Status of HADES beam line

Operations beam physics and techniques salon

GSI, November 7th, 2018

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Wikipedia: God of the dead, the underworld, subterranean regions, night, dreams, curses, death, darkness, the earth, fertility, riches, mortality, the afterlife, and metals.

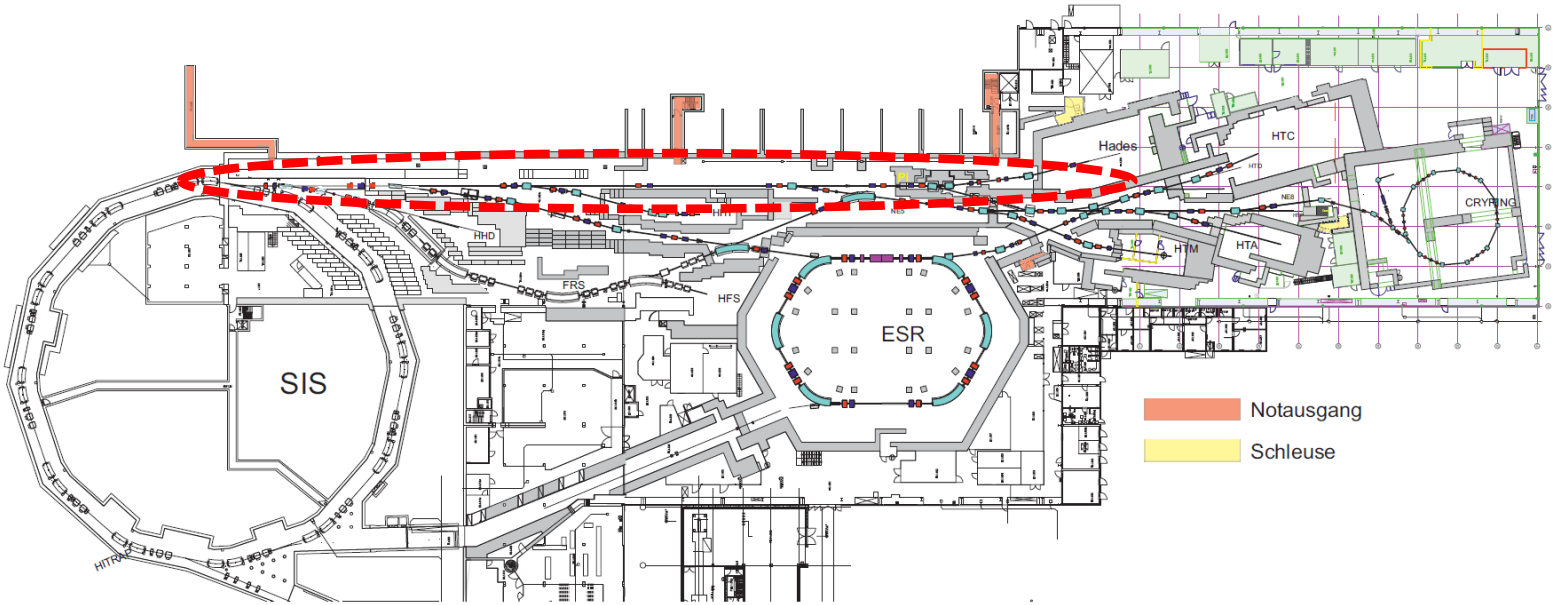
hmm…

Outlook

- Introduction to HADES beam line.
- HADES experiment - physics with silver beam.
- Upgrades during the last shutdown.
- Survey and alingment.
- Optics and recent beam history:
  - June and July optics, radiation alarms
  - 2012 optics (current)
  - alternatives
- Engineering run.
- Some additional expert tools.

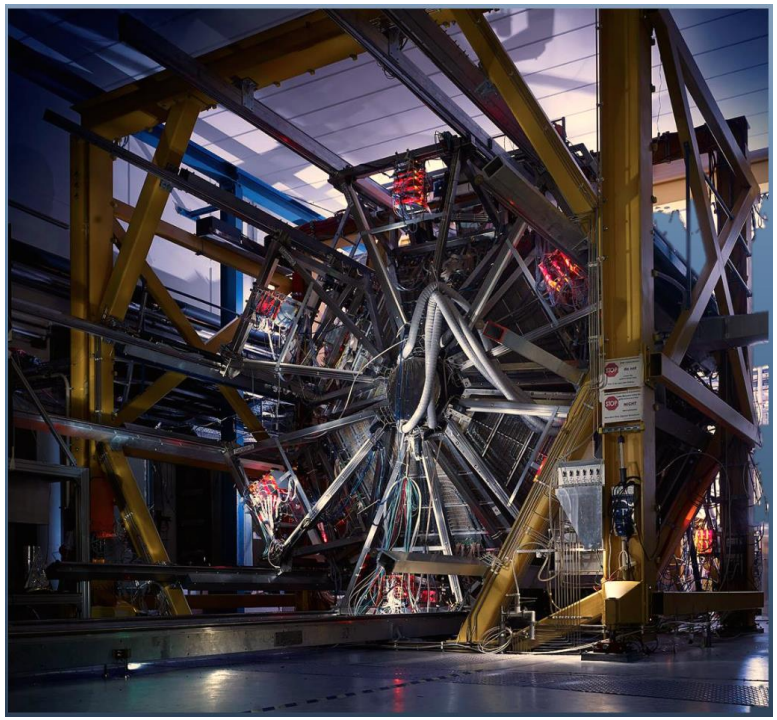
Introduction

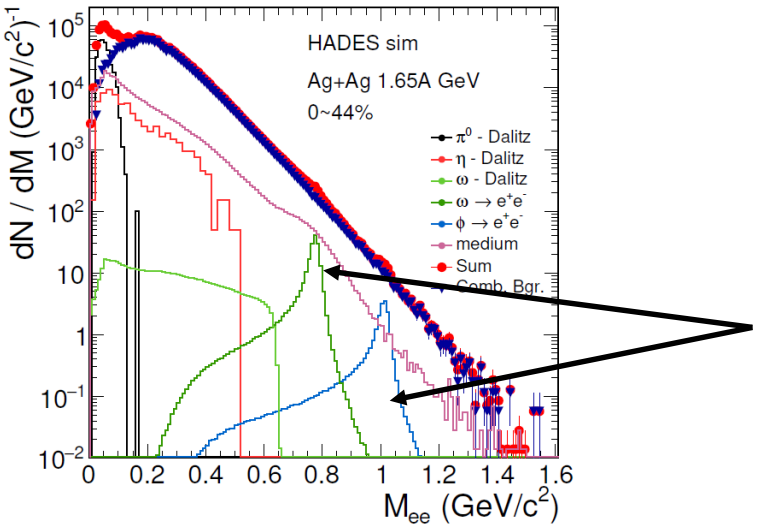
- HADES beamline is a part of HEST
- length: 156 meters
- two modes of operation: with and without pion target
- HADES experiment is elevated, therefore the last section of beam line brings the beam higher, coupling horizontal and vertical optics



HADES physics with silver beam

- HADES: measurement of properties of hadron resonances and baryon-rich matter.
- Next beam time: Ag+Ag at 1.65 GeV/u.
- Several objectives, for instance: spectroscopy of light ω,φ vector mesons in dilepton channels, which allow for distinction between various models of nuclear matter.

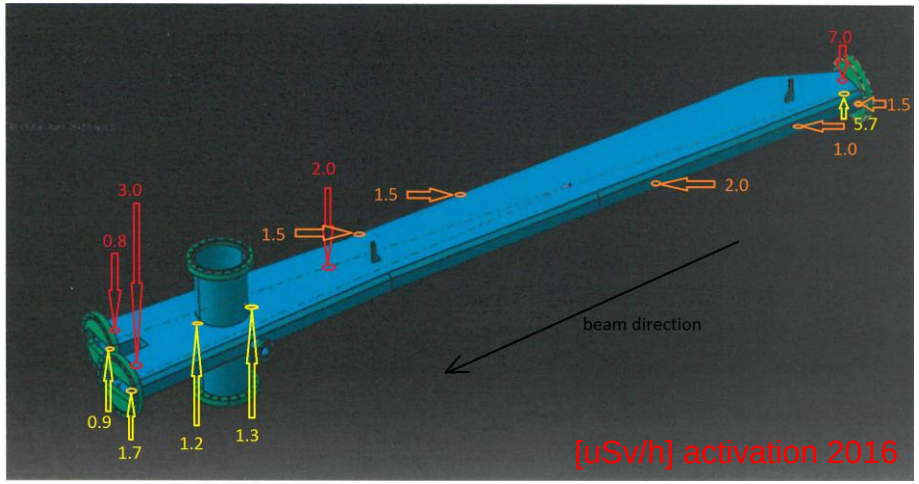




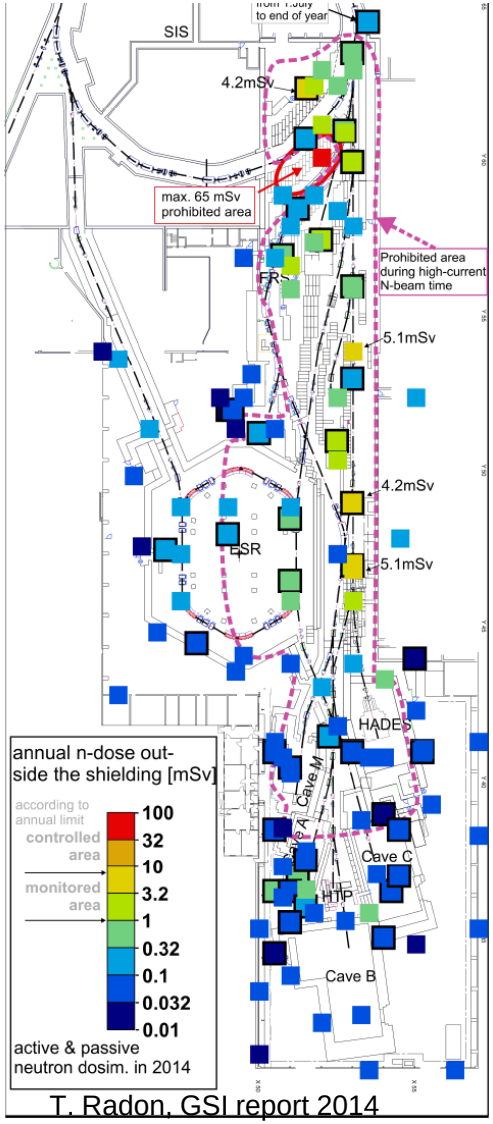
amplitude and shape of these peaks in dielectron spectrum.

HADES beam line upgrades 2016-18

- HADES beam line upgrade was the biggest project on HEST with budget ~500 kEuro.
- It focuses on adaptation to very high intensities, needed for pion run. The 2014 run produced yearly dose within 40 days. (1.9 GeV/u Nitrogen beam with 6E10 ions/s).
- Particularly strong activation at GTH3MU1 and downstream.



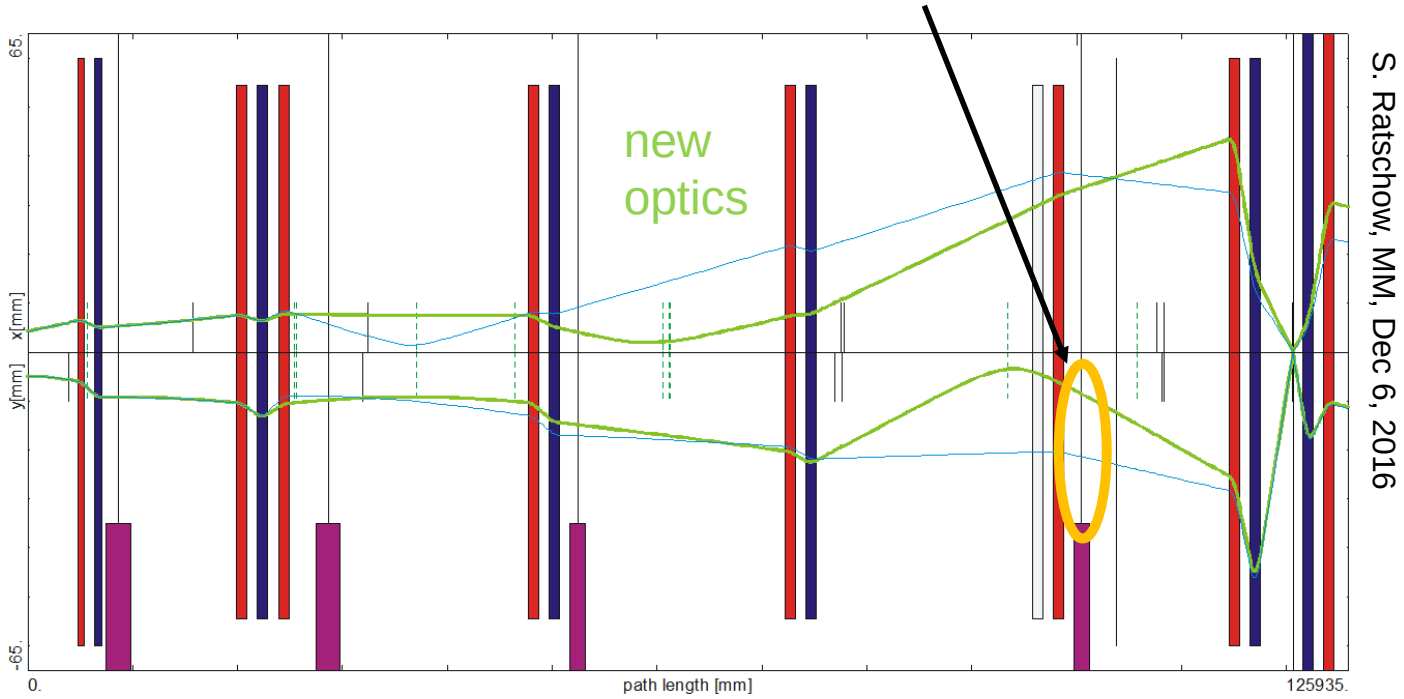
- The next pion run is expected in 2020, but we can profit from some upgrades now.



T. Radon, GSI report 2014

HADES beam line upgrades 2016-18

- New optics minimizing vertical beam envelope in GTH3MU1

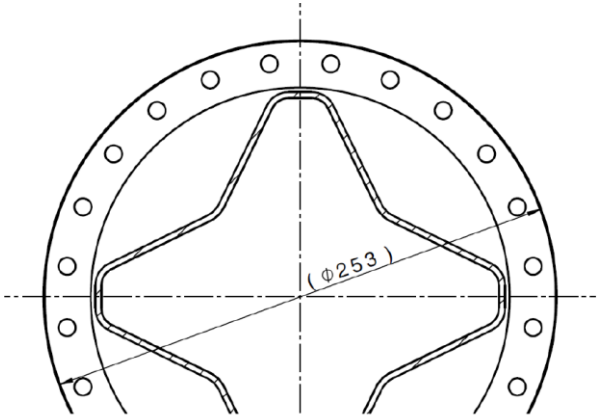


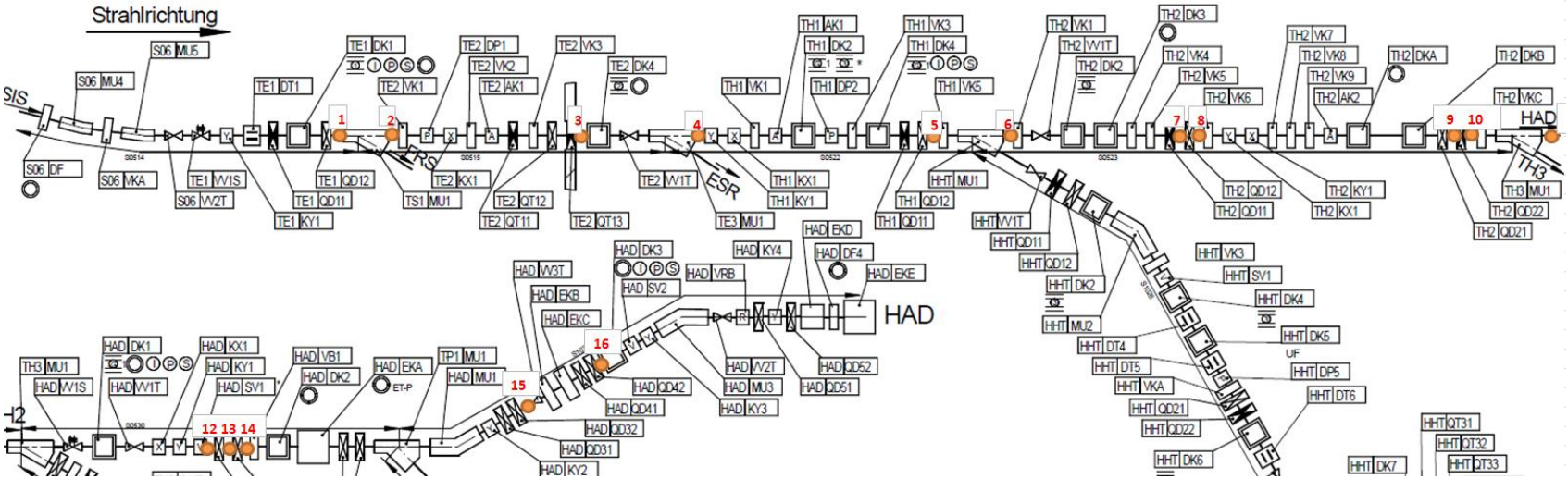
S. Ratschow, MM, Dec 6, 2016

- **Necessary**: run GHADQD12 at 280 A, while nominal current is 271 A. Test done, stable operation also with 295 A.
- **Recommended:** increase physical aperture inside strong focusing quadrupoles GHADQD11/12. Done.
- **Recommended:** increase physical aperture inside GTH2QD21/22.
  Discussed, partly prepared but not done! To be done in 2019.

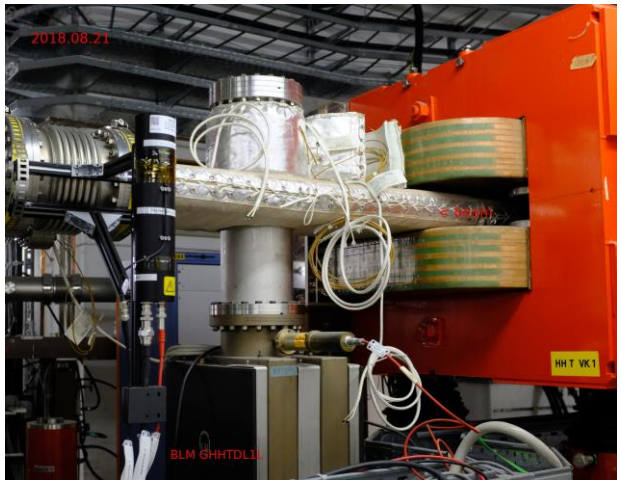
HADES beam line upgrades 2016-18

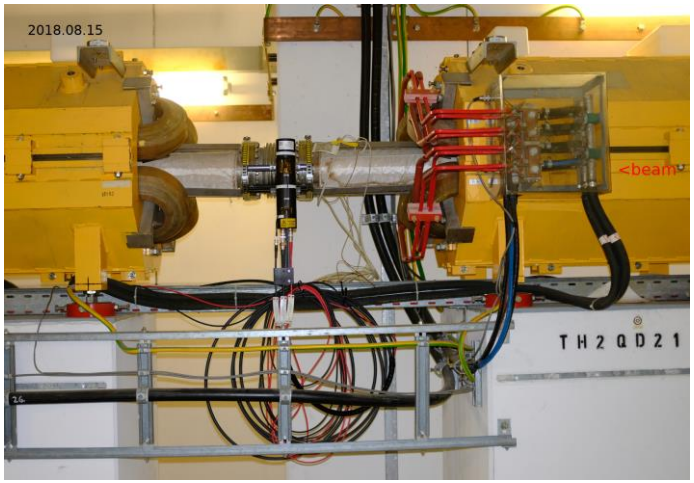
- GHADQD11/12 chambers: aperture increase from 60 to 90 mm (K. Dermati and others).
- Installation of Beam Loss Monitors with FAIR-standard DAQ (LASSIE) (Beata and Plamen)
  - motivation: better localization and estimation of beam losses.
  - scintillators: sensitive to MIPs (not only neutrons as in case of BioRems).
  - ~ MHz counting rate.
  - potential issue with saturation, not useful for fast extraction at all.
  - localization of 16 monitors:

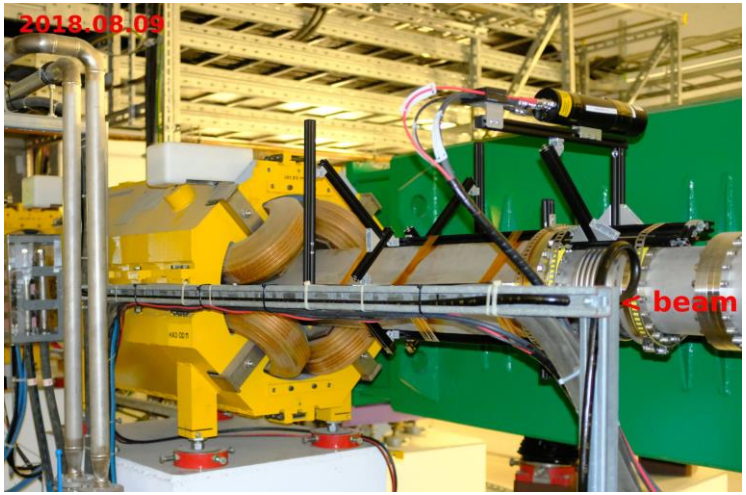


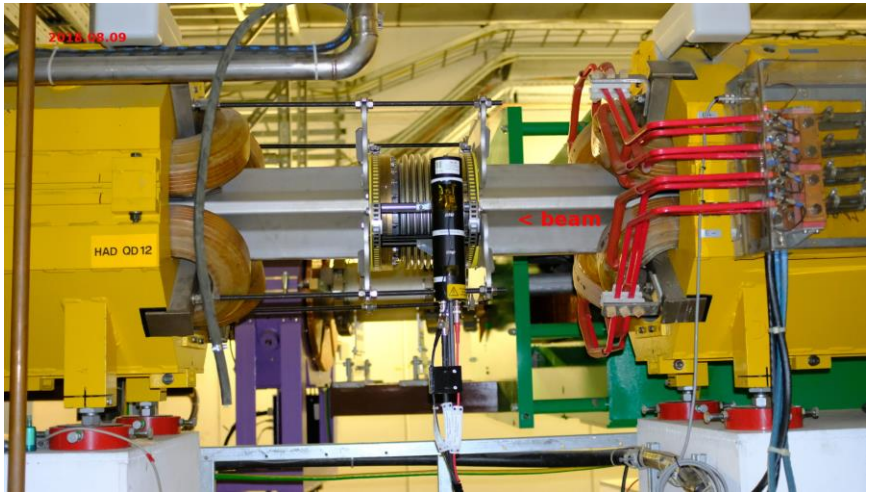


HADES beam line upgrades 2016-18



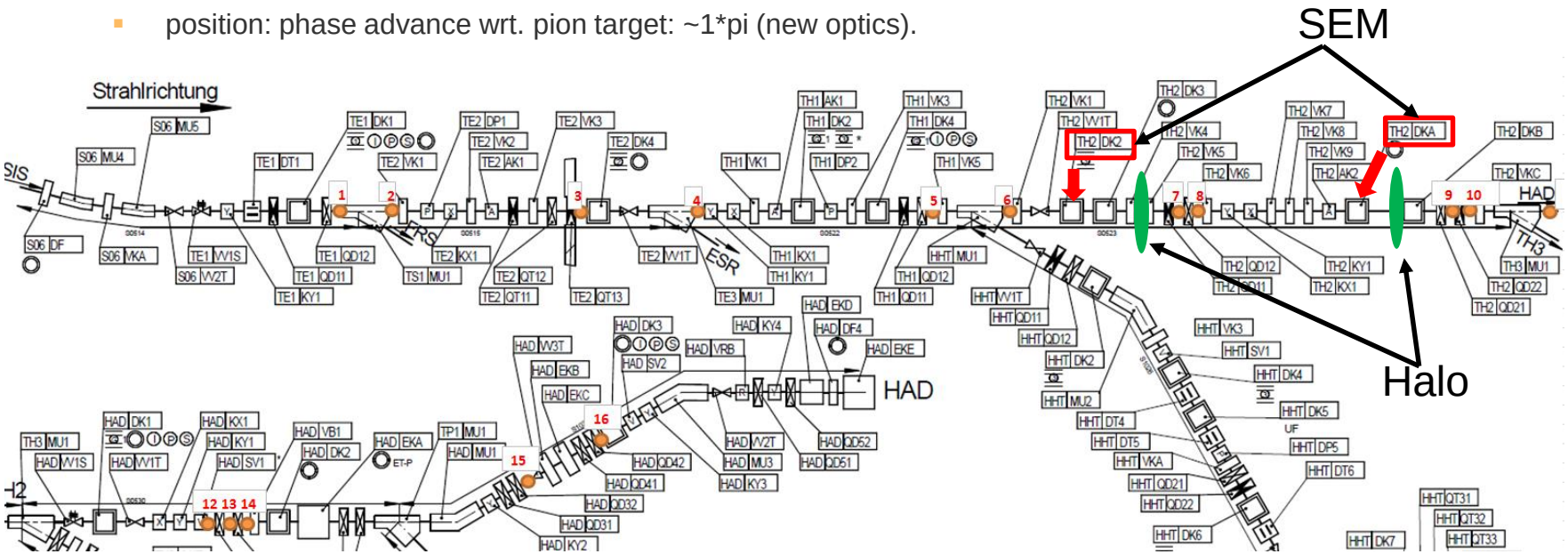






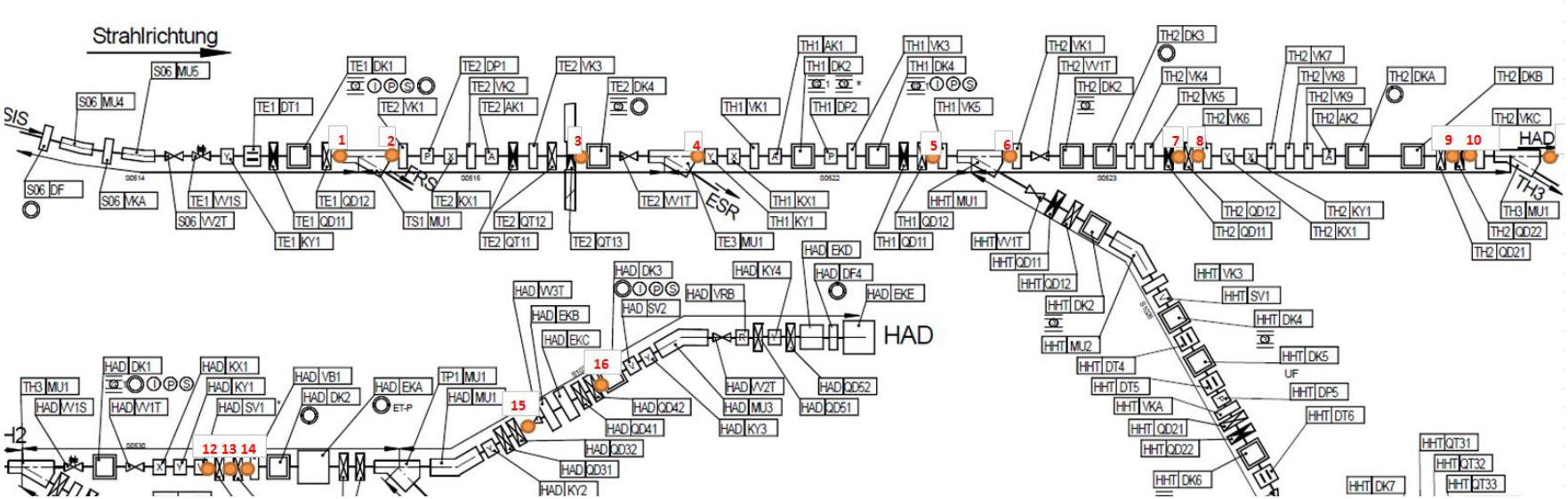
HADES beam line upgrades 2016-18

- Installation of additional SEM detectors (P. Boutachkov):
  - motivation: beam transmission measurement at high intensity, when other PDCs give too much beam scattering therefore trigger radiation alarms.
  - two detectors installed.
- Installation of beam halo monitors (two pairs of scintillators moveable by small steps, Ch. Andre):
  - detectors were unused on the M-branch.
  - motivation: investigation of the beam shape and time structure.
  - position: phase advance wrt. pion target: ~1*pi (new optics).



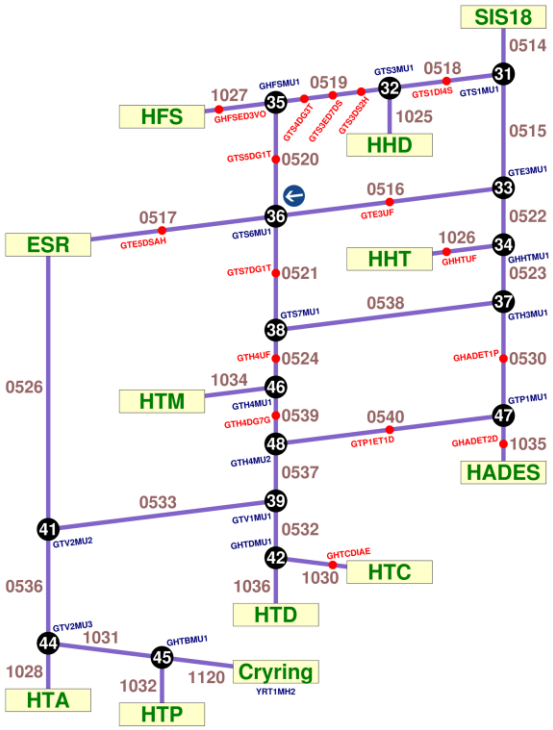
HADES beam line upgrades 2016-18

- Data saving for grids (M.Stein).
- API for grid application (M. Stein, O. Geithner) – allowing COCO application (Closed Orbit COrrection) to read beam positions directly from the grids.
- CUPID – digitization of 3 (out of 10) scintillating screens (B. Walasek). The others will be digitized subsequently.



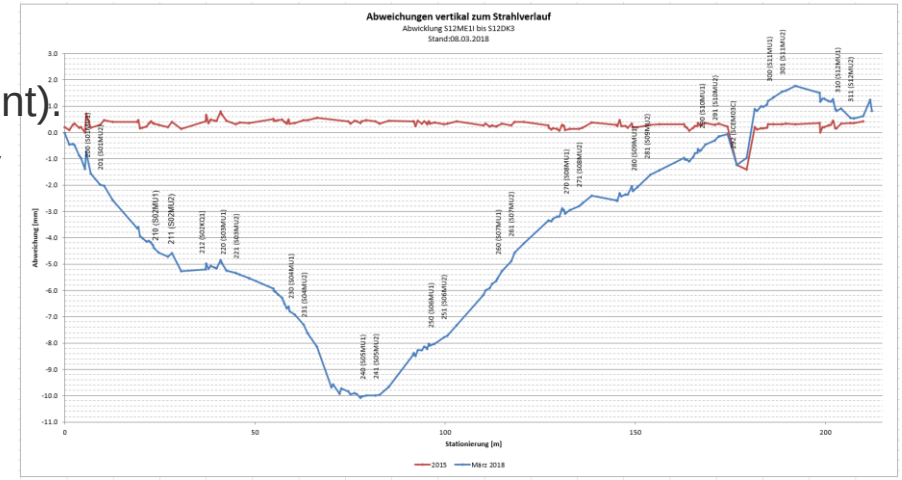
Shutdown 2016-18: LSA

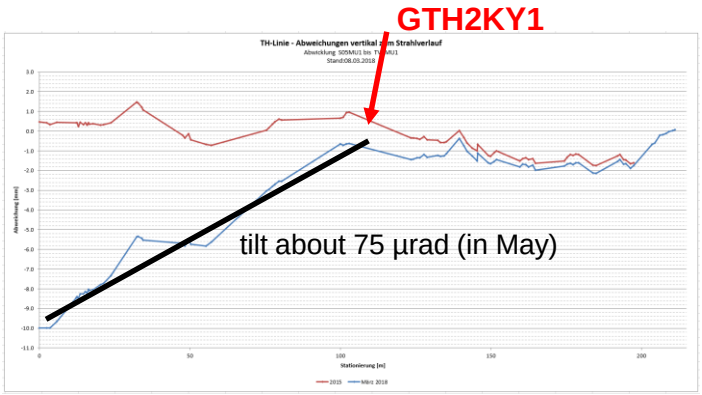
- Change of the control system - major work during shutdown.
- CO took care of front-end adaptation for power converters, BI – for instrumentation.
- Bernd Schlei – responsible for creation of HEST hierarchy in LSA.
- HEST divided into:
  - 31 particle transfers (between switching dipoles)
  - 51 accelerator zones (particle transfers additionally divided in the location of strippers/internal targets/degraders).
- 23 theory optics stored in bbe svn repository (MIRKO files).
- They had to be checked and converted to csv files which are imported to LSA tables.
- There are two tables: with kL-values of magnets and with twiss parameters
- Details were presented at salon on Aug 30th, 2017.

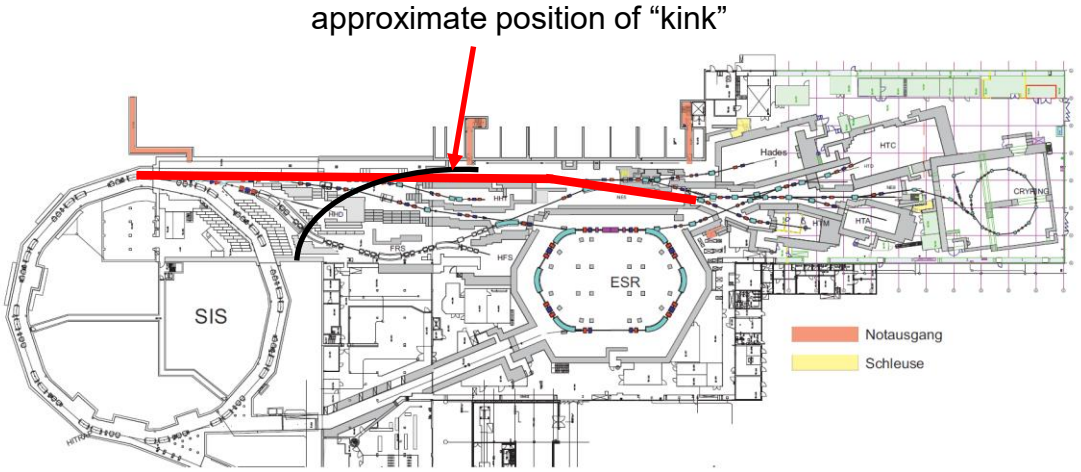


Survey and alignment

- Surveys done by Ina's team.
- SIS18 tilt is about 145 µrad (ground movement).
- HEST tilted following SIS18 until a 'kink' after which beam lines have not moved.
- Decided to compensate the tilt with 100 µrad steering using existing steerers (mainly GTH2KY1), which can steer up to 2.4 mrad at 18 Tm.
- This compensation is NOT in default optics because steerers values are 0 in LSA.

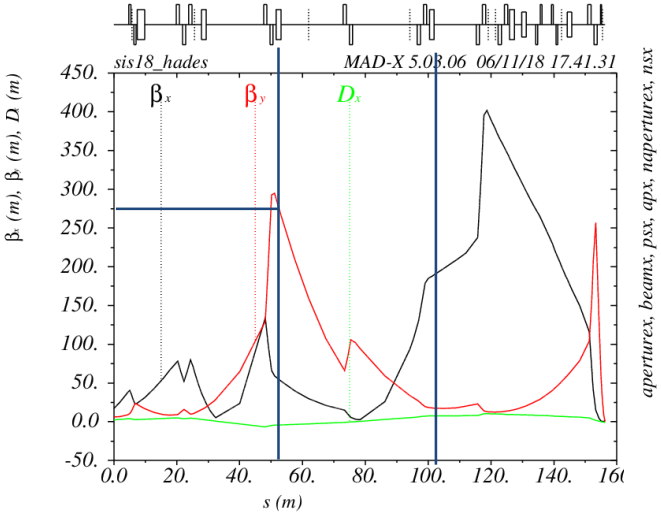




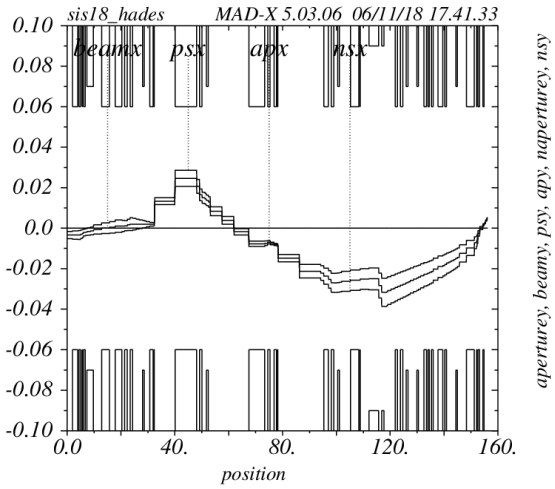


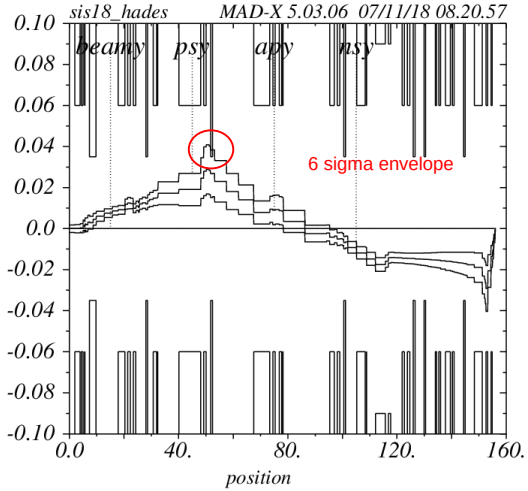
Optics – June 2018

- LSA optics are taken from theory settings (in forms of MIRKO files) stored in bbe svn repository.
- The original HADES optics had errors, it was not used in June.
- June 26 – first attempt to bring beam to HADES, optics taken from IBHS file (2014 run), tuned by David Ondreka. Beam: $^{48}Ca^{20+}$, 520 MeV/u, extraction time 2 s, intensity about 10^8 ions/spill.



target: betaH=1.51 m, betaV=0.59 m



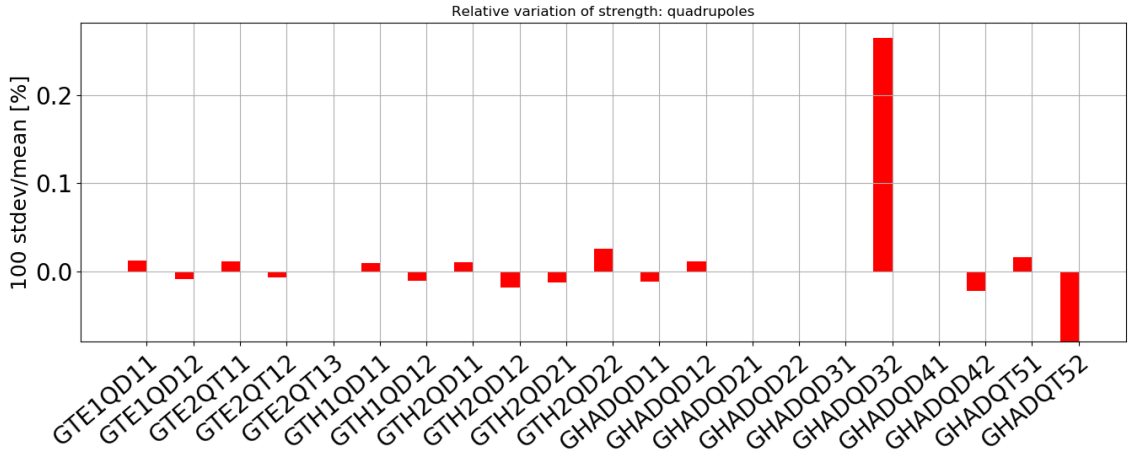


Paramodi save:
2018-06-30_18-28-18_SIS18_RING_HADES_20180628_100425.C1.txt
no digging in trim history!

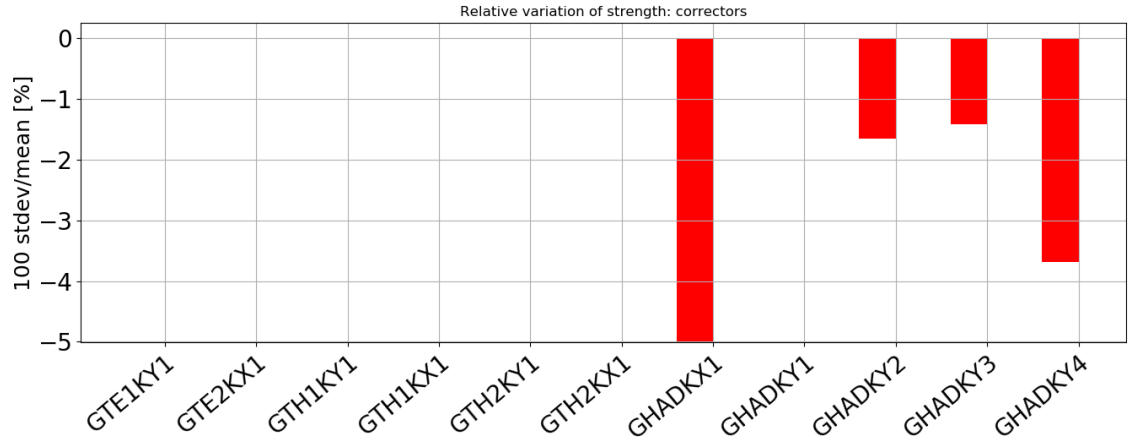
Optics – June 2018 (cont.)

- Beam was seen on all scintillating screens along the beam line.
- Some, very defocused, particles have been seen on HADES segmented diamond detector (but data were not saved).
- It was a good start for further optimization, but:
- Radiation alarms triggered. Due to this and other problems we could not continue.
- Jerzy Pietraszko (HADES) suggested to use 2012 Au+Au settings as default optics.
- 8 IBHS saves from this run are available:
  HS-197AU-120417-1235-SI-TH-HAD.DAT,
  120418-0615, 120419-0553, 120424-0648, 120426-1709, 120427-2246, 120428-1405, 120501-1412
- These saves are very similar one to another (see next slides).

2012 optics – IBHS saves analysis

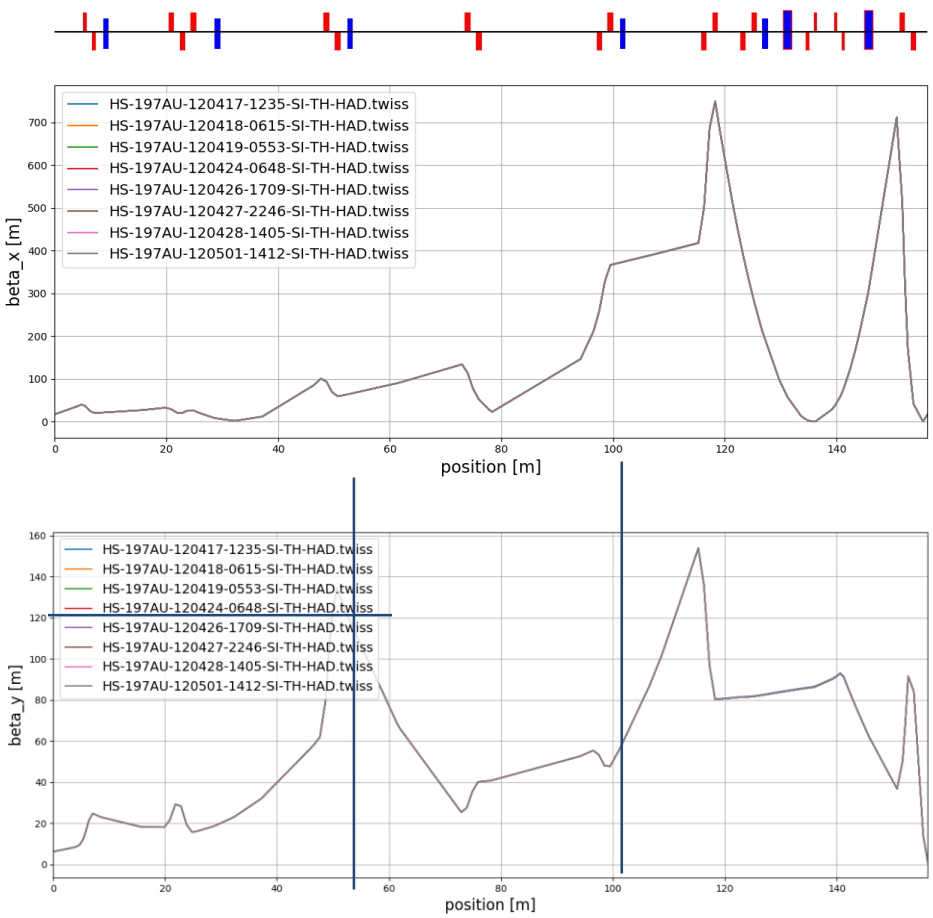


Very small tuning of quadrupoles (beta functions look identical)



Operators were mainly playing with horizontal and vertical steering at the end of the beam. Also GHADMU2 was tuned.

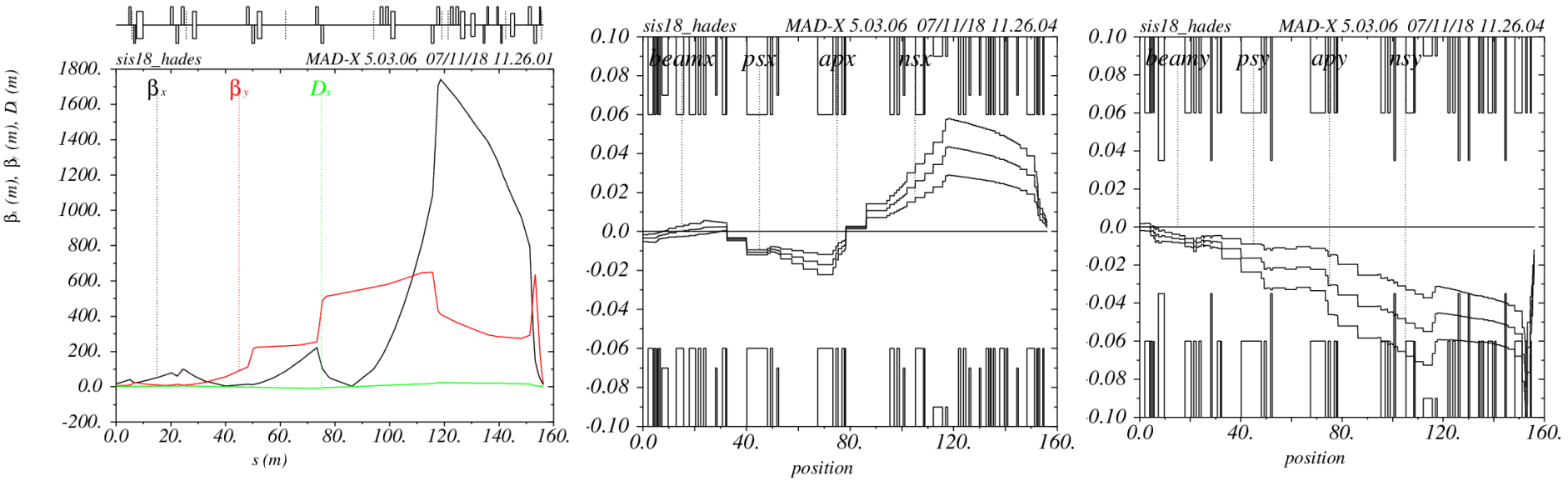
2012 optics – IBHS saves analysis



New optics have larger horizontal beta function then June optics, but vertical beta in GHHTMU1 (critical location) is 3 times smaller.

July test

- The 8 IBHS saves were translated to Paramodi input files and were ready to be applied.
- In addition the Paramodi save of June beam was there.
- However radiation alarms triggered again, control system was not stable and finally a fire in Unilac RF gallery occurred.
- from Paramodi save 2018-08-01_13-30-07_SIS18_SLOW_HADES_CAV_TRANS_20180709.C1.txt we have indication of what has happend:



(no digging to trim history)

Radiation alarms

- Radiation alarms triggered:
  - in HHT Cave (pos B), probably due to losses on GHHTMU1.
    Remedy: use 2012 optics and
    put HHT cave (NE6) into Beam Mode
  - outside of HADES cave, most likely due to losses after pion target. This is generally surprising because such a low intensity beam, even completely lost on vacuum chamber, should not give radiation alarm outside of shielding (2014 run: 10^{10} ions/s).

    Remedy?

positions of radmons which gave signal 5-10 above threshold (3 µSv/h, averaging time 5 s)
data from T. Radon

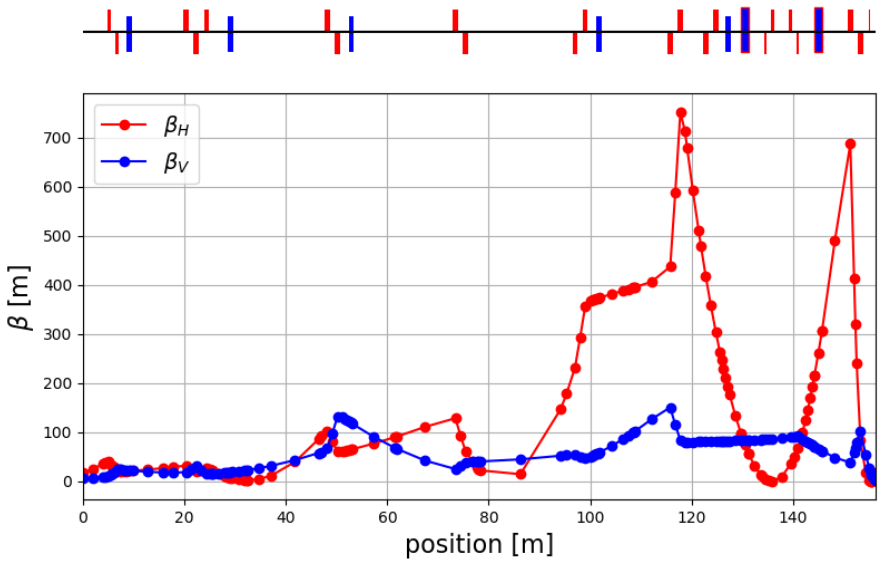
Radiation alarms - cause and remedy (II)

- BioRem software was updated during shutdown, verified by RP team, excluded as a reason for alarm.
- Maybe the beam was lost on an obstacle inside the vacuum chamber producing a very localized loss and the shielding is not good in this location?
  - vacuum chamber opened and inspected, no obstacles found
  - the holes in the shielding has been closed (2 large cable ducts and smaller holes)

- Maybe averaging time should be a little bit longer (10-20 s).
- We will start beam setup with low energy and long spills, pinpoint the losses and then increase energy and intensity.
- We will use BLMs (they were not commissioned in June/July) and maybe install additional BioRems inside the cave.
- In the worst case scenario beam setup could be done with restricted personnel access to Target Halle (?)

New, current optics

In August the default LSA optics has been changed to the one from 2012.



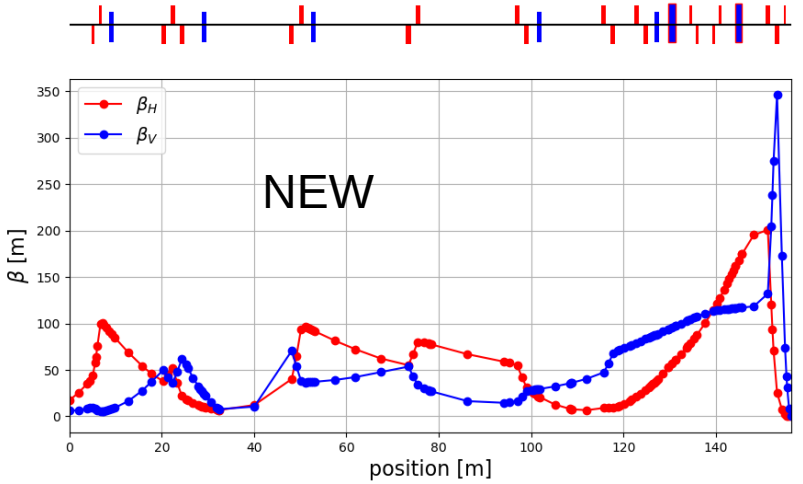
beam spot on target:
beta_H = 17.5 m -> 0.15 m
beta_V = 1.26 m -> 0.22 m

optimization theoretically possible by pushing last quad to max current.

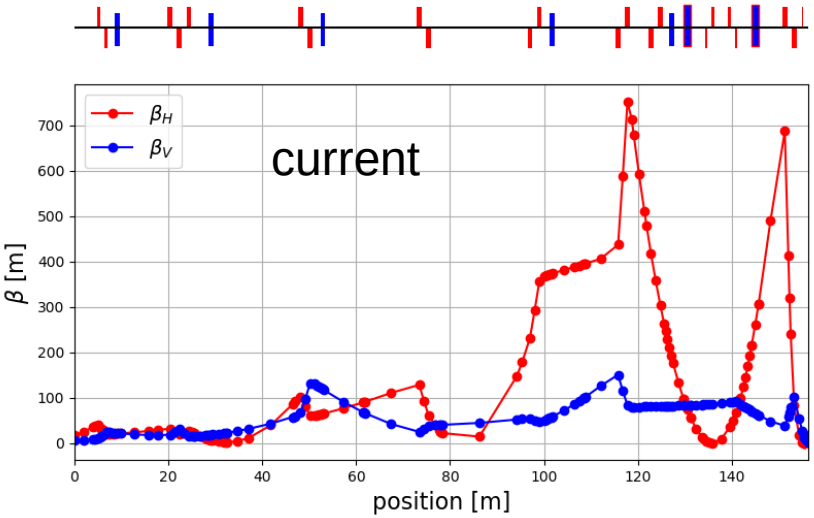
Alternative optics-Sebastian

Sebastian proposes a nice, low-beta optics with small beam spot on target, however:

- most quads have inverted polarity so testing it maybe tricky.



beam spot on target:
beta_H = 1.45 m
beta_V = 0.13 m

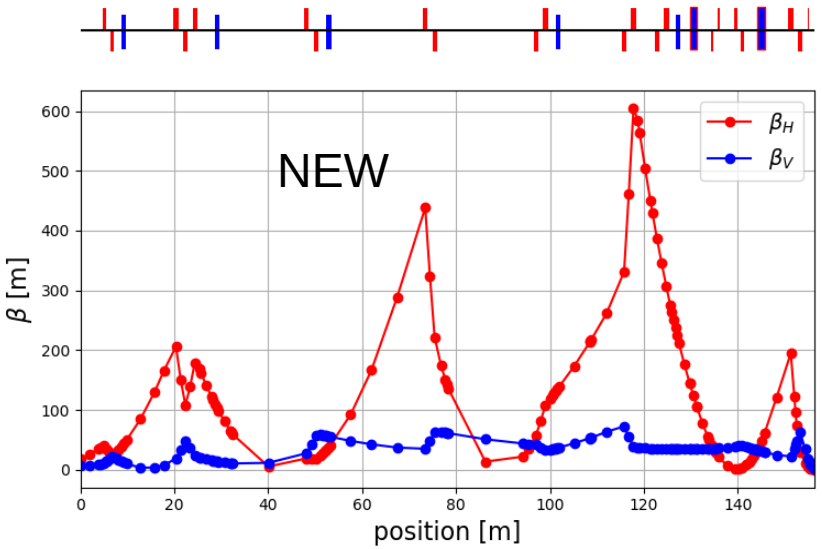


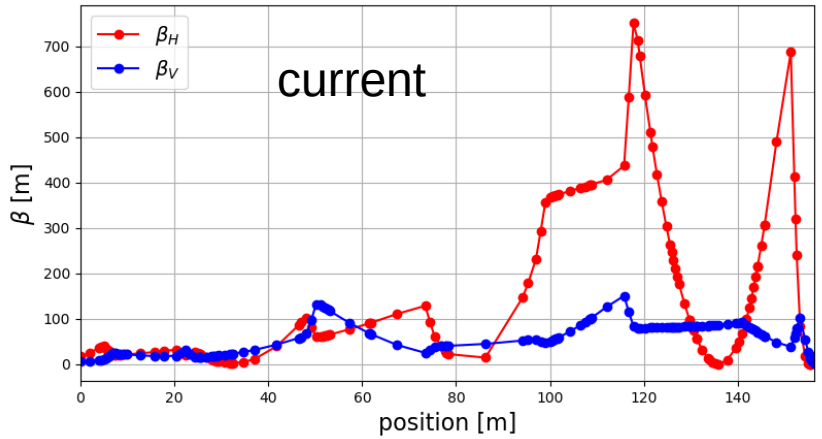
Alternative optics-Sabrina

Sabrina used Bound Optimization By Quadratic Approximation (BOBYQA) algorithm to obtain this optics.
t is a part of research aiming at use of numerical algorithms (also machine learning) to optimize accelerators.

- beam shape on target is opposite to preferred one (horizontal emittance during slow extraction is much smaller than the vertical one)

beam spot on target:
beta_H = 0.36 m
beta_V = 1.27 m



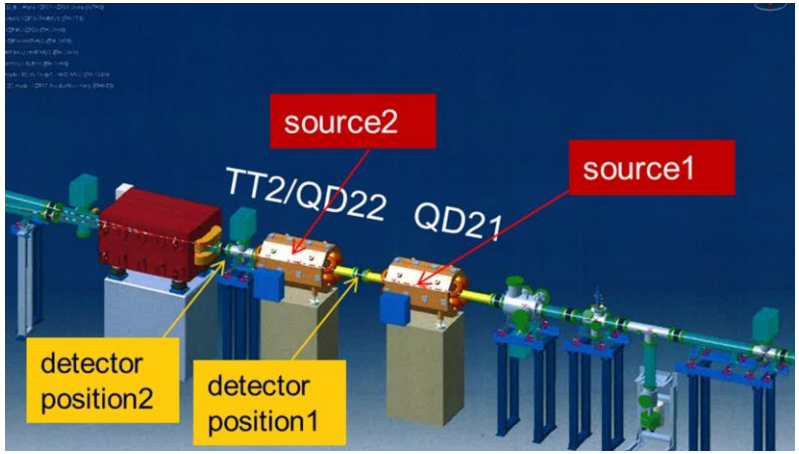


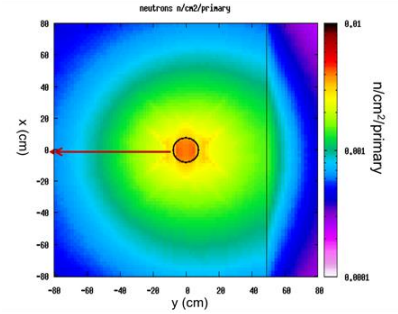
Engineering run

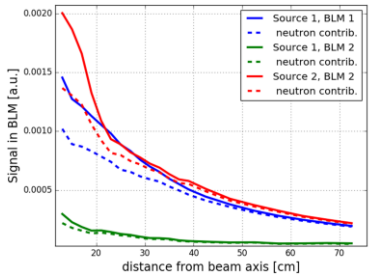
- Main goal is to establish *good* Silver beam to HADES.
- Most important measurements: extraction efficiency, spill quality, beam spot size, beam position stability during spill.
- Other:
  - optimize beam focus on target, test focusing knob
  - optimize beam losses, transmission, cross-check for blind spots
  - test alternative optics
  - test loading IBHS settings to Paramodi
  - measure orbit response matrix, test global correction (COCO and python script)
  - measure optics parameters, especially PSE point to measure for mismatch SIS18-HEST, measure angle of extracted beam, dispersion at screens/grids
  - do quadrupole scan for emittance measurement
  - test pion target optics
  - measure SEM grid position resolution
  - measure beam shape using halo detector
  - check beam stability during parallel operation
  - dynamic aperture measurement

Engineering run – example studies

- Instrumentation
  - BLM commissioning:
    - looking for holes in the BLM system (are there any locations where beam can be lost and is not seen by BLMs).
    - observation of BLM behavior at saturation, finding what typical loss rate leads to saturation (Plamen).
  - Studies of beam losses (FLUKA simulation by Sanja Damjanovic ready)







from IPAC17, paper TUPVA060

Expert tools in HKR

- Not (yet) copied to all HKR computers!

1. IBHS files: all historic IBHS files have been converted to Paramodi import files (see ibhs2paramodi_files).
2. Paramodi optics viewer (see HESTools/MADX_HADES): ./ShowOptics ParamodiFile

```
# Version: 1.0
# Comment:   nach Fokusierung
# Context: WRITE HERE THE CORRECT CONTEXT<<<<<<<<<
# Columns: PARAMETERNAME,VALUE,UNIT,BEAMPROCESSPURPOSE
GTE1QD12/KL,-0.24484,1/m,TRANSFER_EXTRACTION
GTS1MU1/HKICK,0.0,rad,TRANSFER_EXTRACTION
GTS1MU1_0/HKICK,0.0,rad,TRANSFER_EXTRACTION
GTE2KX1/KL,-0.0021425,rad,TRANSFER_EXTRACTION
GTE2QT11/KL,0.15762,1/m,TRANSFER_EXTRACTION
GTE2QT12/KL,-0.31946,1/m,TRANSFER_EXTRACTION
GTE2QT13/KL,0.24298,1/m,TRANSFER_EXTRACTION
GTE3MU1/HKICK,0.0,rad,TRANSFER_EXTRACTION
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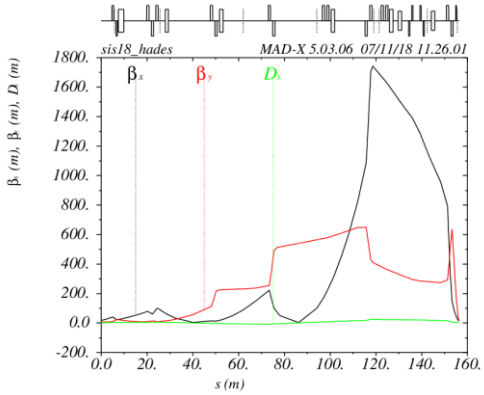

Summary

- Lot of work has been done on HADES beam line, on hardware, software, instrumentation, physics.
- Lot of fantastic, new tools: BLMs, data saving/archiving, knobs, global trajectory correction, etc, etc...
- We are ready for the beam (right now still some ongoing issues, eg. PDC signal loss on long cables).
- Still, there is some worry that radiation alarms, which are not yet understood, will stop us at the beginning of Engineering run.
- Hopefully lot of data will be collected and used to correct the optics models, aperture model, find errors.
- It will be fun. Guaranteed!

Many thanks to those who participated in the upgrade project or in other ways helped with the described works.

And thank you for listening.