

# Analysis of IBHS files

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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) → LHC (from 2004).
- ③ In 2013 CERN stored **online** 50 TB for about 1 million signals.
- ④ Diamond Light Source, UK: 100,000 Signalen.
- ⑤ for instance power converter currents are logged every 1 s – 10 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/trun									
	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 GUH2Q014							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 1.291	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 15:50:00	2014-09-16 08:27:00
13	_28N2-UL-SU-TKG	67	2014-09-13 11:27:00	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).

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

# python GSI Accelerator Data Analysis

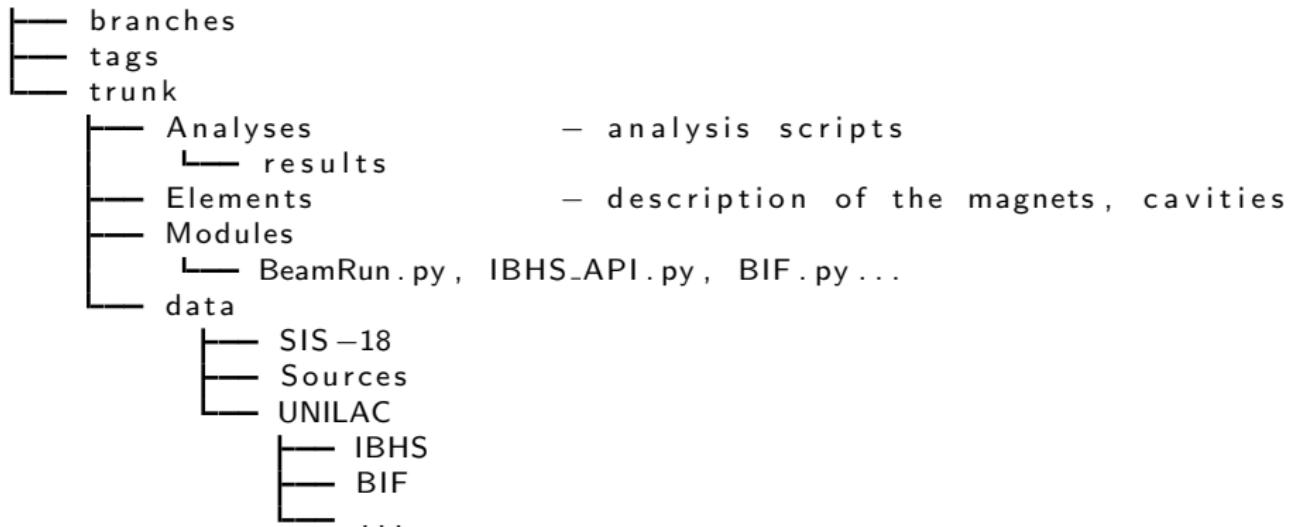
**pyGADA** - a python-based framework for general data analysis

- 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



# Script example

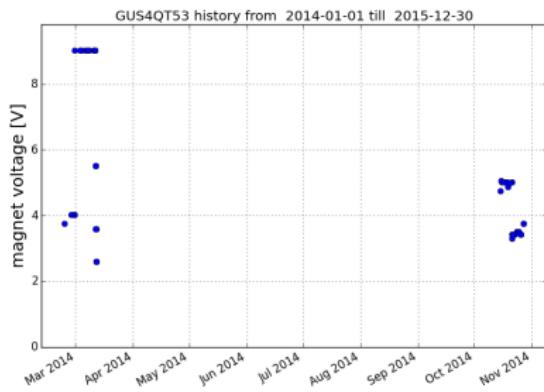
```
# ana-example1.py
import sys
sys.path.append("Modules/") # path to analysis modules
from BeamRun import *      # main class

# 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:

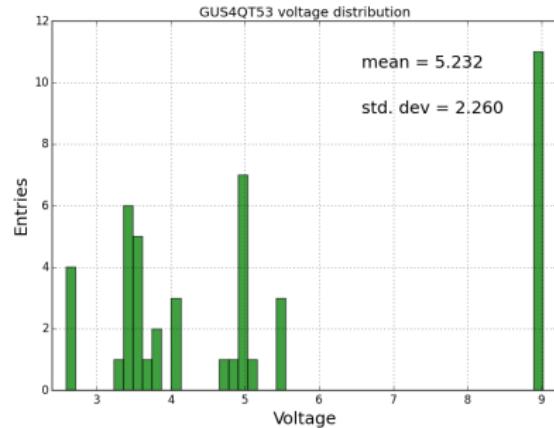
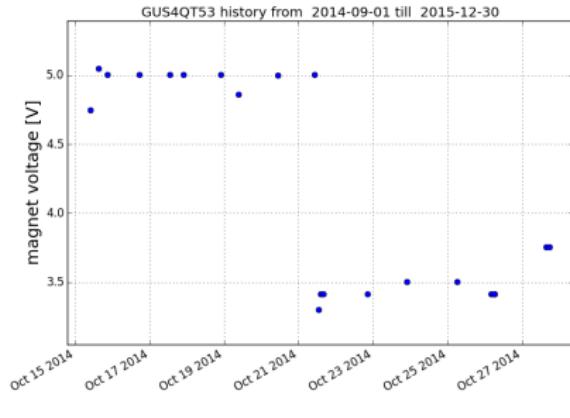
```
b.ibhs.plotVoltHist("GUS4QT53")
```



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

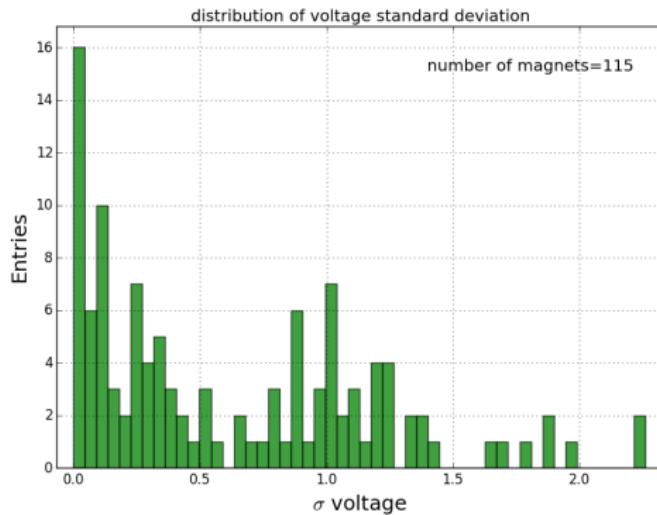
Plot voltage setting for a particular magnet, historical and distribution:

```
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)



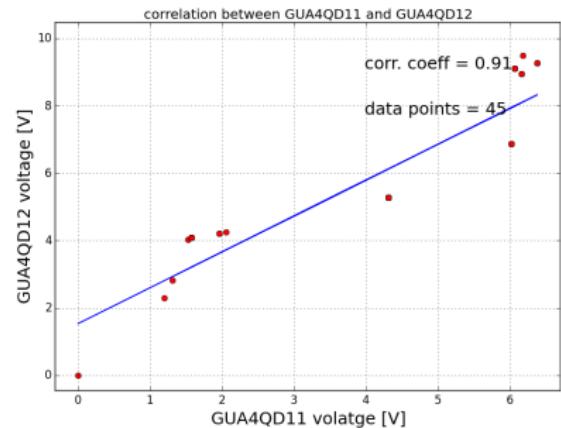
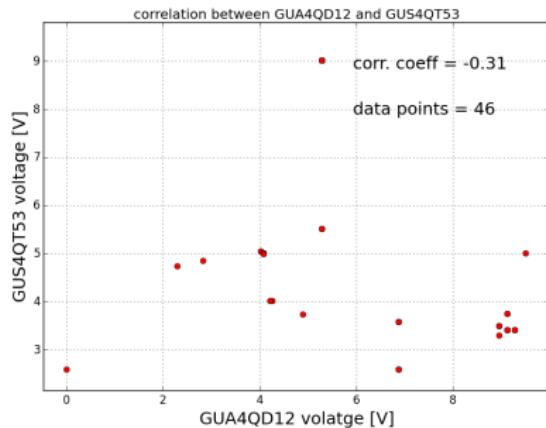
Magnet	$\sigma$
GUA4QD12	2.2
GUA4QD11	2.0
GUS4QT51	1.9
GUS4QT53	2.3
GUA1QS1Z	1.9
GUA2QS3Z	1.8
GUA2QS4Z	1.7

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

```
b.ibhs.plotMagnetsCorr("GUA4QD12","GUS4QT53")
```

# another, more pronounced correlation:

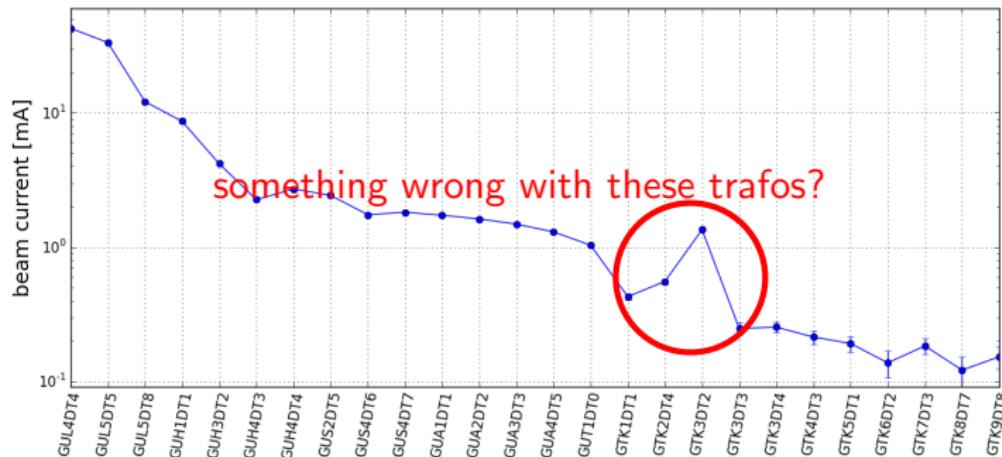
```
b.ibhs.plotMagnetsCorr("GUA4QD12","GUA4QD11",fit=True)
```



## 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()`

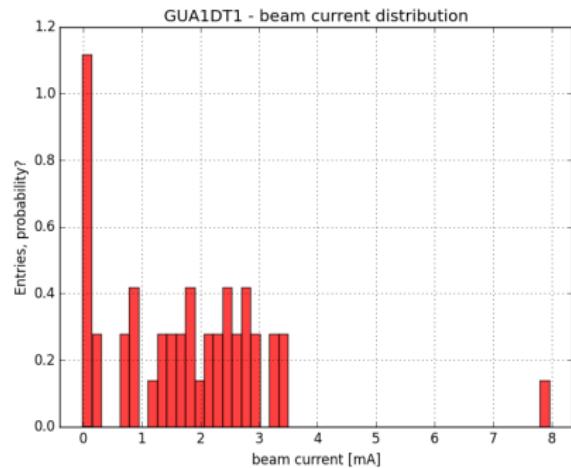
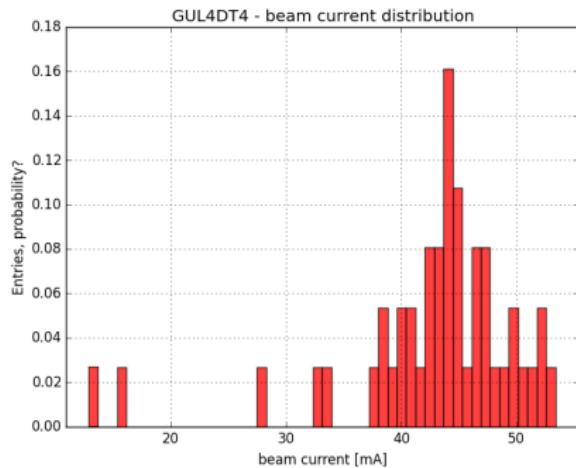


Use two trafos to define global transmission: GUL4DT4 and GUA1DT1:

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

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

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

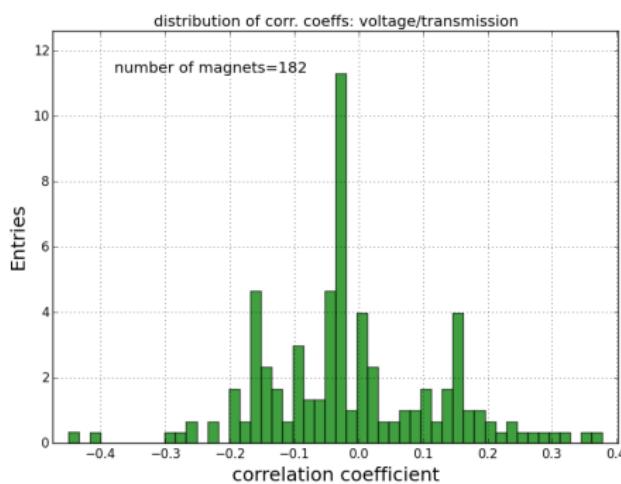


Large spread of data. GUA1DT1: often very small values, single shot transmission data are not very good. Downstream trafos are worse.

# 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

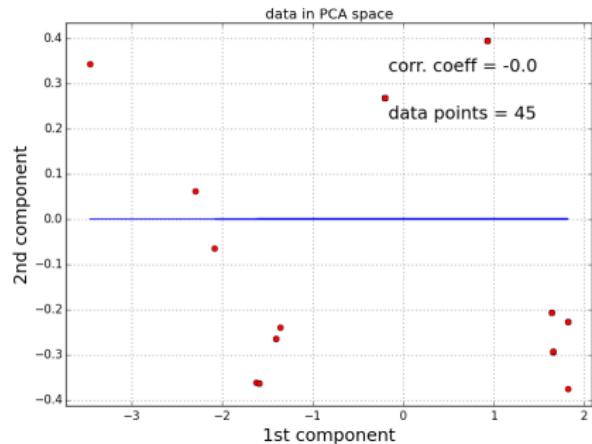
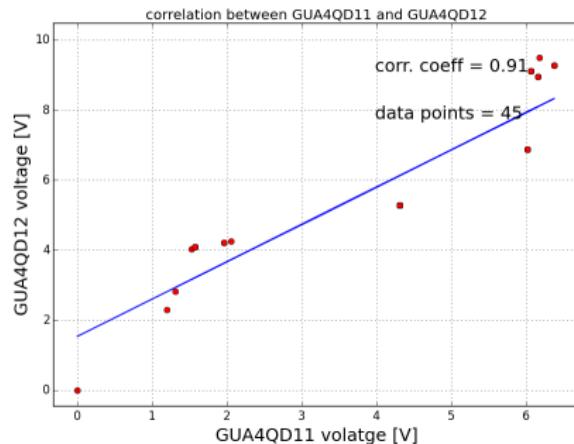
Correlations for single elements are weak. Not surprising - this is why **operators work is challenging!**

Why peak at  $r=-0.04$ ?

# Principal Component Analysis

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

$\text{PCA1} = A * \text{GUA4QD11} + B * \text{GUA4QD12}$  -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()
```

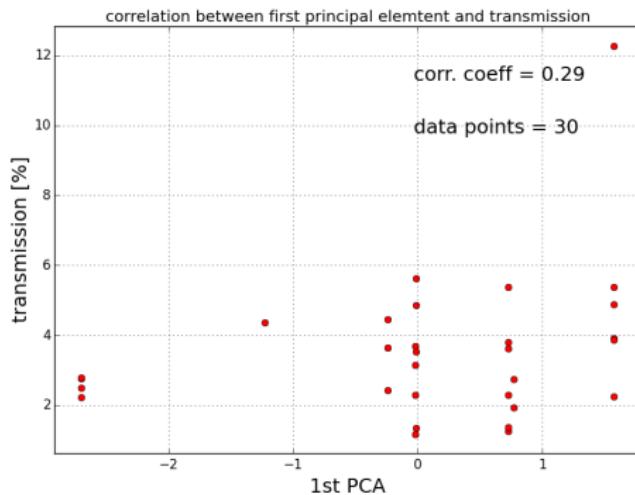
keeping 13  
out of 115  
magnets:

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

# 238U-UL-SU-TKU beam - PCA

Correlation of 1st PCA to transmission

b.ibhs.plot1PCADist()

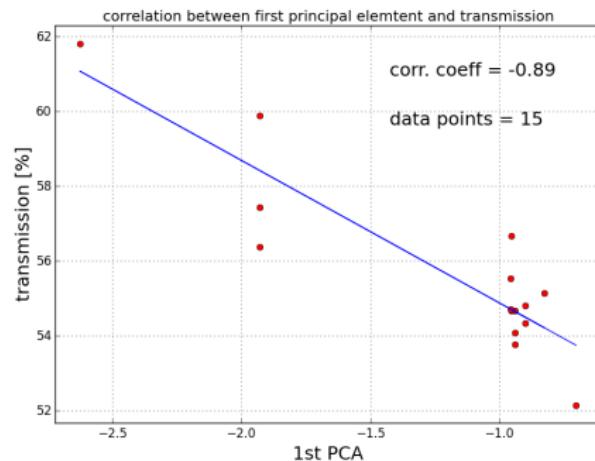
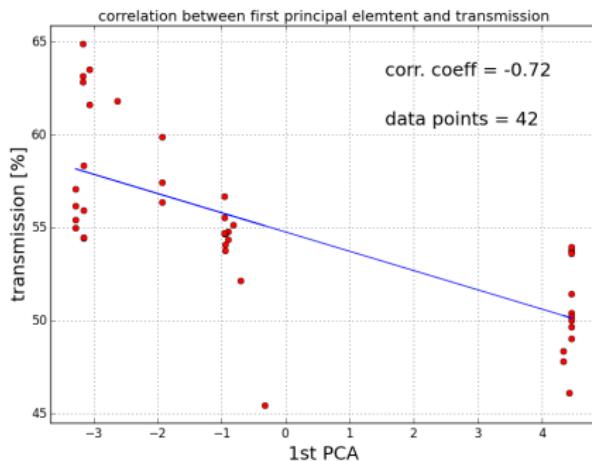


No correlation... ;-( but let's look at other beams!

# 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
```

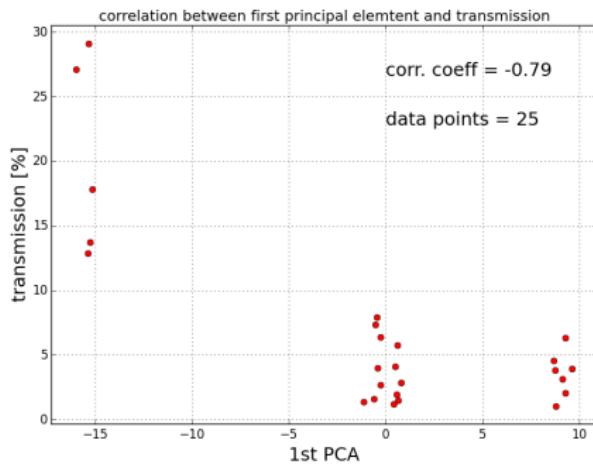


Strong correlation! Based on PCA from 13 magnets. Potentially a suggestion of settings can be done!

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

Correlation of 1st PCA to transmission

b.ibhs.plot1PCADist()



Again a strong correlation!

Potential algorithm:

$$V_{mag1} = a_1 * x$$

$$V_{mag2} = a_2 * x$$

$$V_{mag3} = a_3 * x$$

...

and optimal  $x$ :

$$x = x_1 \dots x_2$$

## Summary and conclusions

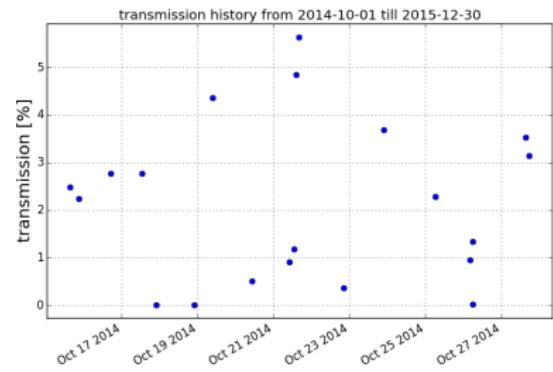
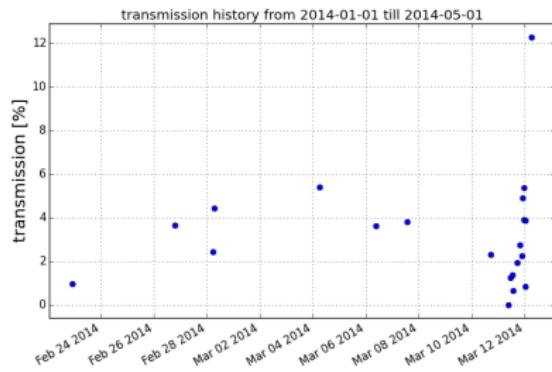
- ① Analysis of machine data improves target-time, setup-time and transmission.
- ② Let's **collect and analyze a significant amount of data in 2016:** BIF, trafos, SIS tune spectrum, IPM, orbit etc.
- ③ (for FAIR a special data archiving system is planned, but will not be ready in 2016)
- ④ Try to **setup 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

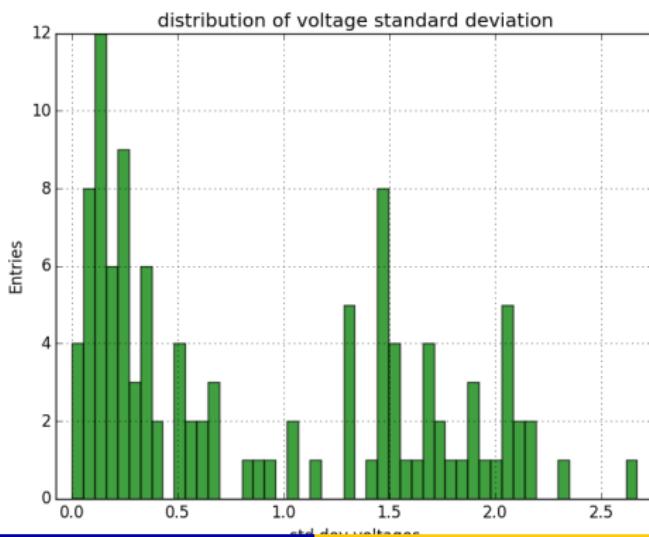
```
b.ibhs.plotTrssHist(end_date=datetime(2014,5,1))  
b.ibhs.plotTrssHist(start_date=datetime(2014,10,1))
```



# 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).

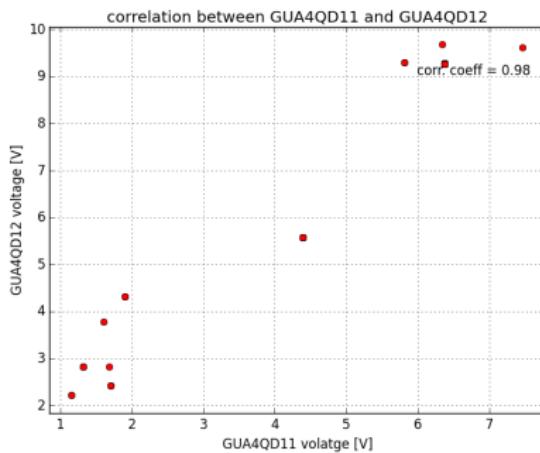
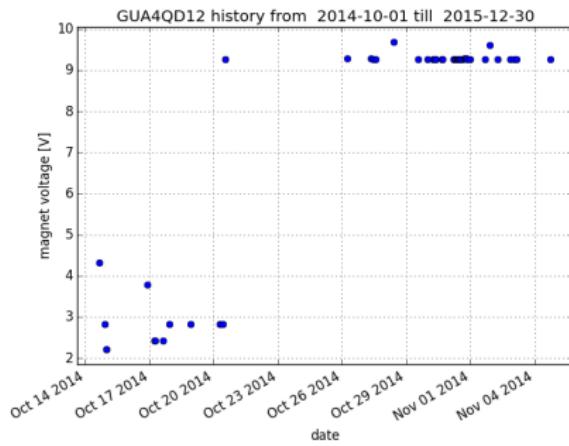
b.ibhs.plotVoltStdDist(printThreshold=2.0)



Magnet	$\sigma$
GUS4QT53	2.1
GUA1QS01	2.1
GUA1QS05	2.1
GUA1QS09	2.0
GUA1QS13	2.0
GUA1QS1Z	2.2
GUA2QS3Z	2.1
<b>GUA4QD12</b>	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

