Analysis of IBHS files

Mariusz Sapinski, LOAO

GSI Helmholtzzentrum für Schwerionenforschung GmbH

Operateursschulung 2016

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Introduction

1. Analysis of the accelerator data = better understanding of the machine.
2. CERN central logging projects: LEP from 1992 (3 years after commissioning) $\rightarrow$ LHC (from 2004).
3. In 2013 CERN stored **online** $50\ \mathrm{TB}$ for about 1 million signals.
4. Diamond Light Source, UK: 100,000 Signalen.
5. for instance power converter currents are logged every $1\ \mathrm{s} - 10\ \mathrm{mins}$.
6. Here we only talk about IBHS files analysis.
7. Original idea from Wolfgang Kaufmann: 'why some IBHS files are better than others'.
8. There is not (yet) answer to this question.

IBHS files

- Contain information about: beam type, magnet strength, RF amplitude and phase and beam current, total about 570 lines.
- Saved manually by **you**, the Operators.

HS-197AU-140419-2025-UR-SU-UZ6.DAT - /home/sapinski/PHYS/bbe/pyGADA/trur

File Edit Search Preferences Shell Macro Windows

```
! Kommentar: Strahl auf Diamant ohne Folie                                                    A4 3.6 MeV/u
! BetriebsMode: Beam                                                                          A4 3.6 MeV/u
! Abschwächung: Abschwächung durch GUH2QQ14                                                   A4 3.6 MeV/u
!Gerät     Prop.     SaveWert     Strom v. IMax NormKons U_ 197AU    140419-2025             A4 3.6 MeV/u
!GUR3QQ01  VOLTS       2.349                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR3QQ01  FIELDS    0.12748E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR3QQ02  VOLTS       3.269                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR3QQ02  FIELDS   -0.17735E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR3QQ03  VOLTS       4.091                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR3QQ03  FIELDS    0.22171E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR3QQ04  VOLTS       3.074                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR3QQ04  FIELDS   -0.16679E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR4QT11  VOLTS       1.370                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR4QT11  FIELDS    0.21667E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR4QT12  VOLTS       2.348                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR4QT12  FIELDS   -0.36979E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR4QT13  VOLTS       0.897                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR4QT13  FIELDS    0.14241E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR4MS1H  VOLTS       0.029                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR4MS1H  FIELDS    0.95931E-04   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR4MS1V  VOLTS      -1.524                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR4MS1V  FIELDS   -0.50414E-02   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR4DT5   [mA]    0.04025
!GUR5MS2H  VOLTS       0.005                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR5MS2H  FIELDS    0.16540E-04   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR5MS2V  VOLTS       1.765                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR5MS2V  FIELDS    0.58386E-02   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR5QD21  VOLTS       1.613                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
#GUR5QD21  FIELDS    0.25479E+01   0.00000*IMax 0.00000 UR 197AU  8 140419-2025    66547 A4 3.6 MeV/u
!GUR5QD22  VOLTS       1.281                    0.00000    197AU  8 140419-2025    66547 A4 3.6 MeV/u
```

IBHS files statistics

- There is about 260 types of files (virtual accelerators) from Dec 2000 till Nov 2015.
- Total number of files: about 3700.

1	238U_-UL-SU-TKU	227	2008-02-14 21:26:00	2014-10-27 17:43:00
2	238U_-UL-SU-TKG	201	2008-02-21 19:53:00	2014-11-04 17:45:00
3	_50TI-UR-SU-UX8	201	2011-04-18 14:04:00	2012-06-18 00:52:00
4	197AU-UR-SU-UX0	158	2008-04-25 21:32:00	2015-09-23 16:28:00
5	197AU-UR-SU-UM3	144	2009-02-16 20:50:00	2015-09-18 12:52:00
6	_40AR-UL-SU-UY7	143	2008-12-09 16:19:00	2010-01-31 18:43:00
7	197AU-UR-SU-UM1	89	2010-02-14 13:55:00	2015-09-24 06:14:00
8	_40AR-UL-SU-US3	89	2004-04-27 17:10:00	2011-07-14 04:44:00
9	_48CA-UN-UN-UX8	74	2014-09-29 13:37:00	2015-10-08 15:07:00
10	_48CA-UN-UN-UY7	71	2014-09-29 11:10:00	2015-10-08 14:51:00
11	__6D3-UL-SU-TKG	69	2014-06-23 17:31:00	2014-06-30 08:20:00
12	_28N2-UL-SU-TKU	69	2011-04-30 08:50:00	2014-09-16 08:27:00
13	_28N2-UL-SU-TKG	67	2014-09-13 10:27:00	2014-10-13 22:16:00
14	_40AR-UL-SU-TKU	52	2008-02-01 20:04:00	2011-05-30 05:58:00
15	238U_-UL-SU-US3	50	2002-08-06 10:52:00	2014-11-04 18:52:00
16	_40AR-UR-SU-UY7	46	2007-06-27 09:01:00	2015-07-25 00:13:00
17	_40AR-UN-UN-UCW	45	2012-09-10 14:47:00	2015-08-06 07:06:00
18	197AU-UL-SU-TKU	44	2012-04-03 23:51:00	2012-05-07 13:58:00
19	_40AR-UR-SU-UX8	43	2006-11-02 13:31:00	2015-07-15 09:26:00
20	_86KR-UL-SU-TKU	40	2010-03-24 12:31:00	2014-04-02 15:02:00

statistical analysis significant from about 30 files

Save IBHS files regularly to increase statistics!

Most interesting beams

Files of the most interest to analyze before 2016 run - maybe we can learn something for this year already? (Daniel Severin suggestions).

- $238\mathrm{U} - \mathrm{UL} - \mathrm{SU} - \mathrm{TKU}$ - $\mathrm{E_{beam}} = 11.4\ \mathrm{MeV/u}$ (2014), 46 files
- $238\mathrm{U} - \mathrm{UL} - \mathrm{SU} - \mathrm{TKG}$ ...
- $197\mathrm{AU} - \mathrm{UR} - \mathrm{SU} - \mathrm{UX0}$ ...
- $197\mathrm{AU} - \mathrm{UR} - \mathrm{SU} - \mathrm{UM3}$ ...
- $197\mathrm{AU} - \mathrm{UR} - \mathrm{SU} - \mathrm{UM1}$
- $48\mathrm{CA} - \mathrm{UN} - \mathrm{UN} - \mathrm{UX8}$ ...
- $48\mathrm{CA} - \mathrm{UN} - \mathrm{UN} - \mathrm{UY7}$
- $238\mathrm{U} - \mathrm{UL} - \mathrm{SU} - \mathrm{UM3}$
- $12\mathrm{C} - \mathrm{UN} - \mathrm{UN} - \mathrm{TKU}$
- $15\mathrm{CH} - \mathrm{UL} - \mathrm{SU} - \mathrm{UM3}$

python GSI Accelerator Data Analysis

pyGADA - a python-based framework for general data analysis

- For the moment contains module for IBHS files (inspired by Peter Gerhard's script) and BIF profiles analysis.
- It is in bbe svn repository - feel free to use it.
- Maybe someone wants to develop it with me?

Future developments (some ideas):

- Include more data: more on trafos, SIS IPM, tune.
- More advanced numerical methods, eg. categorization algorithms.
- Need **YOUR** knowledge on the machine!

Current structure

```
├── branches
├── tags
└── trunk
    ├── Analyses                  – analysis scripts
    │   └── results
    ├── Elements                  – description of the magnets, cavities
    ├── Modules
    │   └── BeamRun.py, IBHS_API.py, BIF.py...
    └── data
        ├── SIS-18
        ├── Sources
        └── UNILAC
            ├── IBHS
            ├── BIF
            └── ...
```

Script example

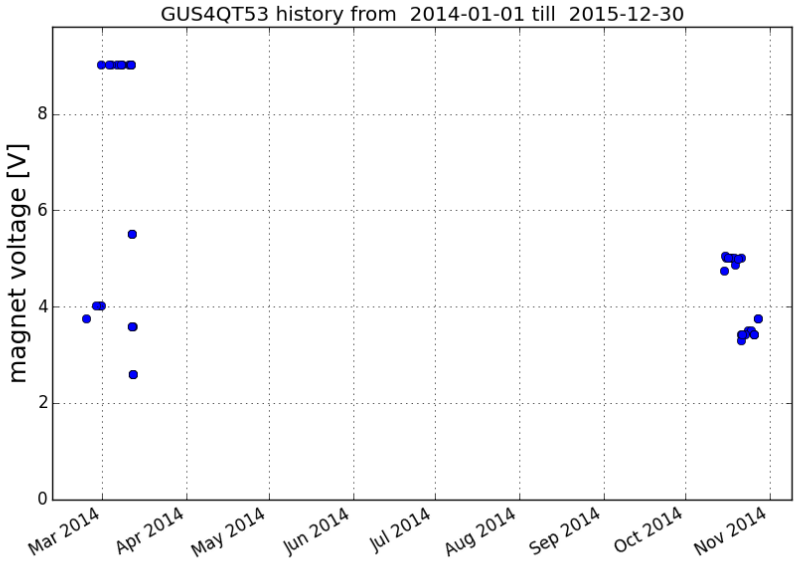
```
# ana_example1.py
import sys
sys.path.append("Modules/") # path to analysis modules
from BeamRun import *     # main class

# declare the beam run (IBHS name patter and dates):
b=BeamRun("data/UNILAC/IBHS/HS-238U_-*UL-SU-TKU.DAT","2014-1-1",dateti
b.addBeamlineSegment("GUL_2015","GUH_2015","GUS_2015",
"GUA_2015","GUE_2015","GUT_2015")
# IBHS data reading:
b.readIBHS()
# test integrity of IBHS files wrt Beamline Segments:
b.integrityIBHS_MAG()
# selection: keep only main magnets (QS, QD, QT and QQ)
b.ibhs.retainMainMagnets()  # optional
# can be:
#b.ibhs.retainSteeringMagnets()
#b.ibhs.retainMagnets(["GUS4QT53","GUA4QT11"])
```

238U-UL-SU-TKU beam - settings variation

Plot voltage setting for a particular magnet, historical and distribution:

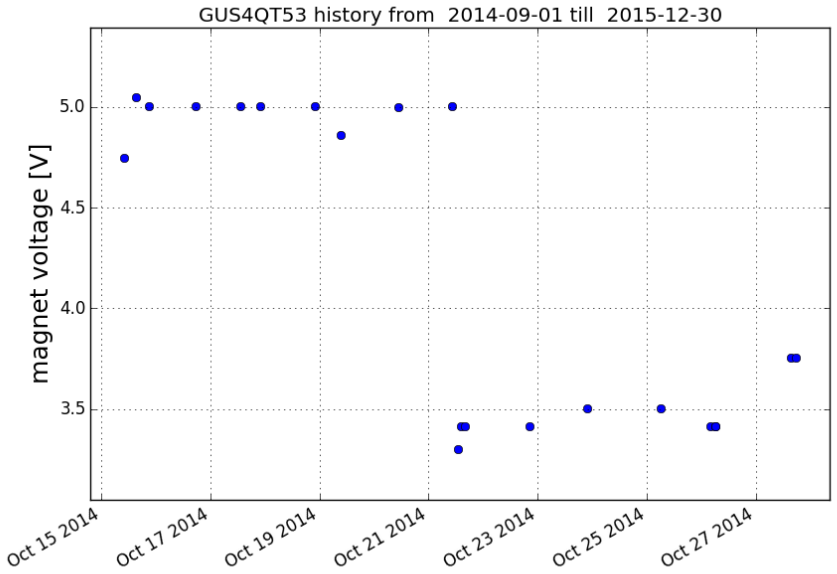
b.ibhs.plotVoltHist("GUS4QT53")

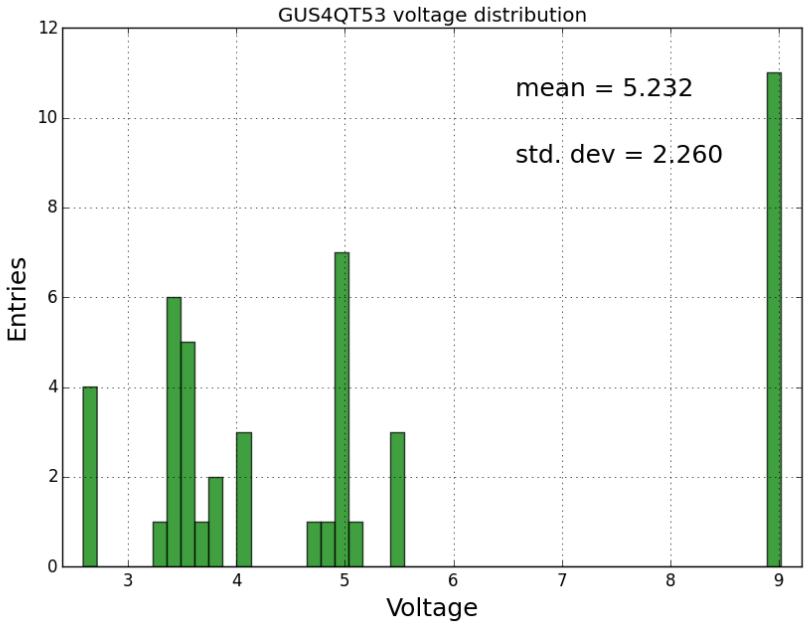


238U-UL-SU-TKU beam - settings variation

Plot voltage setting for a particular magnet, historical and distribution:

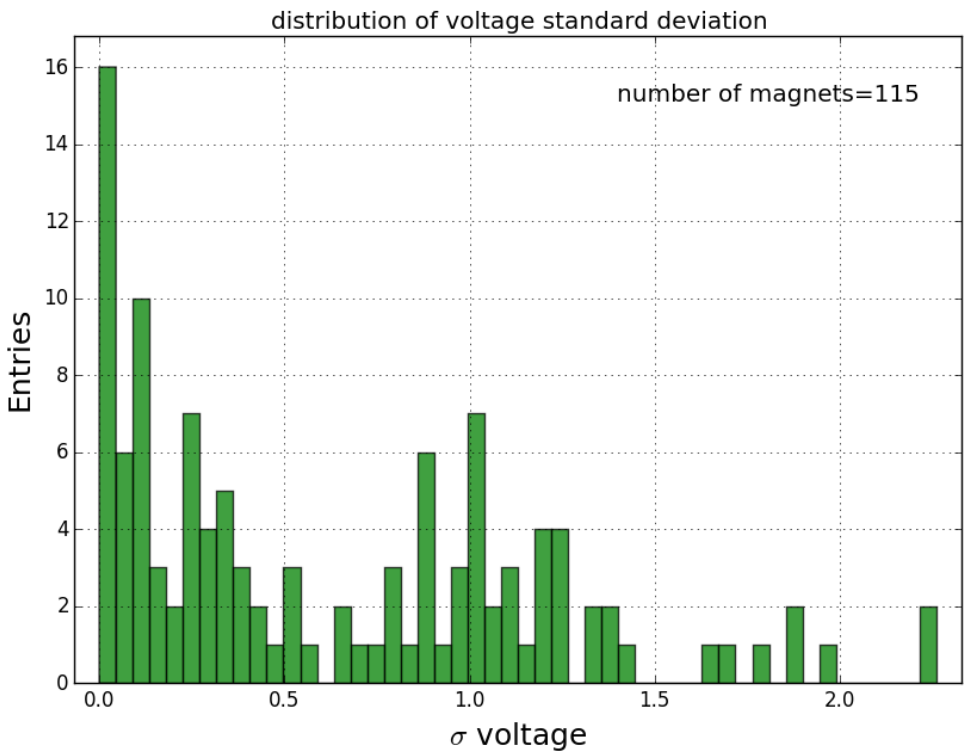
b.ibhs.plotVoltHist("GUS4QT53",start_date=datetime(2014,9,1))
b.ibhs.plotVoltDist("GUS4QT53")





238U-UL-SU-TKU beam - settings variation

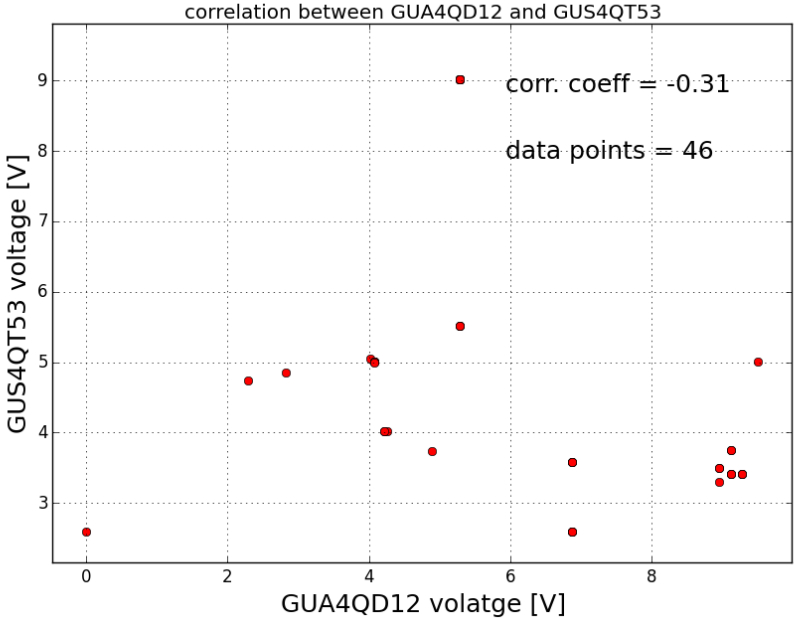
b.ibhs.plotVoltStdDist(stdThr=1.0)

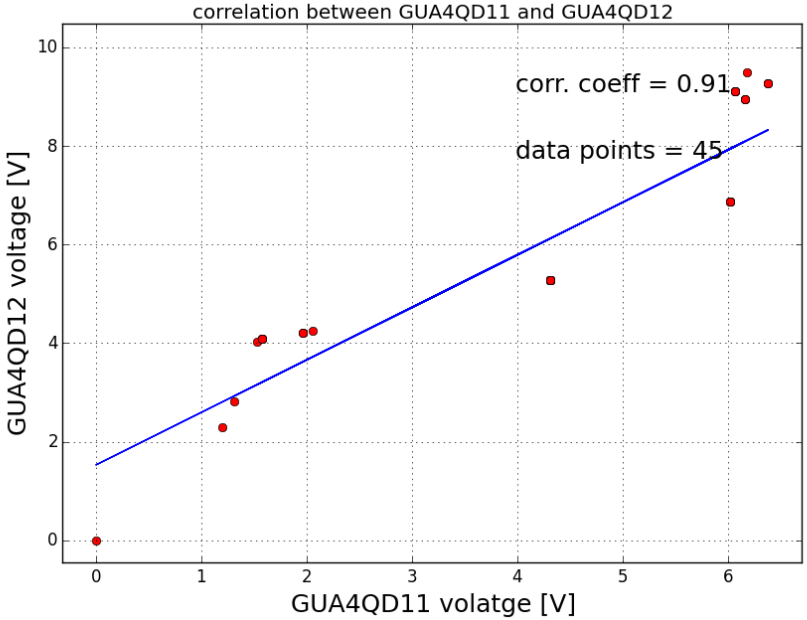


Magnet	σ
GUA4QD12	2.2
GUA4QD11	2.0
GUS4QT51	1.9
GUS4QT53	2.3
GUA1QS1Z	1.9
GUA2QS3Z	1.8
GUA2QS4Z	1.7

238U-UL-SU-TKU beam - correlation between magnets

```
b.ibhs.plotMagnetsCorr("GUA4QD12","GUS4QT53")
# another, more pronounced correlation:
b.ibhs.plotMagnetsCorr("GUA4QD12","GUA4QD11",fit=True)
```

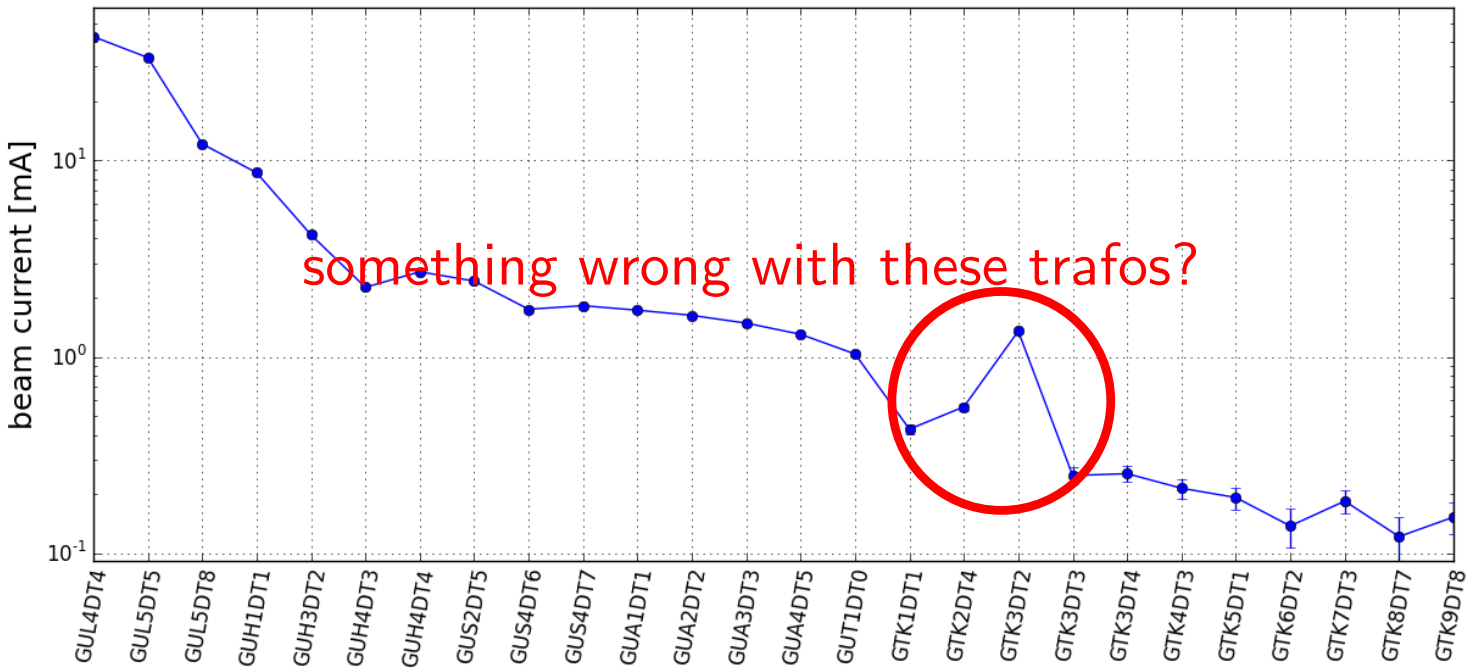




238U-UL-SU-TKU beam - beam current

Trafos are saved in IBHS files for a single shot. That is not representative for setting quality. In the future **better data** are required. Beam current:

b.ibhs.plotBcurLoss()

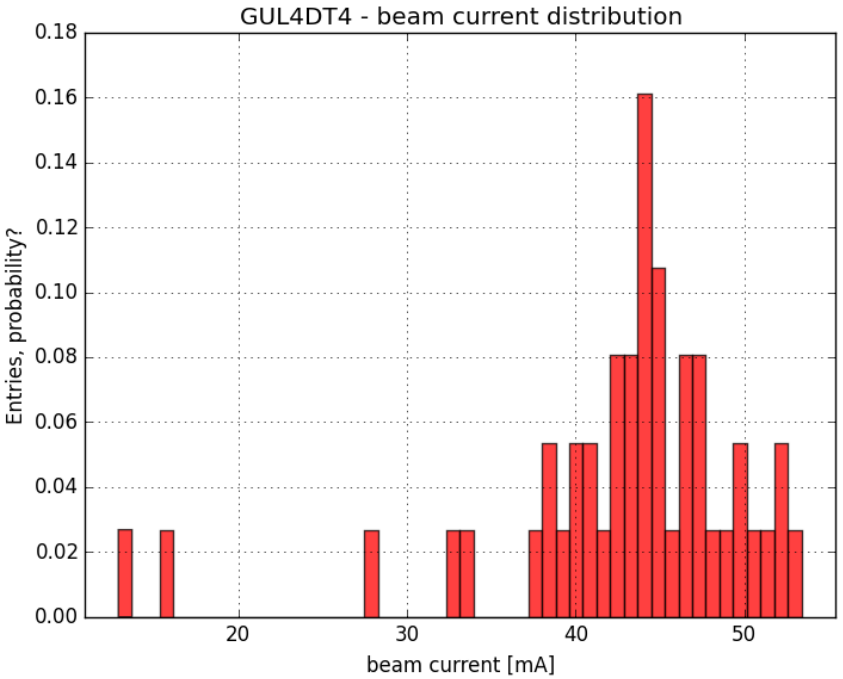


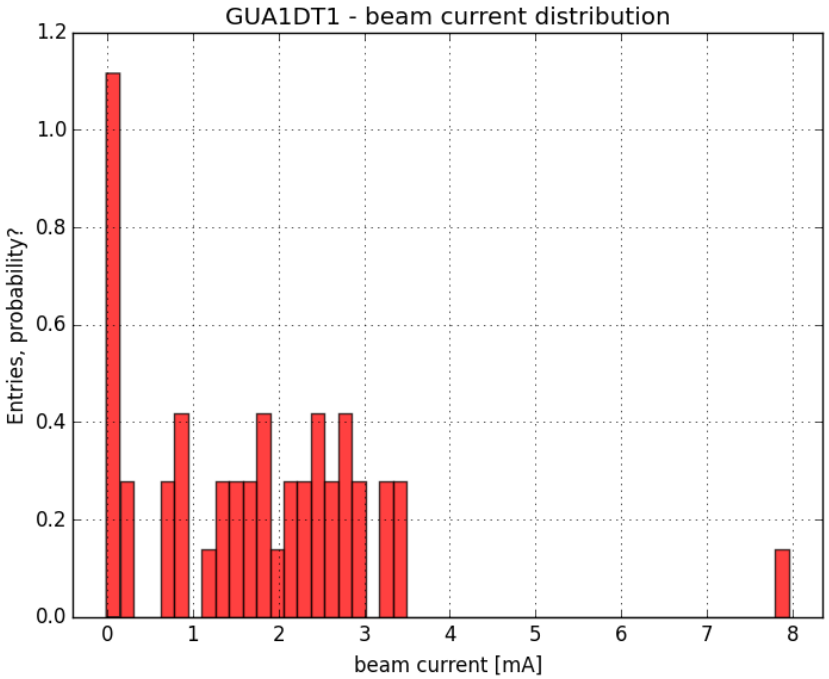
Use two trafos to define global transmission: GUL4DT4 and GUA1DT1:

b.ibhs.defineTrss("GUL4DT4","GUA1DT1")

238U-UL-SU-TKU beam - trafo data quality

b.ibhs.plotBcurDist("GUL4DT4")
b.ibhs.plotBcurDist("GUA1DT1")



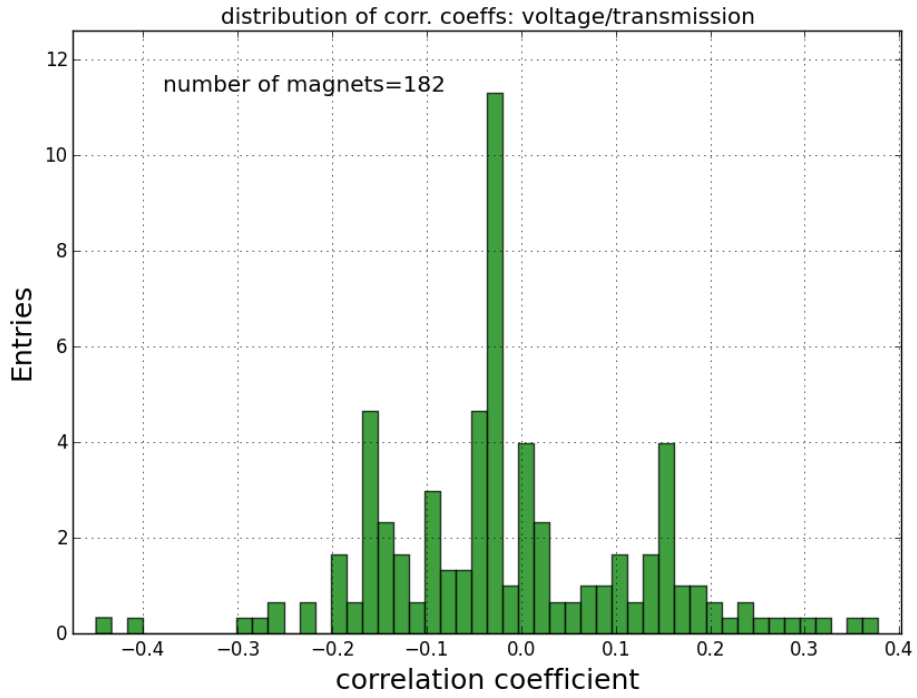


Large spread of data. GUA1DT1: often very small values, single shot transmission data are not very good. Downstream trafos are worse.

238U-UL-SU-TKU beam - correlations

Correlations between magnet settings and transmission.

b.ibhs.plotVoltTrssCorrDist(corrThr=0.3)



Magnet	r
GUH2QQ14	0.377
GUH4MS6V	0.313
GUA4QD11	-0.411
GUA4QD12	-0.450
GTK5MO1	0.350

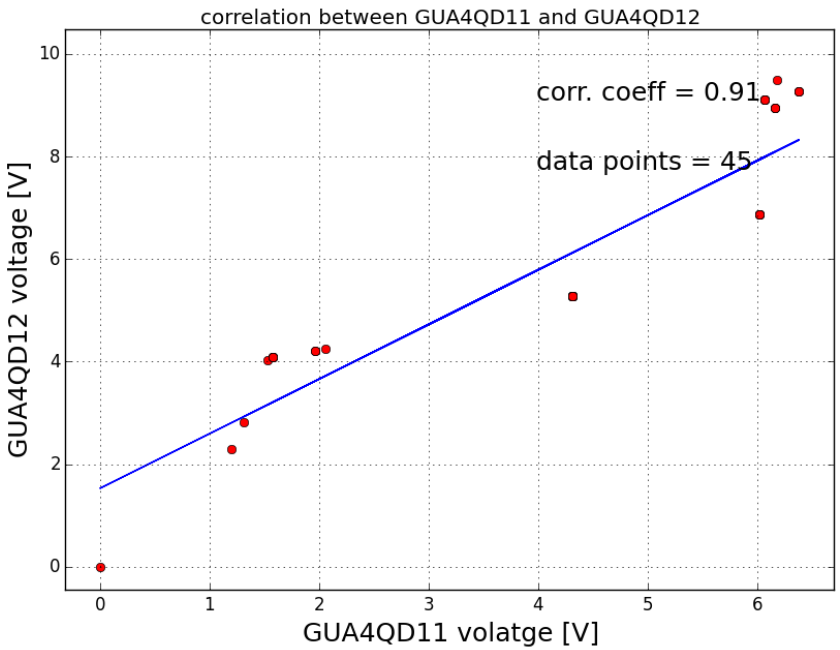
Correlations for single elements are weak. Not surprising - this is why **operators work is challenging!**

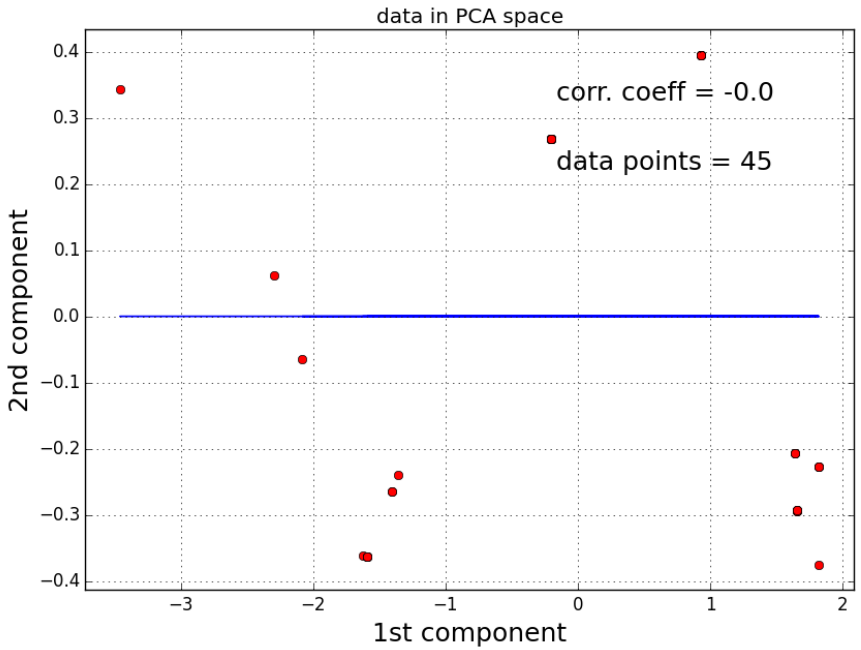
Why peak at r=-0.04?

Principal Component Analysis

PCA is a linear transformation which converts set of possibly correlated variables to uncorrelated ones.

PCA1=A*GUA4QD11+B*GUA4QD12 -describes **trend in data**.





found recently: C. Bloomer, G. Rehm, *Using Principal Component Analysis to Find Correlations and Patterns at Diamond Light Source*, IPAC2014, THPME188

(again: some GBbytes of data analysed!)

238U-UL-SU-TKU beam - PCA

```
# select magnets with high variation of settings:
b.ibhs.retainVaryingMagnets(1.)
b.ibhs.makeMAGrunTsData()  # additional operation
b.ibhs.runRootPCA()
```

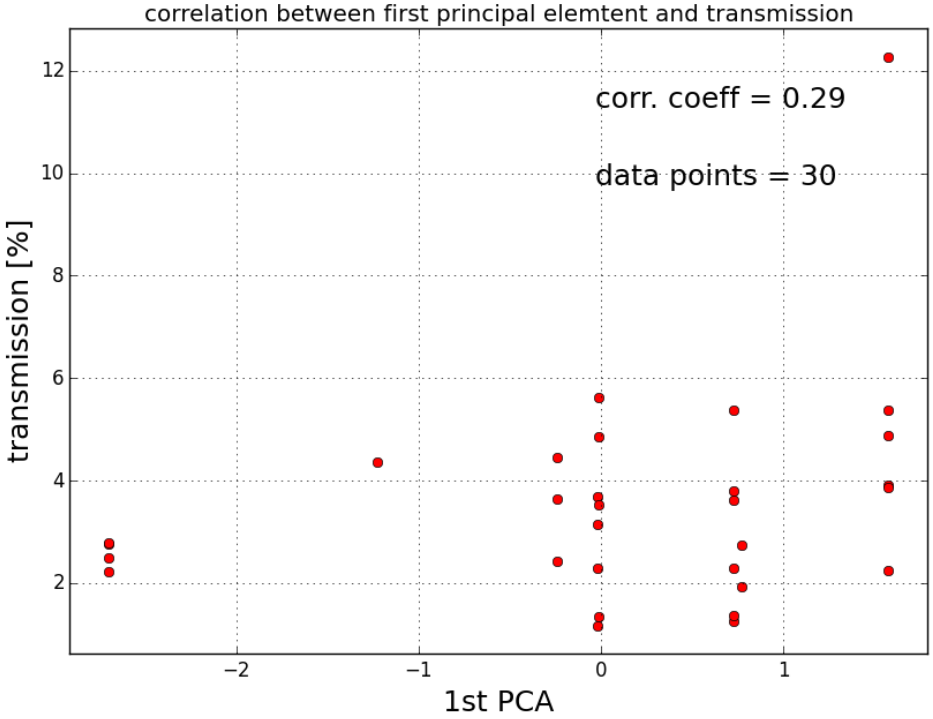
keeping 13 out of 115 magnets:

Magnet	1st comp. contribution
GUH2QQ14	0.015
GUS4QT51	0.081
GUS4QT53	-0.085
GUA1QS1Z	0.169
GUA1QS2Z	0.242
GUA2QS3Z	0.174
GUA2QS4Z	0.192
GUA2QS5Z	0.227
GUA3QS6Z	0.220
GUA3QS7Z	0.228
GUA4QS9Z	0.238
GUA4QD11	0.131
GUA4QD12	0.123

238U-UL-SU-TKU beam - PCA

Correlation of 1st PCA to transmission

b.ibhs.plot1PCADist()

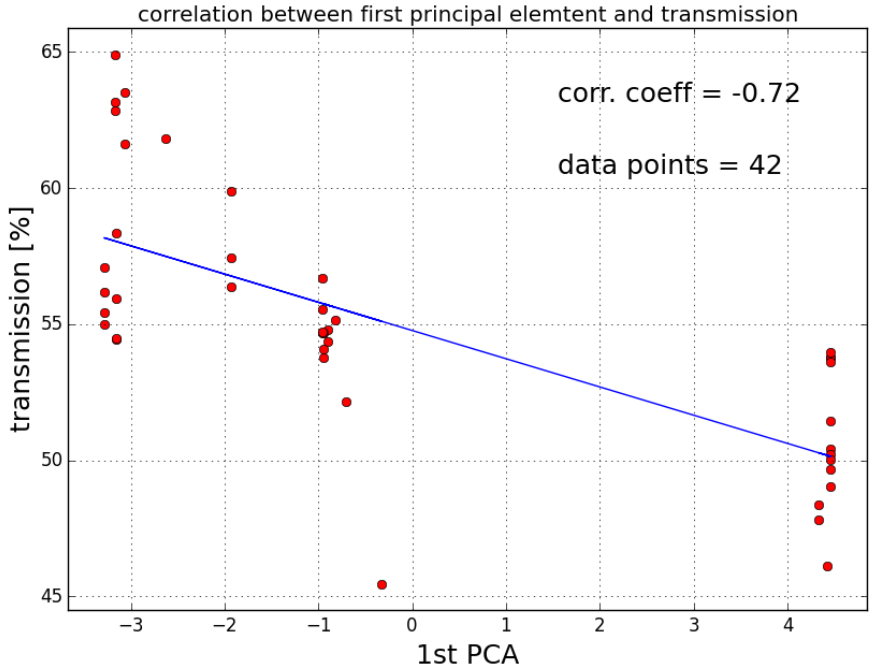


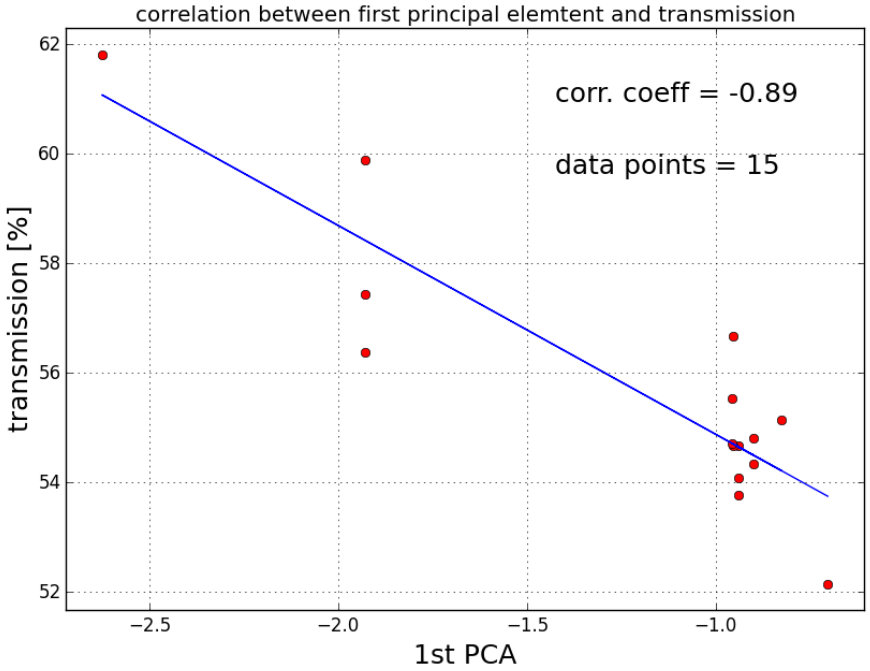
No correlation... ;-(but let's look at other beams!

48Ca-UN-UN-UX8 beam - PCA

Correlation of 1st PCA to transmission

```
b.ibhs.retainVaryingMagnets(1.0)
b.ibhs.plot1PCADist(fitline=True)
b.ibhs.plot1PCADist(pcarange=(-3.,-0.5),fitline=True) # zoom
```



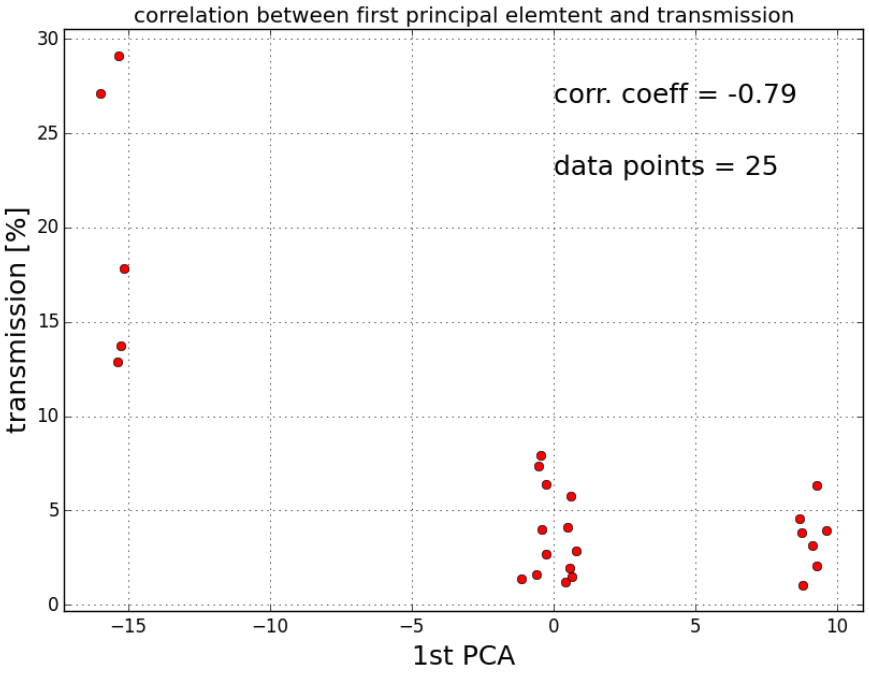


Strong correlation! Based on PCA from 13 magnets. Potentially a suggestion of settings can be done!

197Au-UR-SU-UM3 at 4.7 MeV/u - PCA

Correlation of 1st PCA to transmission

b.ibhs.plot1PCADist()



Potential algorithm:

$$V_{mag1} = a_1 * x$$
$$V_{mag2} = a_2 * x$$
$$V_{mag3} = a_3 * x$$

...

and optimal x:

$x = x_1 ... x_2$

Again a strong correlation!

Summary and conclusions

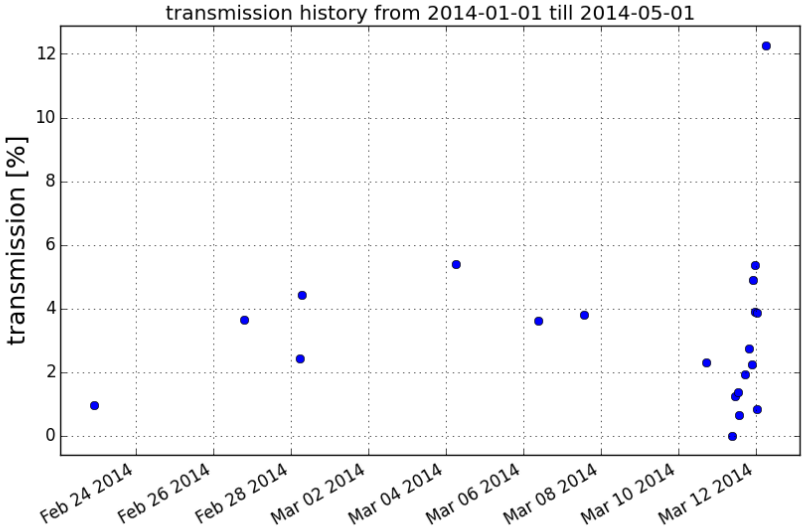
1. Analysis of machine data improves target-time, setup-time and transmission.
2. Let's collect and analyze a significant amount of data in 2016: BIF, trafos, SIS tune spectrum, IPM, orbit etc.
3. (for FAIR a special data archiving system is planned, but will not be ready in 2016)
4. Try to setup some beams in 2016 following results of IBHS files analysis.
5. There is a lot of work with this analysis ahead, maybe someone would like to help? Technologies: basic linux and python.

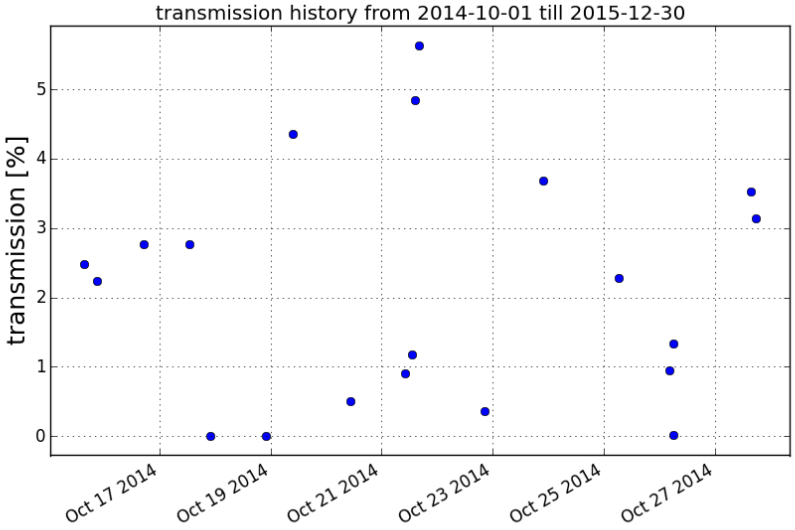
Special thanks to: Wolfgang, Stephan, Petra, Peter.

Thank you for your attention!

238U-UL-SU-TKU beam - transmission evolution

```
b.ibhs.plotTrssHist(end_date=datetime(2014,5,1))
b.ibhs.plotTrssHist(start_date=datetime(2014,10,1))
```

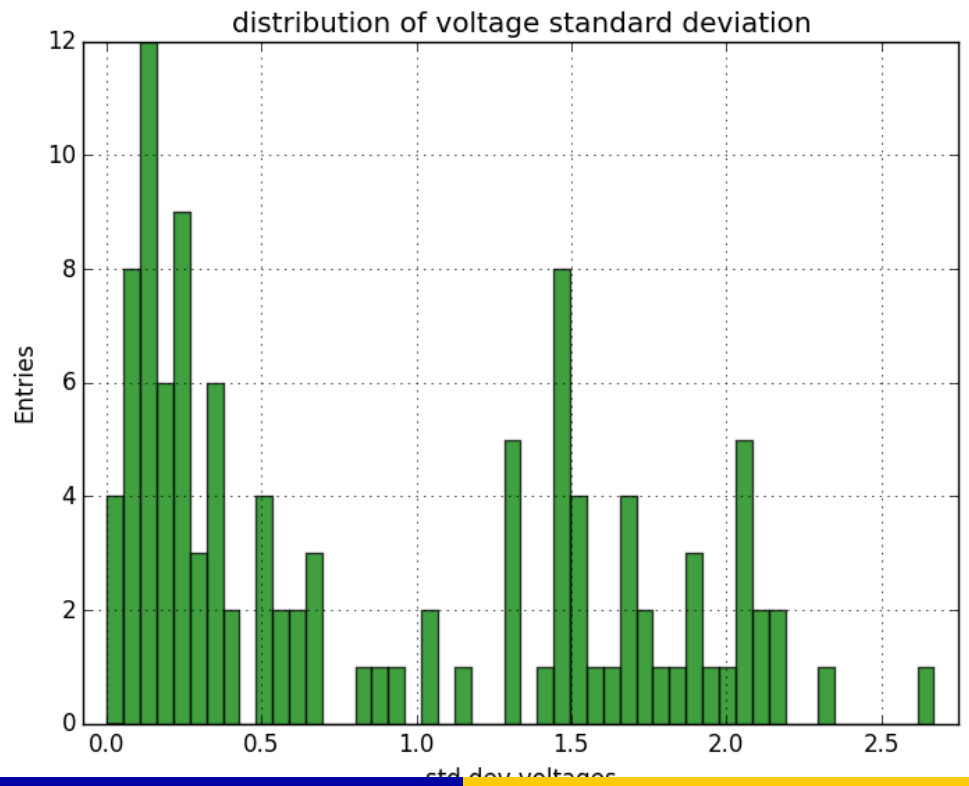




Appendix 1: results 238U UL SU TKG

- xx files from Feb 2008 till October 27th, 2014.
- energy 11.4 MeVn - energy analysis!
- used only 2014 data (62 files).

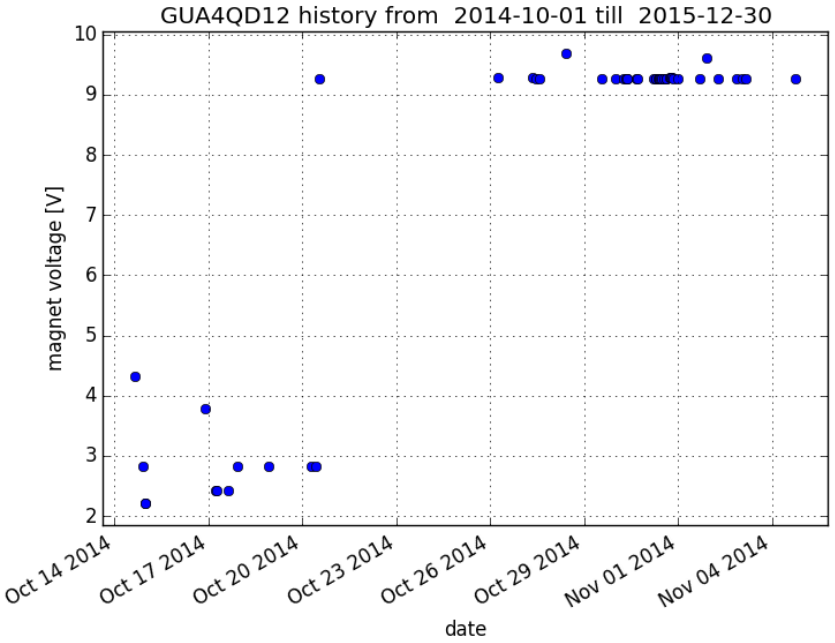
```
b.ibhs.plotVoltStdDist(printThreshold=2.0)
```

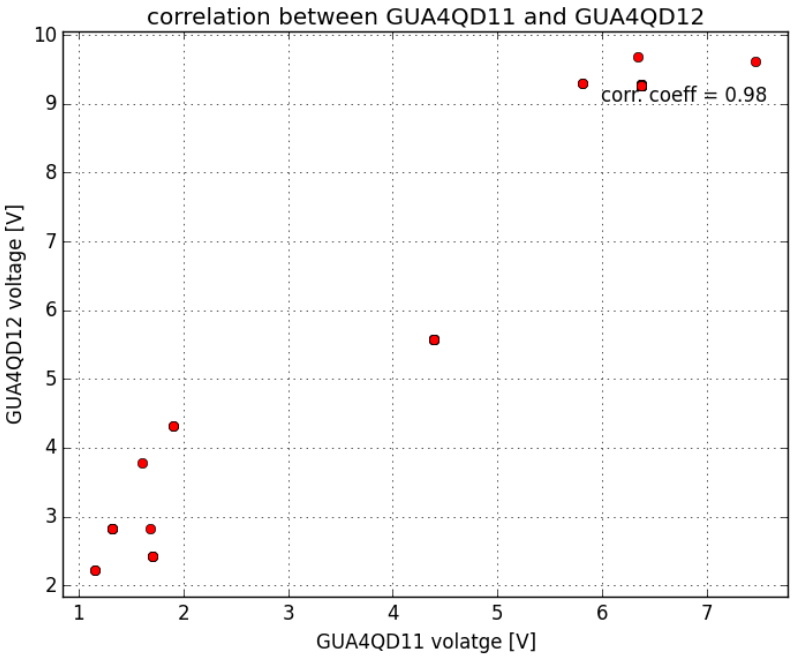


Magnet	σ
GUS4QT53	2.1
GUA1QS01	2.1
GUA1QS05	2.1
GUA1QS09	2.0
GUA1QS13	2.0
GUA1QS1Z	2.2
GUA2QS3Z	2.1
GUA4QD12	2.7
GTK5QD41	2.3
GTK5QT51	2.2
GTK5QT52	2.1

Appendix 1: results 238U UL SU TKG

History and correlations.





Appendix 1: results 238U UL SU TKG