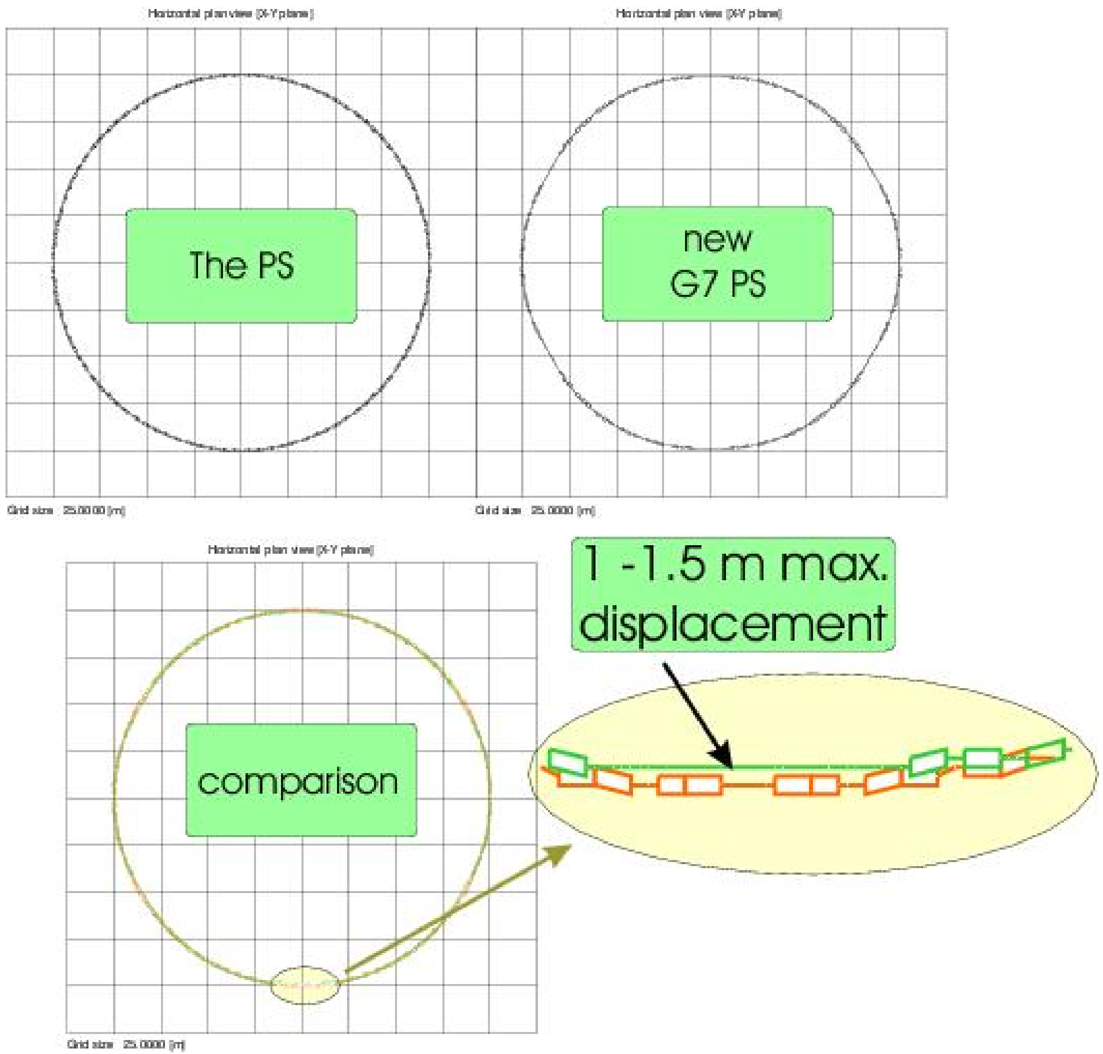
Design report based on GSI001 model and UNK dipole

Proposed s.c. PS G7 Lattice



- Based on bend, s.c. cosΘ magnets, 4 T, 4.5 T/s, R&D for GSI001 SIS200 model magnet, talk W. Scandale „LHC upgrade..“ (15.9.05)
- Doublet focusing, optimized cell layout for peaked loss distribution
- Long arcs (PS like ring), straight sections for Rf systems
- Dispersion free straight sections

PS / PS-G7 Comparison

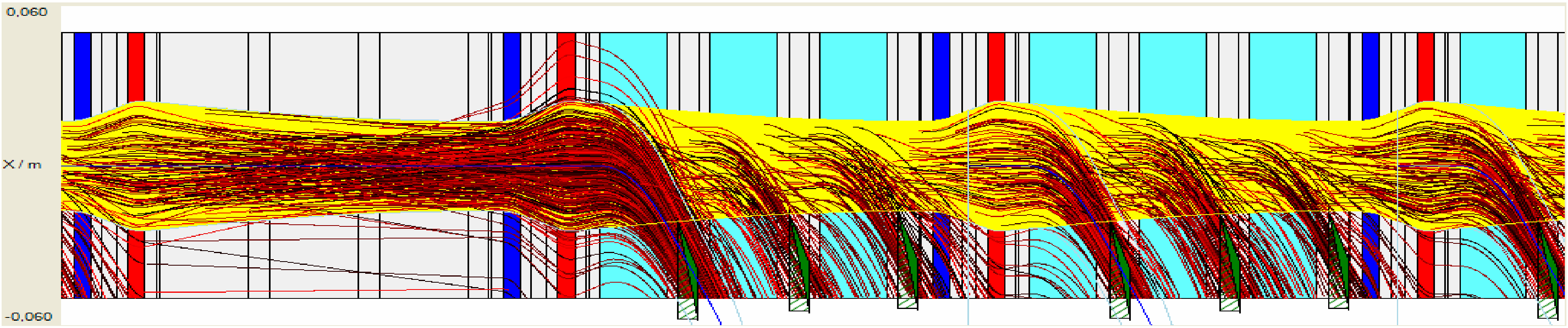


The proposed PS G7 fits into the existing PS tunnel

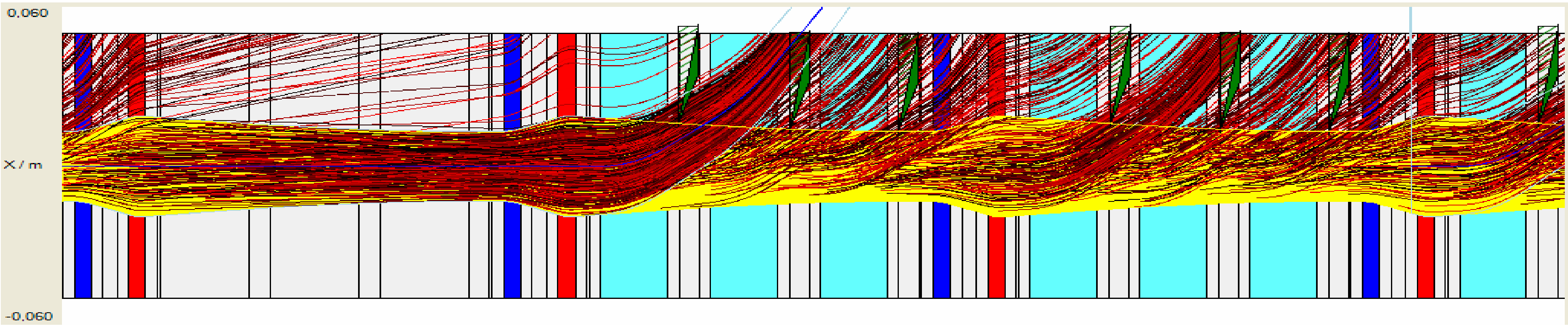
Beam Loss in proposed PS G7

Beta Beams in EURISOL

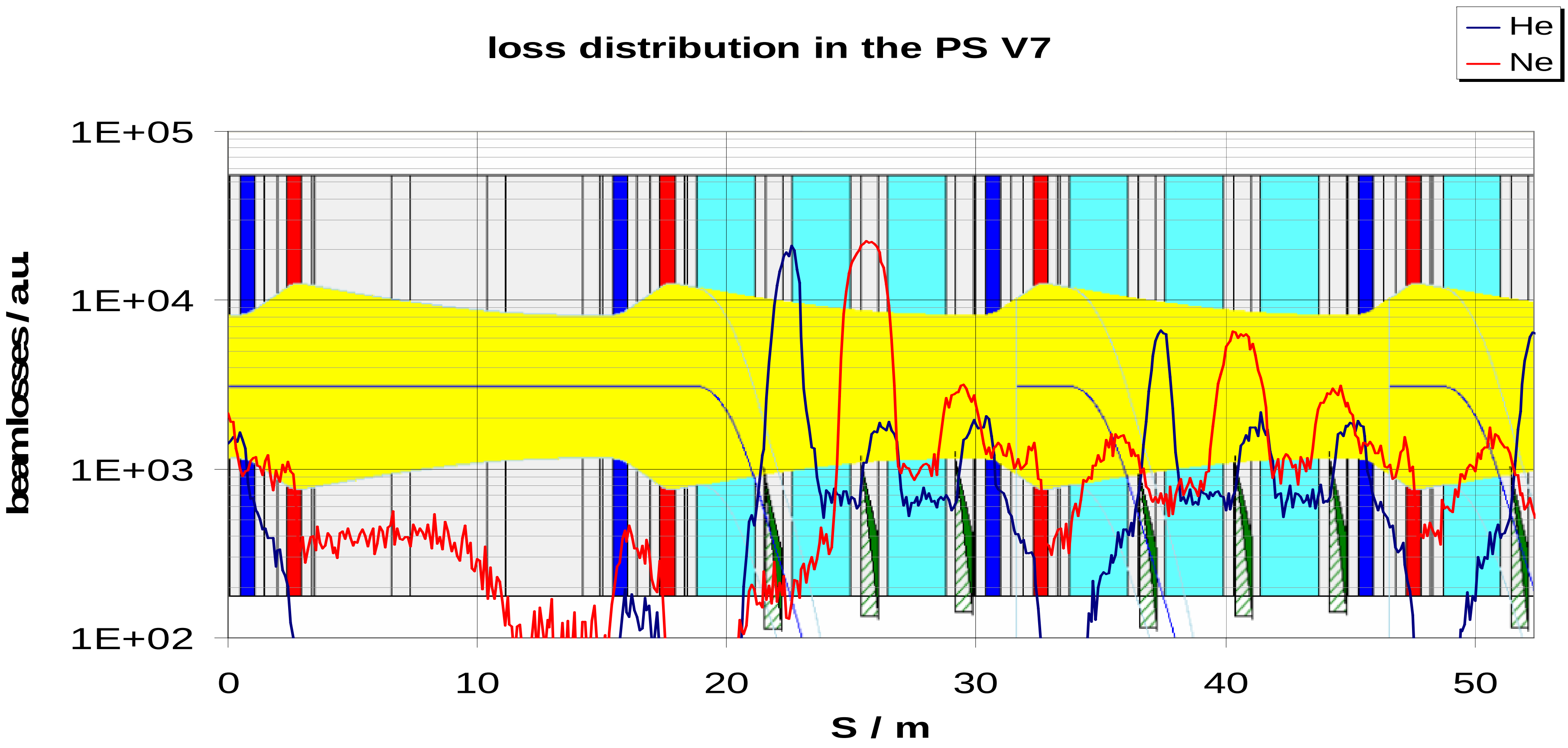
He_{β} beam



Ne_{β} beam

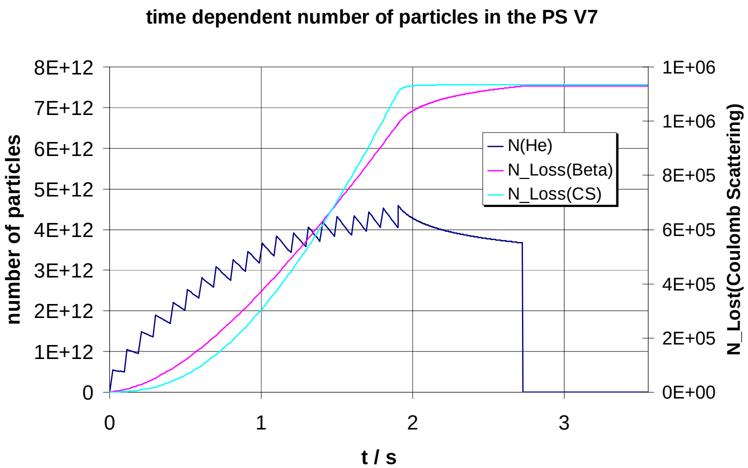


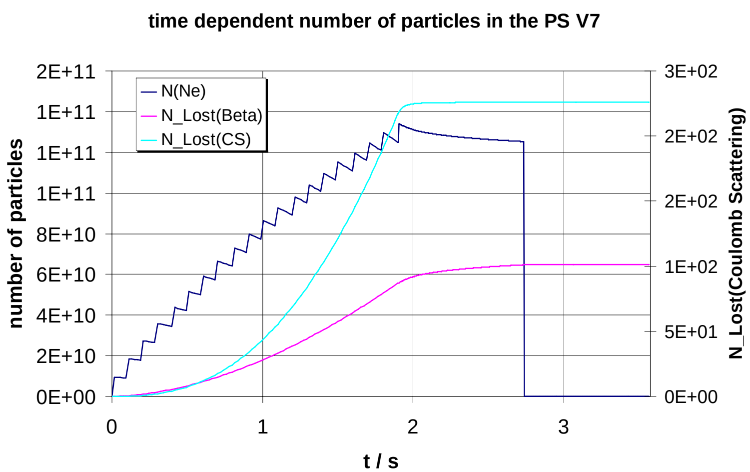
Loss Distribution in proposed PS G7

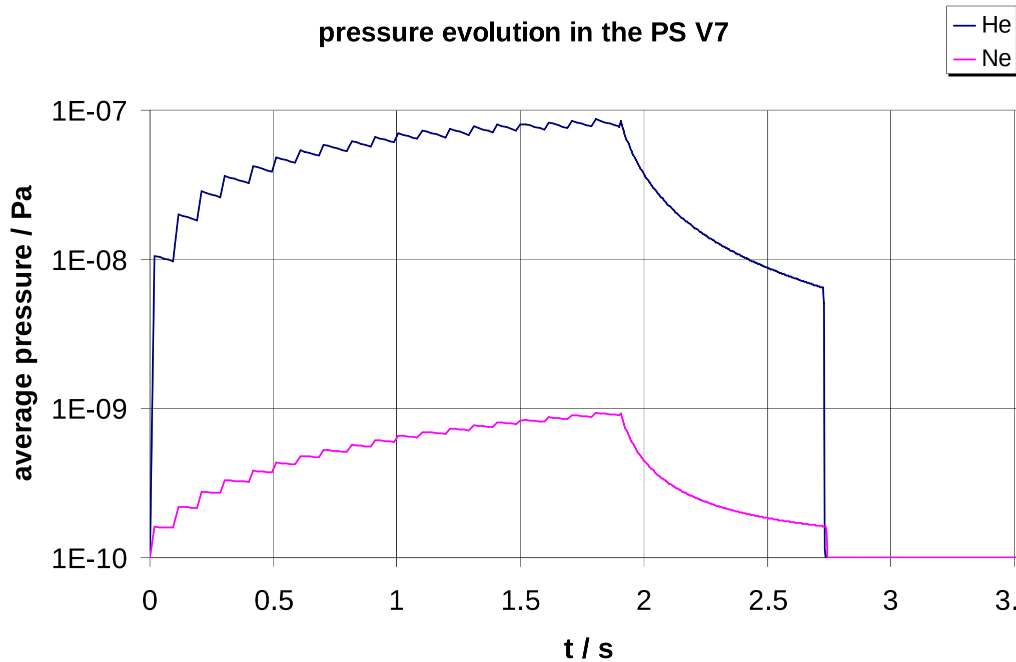


Beam Loss and Pressure in PS G7

Beta Beams in EURISOL







Rf Parameters for PS G7

- Transfer 20 batches from RCS (h=20) to PS (h=21)
- Maximum gap voltage 300 kV
- Rf Cavities, He 7.64-9.96 MHz, Ne 8.93-10 MHz (Cf., Protons 3.5-3.8 MHz at h=8)
- Maximum dB/dt = 4.5 T/s (like SIS100)
- Synchronous phase 22 deg. with 300 kV and 4.5 T/s.
- Acceptance per bucket at injection:

→ 6He2+ 2.5 eVs (cf., 1eVs emittance)

→18Ne10+ 17 eVs (cf., 2eVs emittance)

Single batch transfer of 20 bunches to SPS

Surving Number of Particles

PS (existing)	He	Ne
Injected particles	1.12E+13	1.90E+11
survived particles	3.32E+12	1.22E+11

PS G7	He	Ne
Injected particles	1.12E+13	1.90E+11
survived particles	3.68E+12	1.25E+11

SPS (from existing PS)	He	Ne
Injected particles	3.32E+12	1.22E+11
survived particles	2.98E+12	1.19E+11

SPS (from PS G7)	He	Ne
Injected particles	3.68E+12	1.25E+11
survived particles	3.39E+12	1.23E+11

Summary

- Analysis of the beta beam loss distribution has been performed for the CERN machines PS and SPS and the proposed decay ring
- Dynamic vacuum effects, maximum pressure rise and elastic scattering has been determined.
- The simulation of ramping and energy dependent lifetime of the ions in the beta beam facility has been implemented and decay losses has been calculated.
- A new PS (G7) has been proposed to replace the existing PS – offering a peaked loss distribution for both beta beams, with reduced losses in the magnets and the possibility for an efficient collimation.