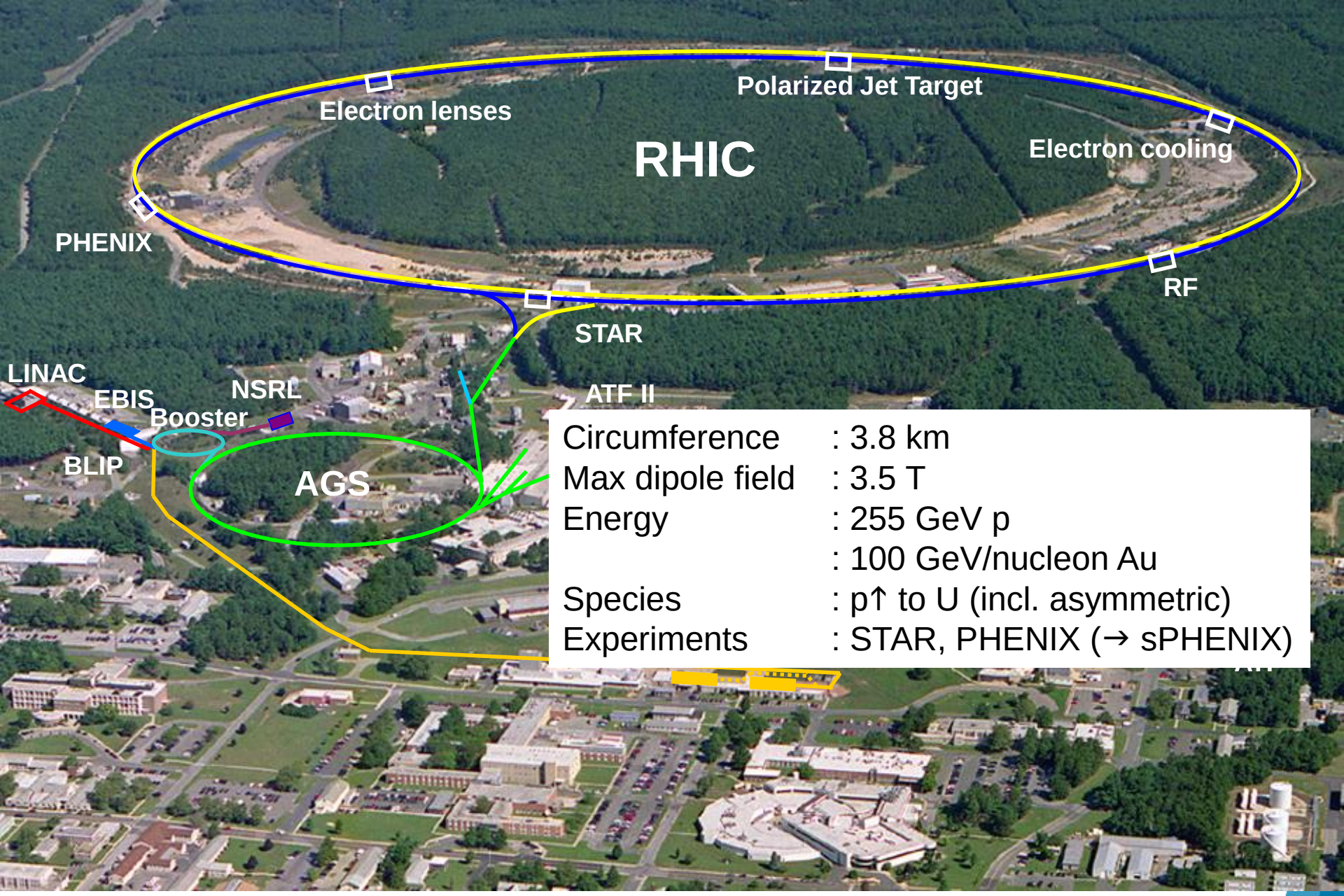
Machine protection studies for RHIC

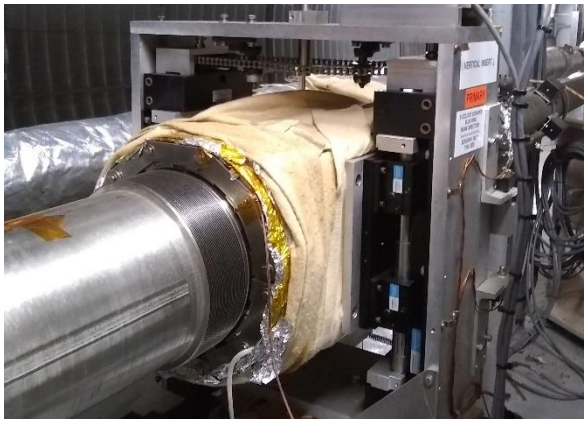
Matthieu Valette
CERN

(with a lot of help from A. Drees, T. Shrey, R. Michnoff, J. Morris, G. Hepner, A. Di Lieto, J.L. Mi, O. Biletski, J. Escalier, C. Schultheiss, W. Fischer, and many more ….)

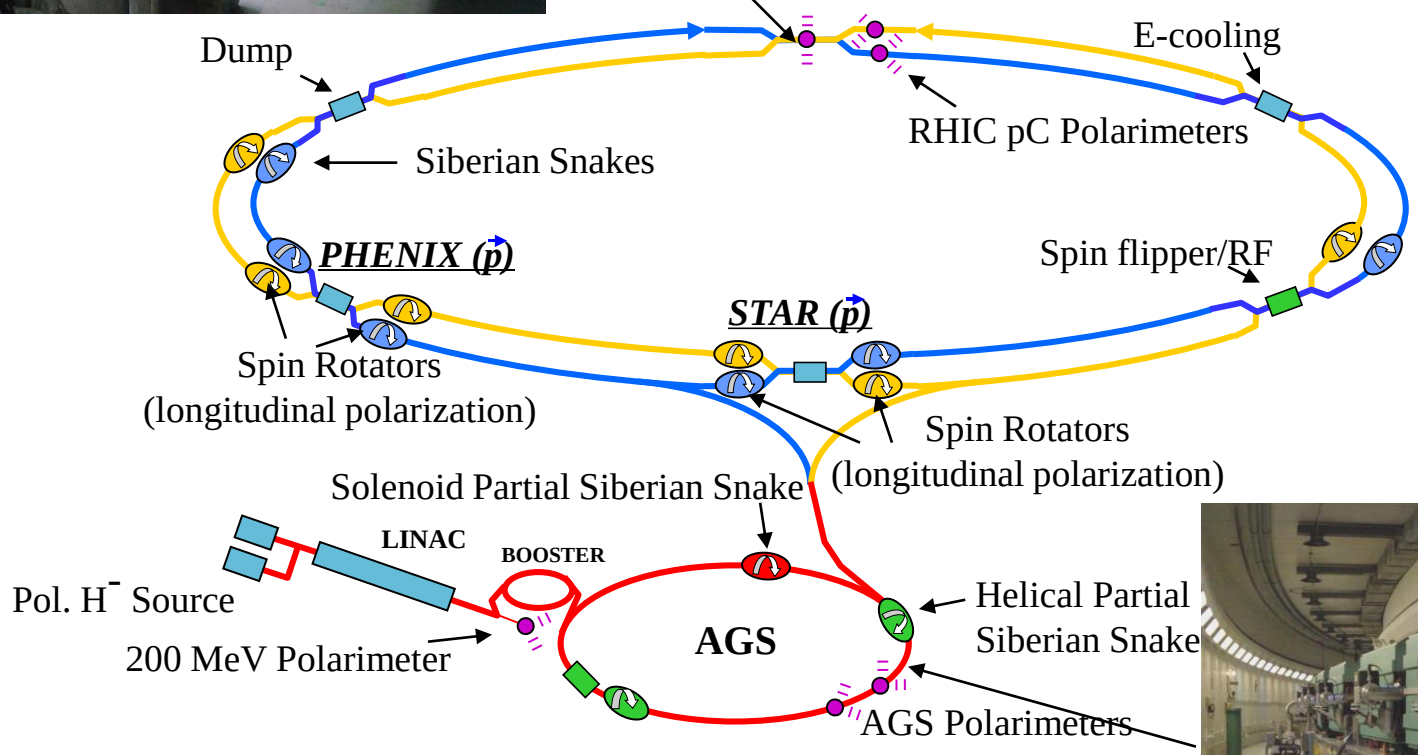
PE section meeting

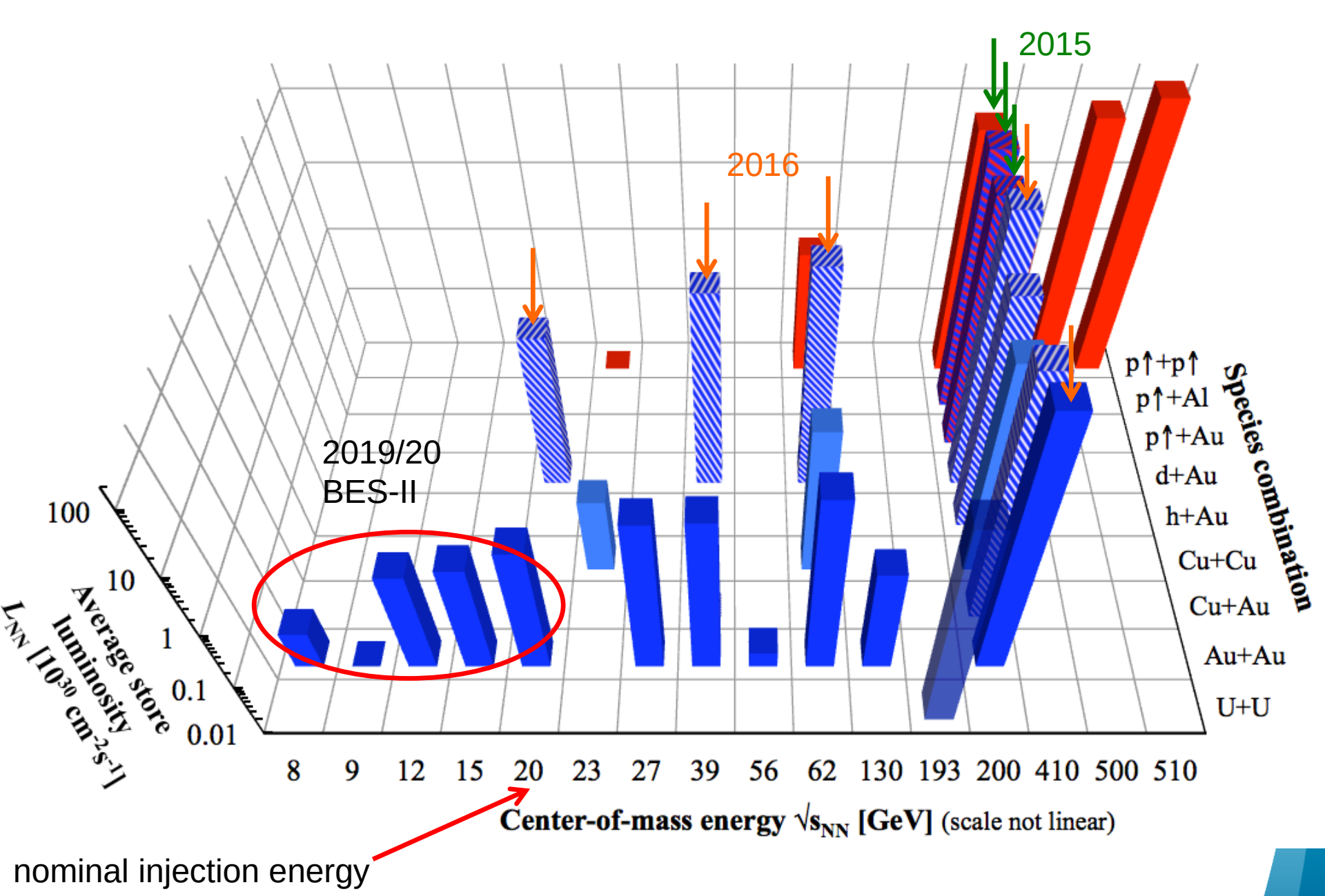


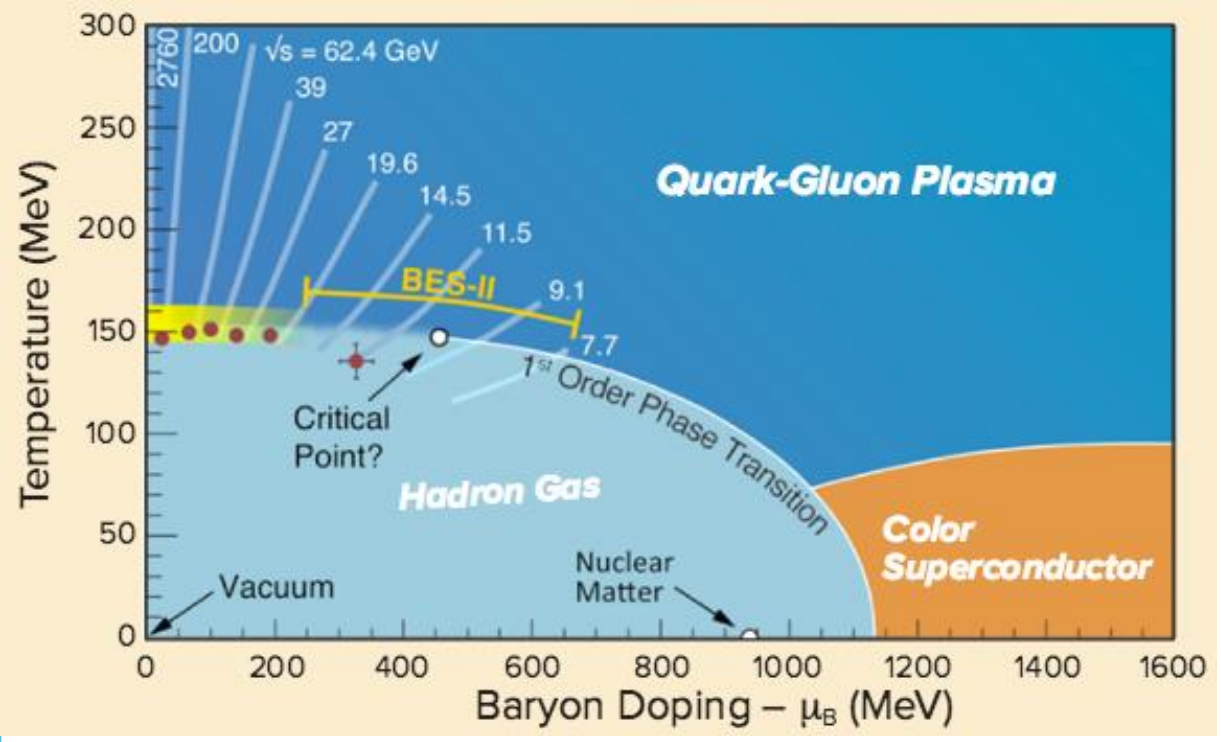
Circumference	: 3.8 km
Max dipole field	: 3.5 T
Energy	: 255 GeV p
	: 100 GeV/nucleon Au
Species	: p↑ to U (incl. asymmetric)
Experiments	: STAR, PHENIX (→ sPHENIX)

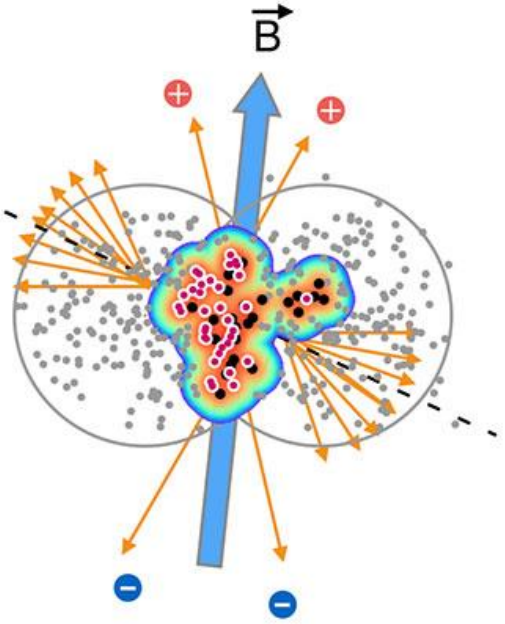


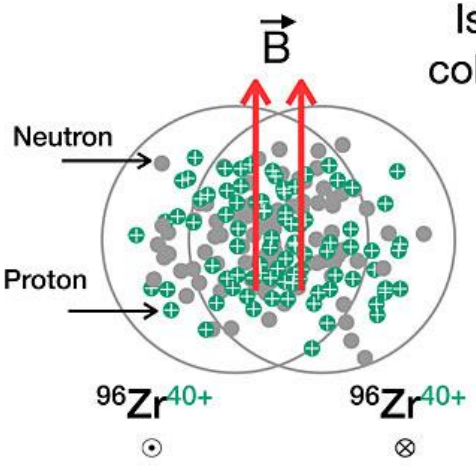
Absolute Polarimeter (H jet)



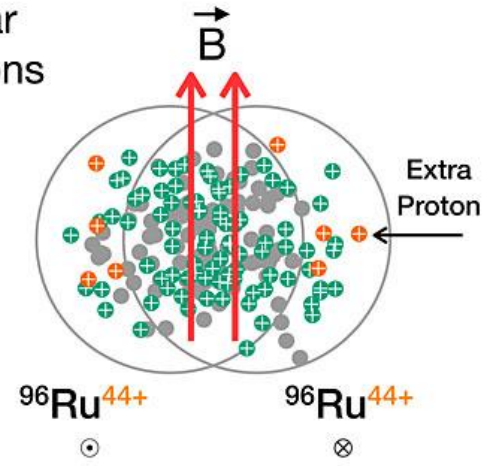

2015
2016
2019/20
BES-II
100
10
1
0.1
0.01
Average store luminosity
L_{NN} [10^{30} cm^{-2}s^{-1}]
p↑+p↑
p↑+Al
p↑+Au
d+Au
h+Au
Cu+Cu
Cu+Au
Au+Au
U+U
Species combination
8 9 12 15 20 23 27 39 56 62 130 193 200 410 500 510
Center-of-mass energy $\sqrt{s_{NN}}$ [GeV] (scale not linear)
nominal injection energy







Isobar collisions

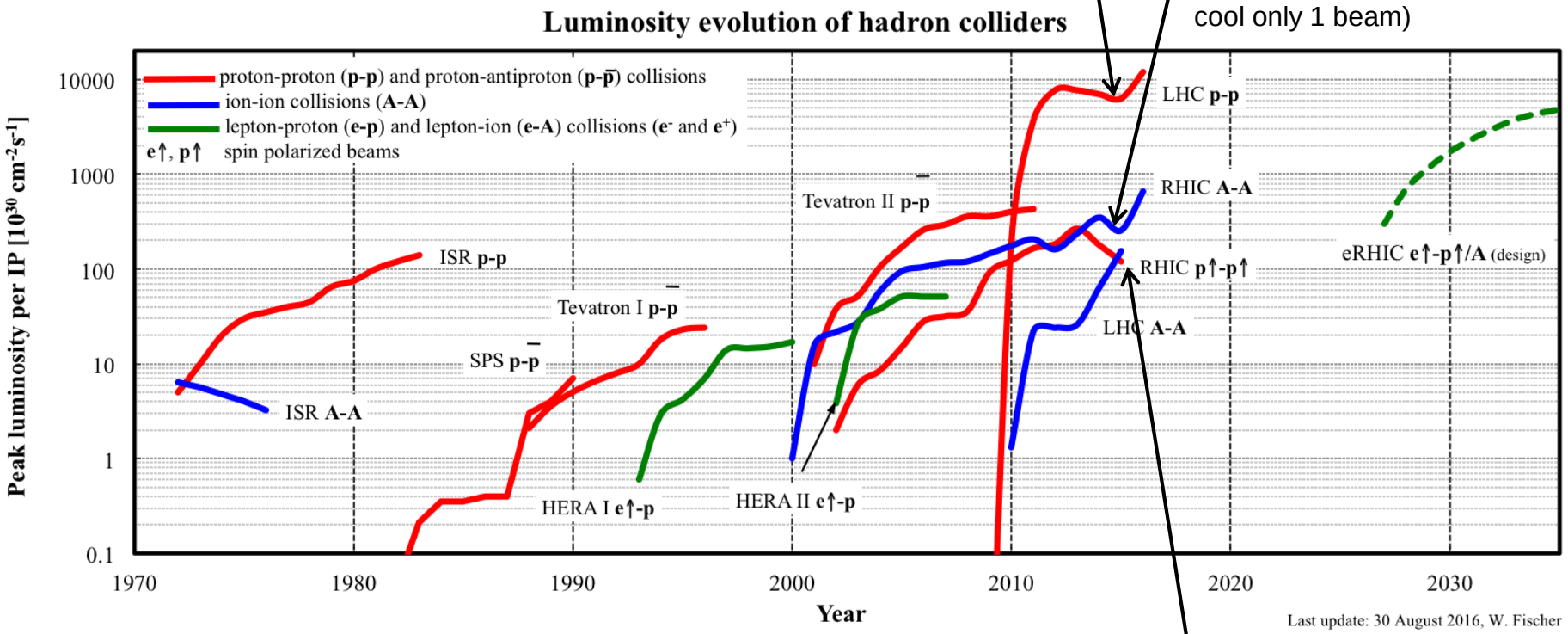


HiLumi HL-LHC PROJECT

Hadron collider luminosities

LHC 25 ns bunch spacing at 6.5 TeV
(previously 50 ns at 4 TeV, e-cloud)

RHIC p↑+A
(previously A+A,
cool only 1 beam)

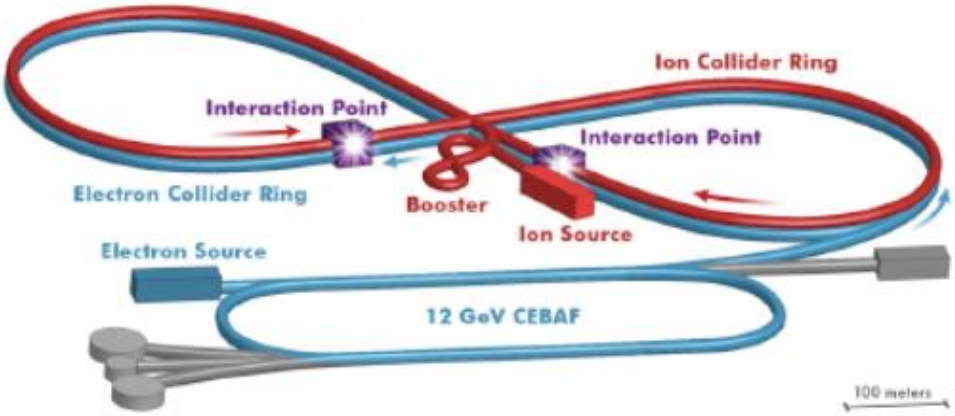


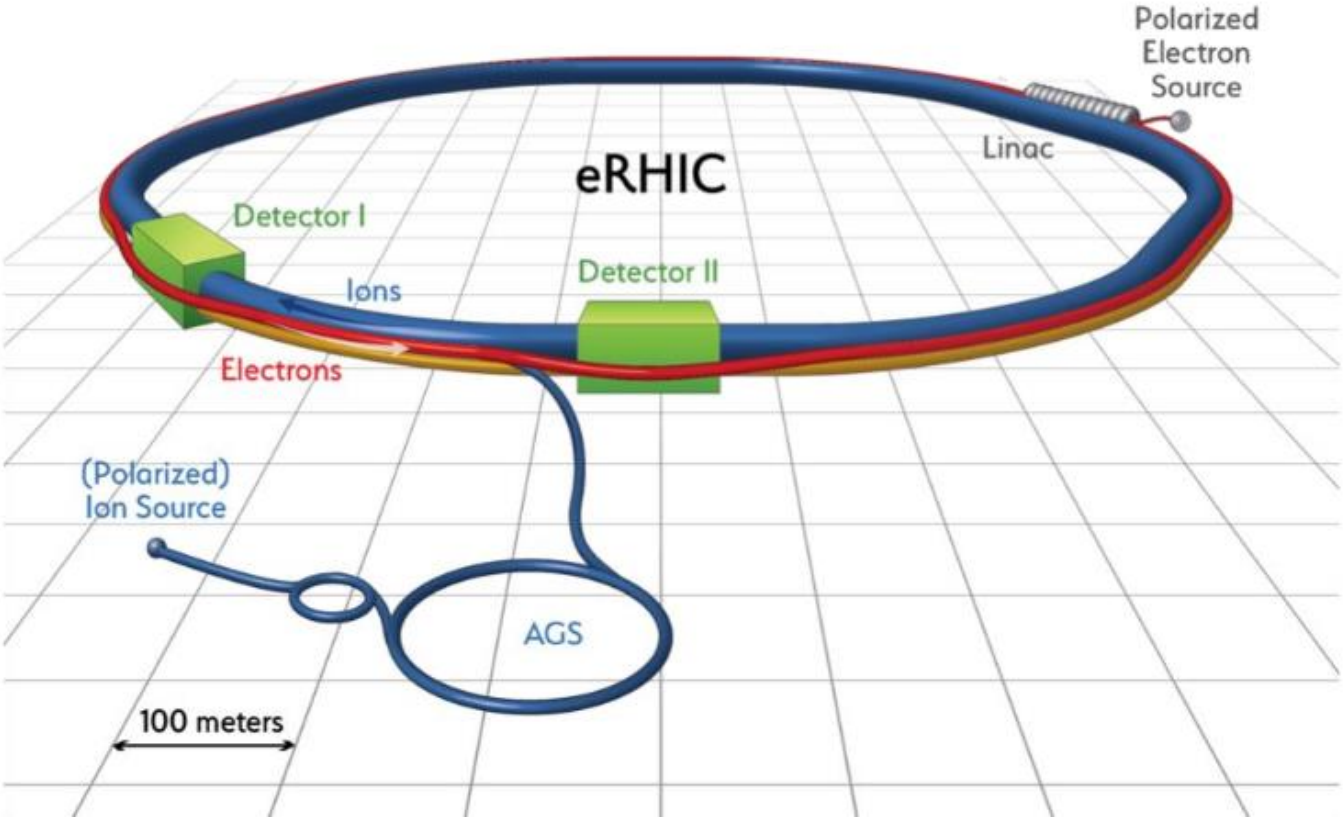
RHIC 100 GeV p↑+p↑
(previously 255 GeV)

average or leveled luminosity L_{avg} now more important than peak luminosity L_{peak}
(burn-off in RHIC, pile-up limit in LHC)

JLEIC

Ring-Ring





Abort kicker pre-fire

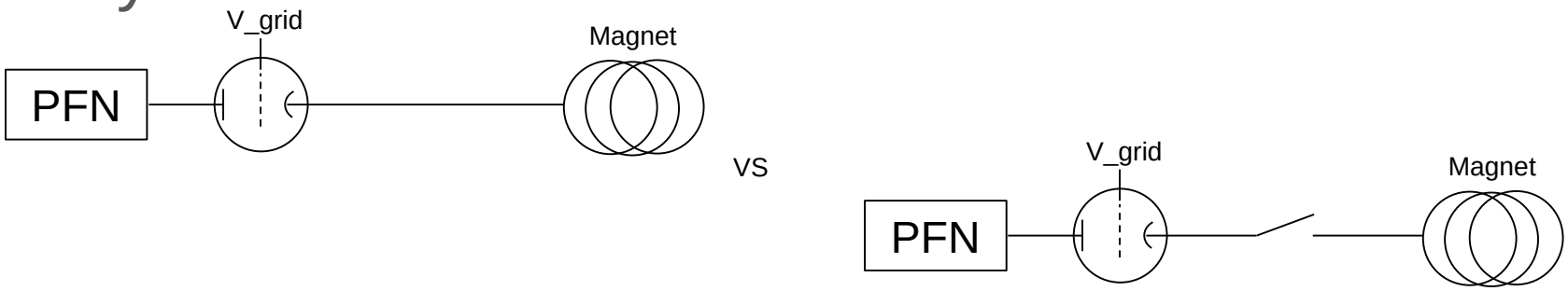
With 100 bunches of 1e9 Au^{79+} at 100 GeV/m the total beam energy in RHIC is 104 kJ, compared to 330 MJ in the LHC beam.

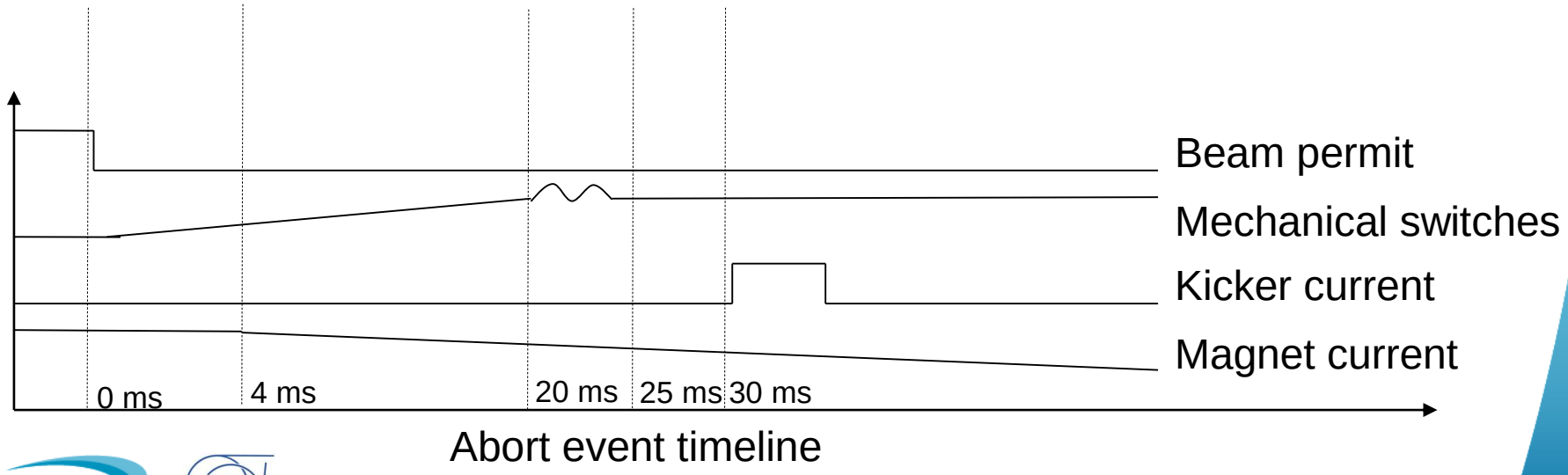
In 2014-2017, pre-fires of the abort kickers were the cause of many quenches and eventually damage to a physics experiment (PHENIX).

Pre-fire: premature discharge of one of the five abort kicker module's thyratron, most likely due to radiation, resulting in 20% of the extraction kick for a significant part of a turn.

Delayed mode of the abort kickers

Mechanical relays in series with thyratrons allow vetoing pre-fires but results in much longer dump delays.

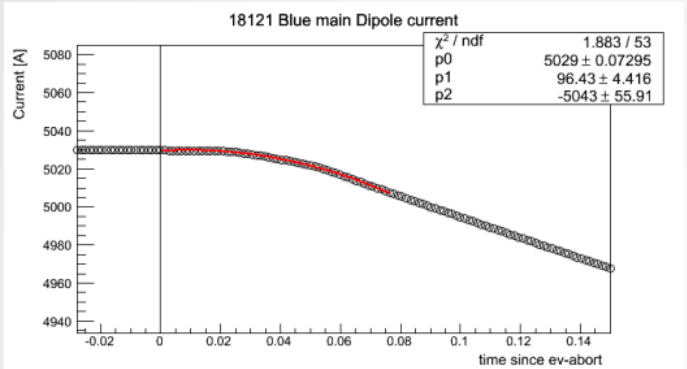


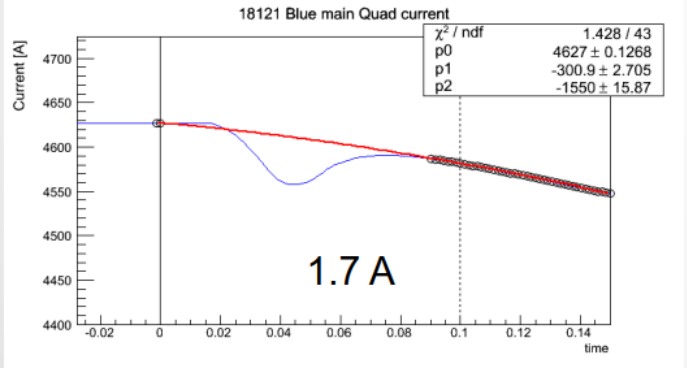


Past experiments

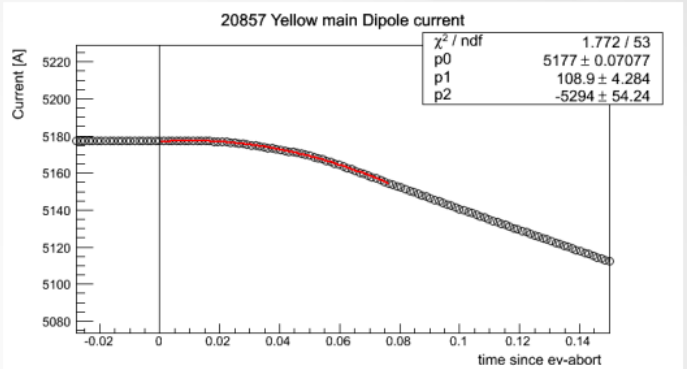
Delayed abort mode tested in 2014 with 30 ms delay to the abort (relay limitation). The whole beam was lost before the dump happened.

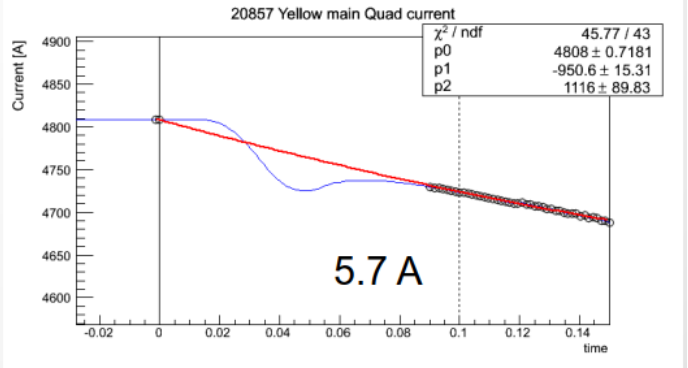
2014





2017

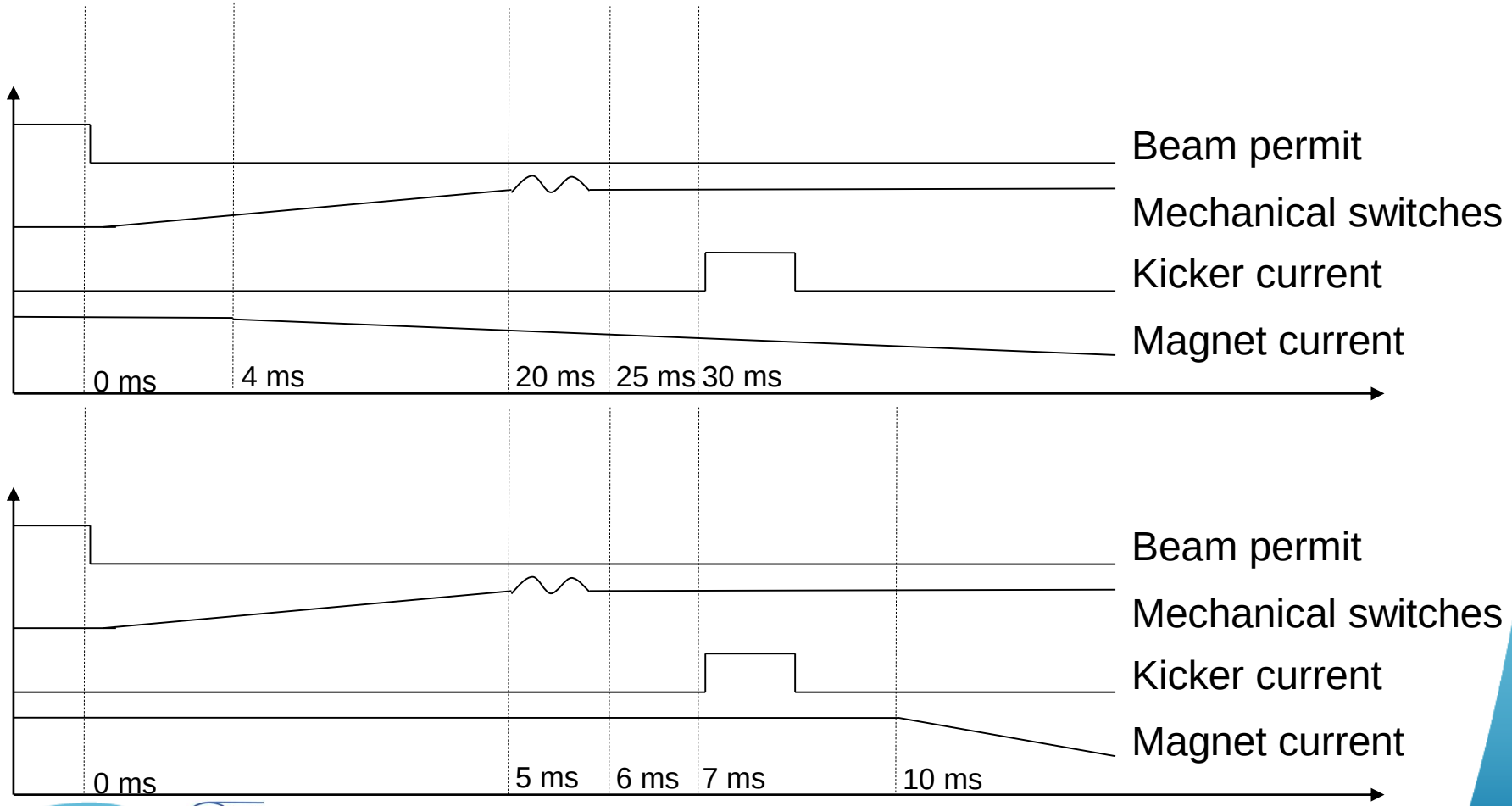




Magnet curent readings during the event are unreliable

Updated delayed mode of the abort kickers

Thanks to efforts of the pulsed power group the relays were upgraded and made faster.



Abort event timeline

Machine development

Goal: determine the safe delay to abort and understand what happened in 2014

Delayed abort were tried in 4 different configurations:

-at injection with a 9 ms delay

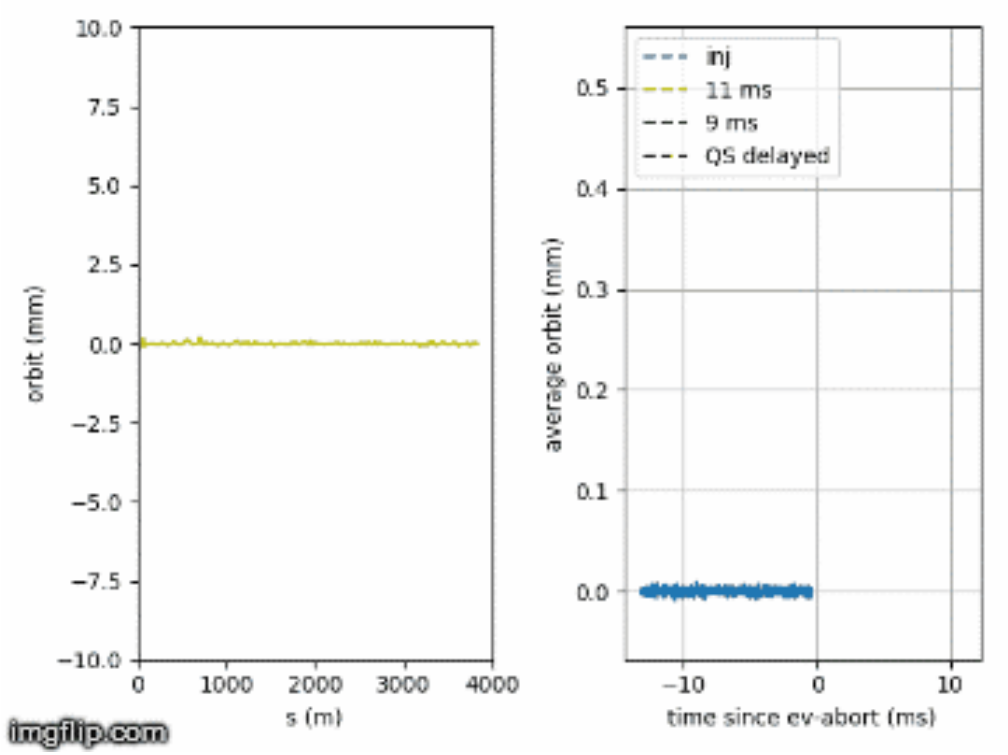
-at store with an 11 ms delay

-at store with a 9 ms delay (for reproducibility)

-at store with a 9 ms delay and the Quench Swich being delayed as well

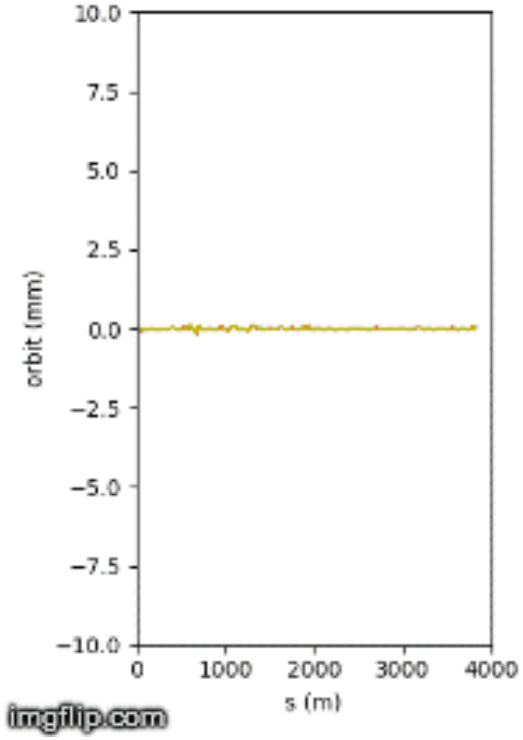
Machine development

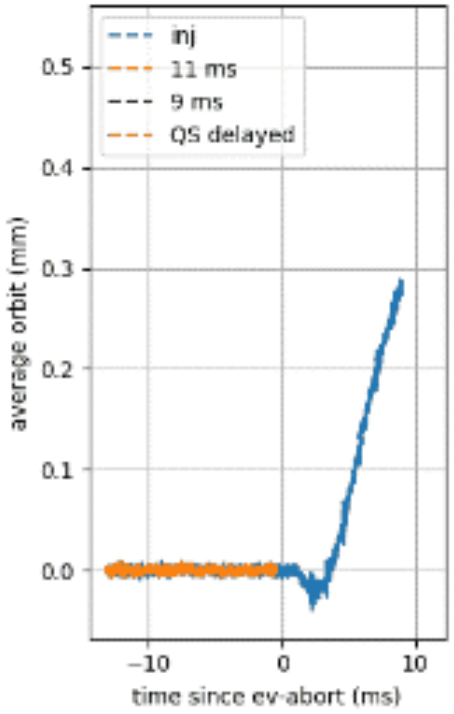
Details of the event at injection



Machine development

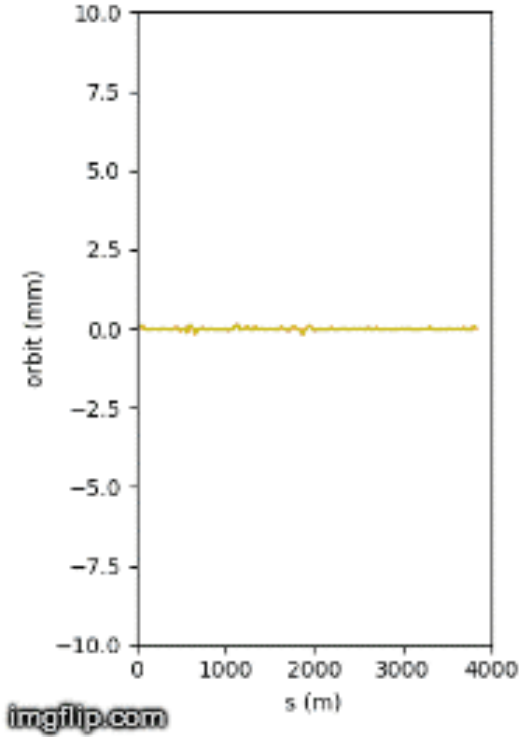
Details of the first event at store

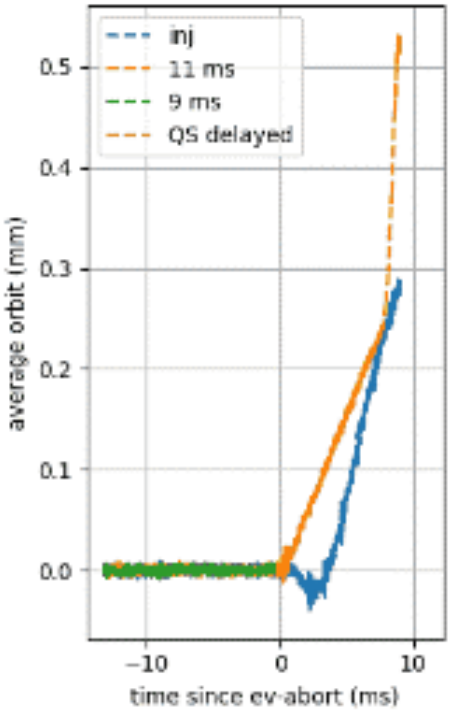




Machine development

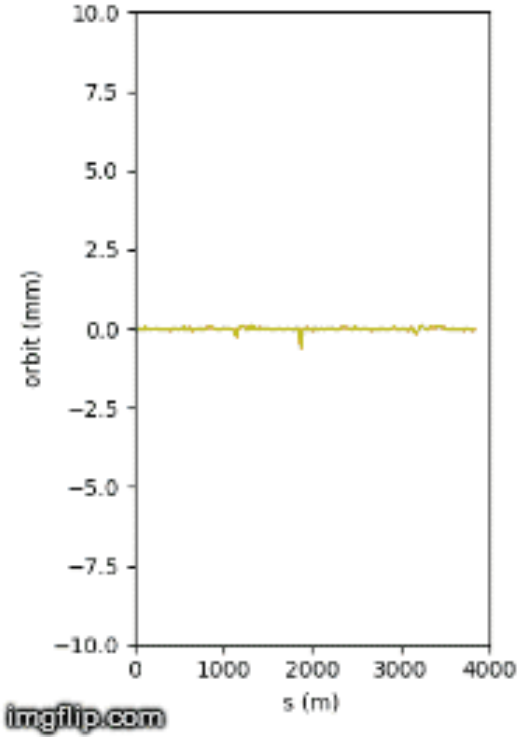
Details of the second event at store

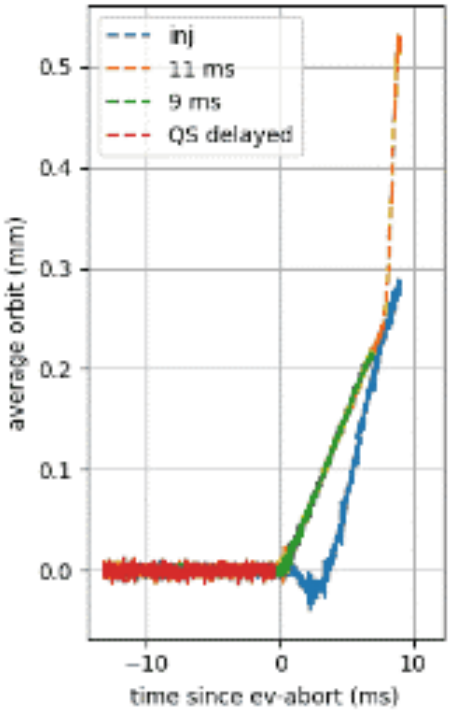




Machine development

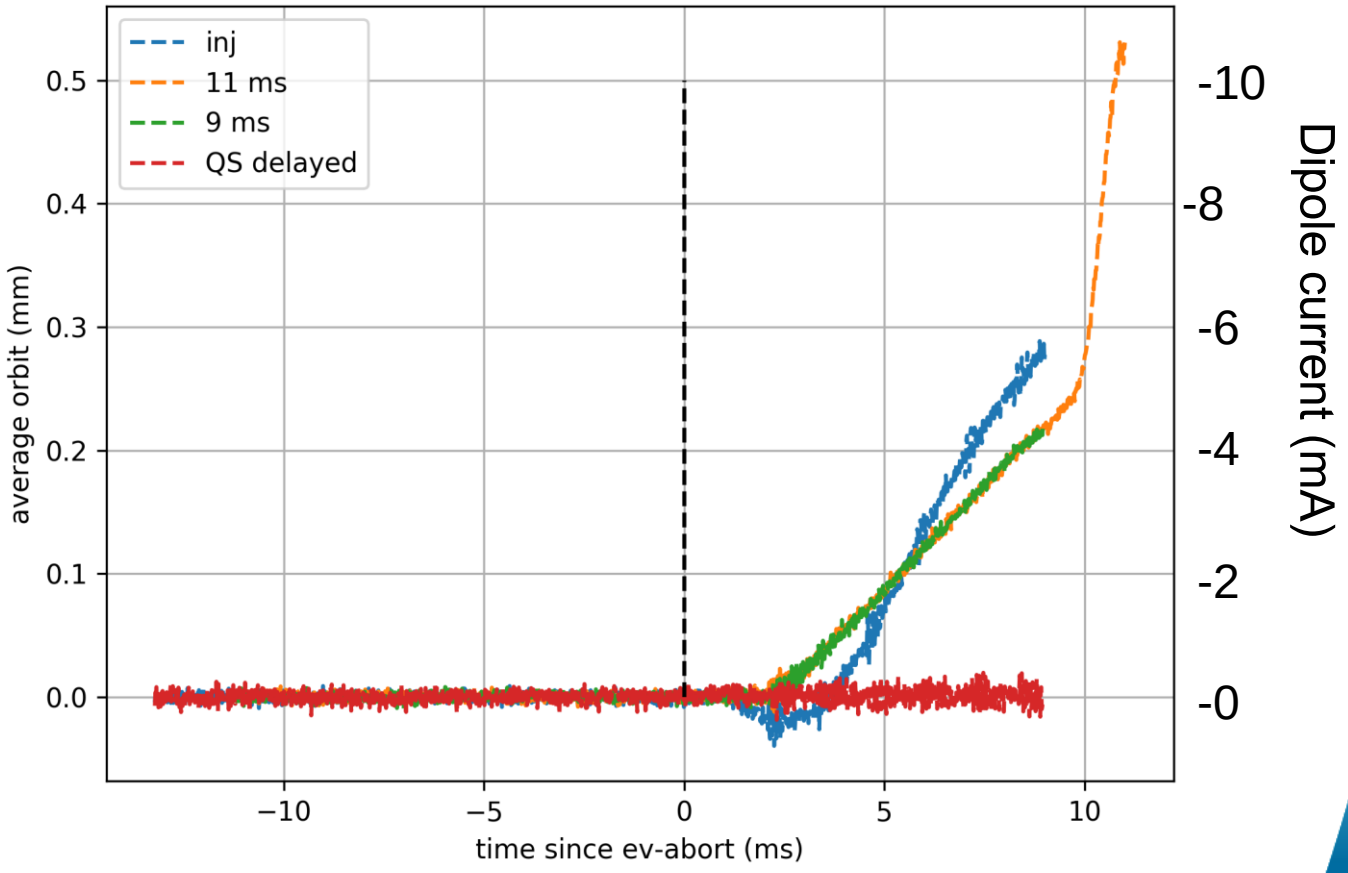
Details of the third event at store





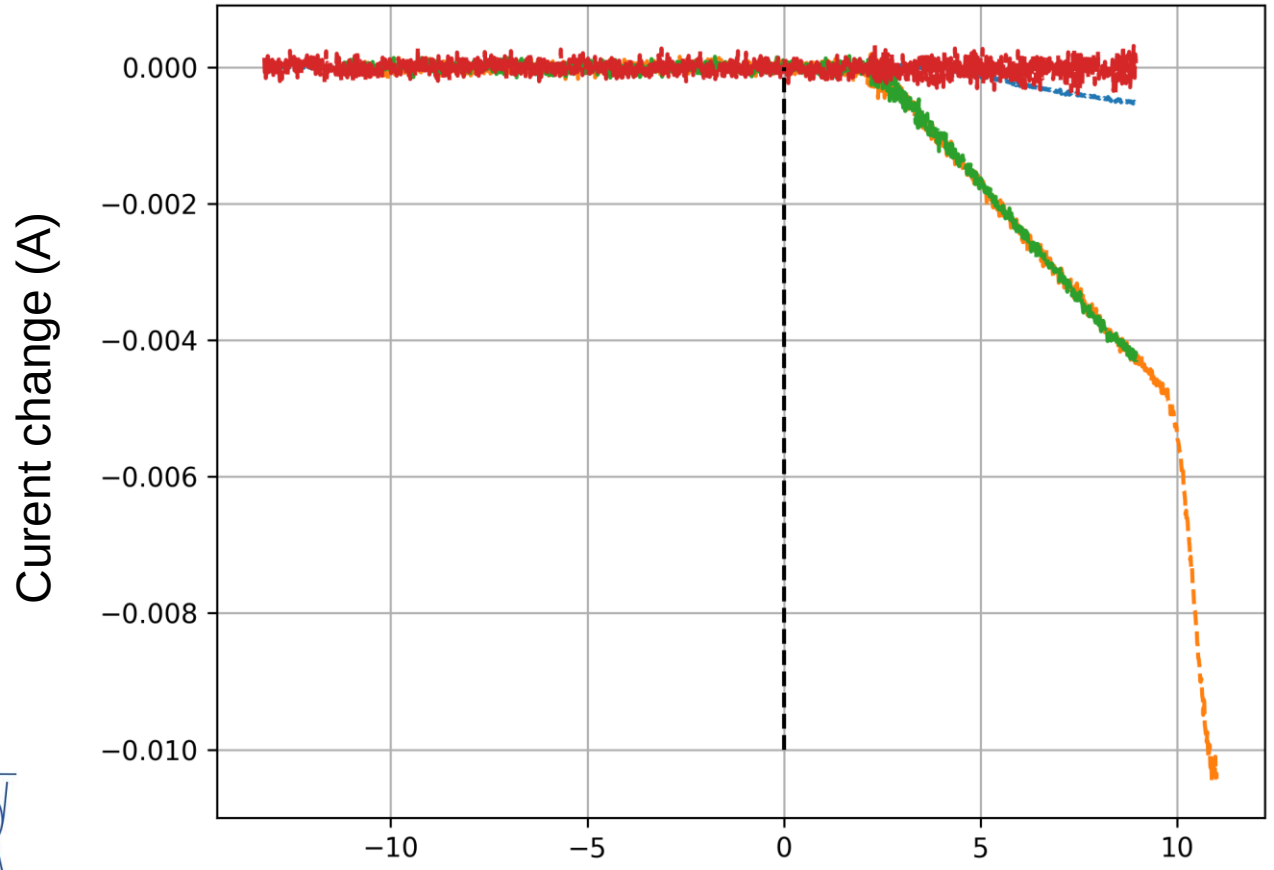
Machine development

Last experiment: abort kickers could be operated in delayed mode safely with a delayed quench switch (if allowed by magnet protection).



Machine development

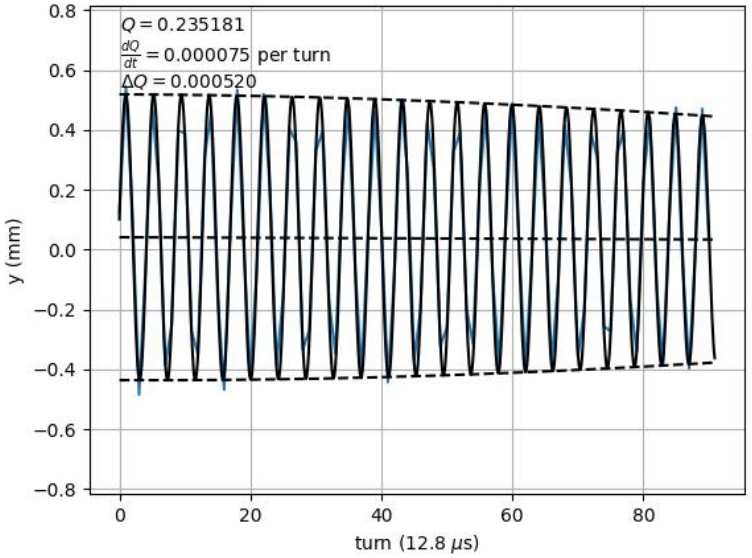
Due to the dipole current decaying, the radius of the machine changes, which allows reconstructing the current in the dipole magnets



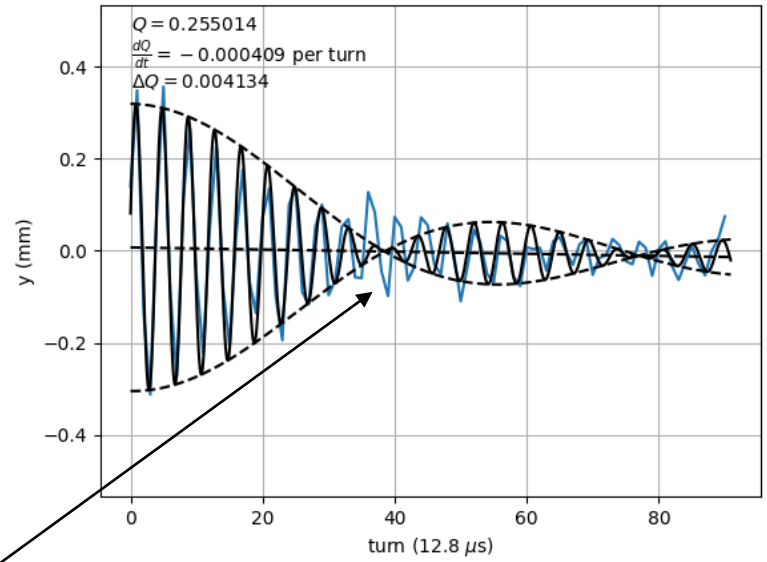
Machine development

Due to the quadrupole current decaying, the tunes were also drifting, an FFT based method proved inconclusive so the orbit measurement fromm all 160 BPM in each plane were fitted.

injection



store

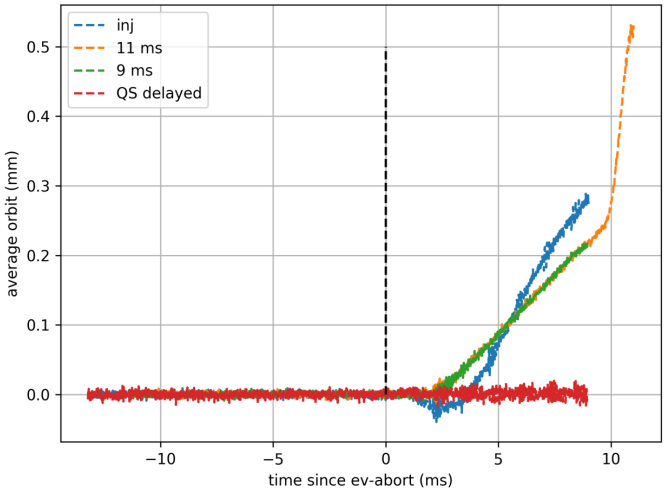


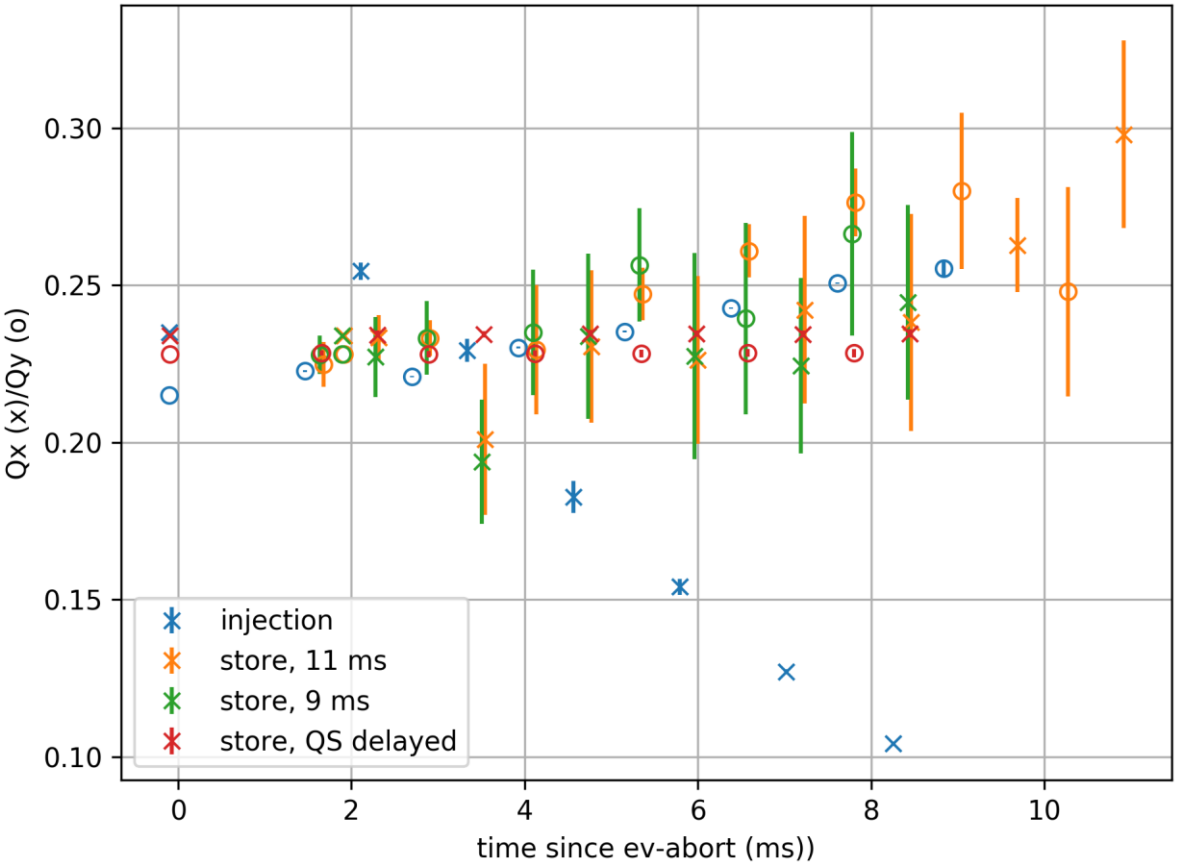
Excitation in the other plane is visible due to coupling

Machine development

The resulting tunes are averaged (still leading to large error bars for the experiments at store). The tune decay matches the orbit decay and confirms that with a delayed quench switch the beam is unaffected.

reminder





Magnet Quench database

One recommendation from Rudiger was to create a database for the Quench history of superconducting magnets, in order to allow for assessment of degradation or damage.

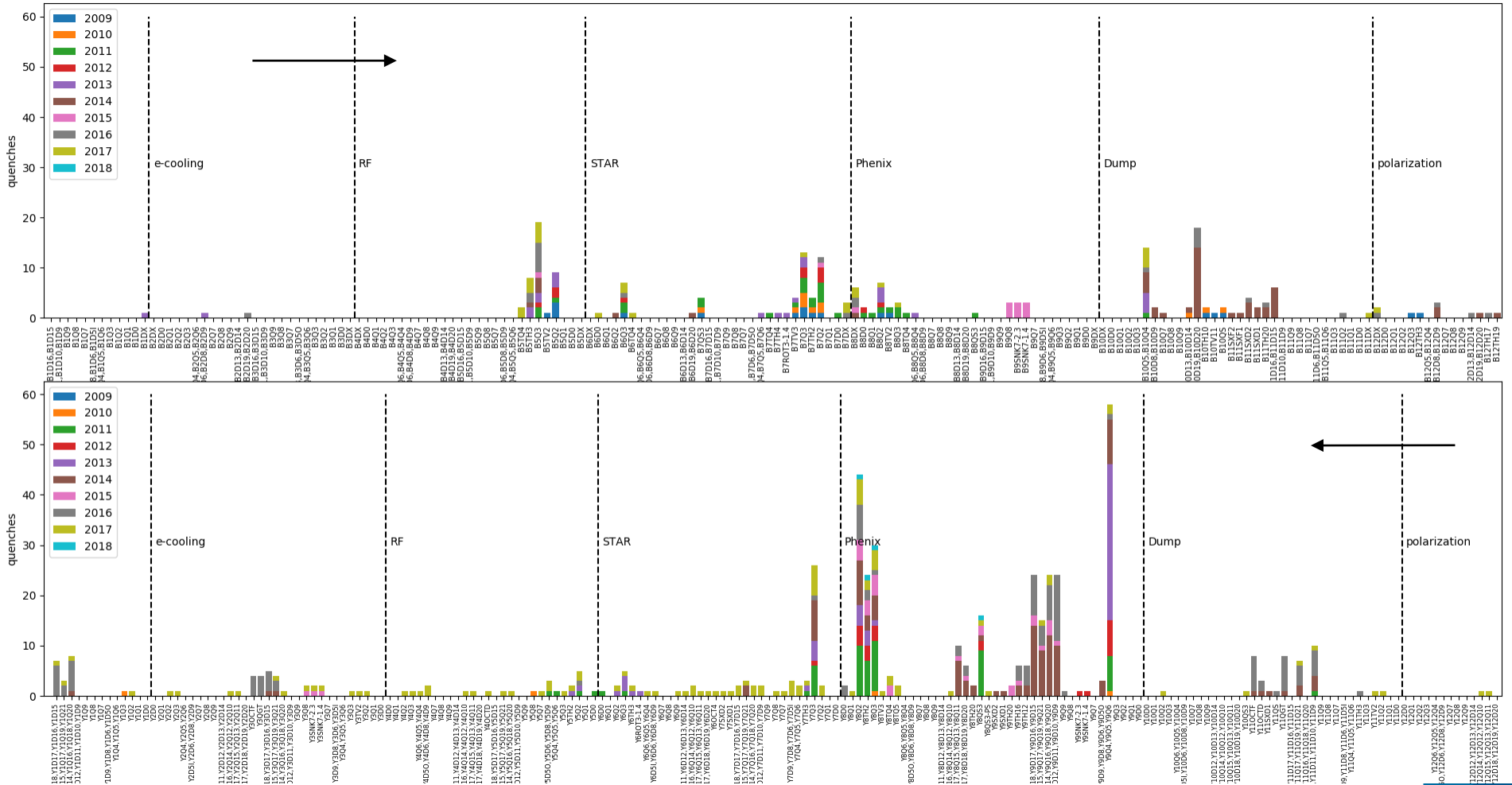
Such a database was reconstructed fro the data meticulously recorded by G. Hepner. Various parameter are stored for each event:

Time, magnets, currents, beam parameters, ….

The analysis is ongoing but some preliminary results are shown after.

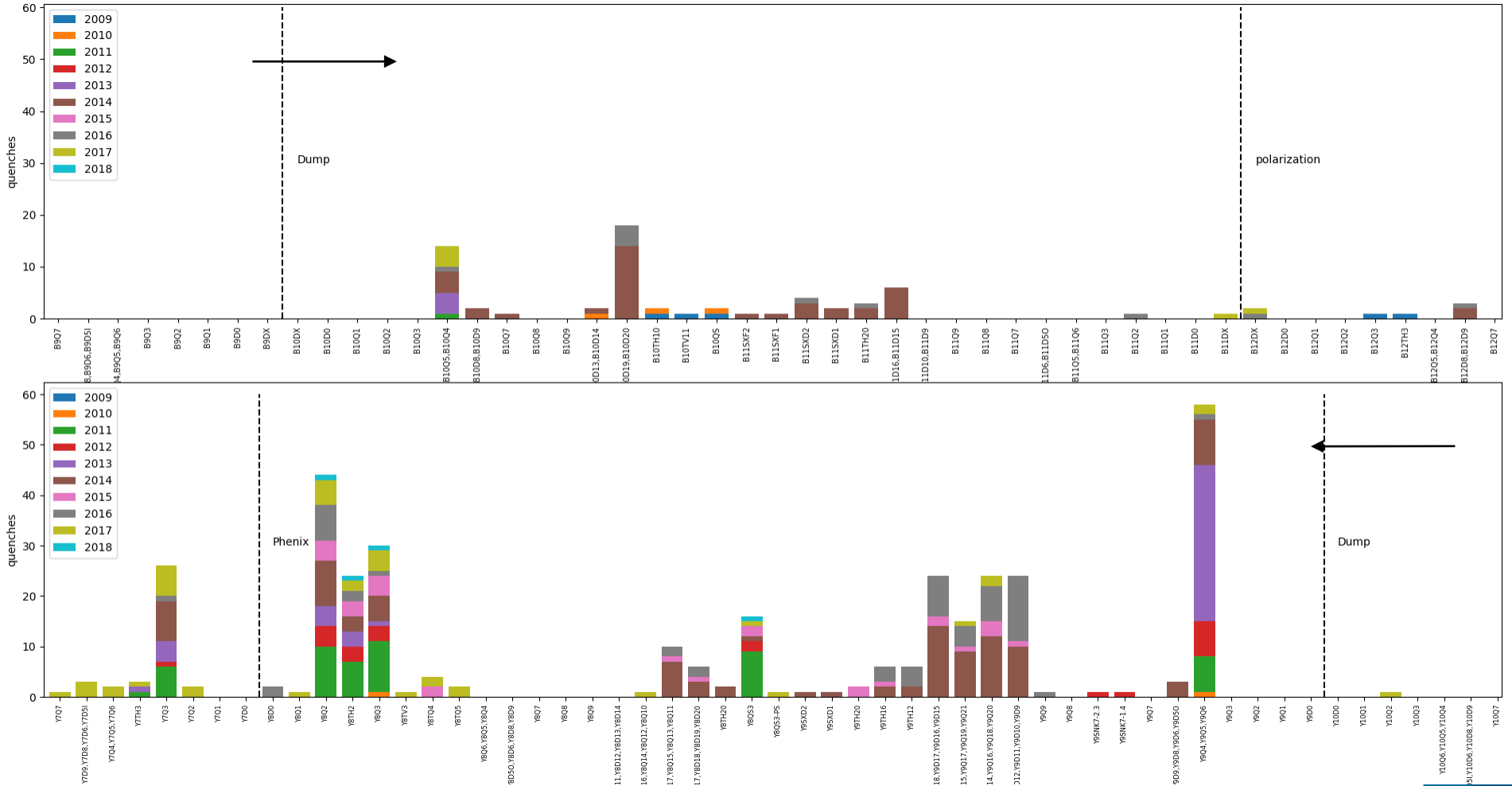
Magnet Quench database

Most of the quenches affected magnets downstream of the dump.



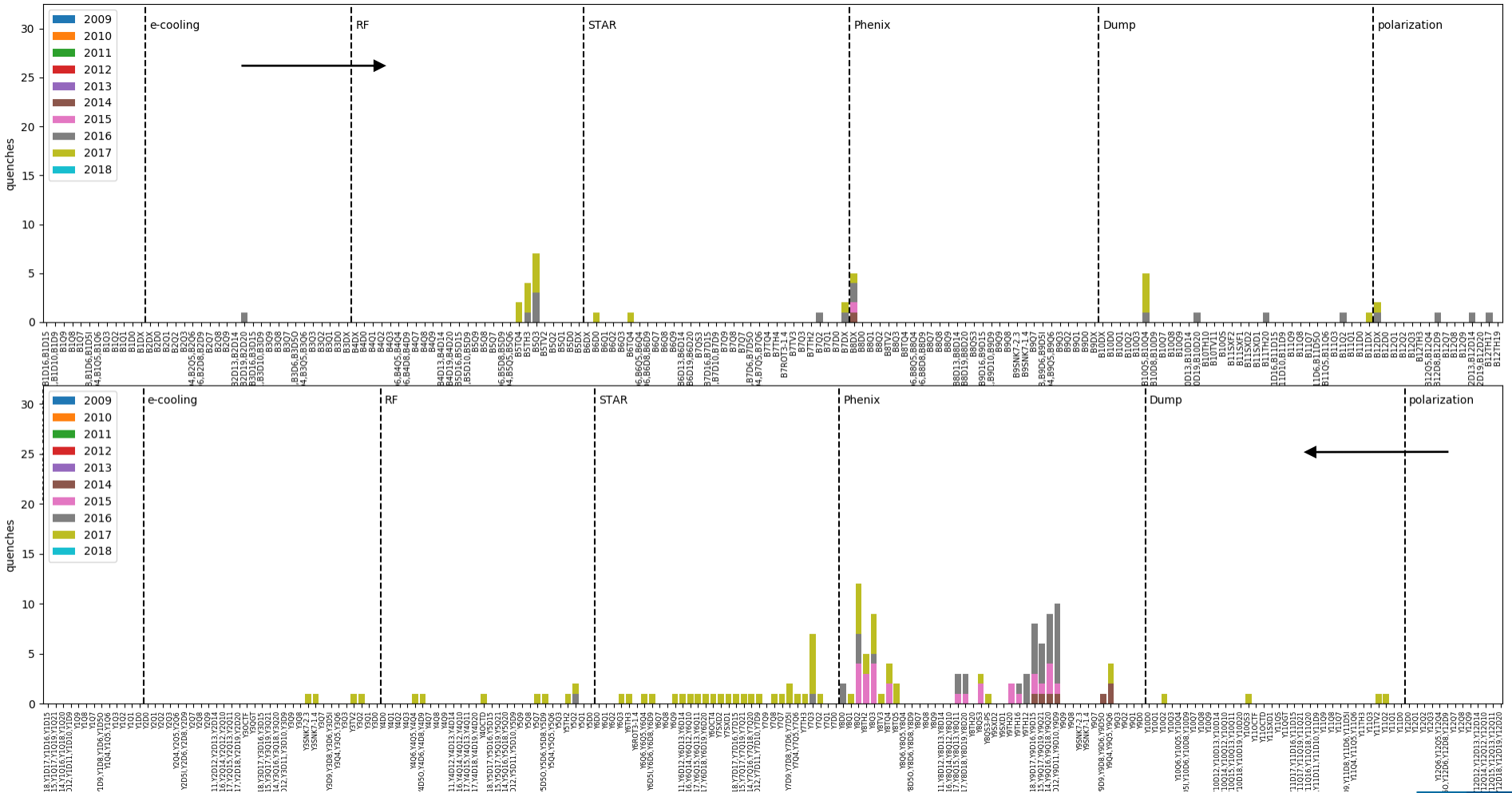
Magnet Quench database

Most of the quenches affected magnets downstream of the dump.



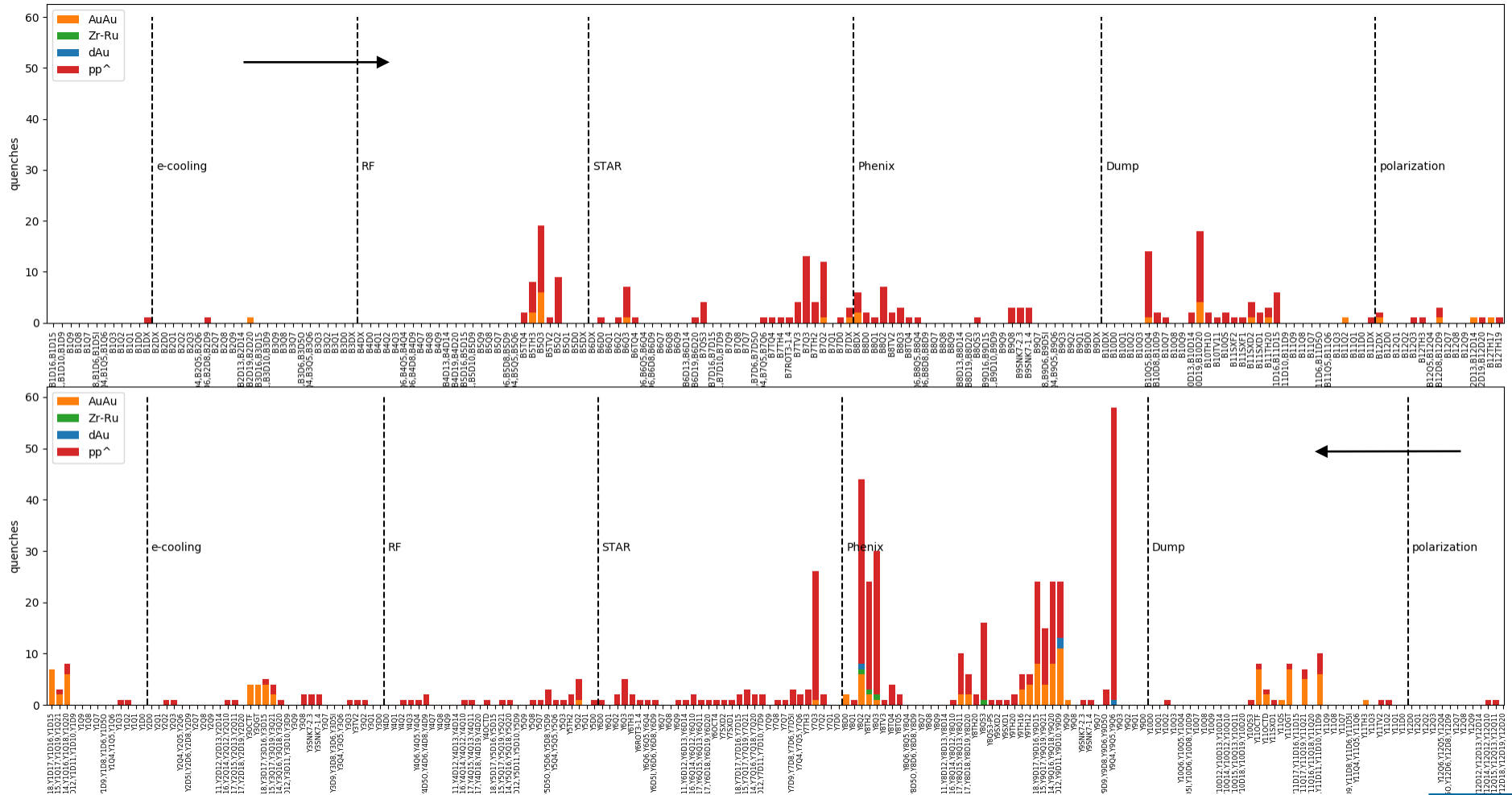
Magnet Quench database

Quenches due to abort kicker pre-fires.



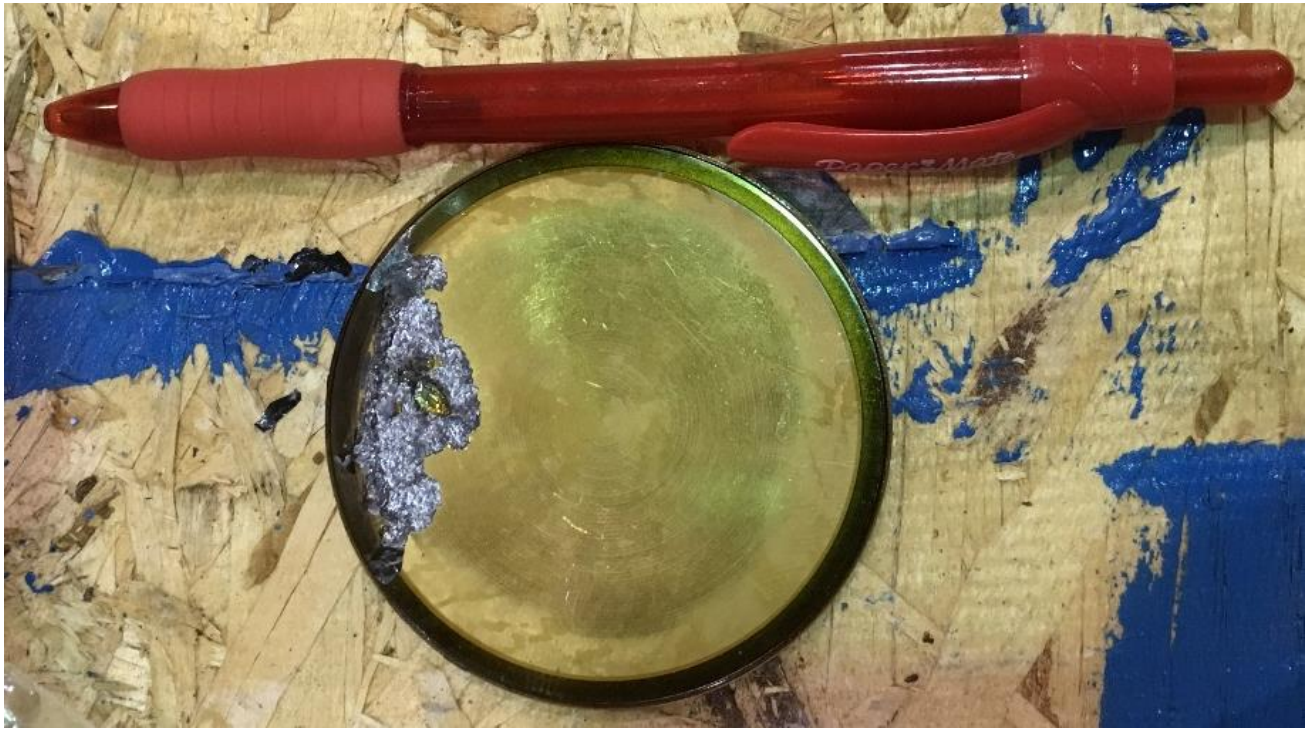
Magnet Quench database

Most of the quenches occurred during proton operation.



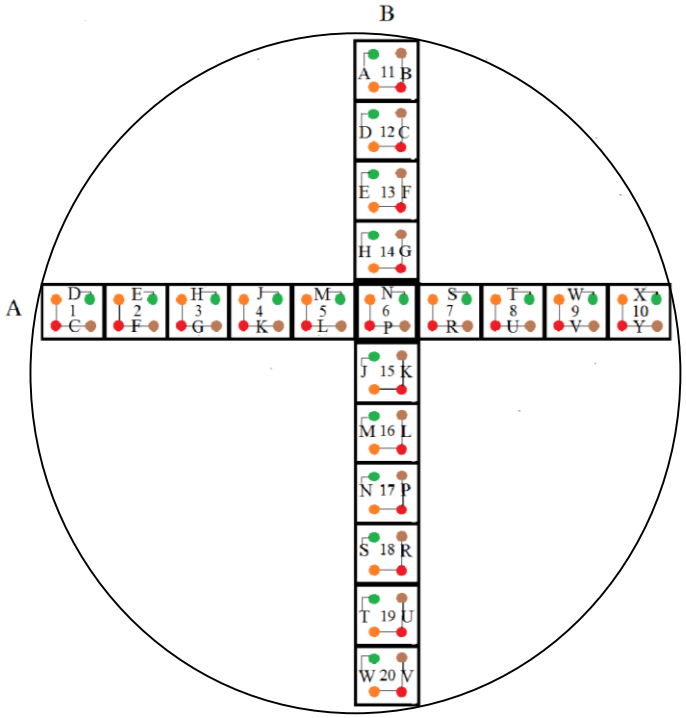
Irradiation damage to diodes

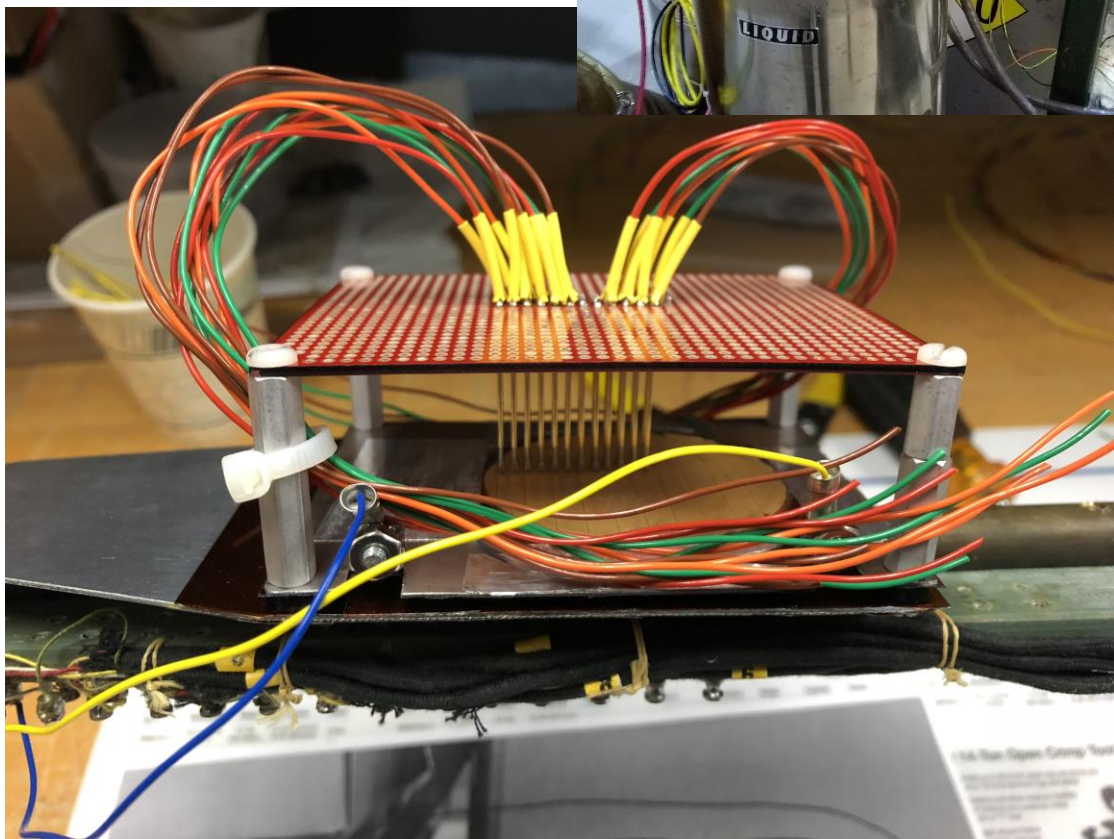
One of the purpose of my visit at BNL was to study the electrical measurements on the irradiated/burnt diodes from RHIC.



Irradiation damage to diodes

Diode measurement fixture.





Conclusion

- The RHIC abort kickers can be operated in delayed mode provided the closing of the quench switch is also delayed.
    - The delayed mode should be tested for reliability next year during the BES run.
- The Quench database should be maintained and updated to allow knowledge of the quench history of magnets and observe trends in quench events.
- Studies of radiation damage on diodes will continue.
- Other further studies could include enegry deposition simulations (FLUKA, Geant, …) to find out where the energy from lost beam is deposited.

Thank you for your attention today and for your hospitality here at BNL during the summer.