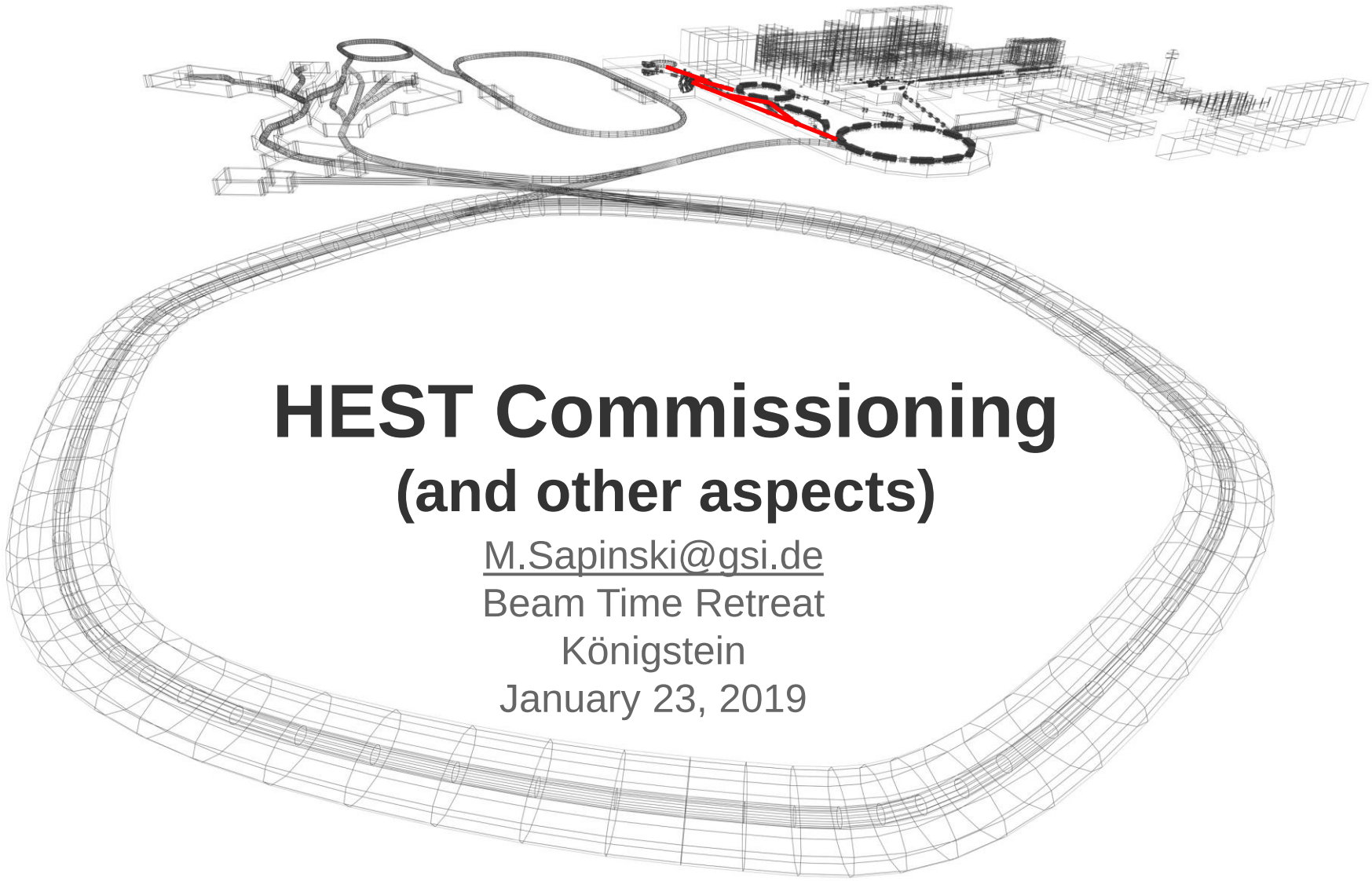


HEST Commissioning

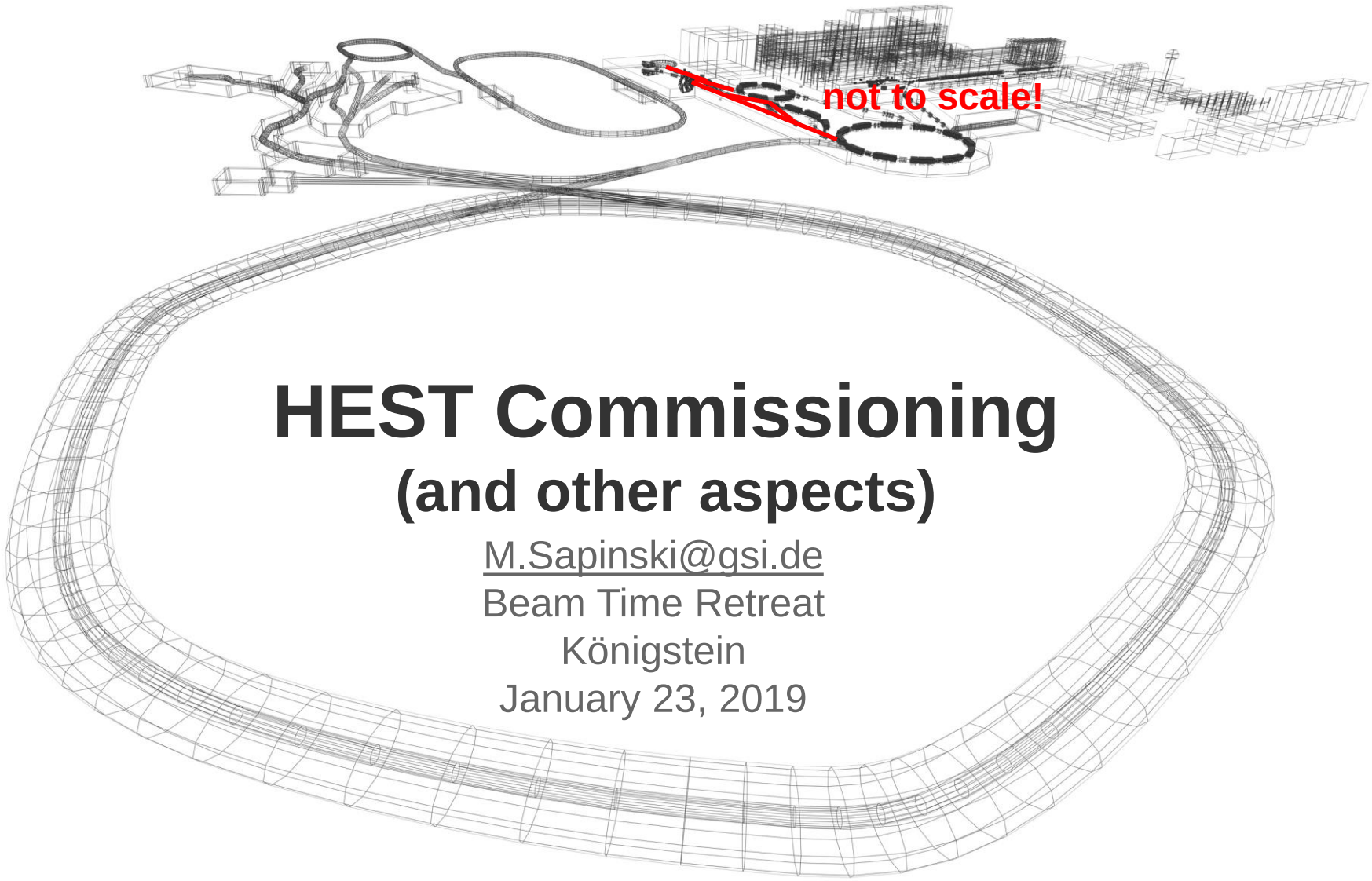
(and other aspects)

M.Sapinski@gsi.de

Beam Time Retreat

Königstein

January 23, 2019



HEST Commissioning

(and other aspects)

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Beam Time Retreat

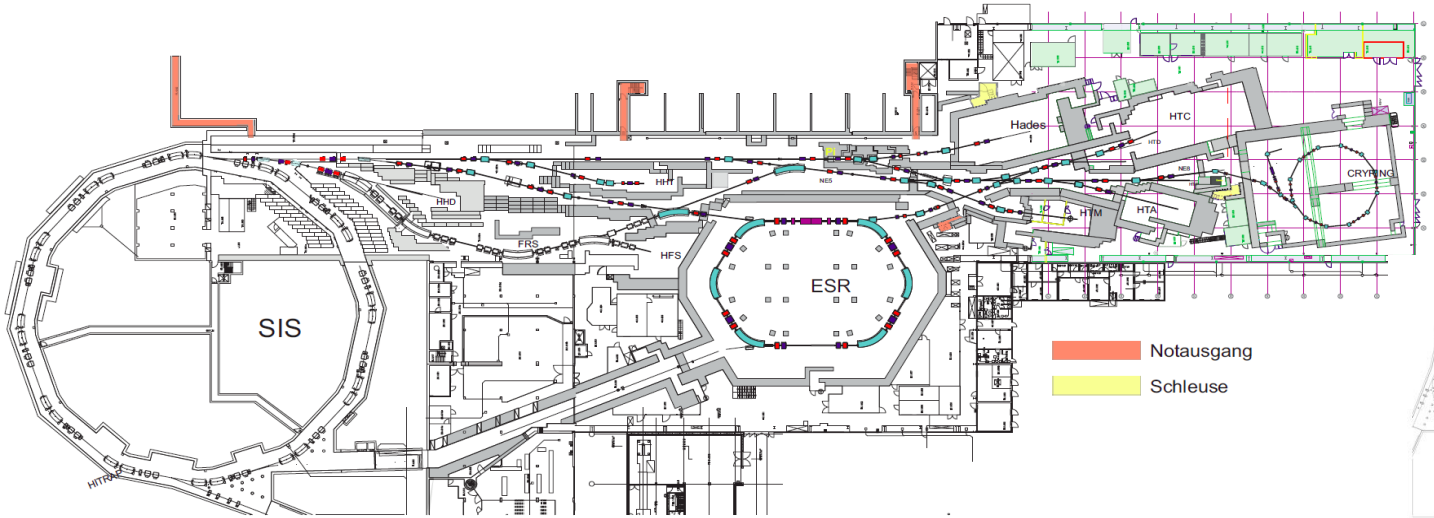
Königstein

January 23, 2019

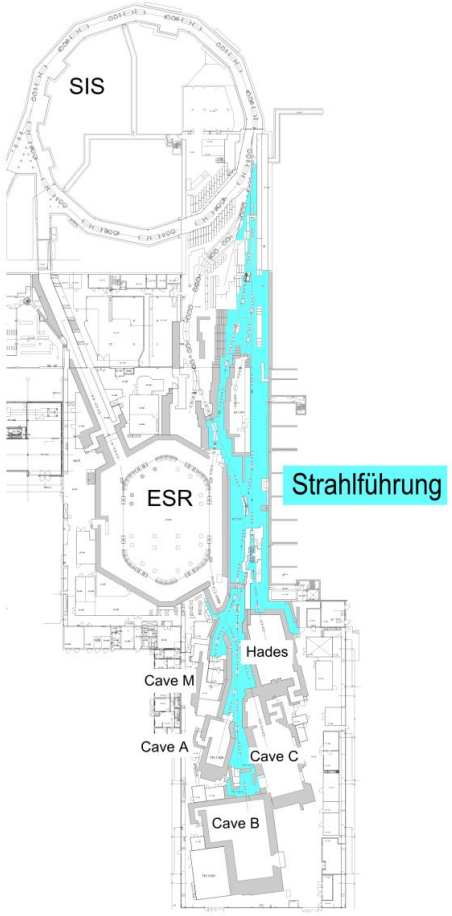
Outlook

- HEST overview.
- Changes during 2016-2018 shutdown.
- Outcome of Engineering Run 2018.
- Optics settings.
- Quality of the optics models.
- Trajctory response matrix.
- Optics measurements.
- Plans for 2019 and behind.
- Summary.

HEST overview (I)



MK: M. Sapinski
(previous: C. Kleffner –
special thanks for help)
STV: P. Schuett
deputy for both: S. Reimann



- About 500 meters of beam transfer lines.
- Role: bring beams from SIS18 to Caves A, C, M, ESR, HADES, CryRing, HFS, HTD, HHT and beam dump (HHD).
- Also from ESR to Cave C, Cryring.
- Areas: NE3, NE5, NE8.
- Close collaboration with experiments.
- Documentation: http://sapinski.web.cern.ch/sapinski/physics/HEST/index.html

HEST overview (II)

lots of particle types, ~20 different beam paths made of segments

→ protons ... uranium, RIPs, pions

HHD ions from **SIS** - ***beam dump***

HFS RIPs from **FRS**

HHT ions from **SIS**

HTM ions from **SIS**

ESR ions/RIPs from **SIS, FRS**

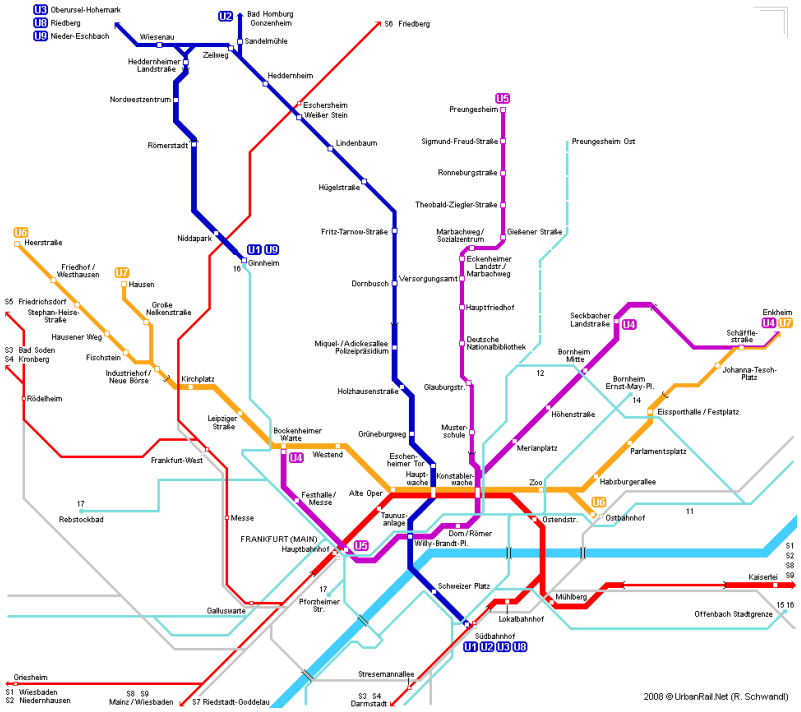
HTA ions from **SIS** or **ESR**
HTA ions from **SIS** or **ESR**

HTB ions/RIPs from **SIS, FRS** or **ESR**
HTB π^- π^+ from **π**-target

HTC,D ions/RIPs from **SIS, FRS** or **ESR**
HTC,D π^- π^+ from **π**-target
HTP ions from **SIS**, **ESR**

HADES ions from **SIS**
HADES π^- π^+ from **π**-target

U-bahn plan by B. Schlei



M.Sapinski@gsi.de

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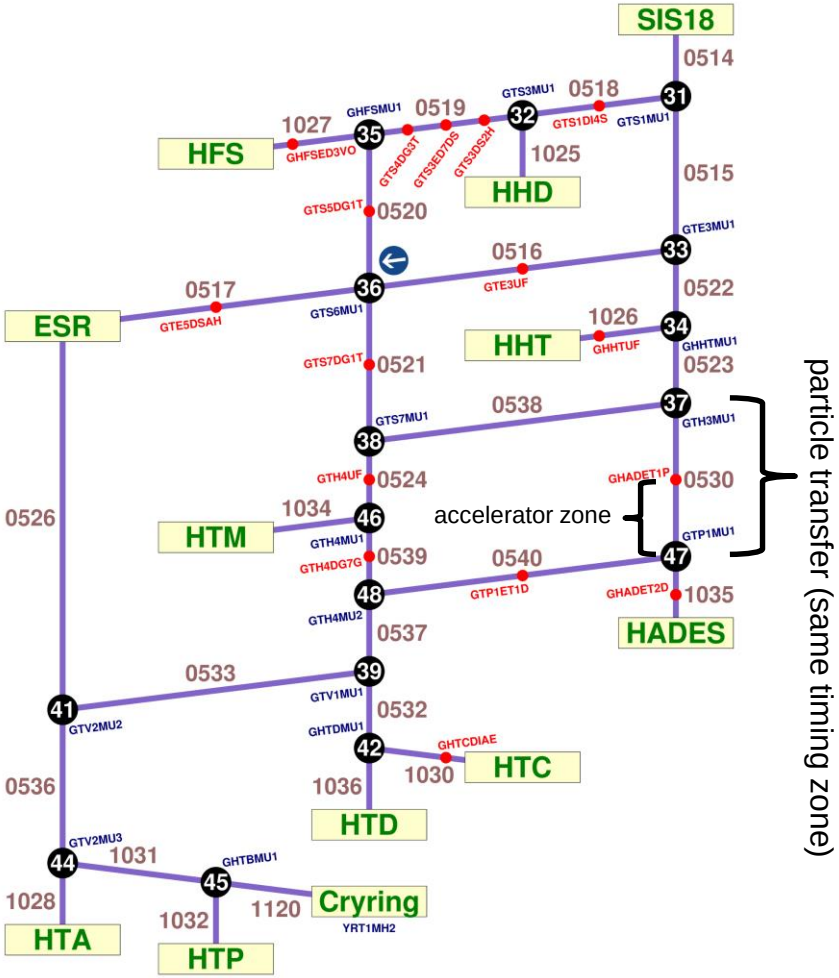


slide ‘stolen’ from C. Kleffner

M.Sapinski@gsi.de

Upgrades during 2016-2018 shutdown

- Installation of mini-CBM: rotation of GHTDMU1 magnet, new vacuum chambers.
- HADES beam line upgrade:
  - new vacuum chambers in GHADQD11/12
  - Beam loss monitoring system, SEM detectors (transmission measurement for high intensity), halo monitors
  - additional shielding of NE5 after July beam time
- Other upgrades of diagnostic: replacement of rad-hard cameras in GS06DFV and GTE1DF1V and connection to digital DAQ (CUPID).
- Connection of GTE2DF3V to CUPID.
- GaF works (constructions in NE5 reparation for SIS100 connection).
- Replacement of vacuum ventiles (VAC group).
- Regular reparations of SEM grids and other equipment.
- Alignment.

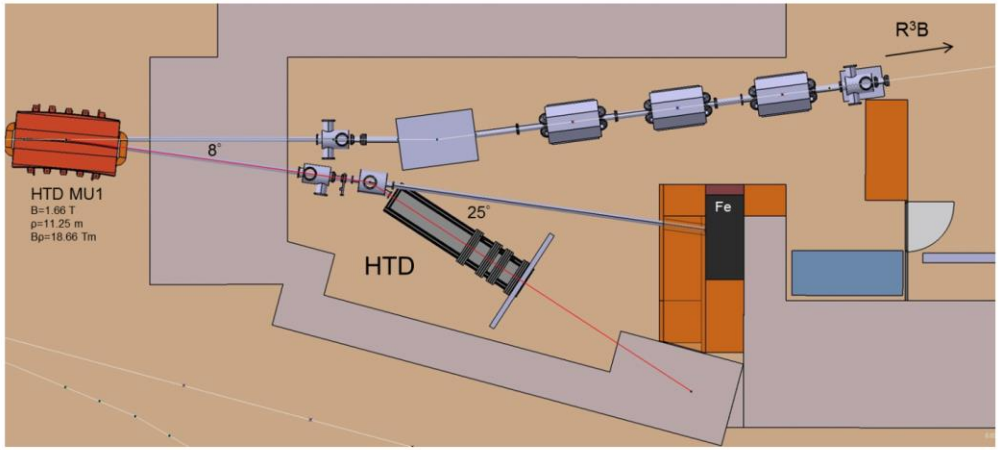
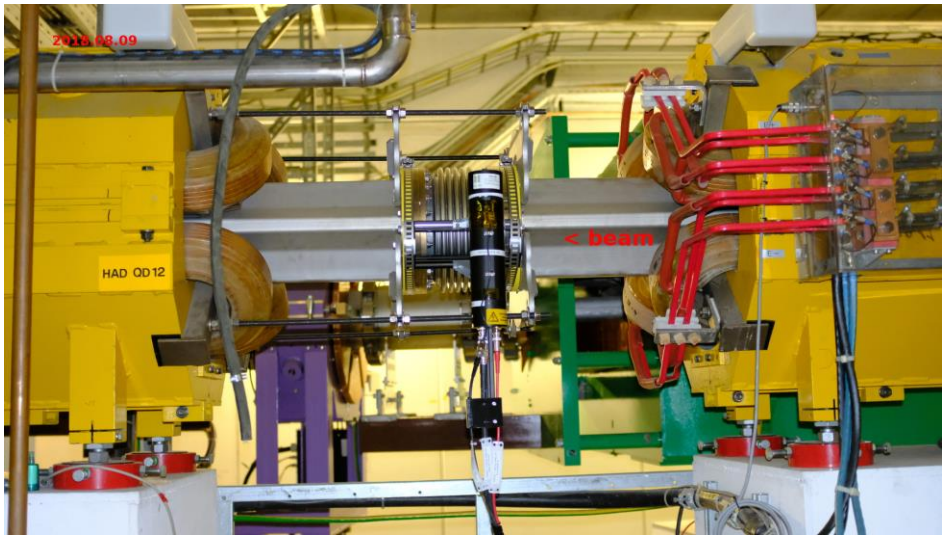


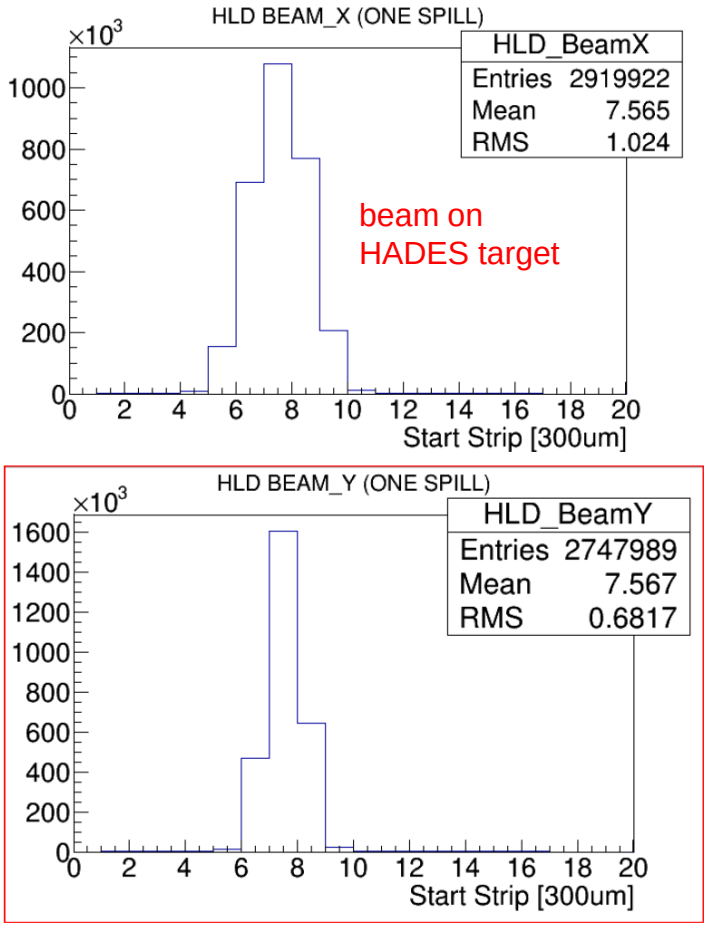
Figure 3: Design of the HTD site for the mCBM@SIS18 test-setup.



Outcome of Engineering Run 2018

- Test of control system, operational tools, settings, etc.
- Beam lines tested: HADES, Cave C and D, Cave A and M (HTP in June).
- Injection to ESR!
- Lot of time spend on HADES, very nice example of collaboration when HKR was using experiment's detector to optimize the beam quality.
- Spill structure optimization study.
- The features most missing for efficient operation:
  - potiboard (November 21st shift: Christoph, Marcus, Henning, GHADMU1 sign)
  - online model (MIRKO expert)

- Control system hugely improved with respect to June 2018.
- Issues: particle counters calibration, some grids got broken



courtesy J. Pietraszko

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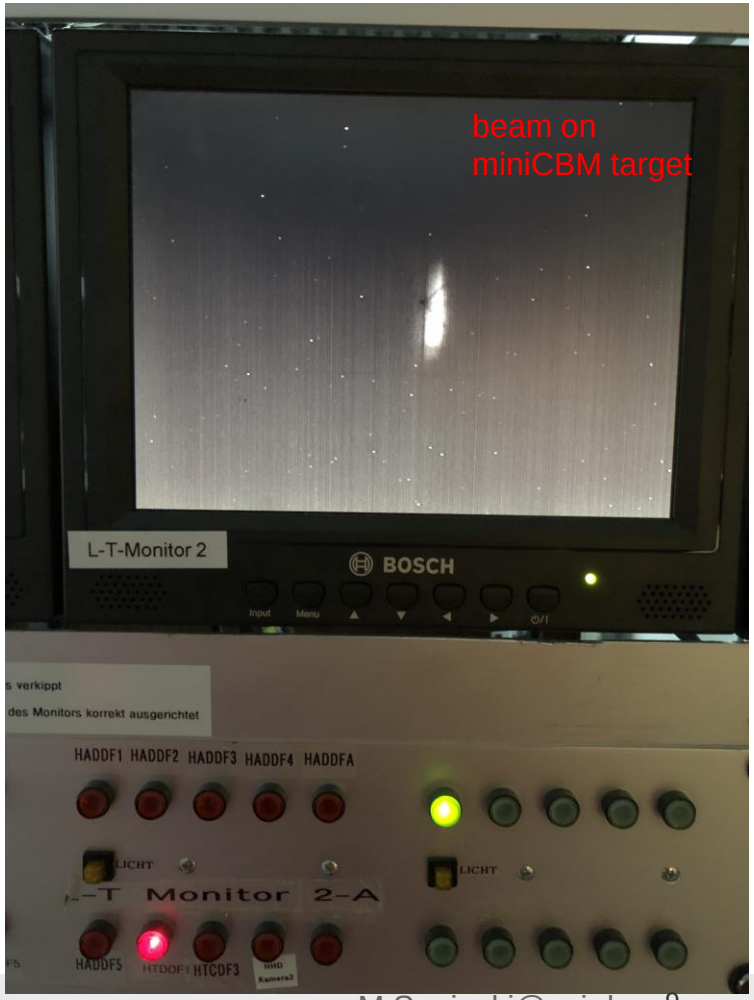
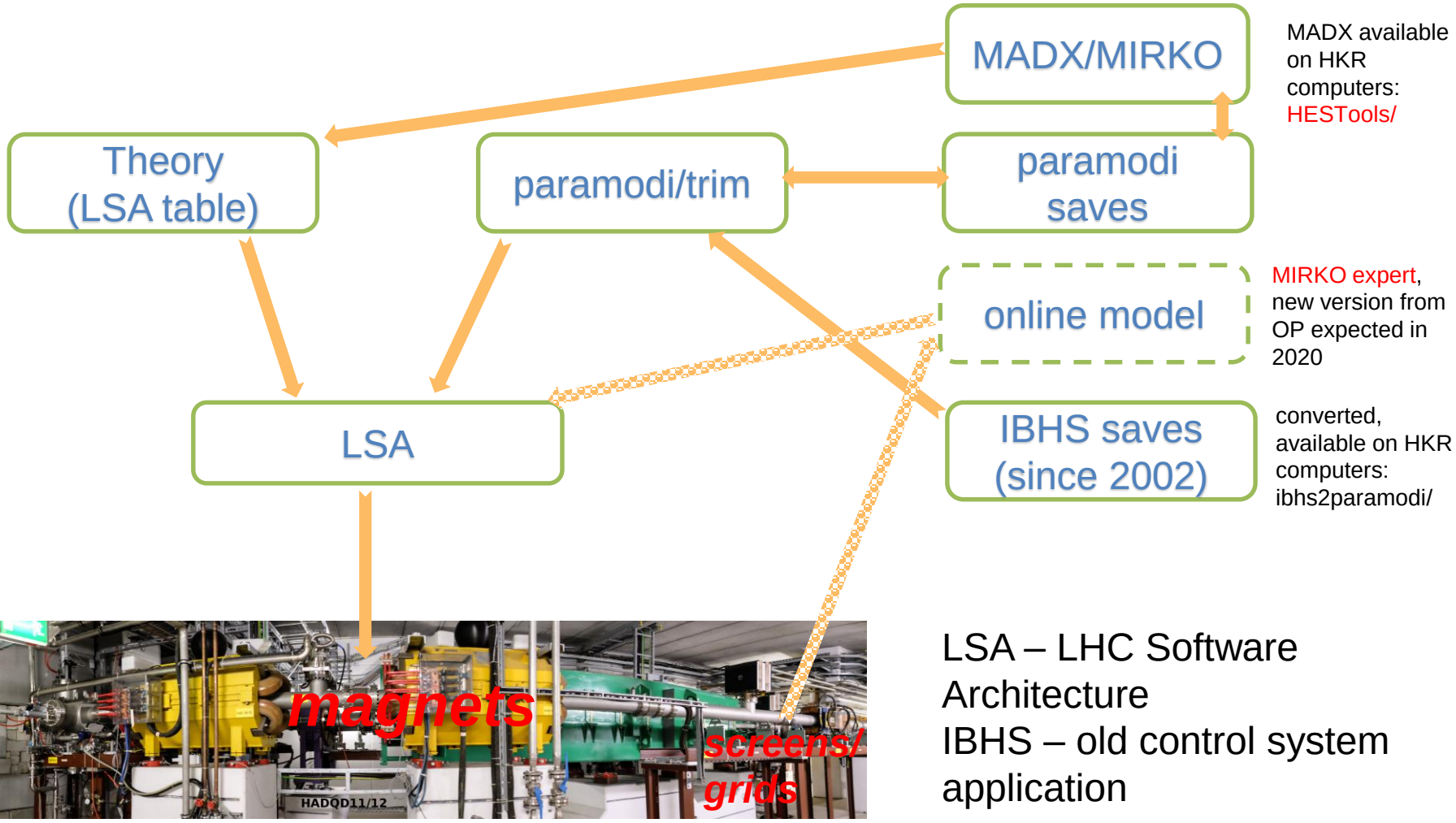


Optics settings: where do they come from?



MADX available on HKR computers: HESTools/

MIRKO expert, new version from OP expected in 2020

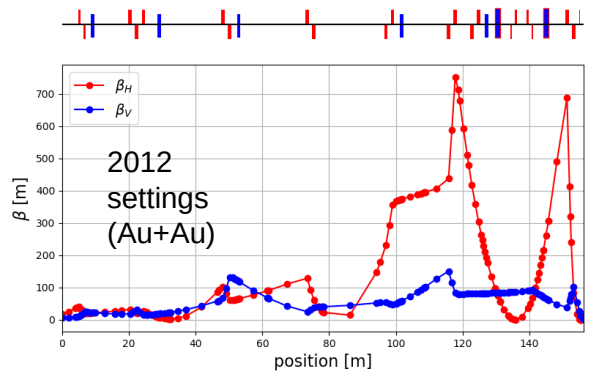
converted, available on HKR computers: ibhs2paramodi/

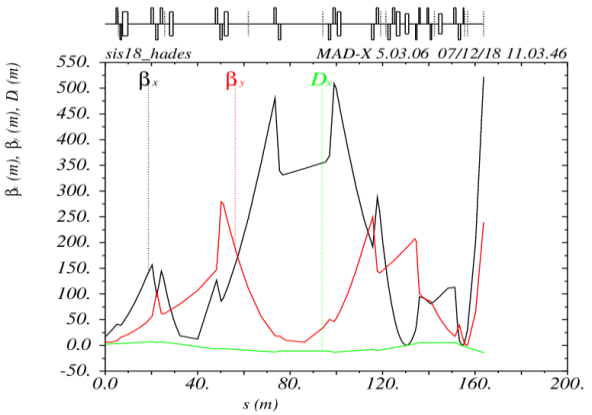
LSA – LHC Software Architecture
IBHS – old control system application

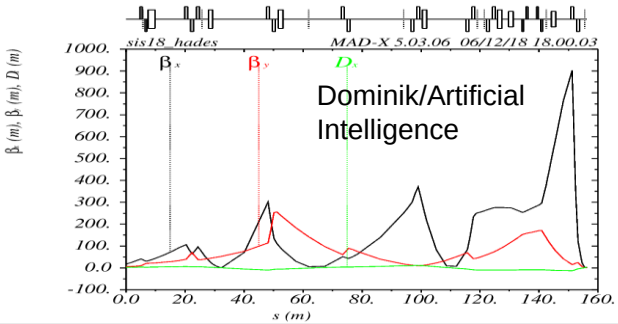
Example: HADES

- June: MIRKO optics from svn archive found not good, suggested to use settings from 2012.
  - rather large horizontal beam size
  - step focusing – good but beam is divergent after target
- October: new solution proposed, with more ‘telescopic’ focus on target.
- Other solutions proposed by S. Ratschow, S. Appel, D. Vilsmeier, some tested – ok.

Theory optics always needs tuning, but mainly with correctors (orbit to magnetic centers of quadrupoles), not too much with quadrupoles.
For example, in case of “telescopic” optics, a few minutes of tuning by a skilled operator gave a good focus.



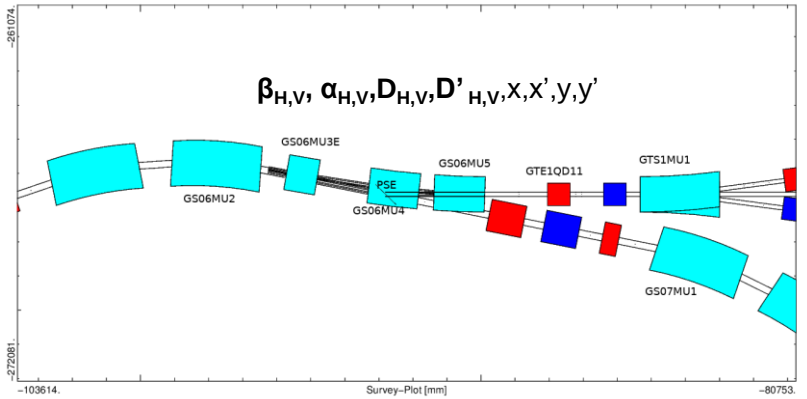


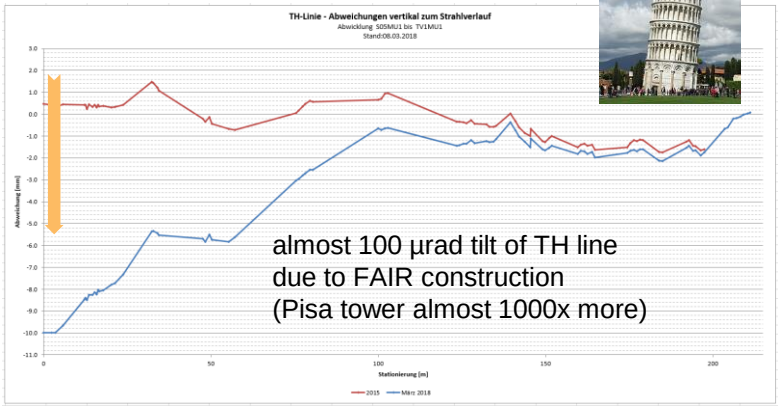


Quality of the optics models

Two groups of uncertainties:

- SIS18 extraction parameters
  - a set of parameters, established by Benno, not changed since years, the same for fast and slow extraction, probably measured, but this measurement is not documented.
- Positions of magnets, alignment, field gradient errors, fringe fields.
  - Benno: MIRKO settings – very good, verified and tuned over years.
  - Translation to MADX is quite tricky, probably some errors introduced during this translation.



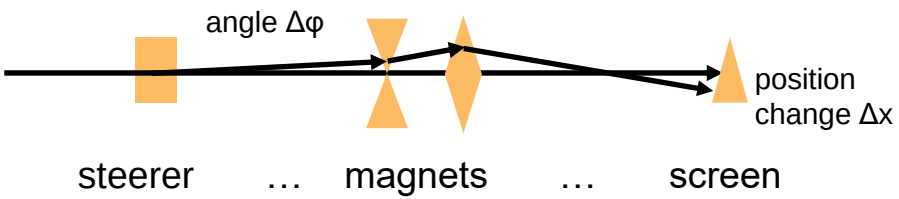


Optics measurement

- Trajectory response matrix measurement (measures transfer matrix).
- Methods to measure the twiss parameters (what includes assumption about SIS-18 twiss parameters at extraction point):
  - dispersion measurement
  - multiple screen method
  - quadrupole scan
  - beam tomography
  - …
- we have relatively good agreement between measured and simulated TRM at the beginning of the beam line, so we could in principle extrapolate twiss parameters to SIS-18 extraction point.

Model verification – response matrix

- Trajectory response matrix (TRM)



TRM element = Δx/Δφ [m/rad]

- MADX simulation, horizontal plane only: (horizontal and vertical planes can be coupled!)

this won't work for slow extraction

mag\grid	GTH1DG2G	GTH1DG4G	GTH2DG2	GHADDG1G	GHADDG4G
GTE2KX1	7.4271	6.3019	-3.3422	4.2328	-1.2284
GTH1KX1	4.734	14.028	14.569	-30.326	-1.1712
GTH2KX1	0	0	0	21.959	2.0856
GHADKX1	0	0	0	0	-5.3911
GHADMU1	0	0	0	0	-1.6931
GHADMU2	0	0	0	0	3.0659

steerers do not affect upstream screens

- Comparison of simulated and measured TRM allows to measure model errors of beam line elements, without extraction parameters!

Response matrix measurement (I)

- measurement on November 27, using Oksana's COCO* application (but paramodi can also do the job)

horizontal plane

preliminary

measurement

mag\grid	GTH1DG2G	GTH1DG4G	GHADDG1G	GHADDG4G
GTE2KX1	5.25	1.5	0	32.25
GTH1KX1	3.75	12	-9.75	-4.5
GTH2KX1	0	0	10.5	-26.25
GHADKX1	0	0	0	-12
GHADMU1	0	0	0	18.75
GHADMU2	0	0	0	-17.25

simulation

mag\grid	GTH1DG2G	GTH1DG4G	GHADDG1G	GHADDG4G
GTE2KX1	5.302	3.285	1.104	20.718
GTH1KX1	4.734	14.028	-9.834	-1.799
GTH2KX1	0	0	10.72	-21.052
GHADKX1	0	0	0	25.16
GHADMU1	0	0	0	1.528
GHADMU2	0	0	0	-2.651

good agreement

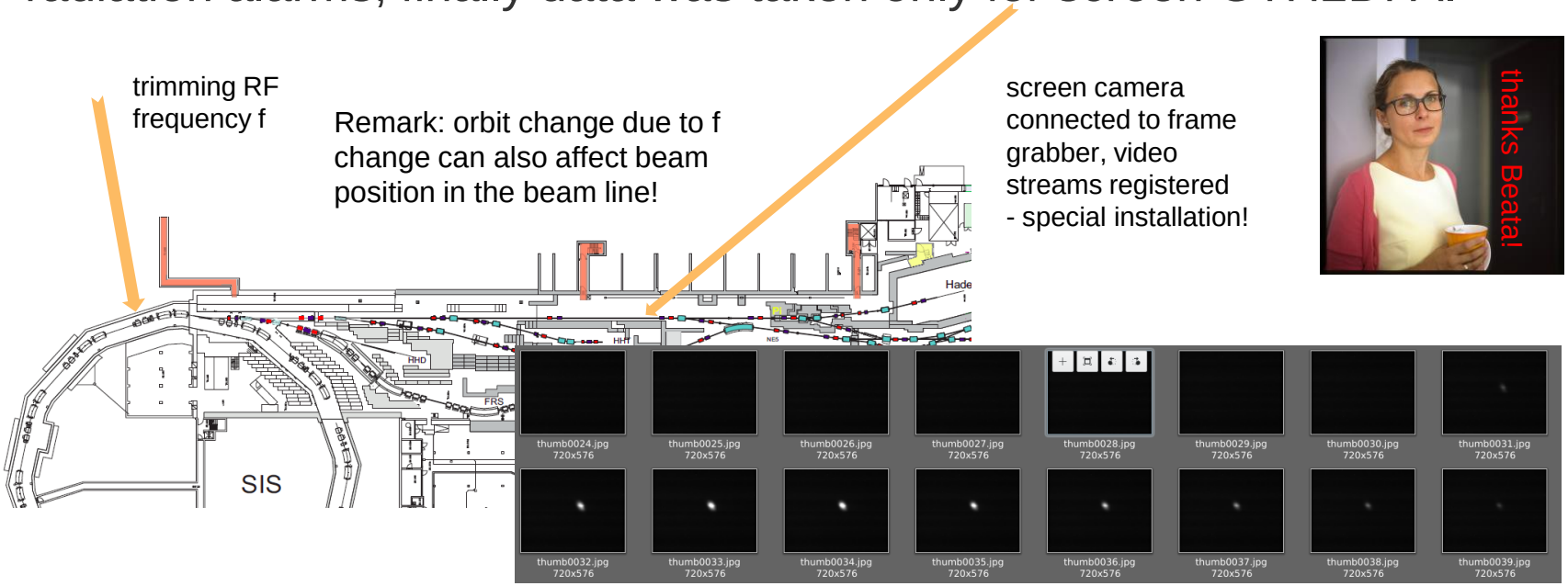
wrong, why?
- beam line layout not correct?
- GHADDG4G calibration problem?

Re-measure TRM in February, digitize GHADDF3V screen.

(*) COCO is an application to perform various orbit corrections (local, global) based on TRM measurement. For the moment it is an expert tool.

Dispersion measurement (I)

- Initially planned to measure dispersion at all screens and grids on HADES beam line, but measurement lead to high beam losses and radiation alarms, finally data was taken only for screen GTH2DFA.



Analysis: video file (mpeg) split into frames. For a subseries of frames (manually selected, spill length depends on frequency trim) with reasonable signal horizontal profiles created and added. Gaussian fit performed, mean value determined. It will be easier next Beam Time!

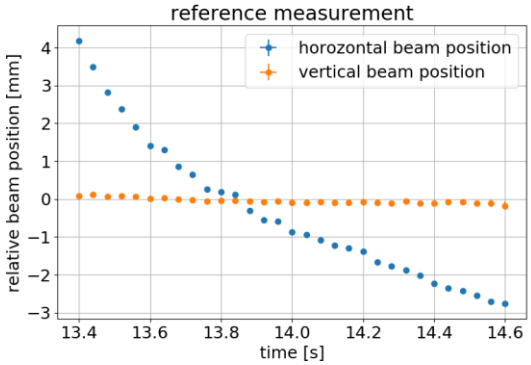
Dispersion measurement (II)

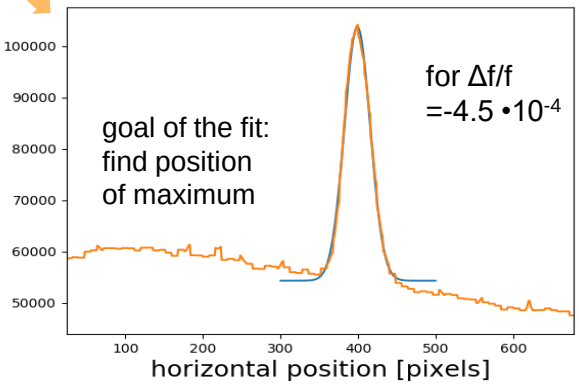
- The beam moves horizontally during the spill, we find the average position for various Δf/f

- $\frac{\Delta p}{p} = -\frac{1}{\eta}\frac{\Delta f}{f}$ where η is slip factor:

$$\eta = \frac{1}{\gamma_{tr}^2} - \frac{1}{\gamma^2}, \qquad \gamma_{tr}^1 = 5.58$$

- result: 1.6 m, but MADX model gives 3.5 m and MIRKO 4 m (Petra).

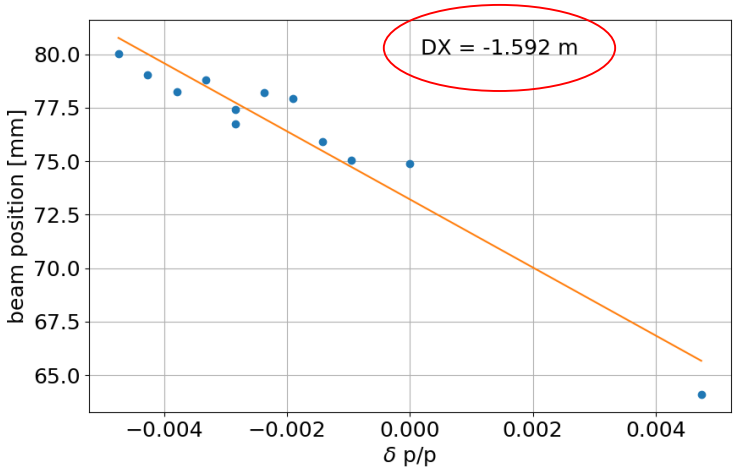




(averaged over spill)

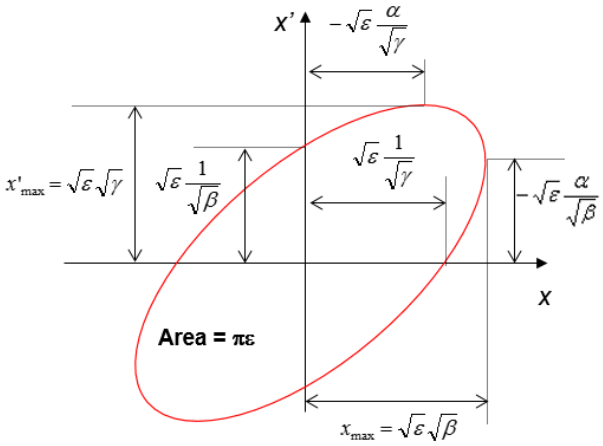
"to be investigated"

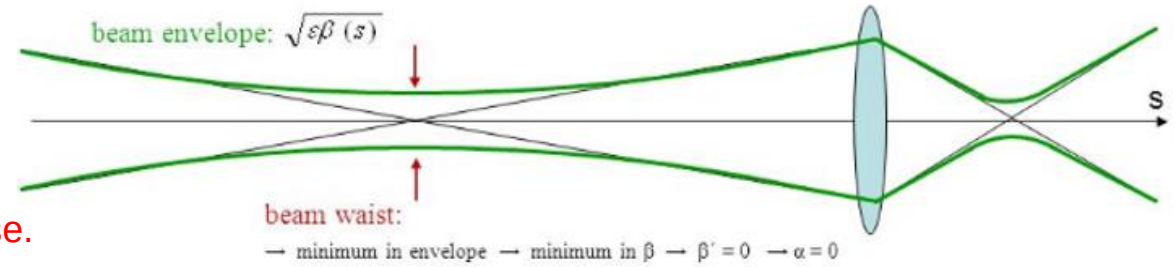
idea: repeat this measurement with KO or fast extraction.

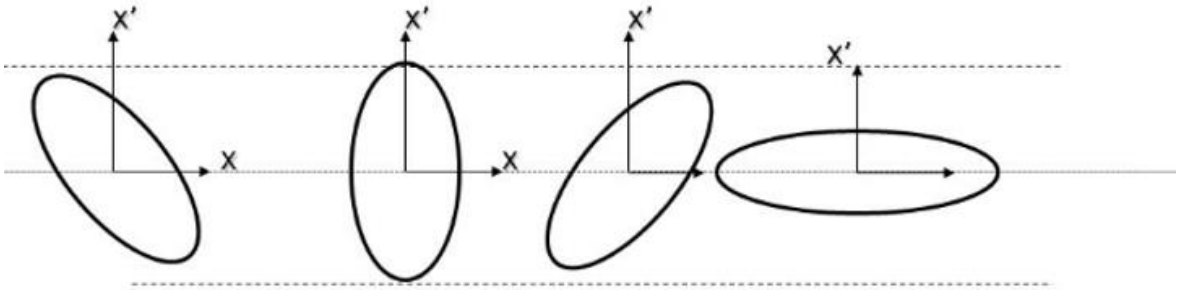


Quadrupole scan - theory

- Beam ellipse = region in phase space containing the beam particles (not always ellipse).
- Ellipse parameters are related to twiss parameters.
- It is easy to measure beam size, but rather difficult to measure distribution of angle of beam particles.
- Ellipse rotates in phase space as beam propagates.
- Rotation is affected by upstream quadrupoles.
- Changing the quad strength and measuring the beam size we obtain various projection of the beam phase space ellipse.
- From those projection we can reconstruct emittance and twiss parameters in the location of quadrupole.



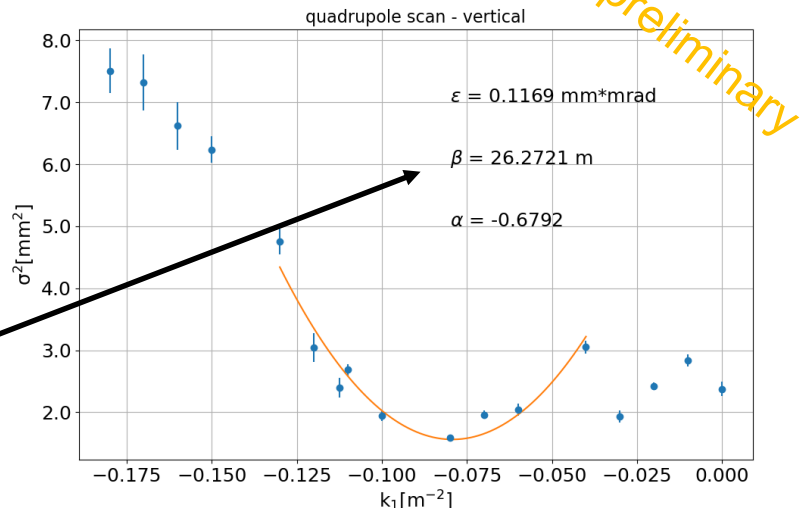


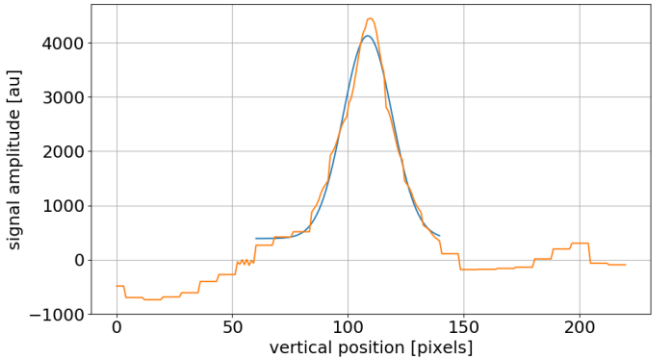


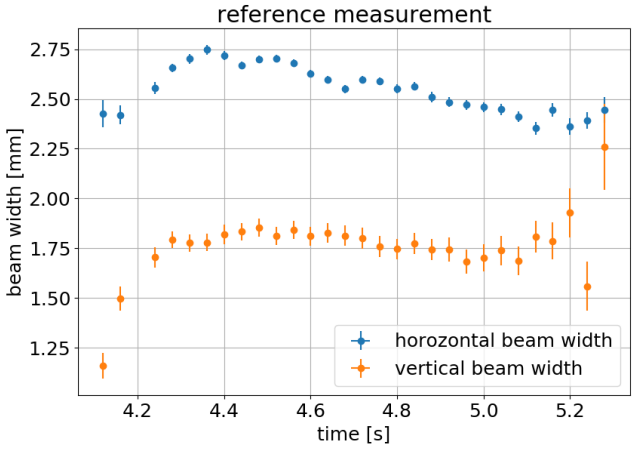
Example of quadrupole scan (I)

- Preliminary results for HADES beam line optics used for physics test.
- Vertical beam size varies during spill by <10%.
- Beam not really Gaussian (try beam tomography in February).
- Profile quality not good (digitization will help).
- MADX model gives:
  - β_y = 17.35 m
  - α_y = 0.87

magnet GTH2QD12:



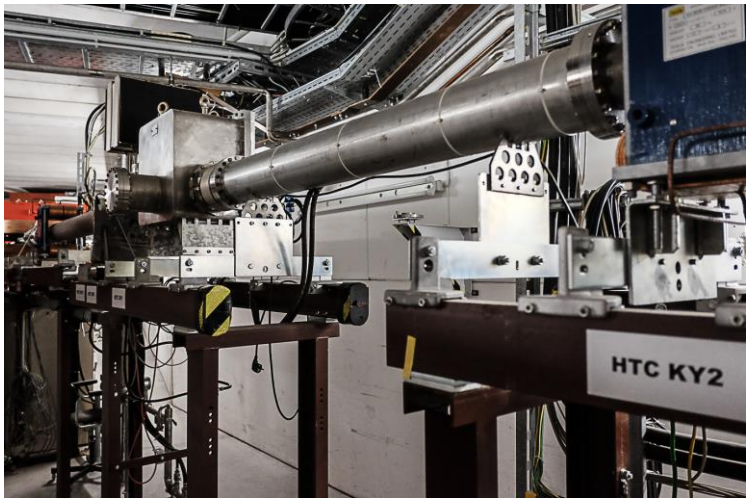




Plans for 2019 and behind

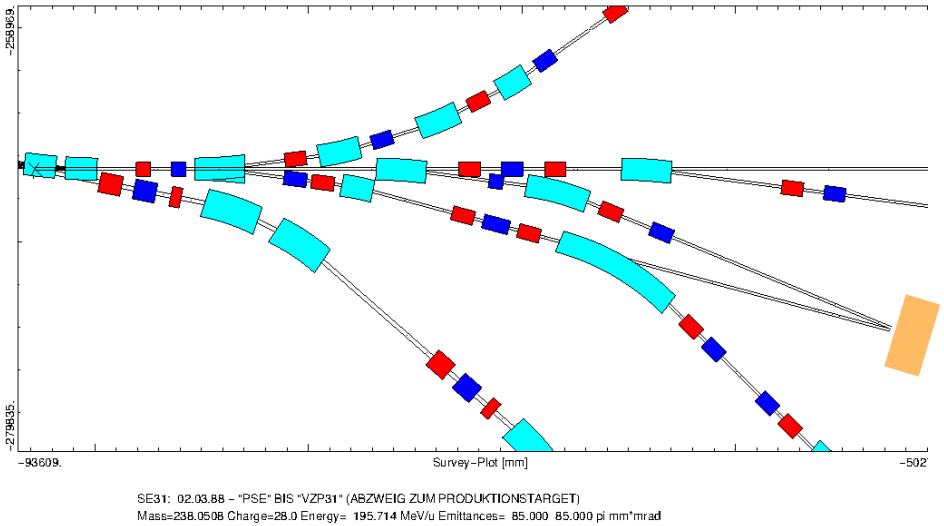
2019:

- Improve optics models quality.
- Digitization (Cupidization) of GTH2DFA (February)
- WiFi installation in NE5
- Scintillating screen and DK in front of Cave C (+ 2 screens in Cave)
- HADES: beam on target steering knobs
- Extra shielding pion target roof
- Exchange of vacuum chambers GTH2QD21/22
- target position knobs for HADES



2020:

- installation of new dump line
- upgrade of vacuum control system
- digitization of other screens
- Exchange GTE2DK4 (beakable SEM-Grid) – new system
- BLM installation inside pion target bunker



Summary

- Goals of the Engineering Run achieved, HEST is *under control*.
- Lot of interesting measurements done (many not discussed here, z.B.: beam loss monitors, particle counters, knob tests, etc, etc.)
- Still a lot of work for modelling! Models contain errors.
- We need online model application and it will be written.
- Acknowledgements: C. Kleffner (previous MK), B. Schlei (LSA hierarchy for HEST), O. Geithner (TRM), S. Ratschow (optics), B. Walasek-Hoechne, Ch. Schmidt (Leuchtargets), P. Boutchakov (BLMs, PDCs), M. Stein (grids software), J. Pietraszko (HADES), Ch. Hessler, operation crew and many others

THANK YOU FOR YOUR ATTENTION

Additional slides

Response matrix measurement (II)

vertical plane

preliminary

measurement

mag\grid	GTH1DG2G	GTH1DG4G	GHADDG1G	GHADDG4G
GTE1KY1	21.75	36.75	-27.75	-1.5
GTH1KY1	4.5	12.75	-4.5	-0.75
GHADKY1	0	0	0	0
GHADKY2	0	0	0	0
GHADKY3	0	0	0	0.75
GHADKY4	0	0	0	0.75

good agreement

factor 2?

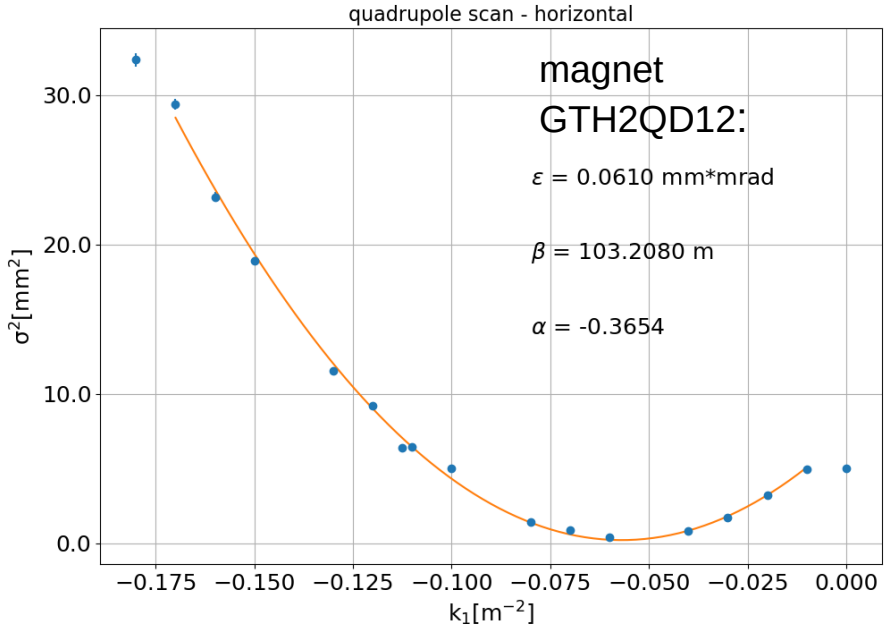
simulation

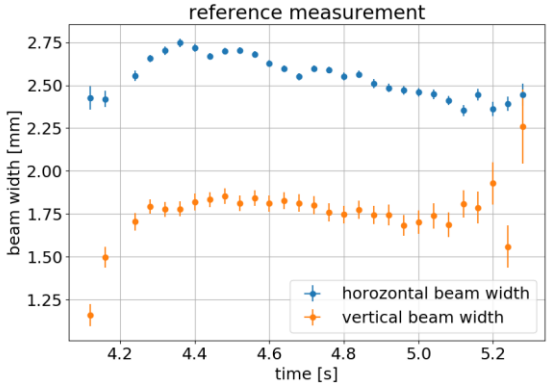
mag\grid	GTH1DG2G	GTH1DG4G	GHADDG1G	GHADDG4G
GTE1KY1	25.355	35.485	-73.513	-75.37
GTH1KY1	5.234	14.528	-10.562	-6.177
GHADKY1	0	0	0	-22.572
GHADKY2	0	0	0	42.89
GHADKY3	0	0	0	12.88
GHADKY4	0	0	0	1.38

wrong beam line layout towards the end:
recheck during shutdown!

Example of quadrupole scan

- Preliminary results for HADES beam line optics used for physics test.
- Location of the measurement is not dispersion free.
- However dp/p for quadrupolar slow extraction is very small, so dispersion effect should be small (discutable).
- Beam size varies during spill by ~10%
- MADX model gives:
  - β_x = 136.5 m
  - α_x = 14.15
- Emittance, typical value *rumor*: 0.25 mm*mrad (factor 4 larger)





Dispersion measurement (I)

- Dispersion measures transverse change of beam position with relative momentum change: $D = \frac{\Delta x}{dp/p}$ [m].
- Dispersion is generated by dipoles, so it is small in vertical plane.
- Dispersion-free regions can be required by experiments (dispersion contributes to the beam size) or to simplify measurement of beam properties (see quadrupole scan).
- Measurement od December 14th

Example of quadrupole scan (II)

- It is always nice to see beam ellipses…
- Fitting the optics to this one measurement gives large discrepancy between model and the fit, mainly due to very different beam parameters at extraction.
- This is not a real result yet, just shows what methods to use, how to proceed with existing data analysis, how to proceed with further measurements, where to improve instrumentation.