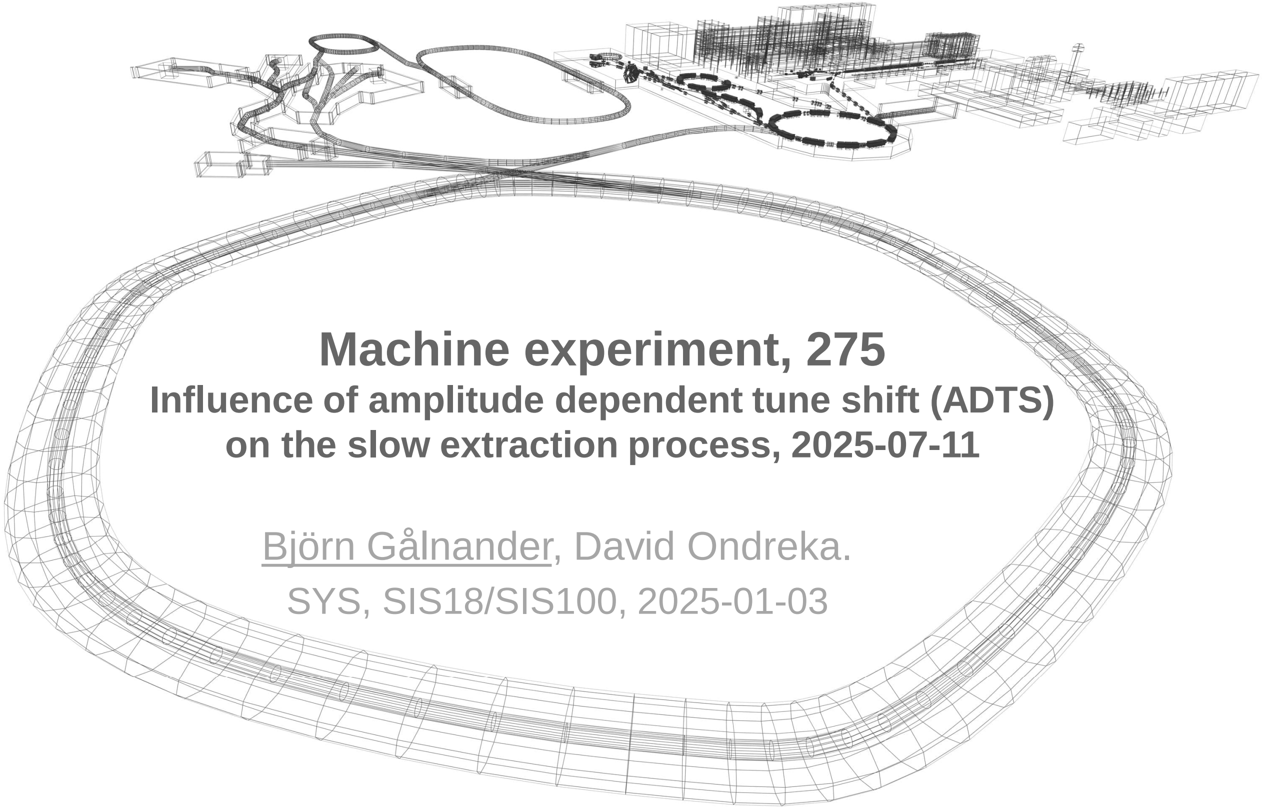


Machine experiment, 275

Influence of amplitude dependent tune shift (ADTS) on the slow extraction process, 2025-07-11

Björn Gålnander, David Ondreka.

SYS, SIS18/SIS100, 2025-01-03

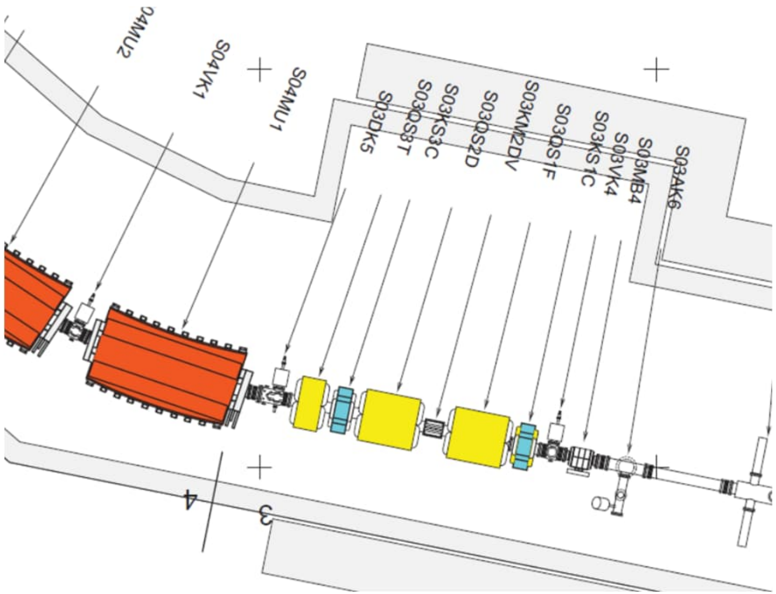
Objective

- Influence of amplitude dependent tune shift (ADTS) on the slow extraction process
  - No octupole magnets in SIS18
  - Exciting the sextupole magnets relatively strongly, in order to achieve second order ADTS
- KO-extraction
- Extraction efficiency compared with tracking simulations

Sextupoles in SIS18

- Two sextupole families in SIS18 Sextupoles GS##KS1 and GS##KS3. in odd sectors, 6 magnets each:
- GS##KS1C, hor corr, and resonant extraction
  - betax, betay, Dx = **29.5**, 7.45, 3.14 m
- GS##KS3C, vert corr
  - betax, betay, Dx = 9.05, **22.3**, 1.72 m

    (values at extraction, doublet optics, tau=1.0)



Natural chromaticity chx, chy = -6.6, -4.1

at extraction, tau=1.0, Qx, Qy, = 4.32, 3.29

Amplitude dependent tune shift (nonlinear detuning)

- Chromaticity correction with sextupoles

$$\Delta\xi_x = -\frac{1}{4\pi}\sum_j k_2 L_j \, \beta_{x,j} \, D_{x,j}$$

$$\Delta\xi_y = +\frac{1}{4\pi}\sum_j k_2 L_j \, \beta_{y,j} \, D_{x,j}$$

- Amplitude-dependent tune shift (ADTS)
  - octupoles (only *Jx* term)

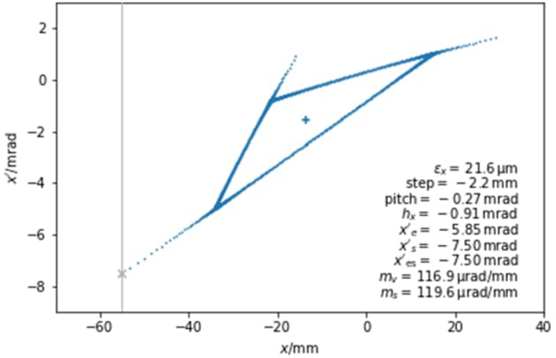
$$\Delta Q_x = \frac{1}{16\pi}\sum_j k_3 L_j \beta_{x,j}^2 \, J_x \;\propto\; k_3$$

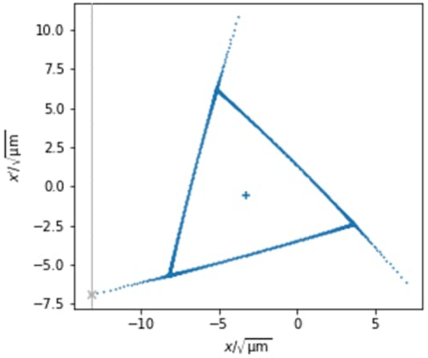
  - sextupoles in second order (only *Jx* term)

$$\Delta Q_x = \frac{1}{64\pi}\sum_{j,k} k_2 L_j \, k_2 L_k \, \beta_{x,j}\beta_{x,k} \, F_x^{(j,k)} \, J_{xx} \;\propto k_2^2$$

see Lee, Wiedemann…

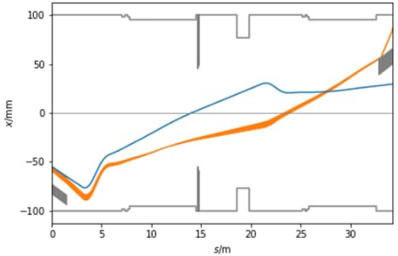
ADTS from sextupoles, effect on separatrix

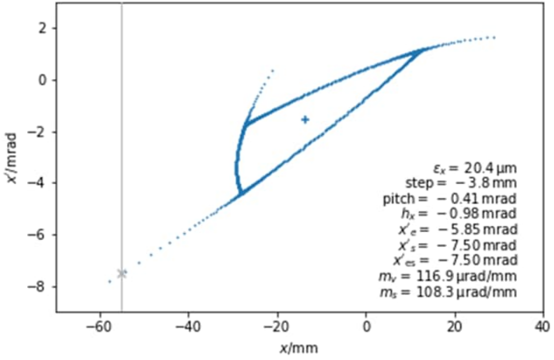


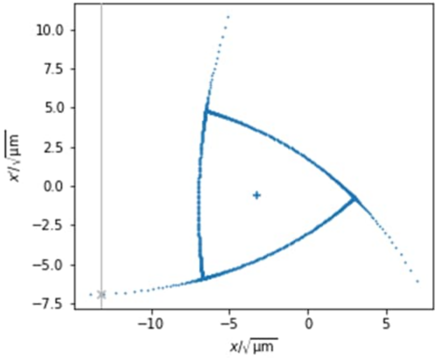


dqh = 0.0022
samp = 0.03 1/m2
sphi = 64
choff KS1C= 0.0 1/m2
cvoff KS3C = 0.0 1/m2

chx, chy = -6.6, -4.8
dnuxdjx = 52





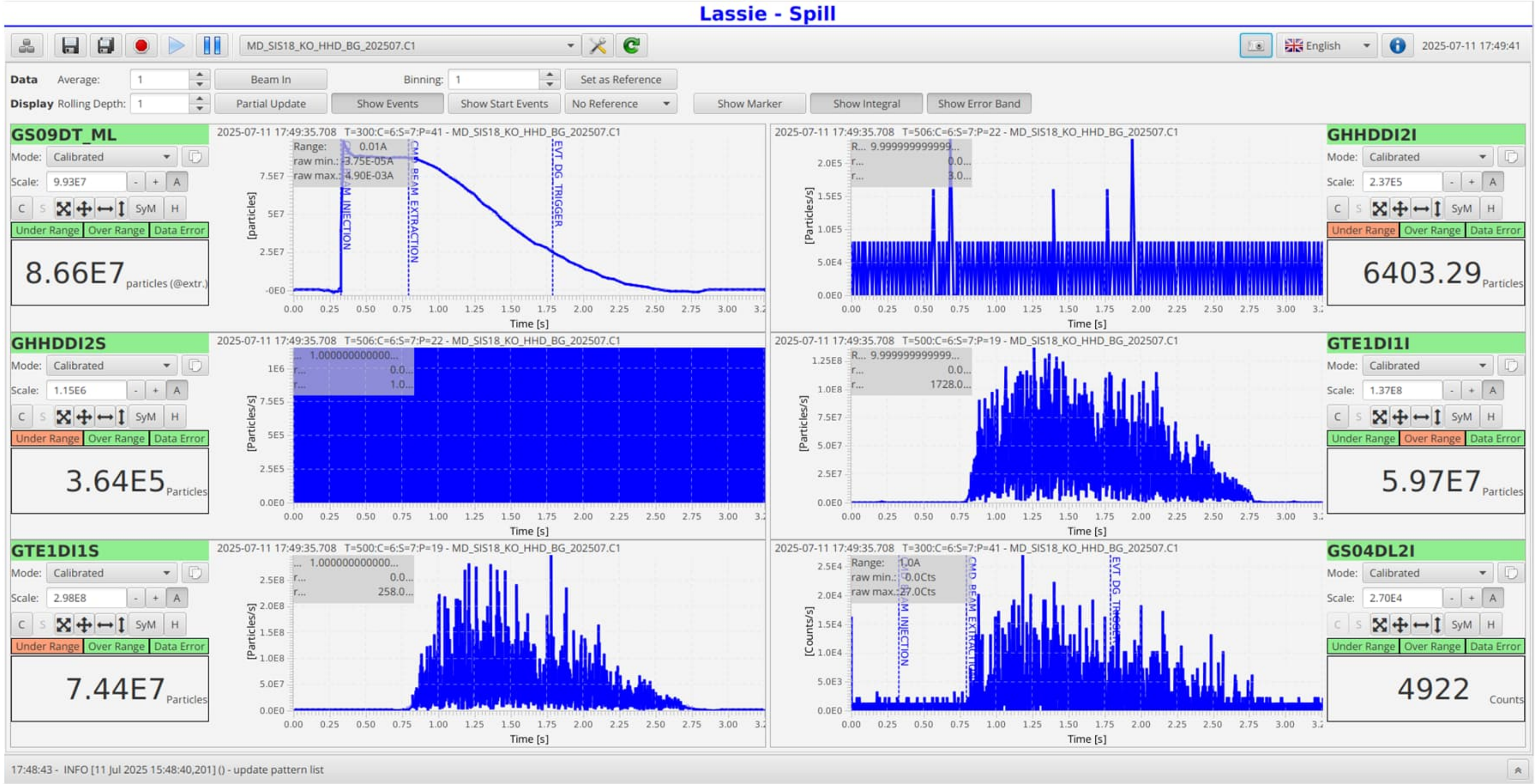


dqh = 0.0028
samp = 0.03
sphi = 23
choff = 0.25
cvoff = -0.654

chx, chy = 0.0, 3.3
dnuxdjx = 89

dipole k2L = 0.04 1/m2
no quad fringe fields

Diagnostics

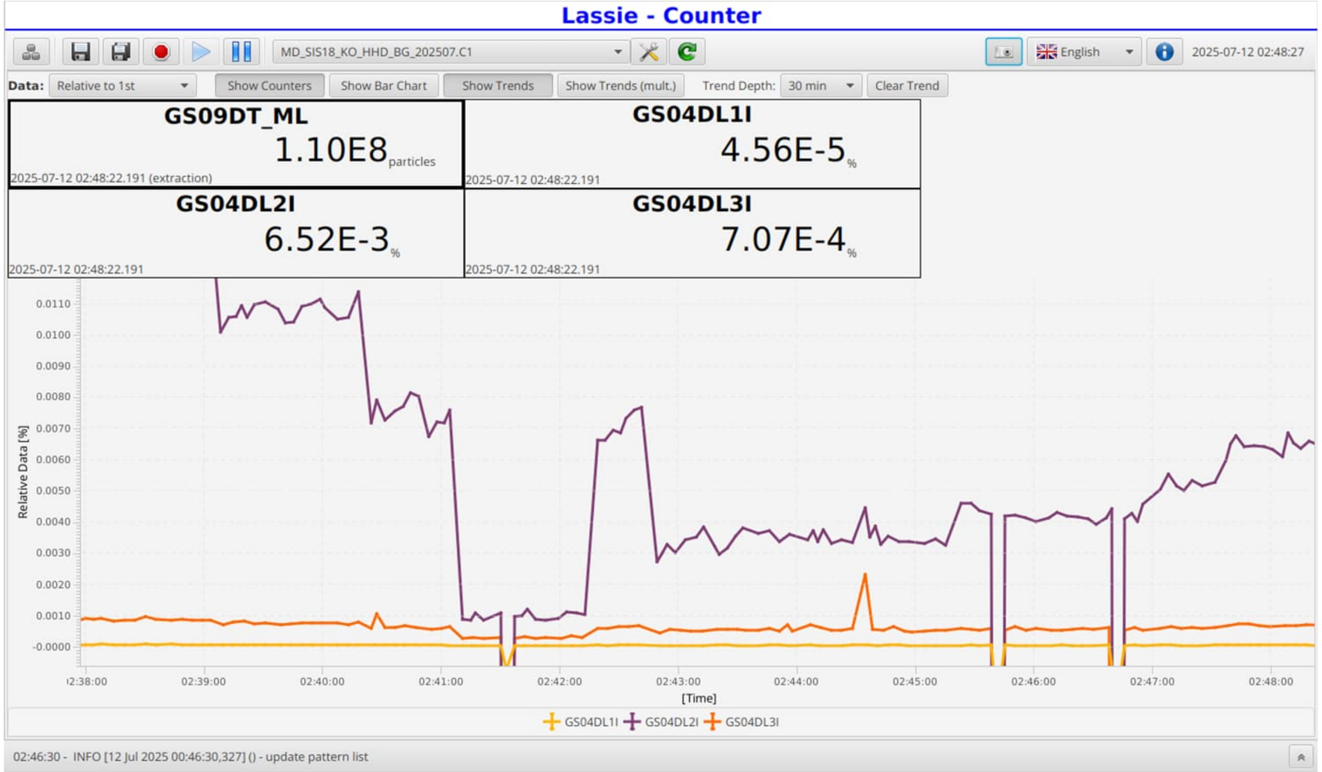


Transmission

particle count relative to flattop DCCT

sphi modified to optimise transmission
-- align separatrix with ES angle

Losses at ES



Lassie - Counter
MD_SIS18_KO_HHD_BG_202507.C1
English
2025-07-12 02:48:27
Data: Relative to 1st
Show Counters
Show Bar Chart
Show Trends
Show Trends (mult.)
Trend Depth: 30 min
Clear Trend
GS09DT_ML
1.10E8 particles
2025-07-12 02:48:22.191 (extraction)
GS04DL1I
4.56E-5 %
2025-07-12 02:48:22.191
GS04DL2I
6.52E-3 %
2025-07-12 02:48:22.191
GS04DL3I
7.07E-4 %
2025-07-12 02:48:22.191
Relative Data [%]
[Time]
GS04DL1I
GS04DL2I
GS04DL3I
02:46:30 - INFO [12 Jul 2025 00:46:30,327] () - update pattern list

Results

- Adjusting sphi to minimse losses, for two different cases correcting chx = 0
- Problem going to higher sextupole strengths…see below

choff KS1= 0.14 1/m2
cvoff KS3 = 0.0 1/m2
chx, chy = 0.0, -5.8

Experiments			Simulations		
samp (1/m2)	sphi	dqh	sphi	dqh	dQx/dJx
0.02	**50**	0.0198	**-8**	0.0027	67
0.03	**40**	0.0204	**15**	0.0034	84
0.05	**70**	0.0224	**29**	0.0048	139
0.07	**70**	0.0241	**35**	0.0062	222

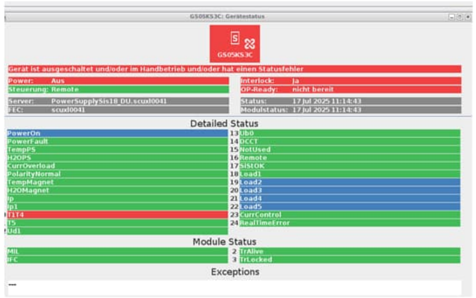
choff KS1= 0.082 1/m2
cvoff KS3 = 0.35 1/m2
chx, chy = 0.0, -13.3

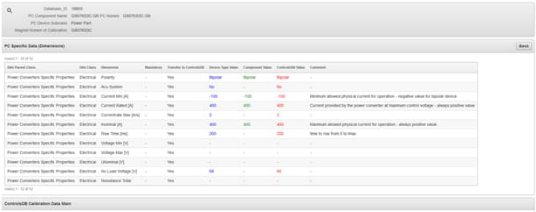
Experiments			Simulations		
samp (1/m2)	sphi	dqh	sphi	dqh	dQx/dJx
0.02	**50**	0.0247	**12**	0.0029	20
0.05	**60**	0.0253	**39**	0.0052	65
0.07	**60**	0.0257	**46**	0.0067	98

- following same trend in adjusting sphi for different samp, different adts,
- but not matching experimental values, not fully understood

Sextupole power supplies limitation

- Limits for sextupoles leading to PS fault, T1T4, when going to too high currents.
- PS for sextupoles:
  - LOGICAL.GS01KS1C/B2L LSA: MIN(-3.5633236) MAX(14.25359)
    For Brho = 12 Tm, max k2l = 14.2/12 = 1.2, min = -3.6/12 = 0.3
  - LOGICAL.GS01KS3C/B2L LSA: MIN(-14.25359) MAX(3.5633236)
    For Brho = 12 Tm, max k2l = 0.3, min = -1.2
- I = 28 * B2L
- Limits, -100 – 400 A (KS03 have a negative sign for current.)





- Problem time for ramping to max current, **200 ms**
- in KO ramping in pre_extraction BP 40 ms default.
  - in slow extraction (qdr) 32 ms for ramping, in beginning of the slow extraction.
- For max currents ramp time has to be prolonged. LSA model change would be helpful.

- Realized and tested separately, 2025-07-17, together with EPS

olog ID 924091 https://olog.acc.gsi.de/olog/event/showEvent/924091

Summary

- Studied amplitude dependent tune shift, ADTS, by using both sextupole families, KS1 and KS3.
- Results show qualitativity expected results, but sextupole phase, sphi, settings to minimize losses not quantitatively matched in simulations.
- Problems with power supply faults limited range of experimental parameters that could be tested.
- Ramp time when ramping to max currents > 200 ms (now 40 ms default)
  - For “normal” usage, chromaticity correction to chx = 0.0, this is not a problem.
  - But a modification of the LSA model would be helpful.

- Further studies with higher sextupole strengths for larger variation of ADTS needed.

- Acknowledgements:

A. Pastushenko

H. Lieberman, for LSA, Paramodi support

B. Zipfel et al. exp 241 for beam-sharing

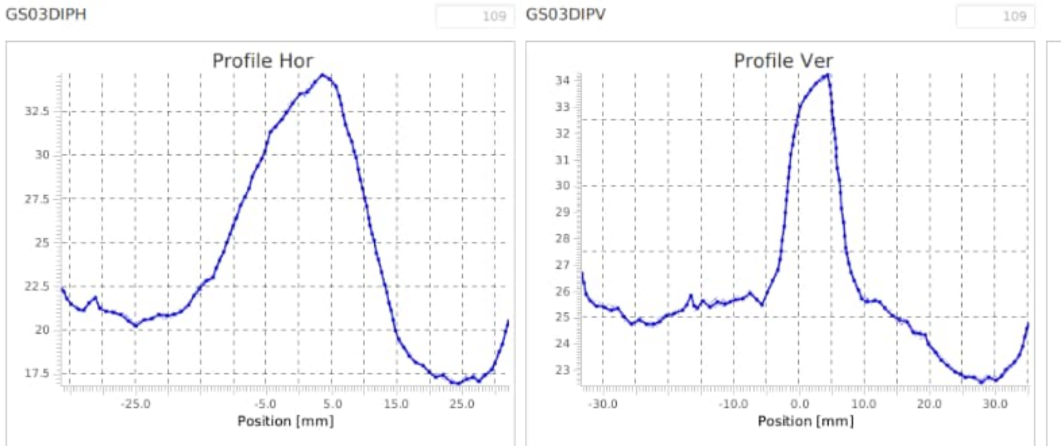
U. Clausen, W. Orlov, EPS for follow-up, error solving and testing

- IPM flattop (evt 45), 2025-07-11, 21:37
- U73+ 500 MeV/u
- Beam size +- 15 mm

  betax = 13.25

  em_x = 15^2/13.24 = 17 mm mrad

  implies, em_x = 24 mm mrad at 350 MeV/u



Sextupoles with chromaticity correction, KO

- Either setting chromaticity, both K1 and K3
- Or, an offset, only correcting K1,