Vacuum Simulations

RCS, PS, SPS and Stabilization

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Outline

- Overview of StrahlSim
- RCS, PS and SPS: Losses and dynamic vacuum
- Collimation: Stopping distances and activation
- Summary

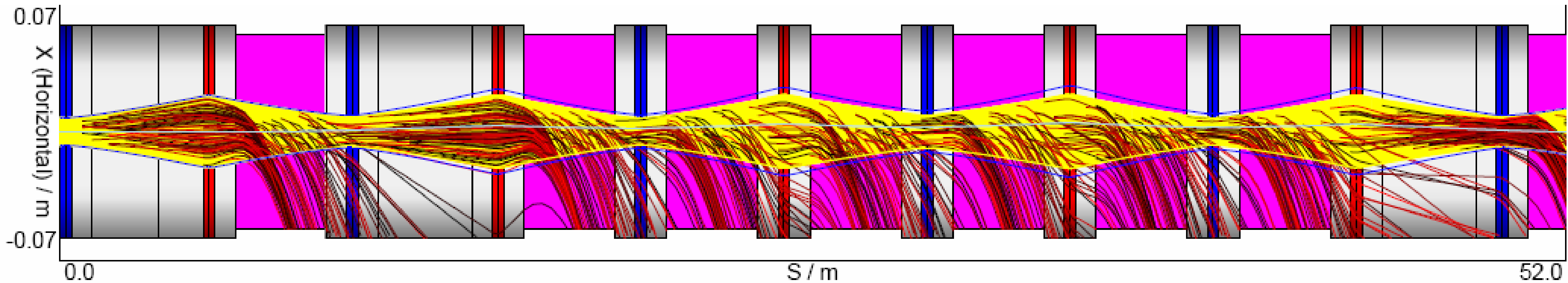
Tracking and Dynamic Vacuum: StrahlSim by C. Omet (GSI)

Implementations

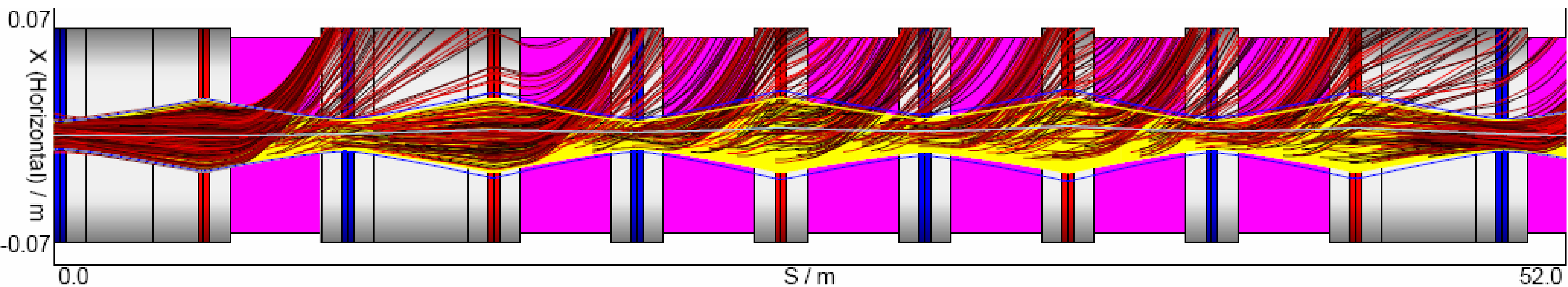
- Initial systematic beam losses (e.g. multi turn injection losses, RF capture losses)
- Projectile and target ionization and capture cross sections and the resulting ionization and multiple ionization degree
- Collimation efficiency for each generated charge state
- Energy dependence of the collimation 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
- Import sextupoles and combined function magnets
- Export to WINAGILE, MAD-X and MIRKO, import from WINAGILE and MIRKO

Beam Loss in the RCS

He_β beam



Ne_β beam

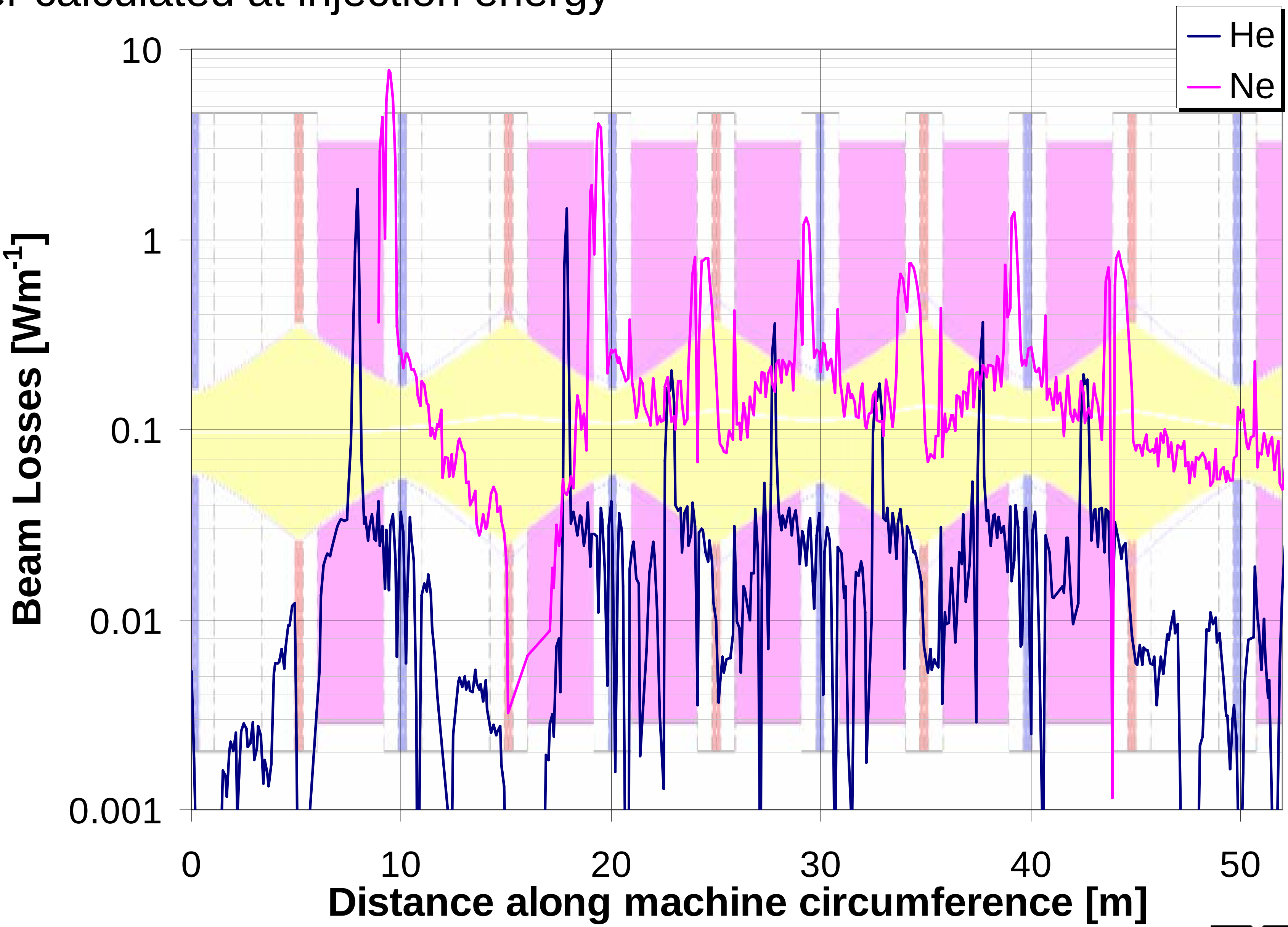


Most of the losses are in the dipoles

Loss Distribution in RCS

Beta Beams in EURISOL

Power calculated at injection energy



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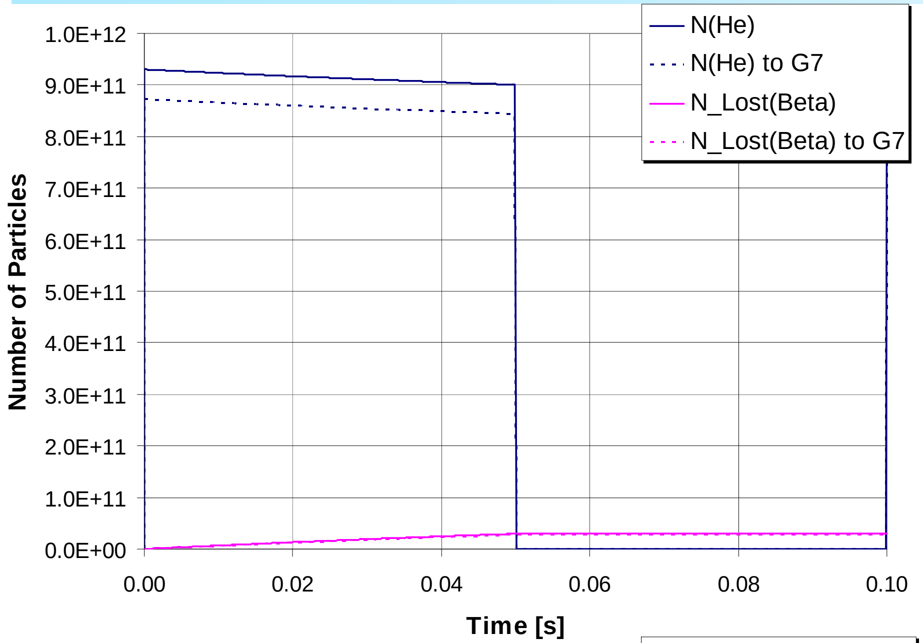
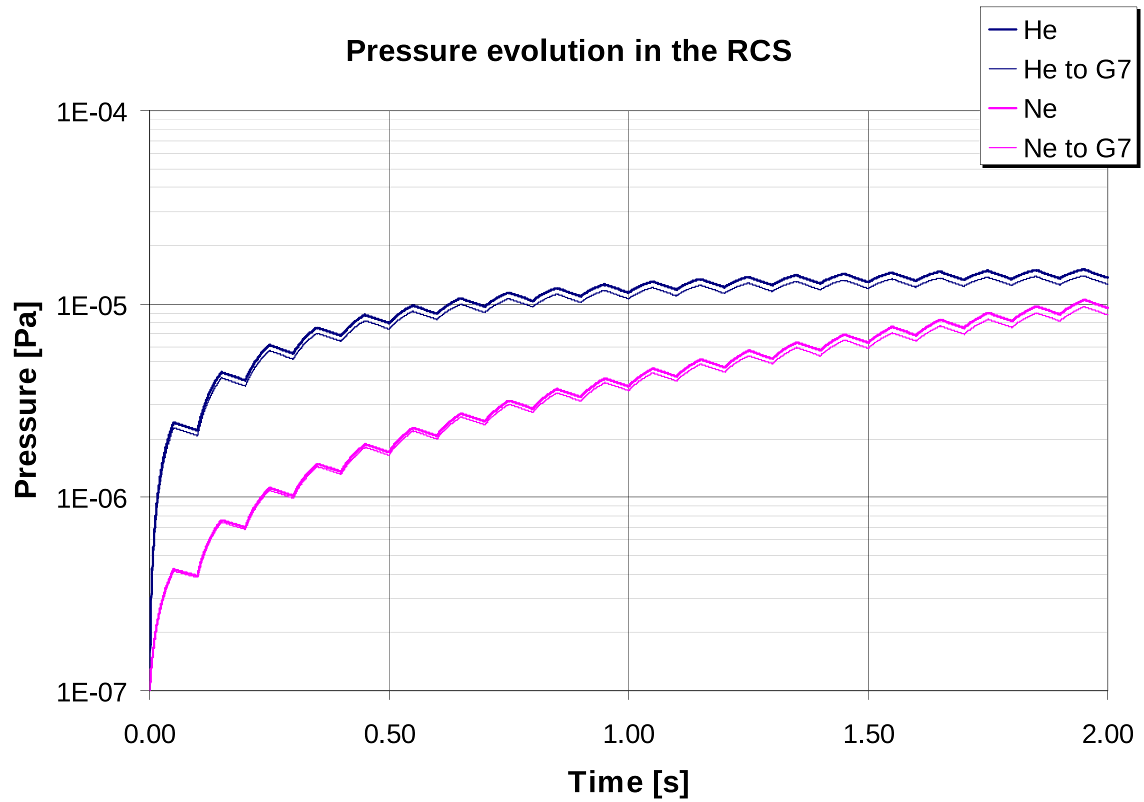
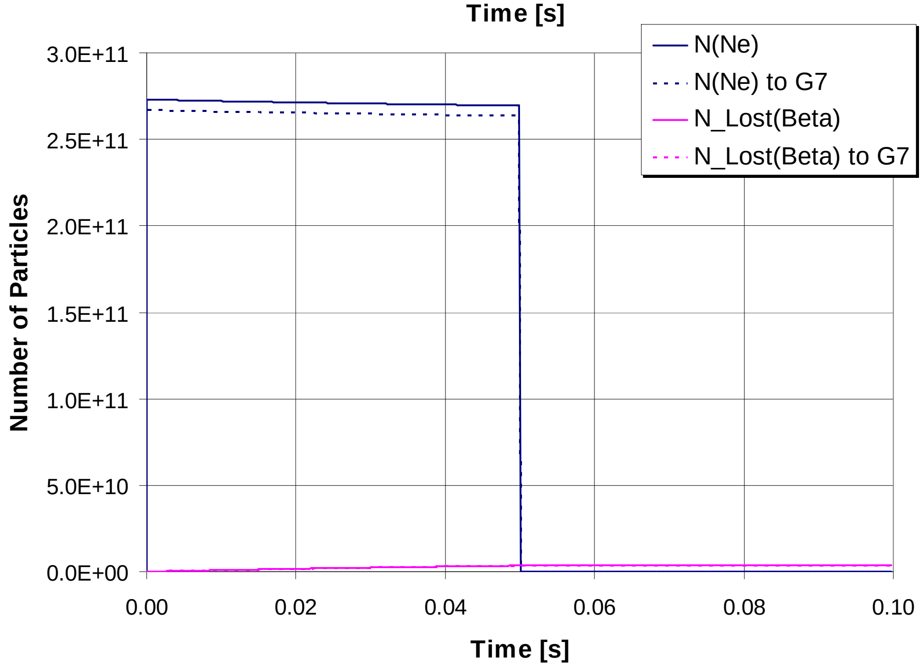
Beam Loss / Pressure in RCS

Beta Beams in EURISOL



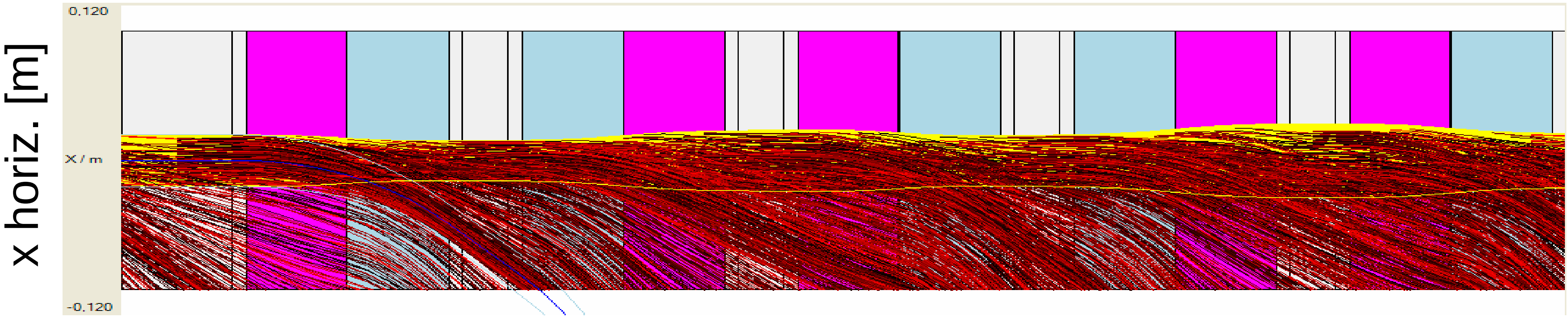




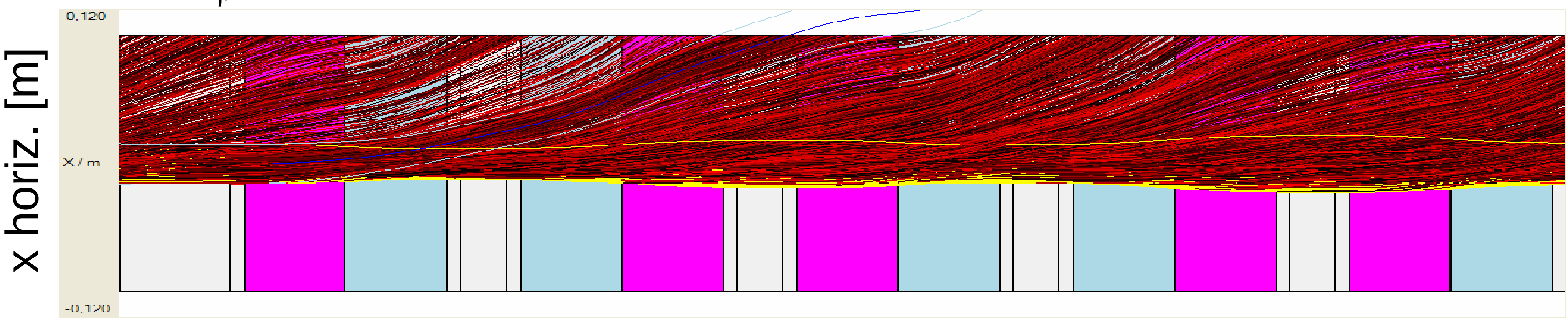
Beam Loss in existing PS

Beta Beams in EURISOL

He_{β} beam



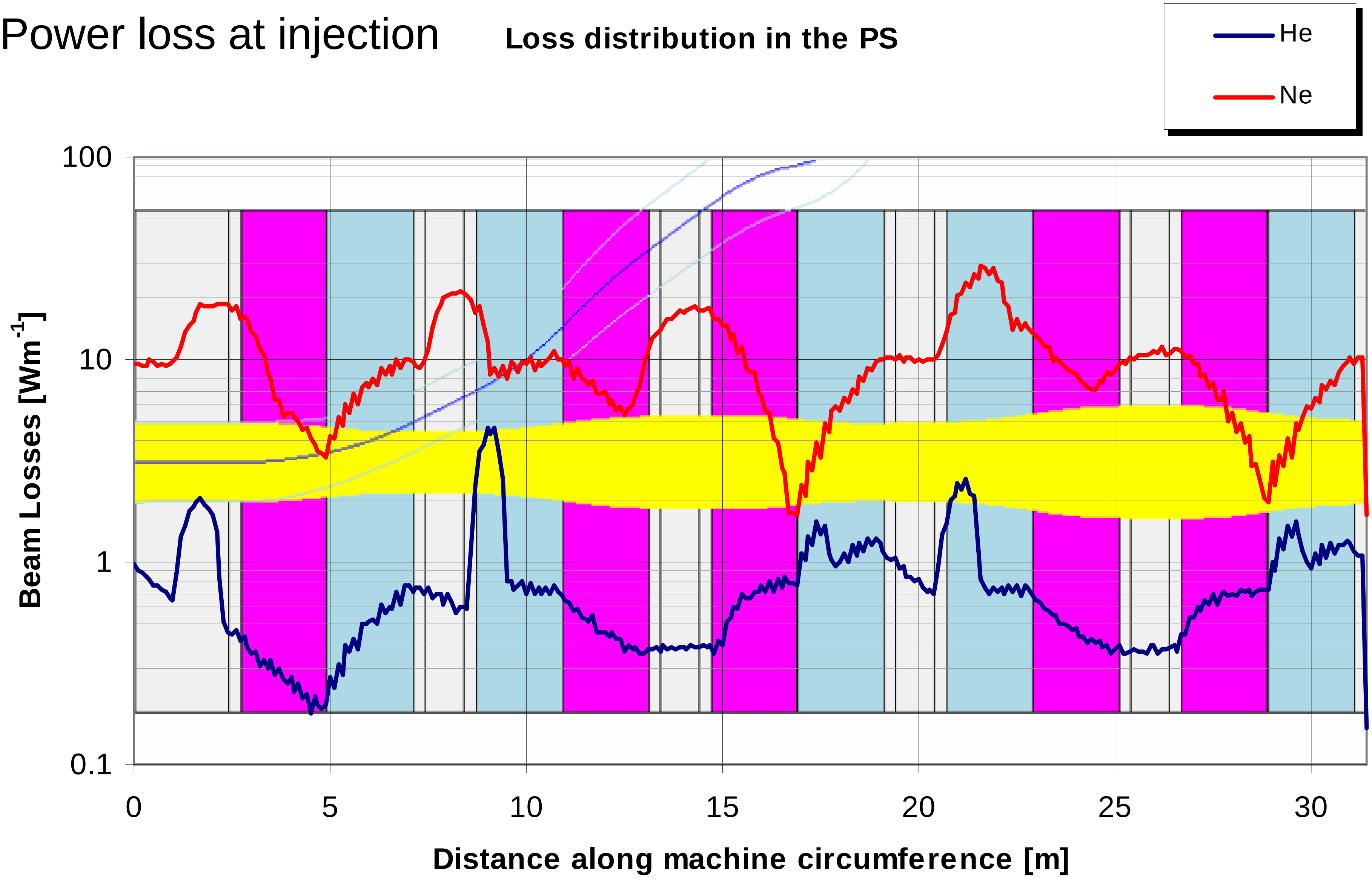
Ne_{β} beam



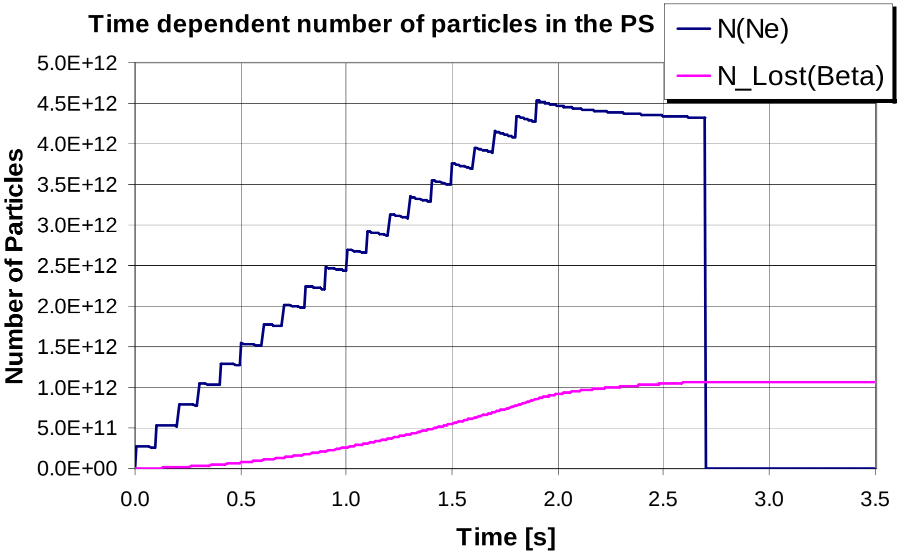
Loss Distribution in PS

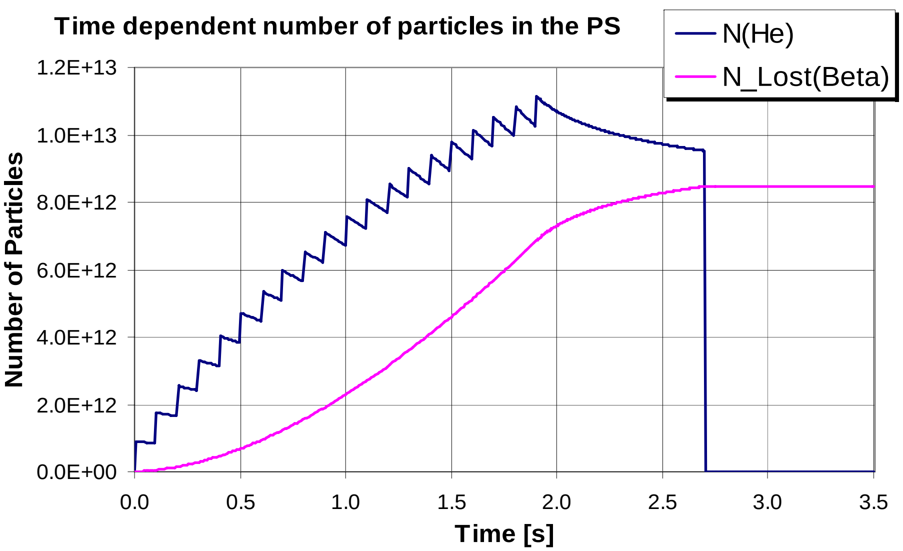
Beta Beams in EURISOL

Power loss at injection

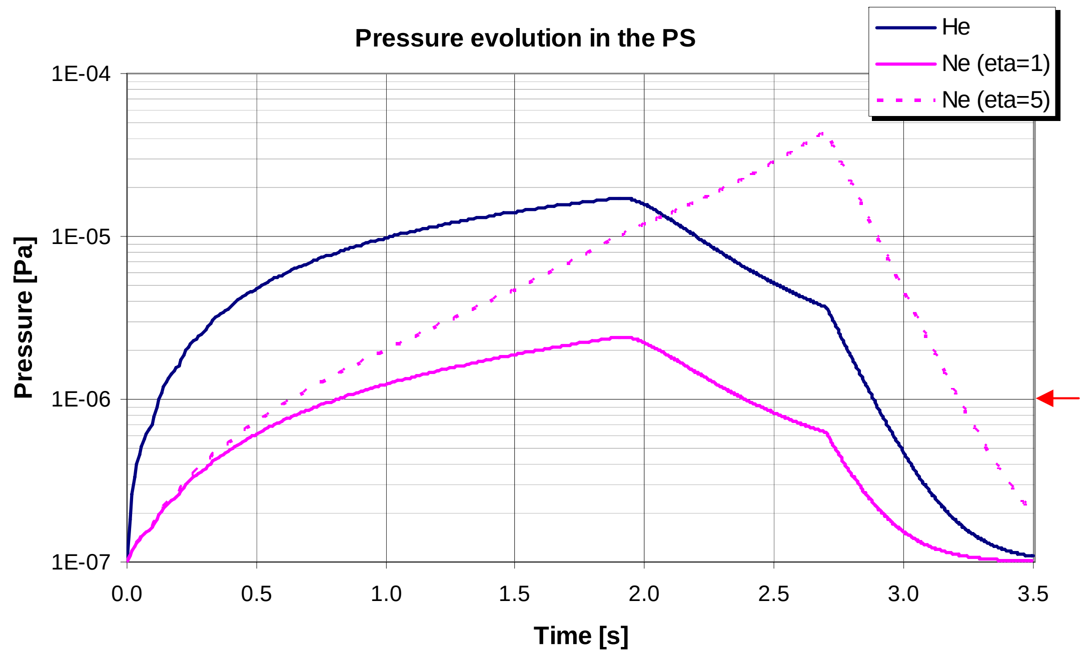


Beam Loss / Pressure in PS





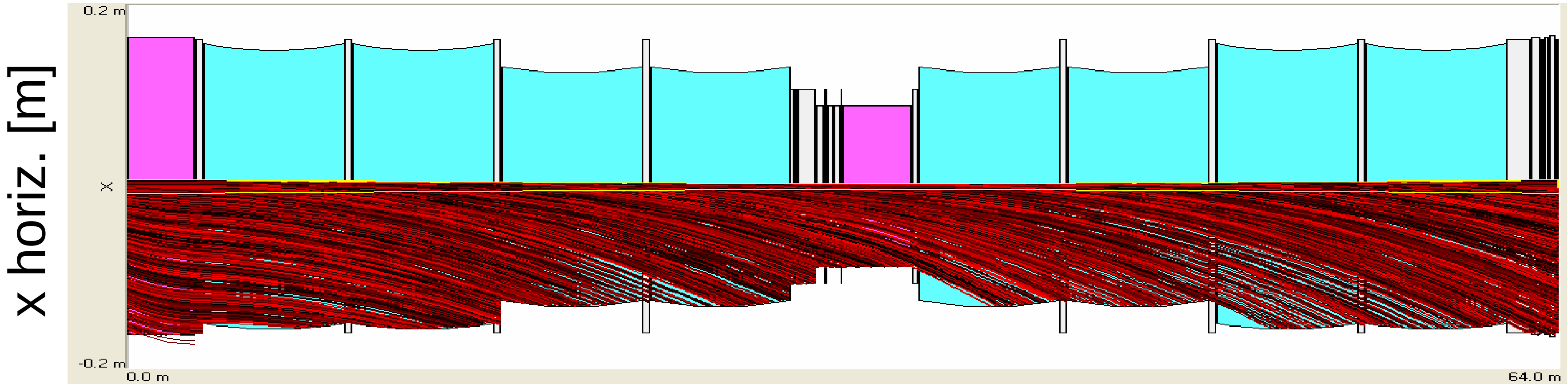
Pressure during Ne operation plotted for 2 desorption yields due to „target ionized“ rest gas molecules



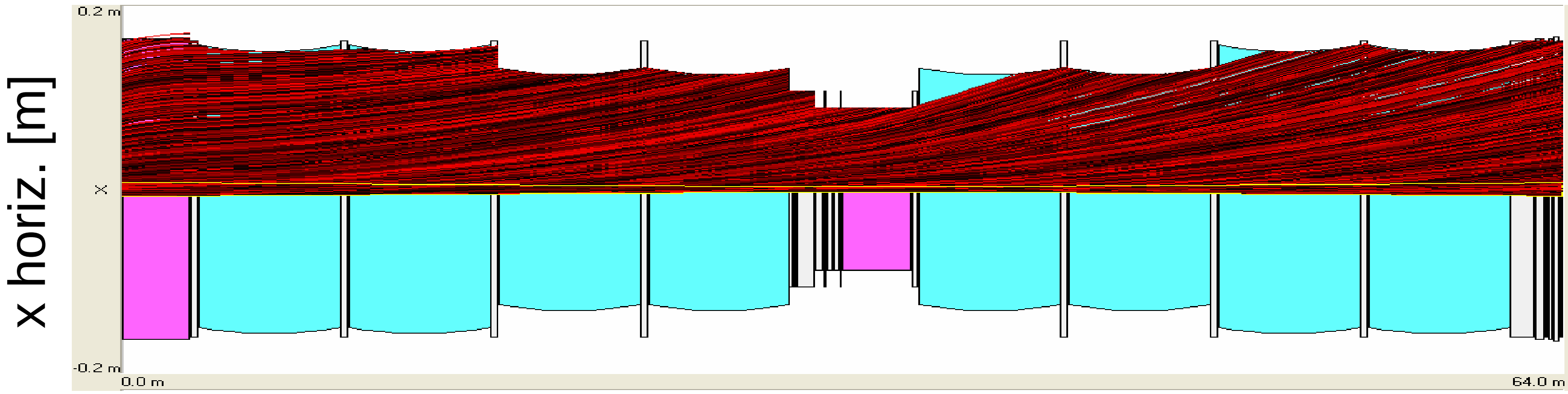
Yield may in our case vary from 0.1-10 depending on impact energy (few keV)

Beam Loss in existing SPS

He$_\beta$ beam



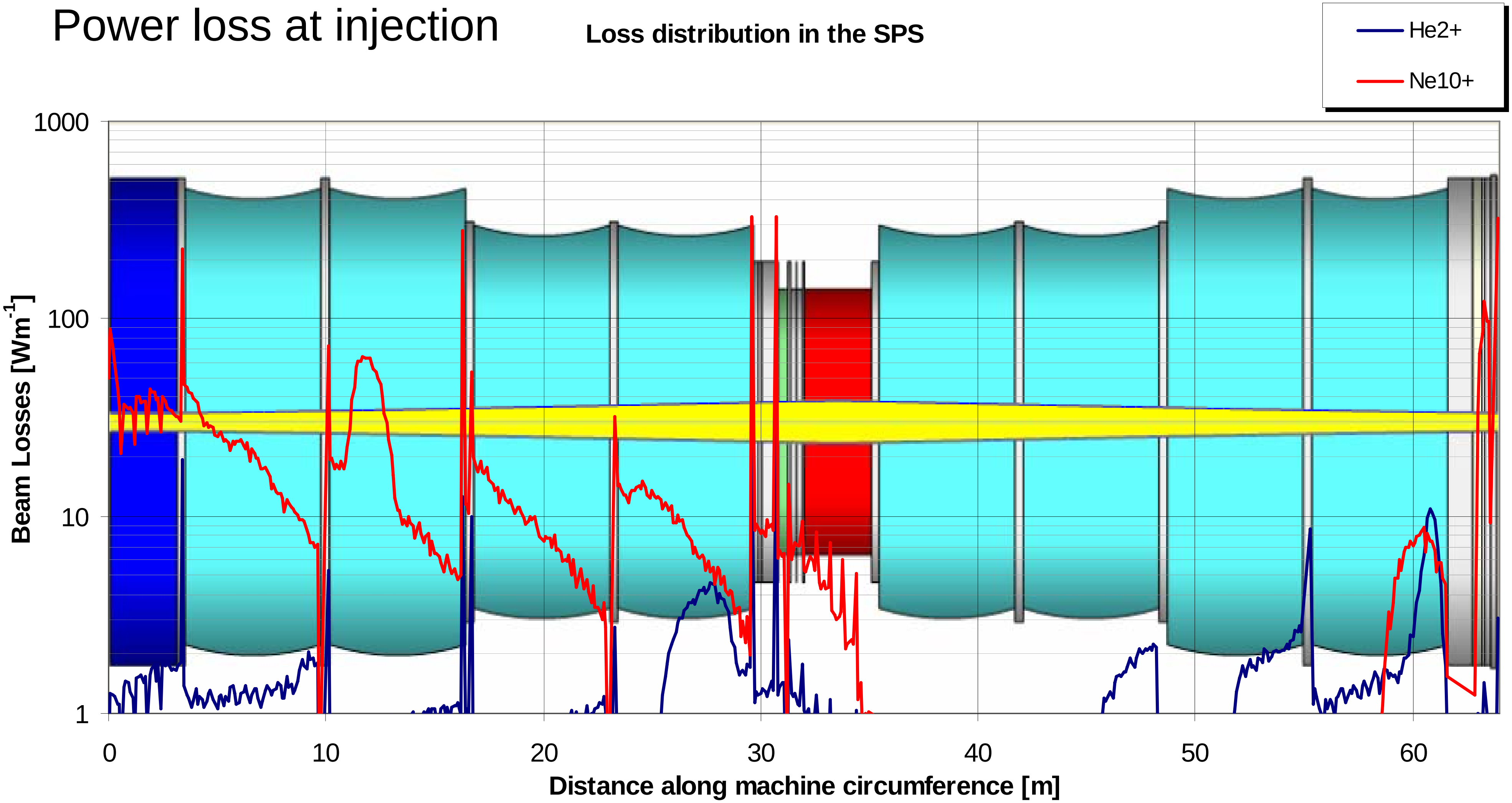
Ne$_\beta$ beam



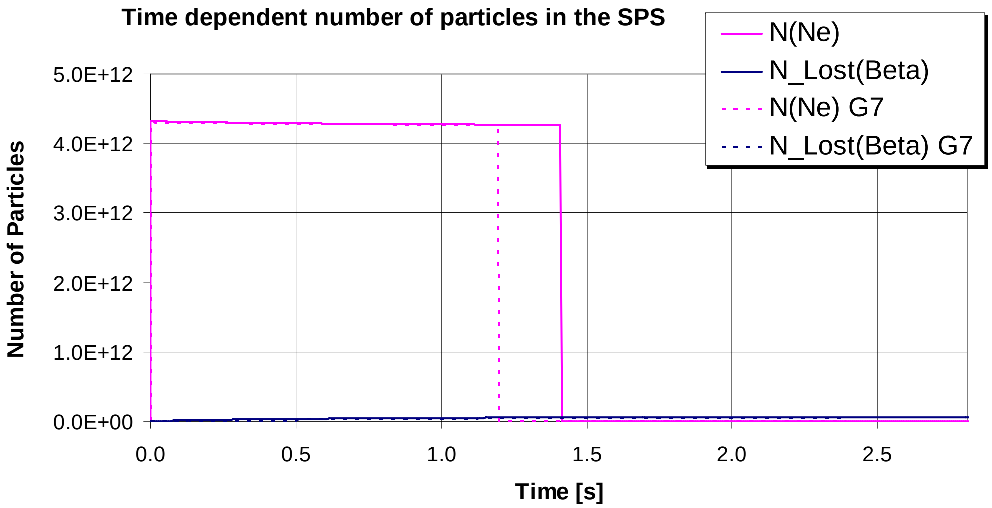
Loss Distribution in SPS

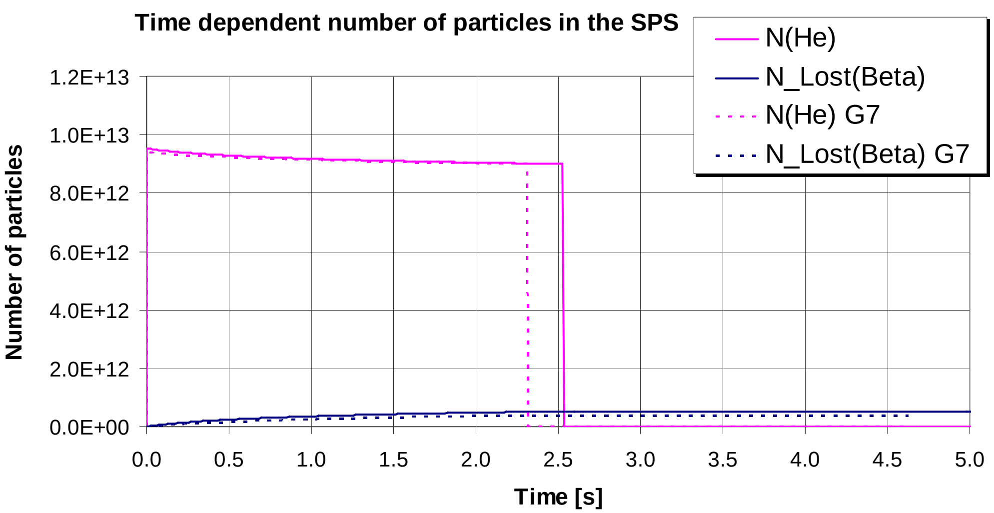
Beta Beams in EURISOL

Power loss at injection

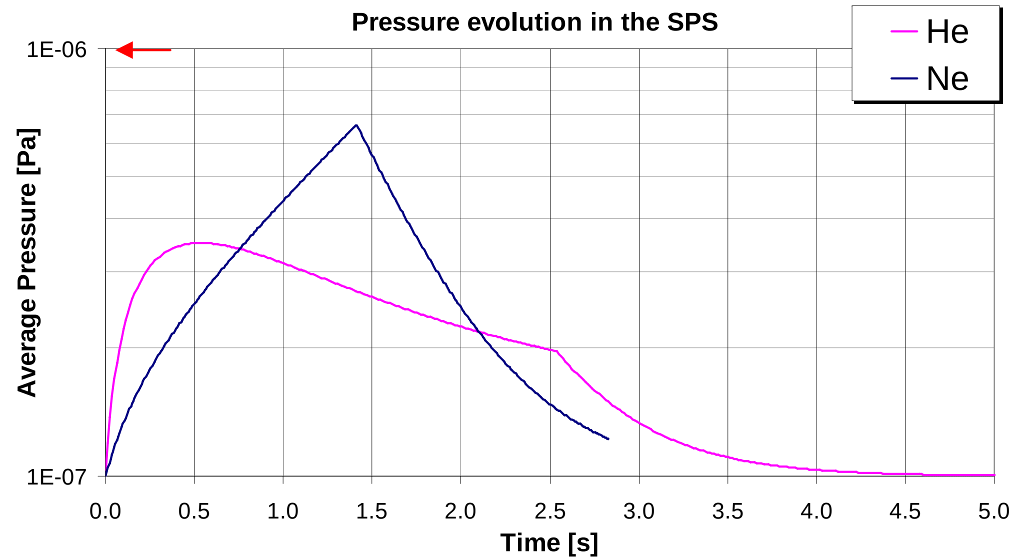


Beam Loss / Pressure in SPS





„Target ionization“ yield: eta=10



Surving Number of Particles

Top-down analysis. Goal is the number of ions survived at the point of extraction to the decay ring (Fabich et al.)

RCS	n	He	per Inj	Ne	per Inj
Injected particles	1	9.30E+11	9.30E+11	2.74E+11	2.74E+11
survived particles		9.00E+11		2.70E+11	

PS	n	He	per Inj	Ne	per Inj
Injected particles	20	1.80E+13	9.00E+11	5.39E+12	2.70E+11
survived particles		9.53E+12		4.32E+12	

SPS	n	He	per Inj	Ne	per Inj
Injected particles	1	9.53E+12	9.53E+12	4.32E+12	4.32E+12
survived particles		9.00E+12		4.26E+12	

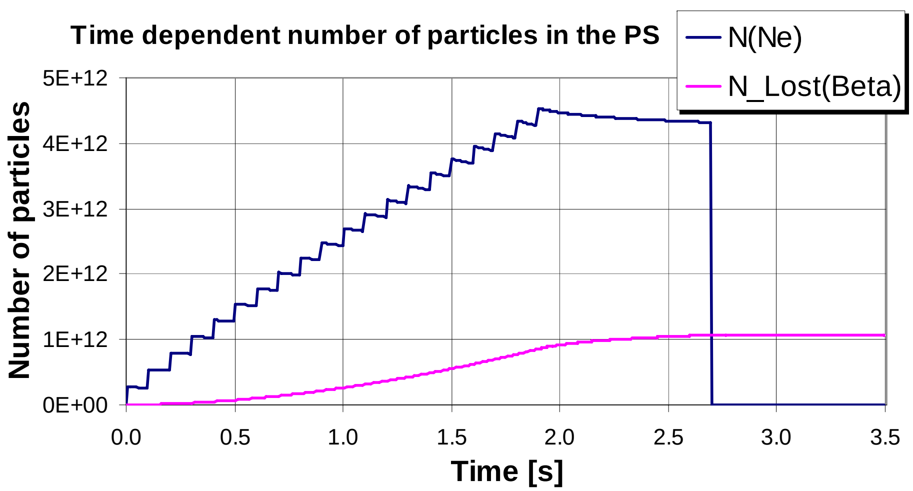
For Helium: RCS injected 4% higher than previously estimated. Likewise 0.2% for PS and <0.05% SPS

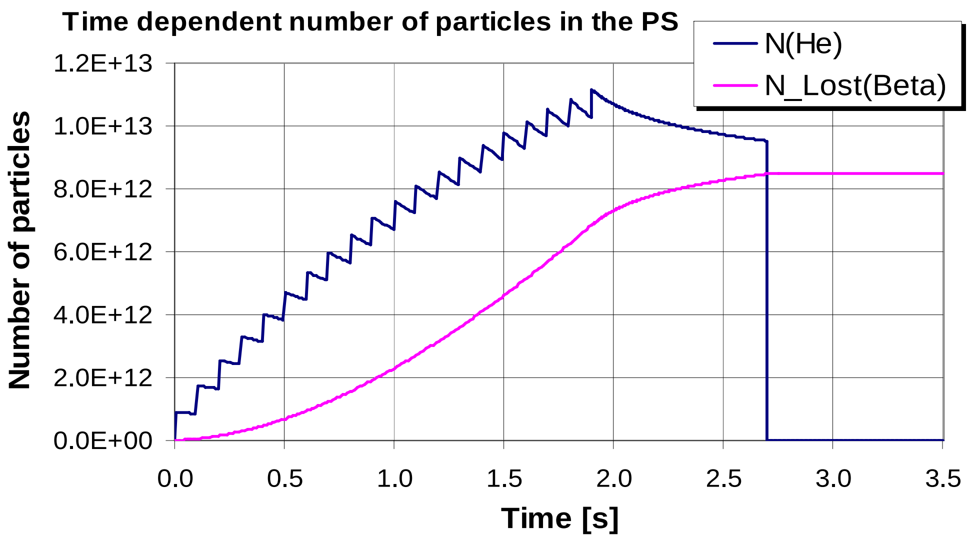
For Neon: RCS injected 2% higher than previously estimated. Likewise 0.4% for PS and 0.2% SPS

Pressure Stabilization in PS

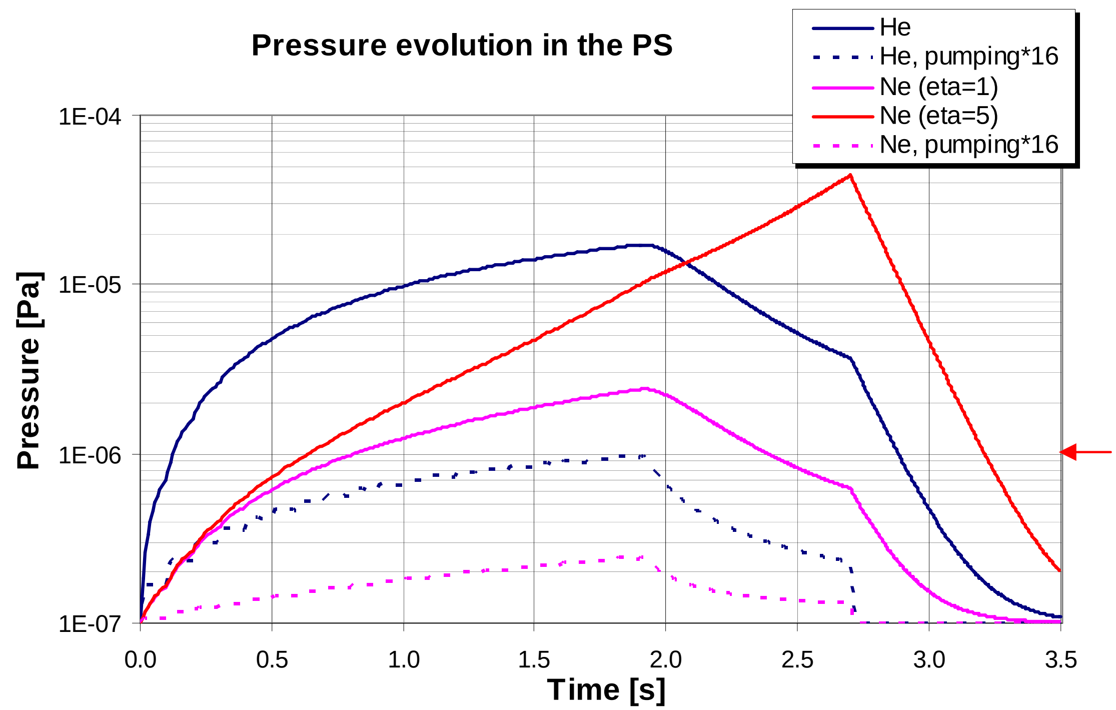
Beta Beams in EURISOL

Factor of 16 increase in pumping required to keep pressure below 10^{-8} mbar





Faster pumping scenario assumes a target ionization yield of 10



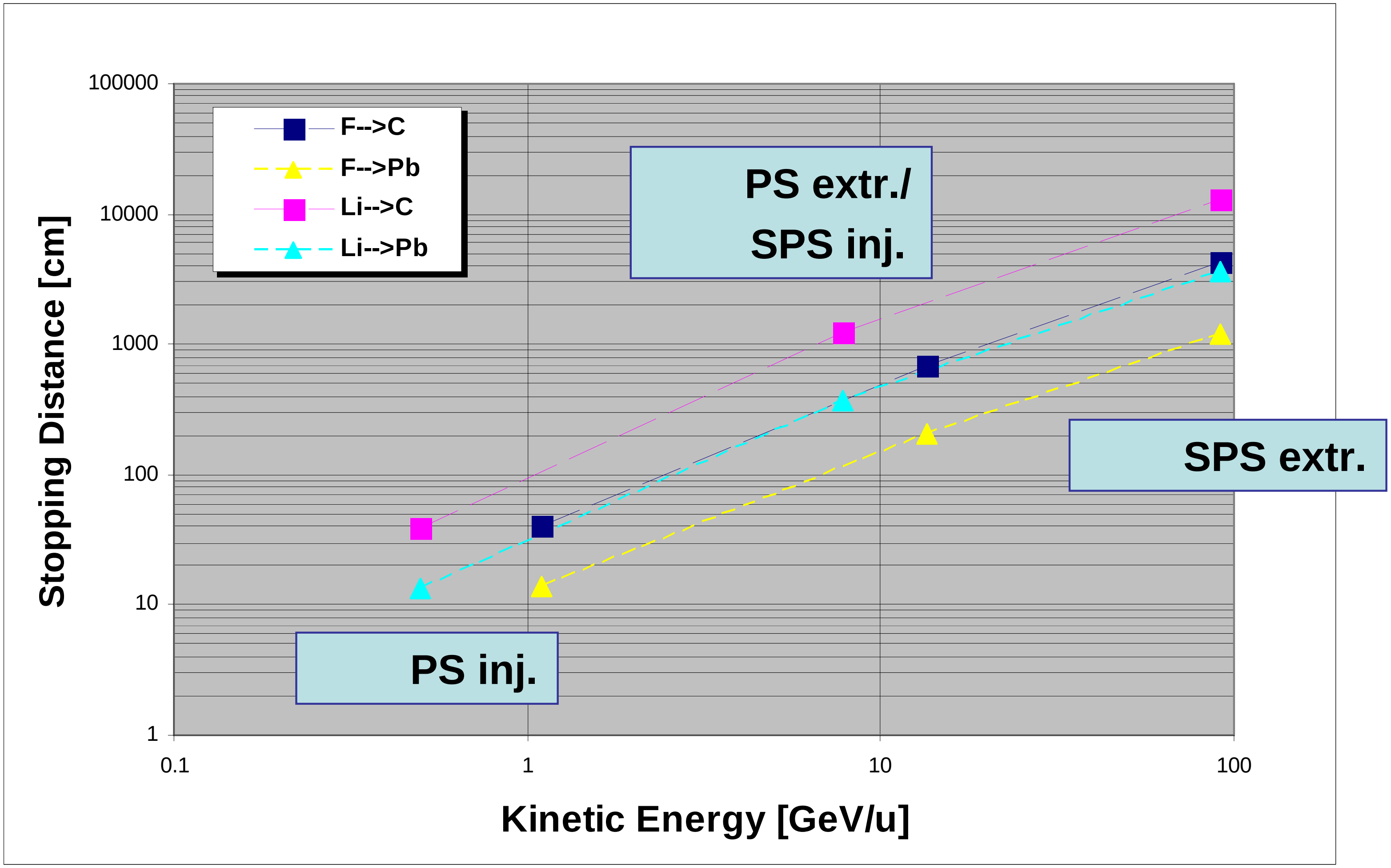
Ranges in Collimators (1)

- Collimators are typically W, Cu, Pb, C or Steel
- C has low activation but long range whereas Pb has a shorter stopping range but at the cost of a higher activation.
- Cu has low desorption yield (SIS-18/100/300) and W has a high melting point
- ATIMA (electronic stopping, straggling)
- Incident particles:
- → ^{6}He decay daughter $^{6}Li^{3+}$ (0.5-92 GeV/u)
- → ^{18}Ne decay daughter $^{18}F^{9+}$ (1.1-92 GeV/u)

Ranges in Collimators (2)

Produced by the ATIMA code (GSI).

Inelastic collisions with nuclei not included.



Beam Loss and Activation (1)

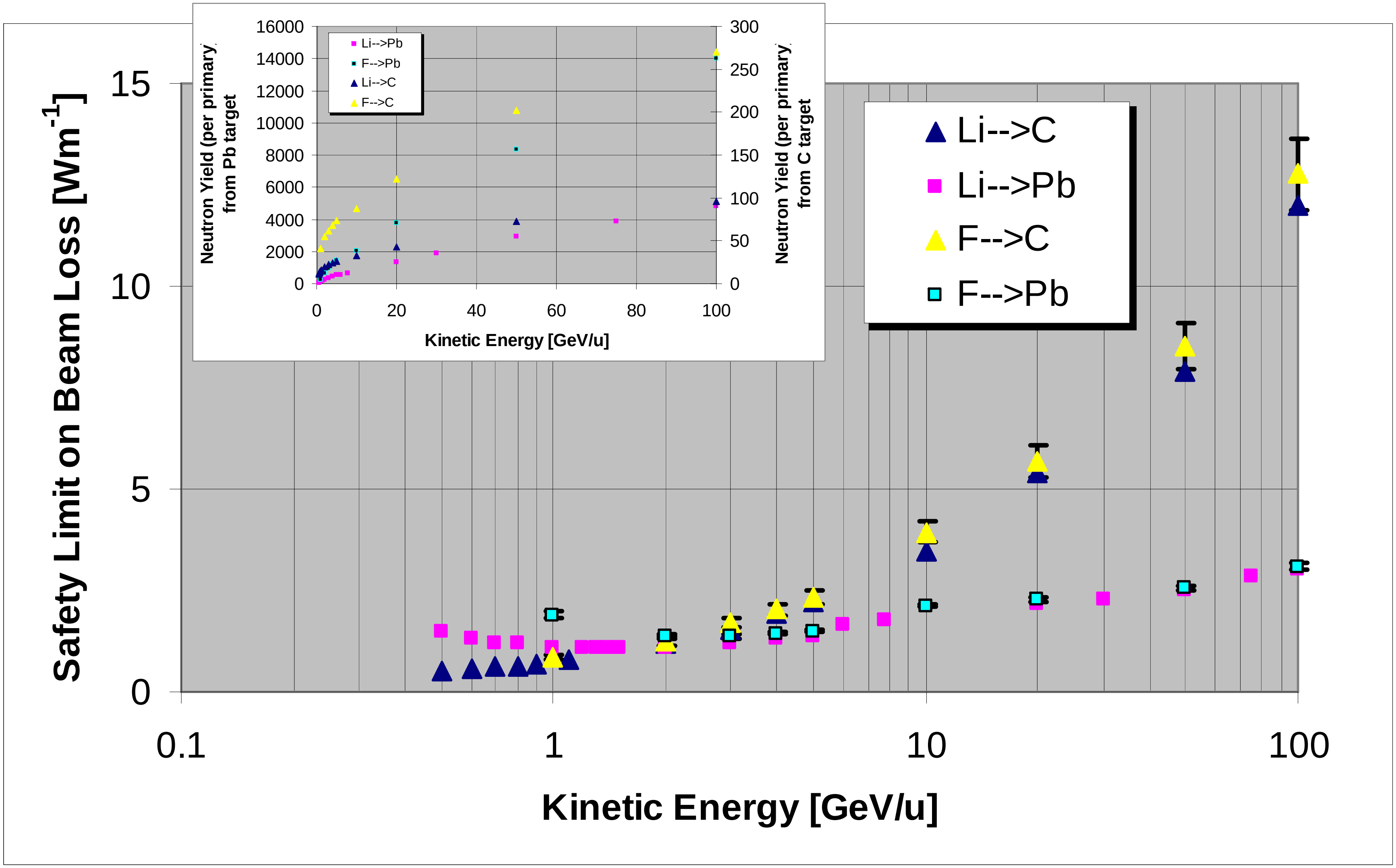
- Similar analysis made for FAIR project (Mustafin et al.)
- Neutrons are the dominant source of activation
- Average of 1W over the machine circumference of protons at 1GeV is regarded a safe loss limit to allow „hands on" maintenance [SNS→Wangler]
- Assume activation scales with total neutron yield
- Can estimate tolerable losses for heavy ions
- FLUKA used to determine the yield of neutrons from all processes per incident primary
- Normalized total neutron yield plotted as a function of incident heavy ion energy. Viz.,

$$\frac{Y_{total,HI}}{Y_{total,p}} = \frac{1}{A}\left(\frac{T_p}{T_{/u,HI}}\right)\left(\frac{Y_{per\ primary,HI}}{Y_{per\ primary,p}}\right)$$

Beam power loss per meter for heavy ions at a given energy is the same as that for 1GeV protons

Beam Loss and Activation (2)

Beam loss safety limit is $\left[Y_{total,HI}/Y_{total,p}\right]^{-1}$



Summary

- The intensity goals in the decay ring still look possible without resorting to demands for considerably higher intensity further upstream from the PS.
- Pressure in the PS exceeds the nominal operating threshold limit (10^{-8} mbar).
- Target ionization desorption yields $\eta>5$ in the PS lead to vacuum instability which may be cured with a factor 16 increase in pumping speed.
- ATIMA calculations reveal electronic stopping distances well beyond the maximum possible collimator thickness, except near the PS injection energy.
- Activation in C and Pb collimators has been studied with FLUKA.

References

- J. Wei et al., Beam-Loss Driven Design Optimization for the Spallation Neutron Source (SNS) Ring, PAC 1999
- T. Wangler, RF Linear Accelerators, Wiley & Sons, p. 285
- E. Mustafin, I. Hofmann, H. Weick, Influence of electronic stopping power on the total neutron yield of energetic heavy ions, NIM A (2003)
- A. Fabich, M. Benedikt, Decay losses along the accelerator chain of the EURISOL Beta-beam baseline design, CERN-AB-2006-xxx