

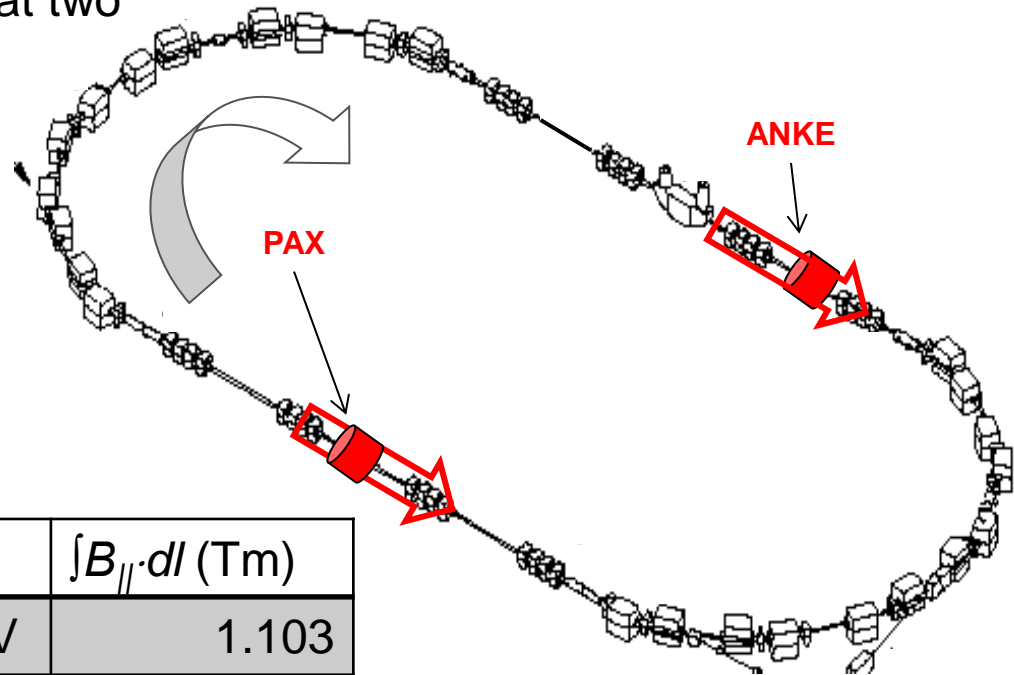
Commissioning of the Siberian Snake in COSY

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December 19, 2016 | Andreas Lehrach, FZ Jülich (IPK-4) & RWTH Aachen (Ex.Physik IIIb)

Physics at COSY using Longitudinally Polarized Beams: **Original Plan**

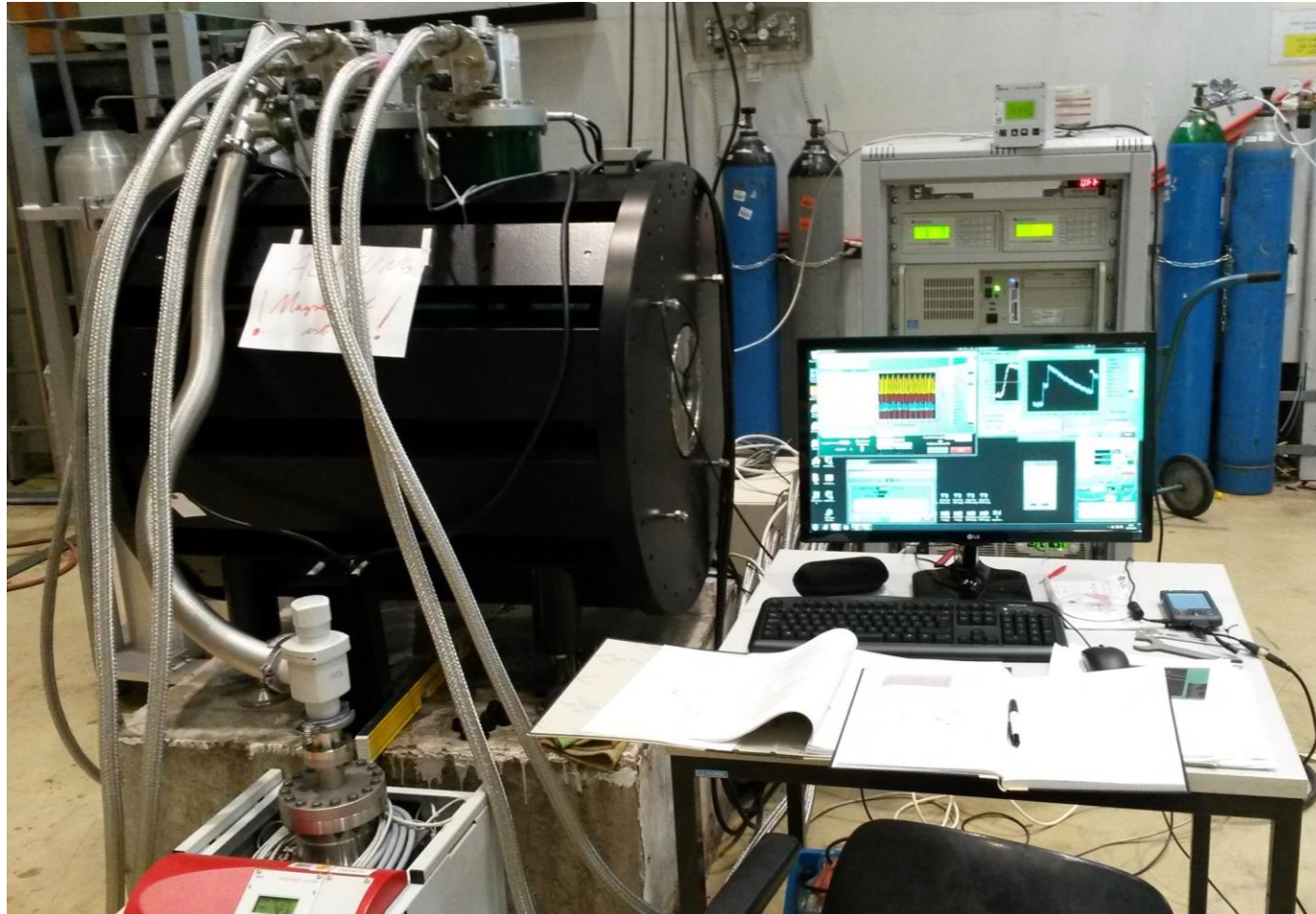
- Should allow for flexible use at two locations
- Fast ramping < 30s
- Integral long. field > 4.7 T m



	$\int B_{\parallel} \cdot dl$ (Tm)
COSY Injection Energy 45 MeV	1.103
$pn \rightarrow \{pp\}_s \pi^-$ at 353 MeV	3.329
PAX at COSY 140 MeV	1.994
PAX at AD 500 MeV	4.090
T_{\max} at COSY 2.88 GeV	13.887

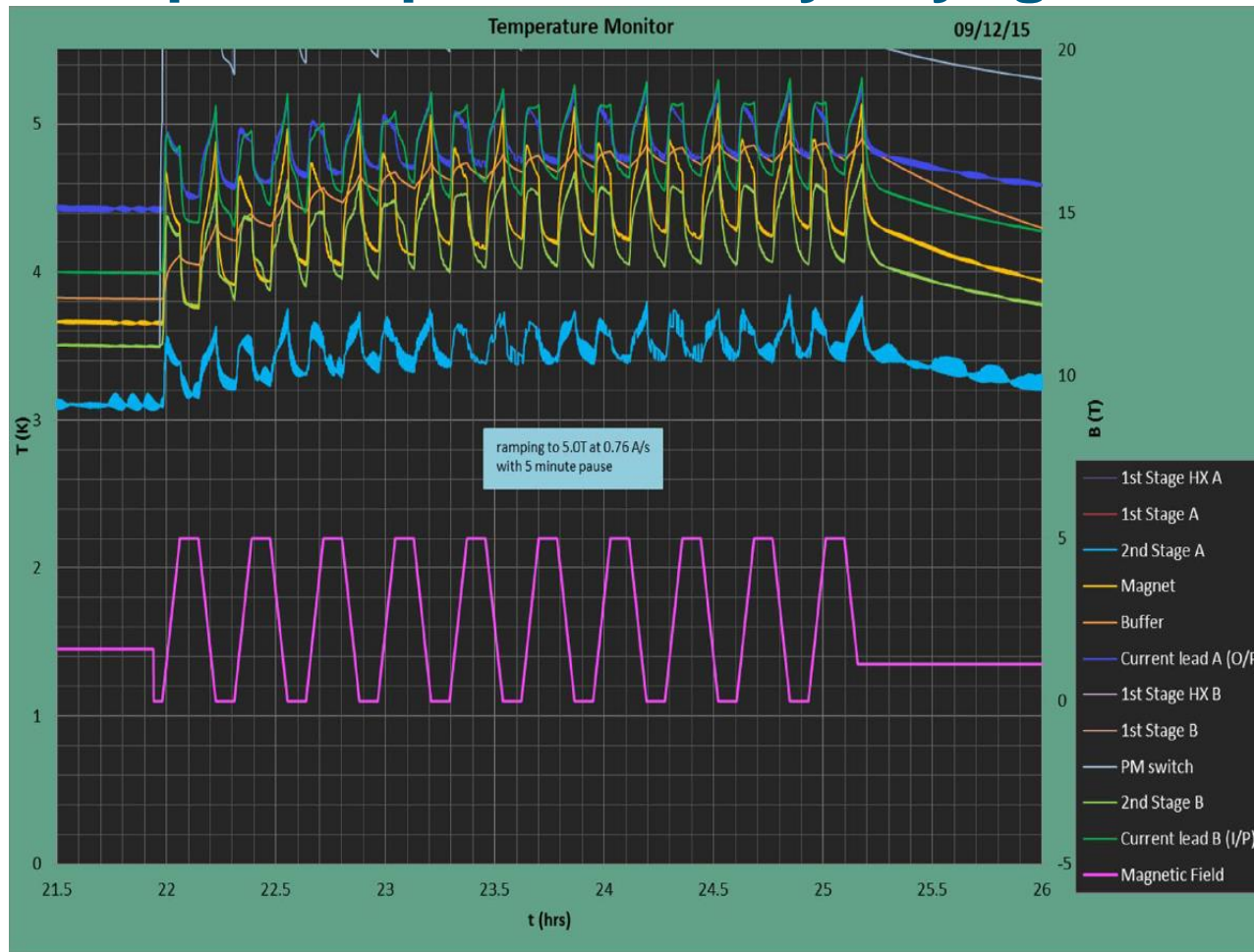
- Ramp rate roughly a factor of 10 smaller
- Delivery delayed by more than 3 years

SC Solenoid Setup



Setup of the SC Solenoid at the test stand in the COSY hall.

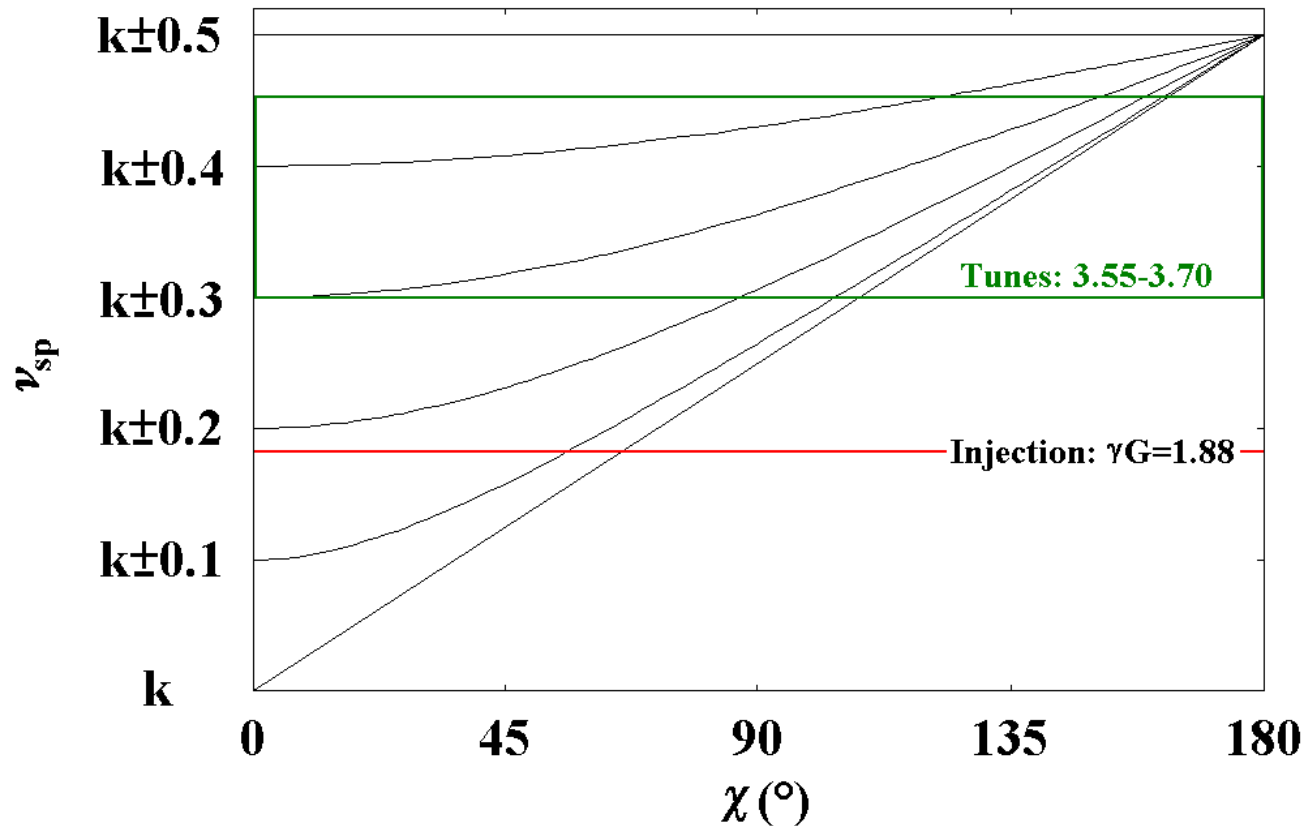
Test Sequence performed by Cryogenics



A sequence of ramps to 5 T at a ramp rate of 0.76 A/s (0.018 T/s) measured with a hall probe (lower graph).

Temperatures in different subsystems of the snake are shown in the upper curves.

Spin Tune



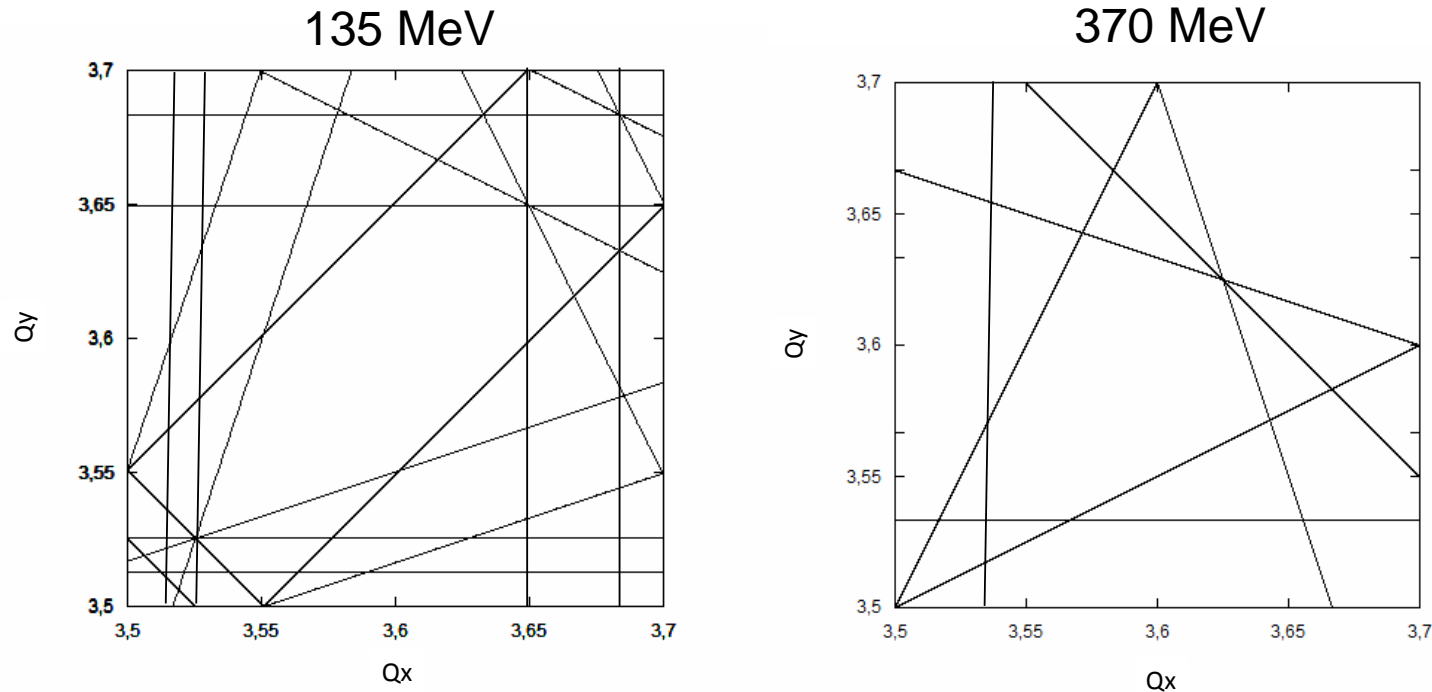
Spin tune ν_{sp} versus rotation angle χ of the spin in the snake, k is an integer.

Energy for half integer spin tune: $E_{kin} = 370\text{MeV} + k \cdot 523\text{MeV}$

Strategy for Commissioning

- Start with a beam momentum of 911.86 MeV/c (kinetic energy of 370 MeV), where the spin tune $\nu_{sp} = \gamma G$ without snake equals 2.5
→ depolarizing resonances are not crossed during the snake ramp
- In a stepwise approach we will move γG close to integer and study spin resonance crossing during the snake ramp.
- Investigate the beam momentum of 521 MeV/c (135 MeV), where γG equals 2.05 to study snake resonances. This beam momentum is proposed for the TRIC and PAX experiment.
- The operation of strong solenoidal fields with respect to HESR is studied, especially betatron tune shifts and phase space coupling.

Higher-Order Depolarizing Resonances

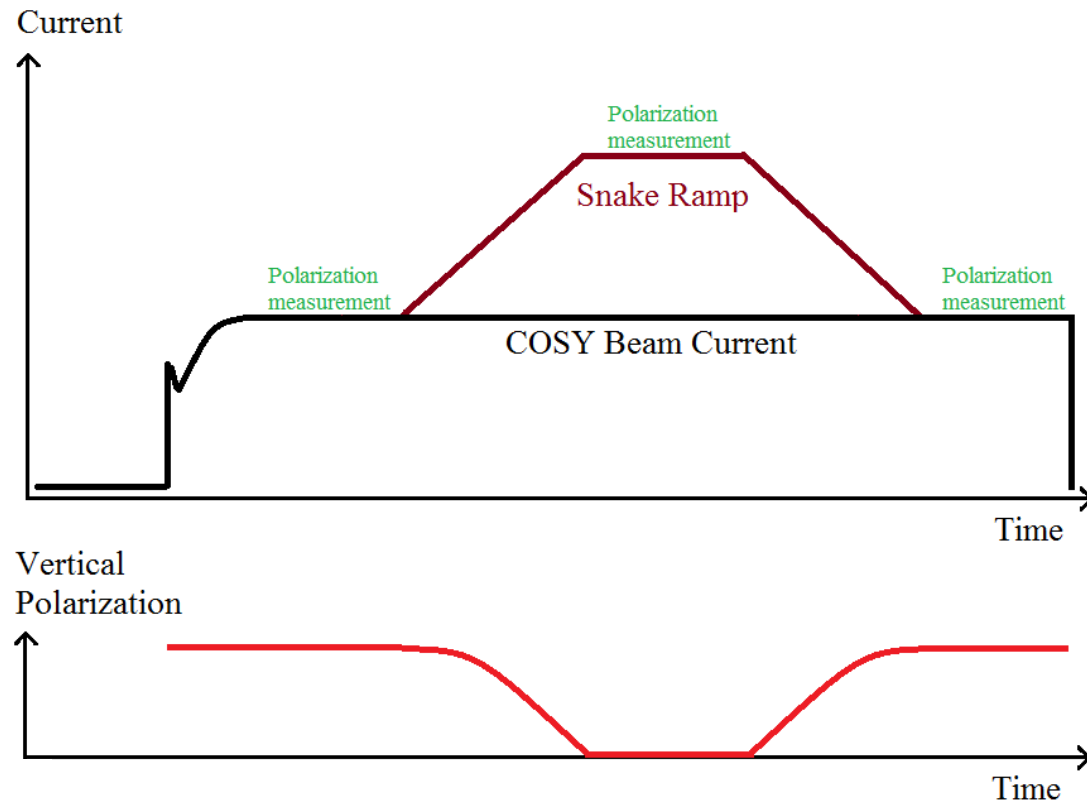


Higher-order depolarizing resonances at 135 MeV up to fourth order plotted in a betatron tune diagram (left): $2+Q_x-Q_y$, $2+Q_x-Q_y$, $-5+Q_x+Q_y$, $-5+2Q_x$, $-5+2Q_y$, $-9+Q_x+2Q_y$, $-9+2Q_x+Q_y$, $13-2Q_x-Q_y$, $13-Q_x-2Q_y$, $13-3Q_x$, $13-3Q_y$, $-9+3Q_x$, $-9+3Q_y$, $-5+3Q_x-Q_y$, $-5-Q_x+3Q_y$, $-12+2Q_x+2Q_y$, $9+Q_x-3Q_y$, $9-3Q_x+Q_y$, $-12+4Q_x$, $-12+4Q_y$.

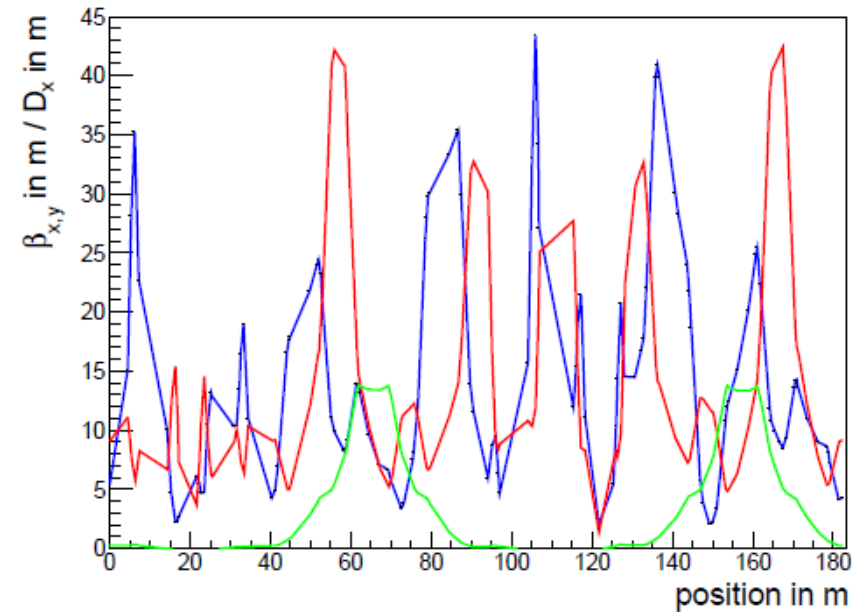
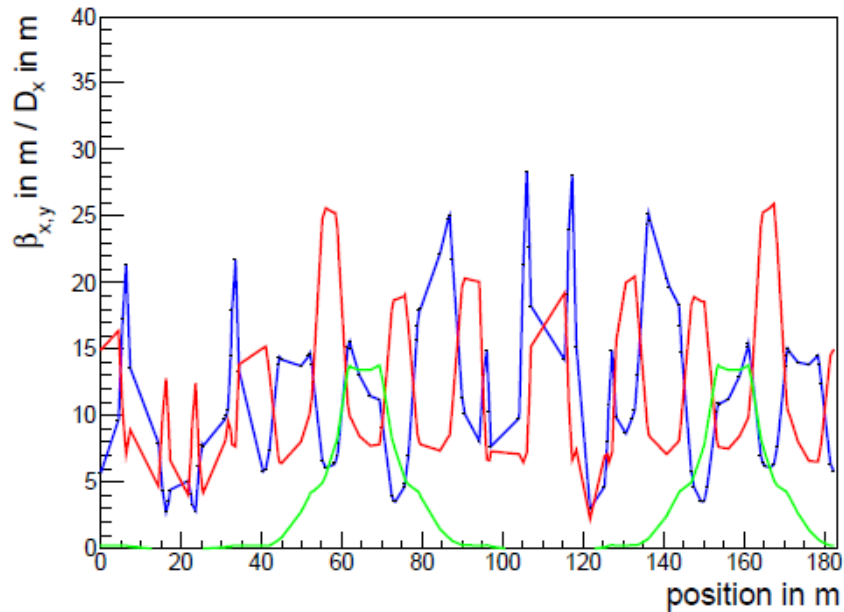
Higher-order depolarizing resonances at 370 MeV up to fourth order plotted in a betatron tune diagram (right): $-1+Q_x$, $-1+Q_y$, $-1+2Q_x-Q_y$, $-1-Q_x+2Q_y$, $-12+3Q_x+Q_y$, $-12+Q_x+3Q_y$, $-12+2Q_x+2Q_y$, $-12+4Q_x$, $-12+4Q_y$.

Measurement Cycle for Commissioning

- Injection of vertically polarized beam
- Acceleration to desired momentum (135 – 370 MeV)
- Measurement of the polarization using EDDA detector
- Turning on the snake to $\chi = 180^\circ$
- Measurement of vanishing vertical polarization with EDDA
- Turning of the snake
- Measurement of the reappearance of vertical polarization with EDDA
- Deceleration and next injection



Beam Optics



Beam optics without (left) and with (right) Siberian snake turned on. The transverse betatron amplitudes $\beta_{x,y}$ (blue, red line) and horizontal dispersion D_x (green line) are plotted versus the position in the COSY ring.

The betatron tunes are shifted from $Q_{x,y} = 3.62, 3.59$ without snake to 3.76 resp. 3.57 with the snake turned on.

SC Solenoid Parameters and Performance

- Length of the cryostat: 975 mm
- Bore diameter (i.e. inner diameter of vacuum tube): 90 mm
- Maximum field integral along axis: 4.7 Tm; maximum field: 6 T at 258.83 A
- Cryogen-free operation (no external liquefier, no manual refill of cryogenic liquids)
- Turnkey, stand-alone system required including all the auxiliary systems (compressors, power units, re-condensing system, Hall sensors, temperature sensors)

Maximum field / T	Ramp rate / A/s	Sequence	Dwell time / s
3	1.6	yes	300
4	1.0	yes	300
5	0.76	yes	300
6	0.24	no	-

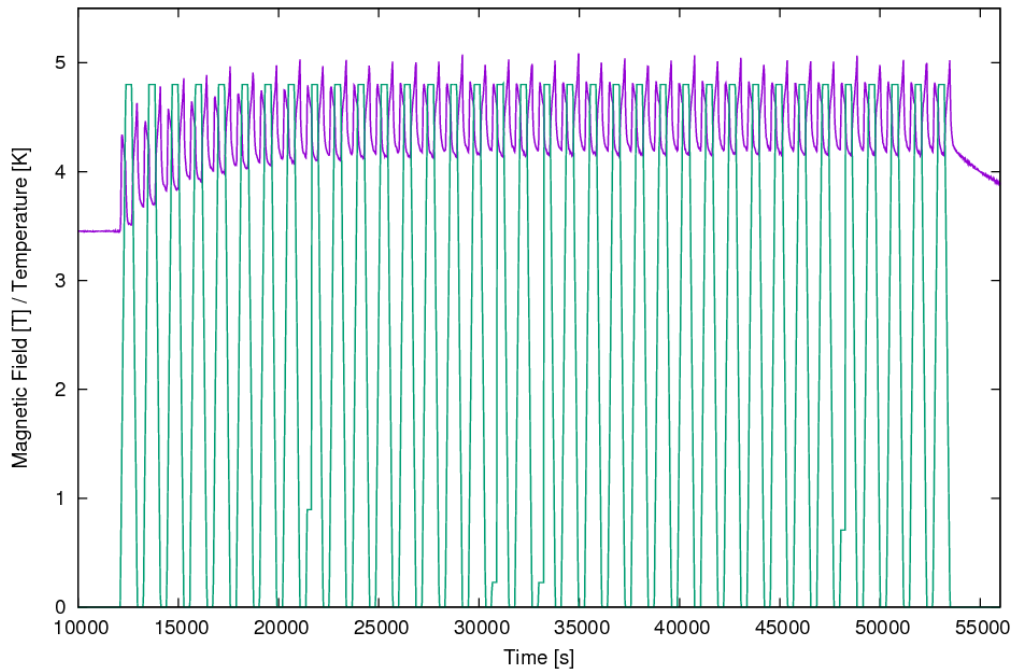
0.76 A/s equals 0.018 T/s

To realize a full Siberian snake a magnetic field of roughly 2.7 T at a beam momentum of 521 MeV/c and 4.8 T at 911.86 MeV/c has to be provided by the SC solenoid.

Test Sequence in Jülich

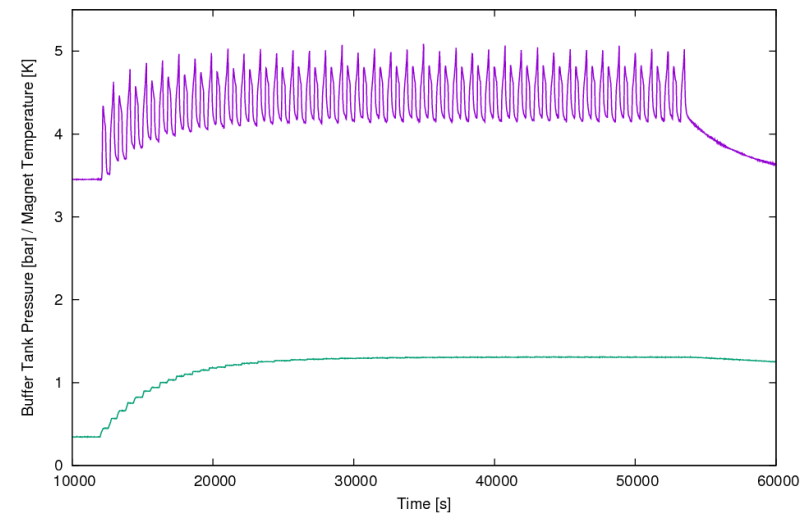
36 ramps to 4.8 T with 300 s dwelling time

The Temperature Development during 36 Ramps up to 4.8 T



Courtesy:
R. Engels

Temperature/Pressure Development of the Magnet during 36 Ramps up to 4.8 T



Conclusion / Outlook

- The delivered 4.7 Tm superconducting solenoid allows to adjust a longitudinal polarized beam at EDDA/PAX.
- Commissioning at beam momenta between 520 and 920 MeV/c.
- Only the change of the vertical beam polarization can then be measured with the EDDA detector.

- Upgrade of hard- and software controls to allow starting a sequence of ramps with external trigger is finalized.

- Implementation of SC solenoid in COSY is planned for the winter shut down 2016/2017 at the ANKE location.

- Requested beam time (2 weeks + MD) has been recommended by CBAC #4 with triple A.

- Commissioning early next year would be favorable.

