Status report on EmTEx at GSI

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M. Chung, FNAL

Emittance **T**ransfer **Ex**periment

EmTEx

at the

GSI Helmholtzzentrum für Schwerionenforschung GmbH

Darmstadt, Germany

ID: 2107 - THOBA02 Status Report on the Emittance Transfer Experiment EMTEX at GSI, Michael Tobias Maier (GSI, Darmstadt)

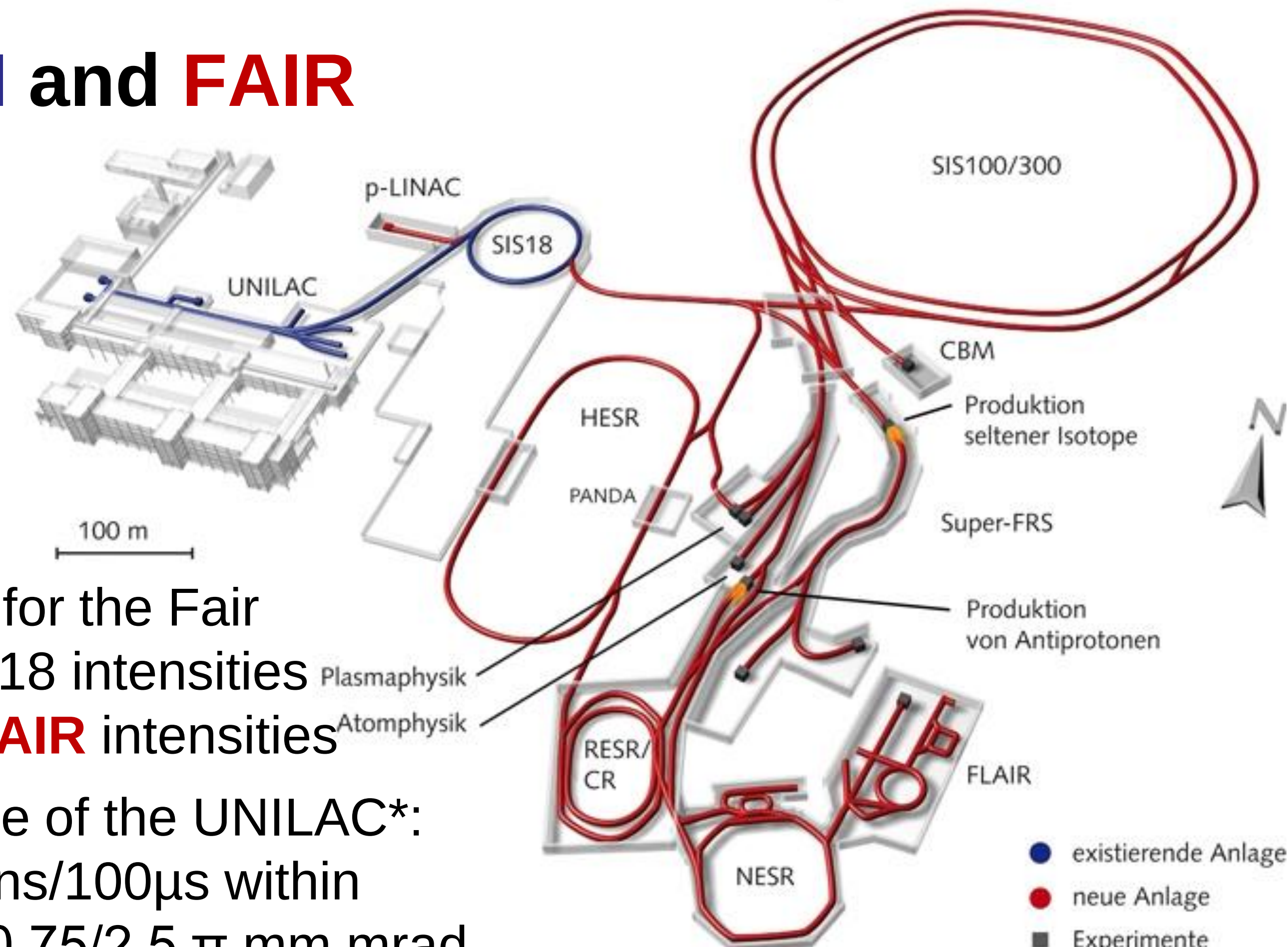
Thu 11:45 - main hall

Overview

- Overview
- Purpose of EmTEx
- Working scheme of EmTEx
- EmTEx beam line
- Status and first commissioning results
- Conclusion

FAIR accelerator chain

GSI and FAIR



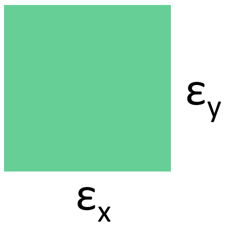
As **GSI** serves as injector for the Fair facility the achievable SIS18 intensities are linked to achievable **FAIR** intensities

FAIR design values require of the UNILAC*:
15 emA U^{28+} ~ $3.3x10^{11}$ ions/100µs within transverse emittances of 0.75/2.5 π mm.mrad

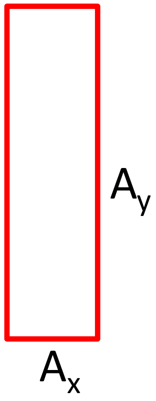
***TAC Report GSI-FAIR U-Chain, Nov (2013)**

Purpose of EmTEx

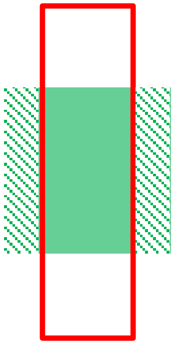
- beam delivered from a linac is generally „round",
  i.e. $\boldsymbol{\varepsilon_x = \varepsilon_y}$



- **M**ulti **T**urn **I**njection **MTI** imposes „flat" ring acceptances,
  i.e. $\boldsymbol{A_x < A_y}$



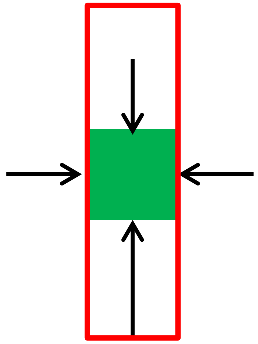
- so even if $\varepsilon_x \cdot \varepsilon_y < A_x \cdot A_y$, the MTI-efficiency might be poor



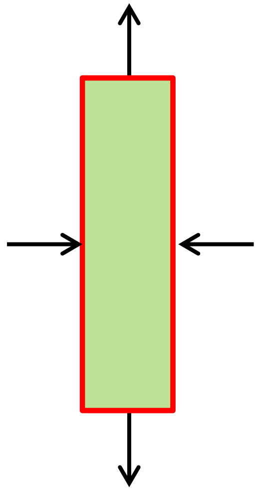
Purpose of EmTEx

To improve performance for multi-turn injection filling circular accelerators

- emittance shrinkage in both planes requires brighter beam from source and/or cooling

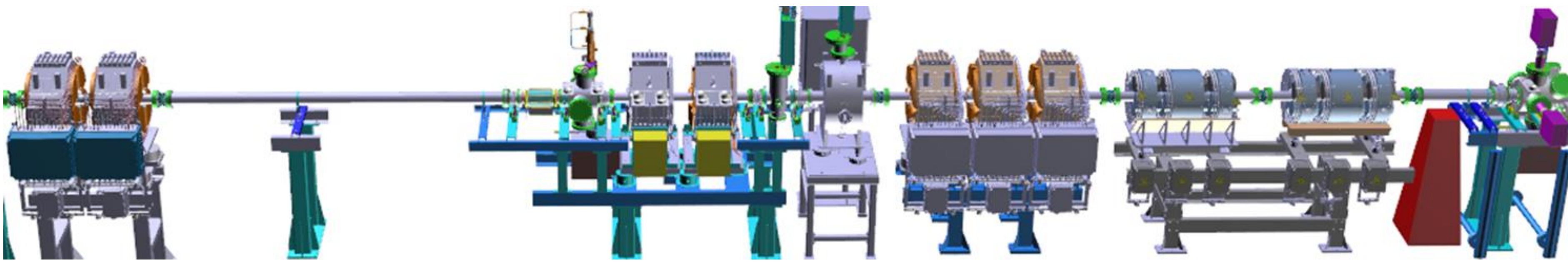


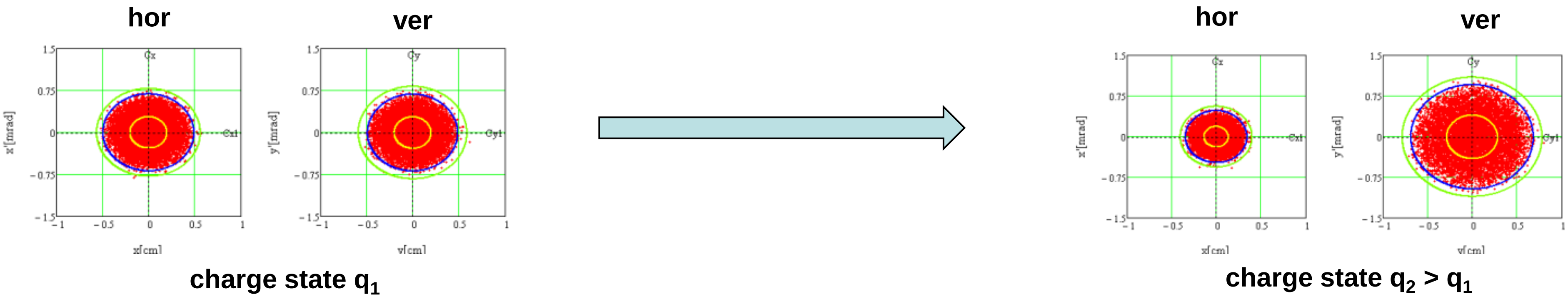
- **EMITTANCE TRANSFER** preserves $\varepsilon_x \cdot \varepsilon_y$, hence it does not require brighter source beams nor cooling



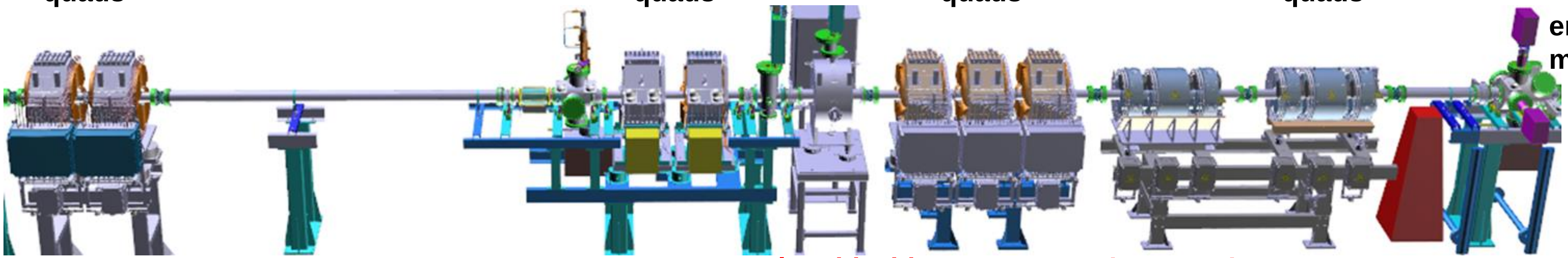
Emittance transfer experiment

- EmTEx means Emittance Transfer Experiment
- It changes the charge state and transverse emittance partitioning of the beam
- It does not cause beam loss
- It works by varying one single magnet field, which controls the partitioning



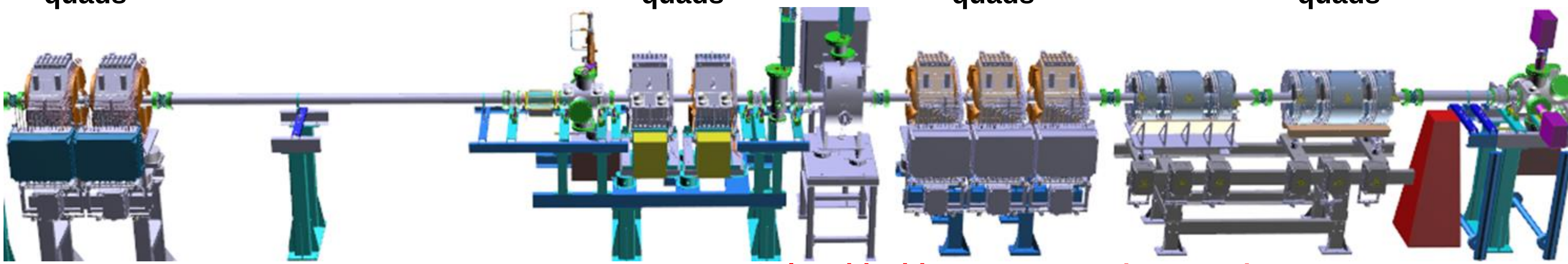


Working scheme of EmTEx



- To change the charge state and transverse emittance partitioning of the beam a split solenoid with a stripping foil in its center is used.
- The change of charge state inside solenoid causes entrance & exit fringe fields to act different with respect to the amount of „torque“ imposed on the beam.

Working scheme of EmTEx



- The change of charge state inside the solenoid creates an „effective stand-alone“ solenoid fringe field, as Bρ differs at the entrance and exit fringe field.
- This causes a transformation changing the beam eigen-emittances defined through:

4d beam matrix

skew symetric matrix

$$\varepsilon_1 = \frac{1}{2}\sqrt{-tr[(CJ)^2] + \sqrt{tr^2[(CJ)^2] - 16det(C)}}$$

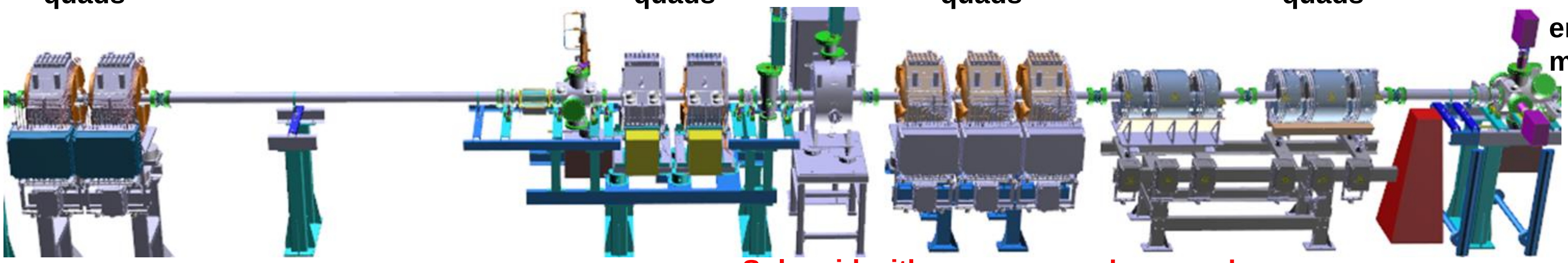
$$\varepsilon_2 = \frac{1}{2}\sqrt{-tr[(CJ)^2] - \sqrt{tr^2[(CJ)^2] - 16det(C)}}$$

$$C = \begin{bmatrix} <xx> & <xx'> & <xy> & <xy'> \\ <x'x> & <x'x'> & <x'y> & <x'y'> \\ <yx> & <yx'> & <yy> & <yy'> \\ <y'x> & <y'x'> & <y'y> & <y'y'> \end{bmatrix}$$

$$J := \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

$$E_{4d} = \varepsilon_1 \cdot \varepsilon_2$$

Working scheme of EmTEx



- the „effective stand-alone" solenoid fringe field preserves the 4d rms-emittance:

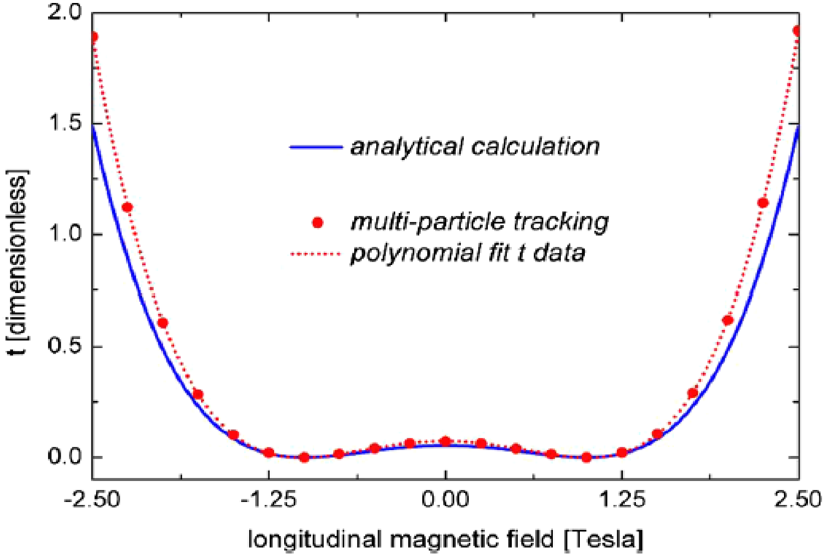
$$E_{4d}^2 = det \begin{bmatrix} <xx> & <xx'> & <xy> & <xy'> \\ <x'x> & <x'x'> & <x'y> & <x'y'> \\ <yx> & <yx'> & <yy> & <yy'> \\ <y'x> & <y'x'> & <y'y> & <y'y'> \end{bmatrix} \qquad E_{4d} = \varepsilon_1 \cdot \varepsilon_2$$

- it causes x-y coupling with $\varepsilon_x \cdot \varepsilon_y > \varepsilon_1 \cdot \varepsilon_2$, $\varepsilon_{x,y}$: rms-emittances
- skew quads remove that coupling, i.e. $\varepsilon_x = \varepsilon_1$, $\varepsilon_y = \varepsilon_2$
- skew quads preserve $\varepsilon_1, \varepsilon_2$, and E_{4d}
- more details in prst-ab **16**, 044201 (2013) , arXiv 1403.6962 (2014), and refs therein

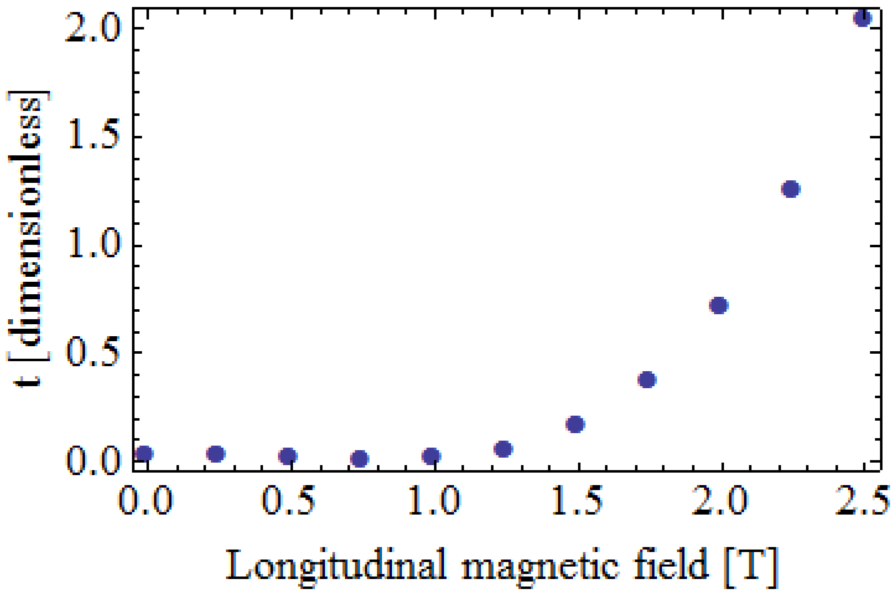
Independent confirmation of scheme

Defining a coupling parameter $\boldsymbol{t} := \frac{\varepsilon_x \varepsilon_y}{\varepsilon_1 \varepsilon_2} - 1 \geq 0$

with t = 0 there is no inter-plane coupling, i.e. the beam is fully decoupled. The two plots of *t* at EmTEx exit versus the solenoid field shown below have been obtained in simulations using two different methods at different labs.

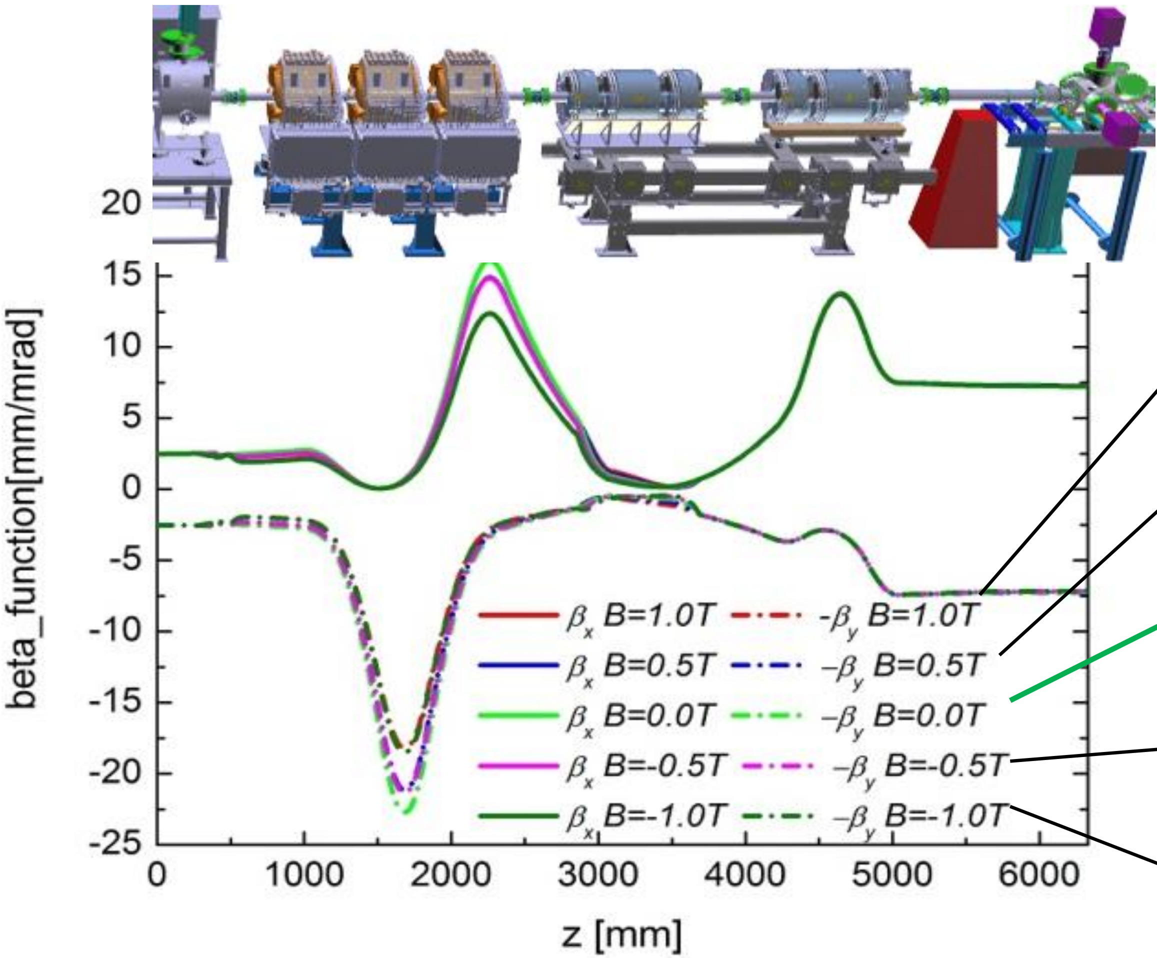


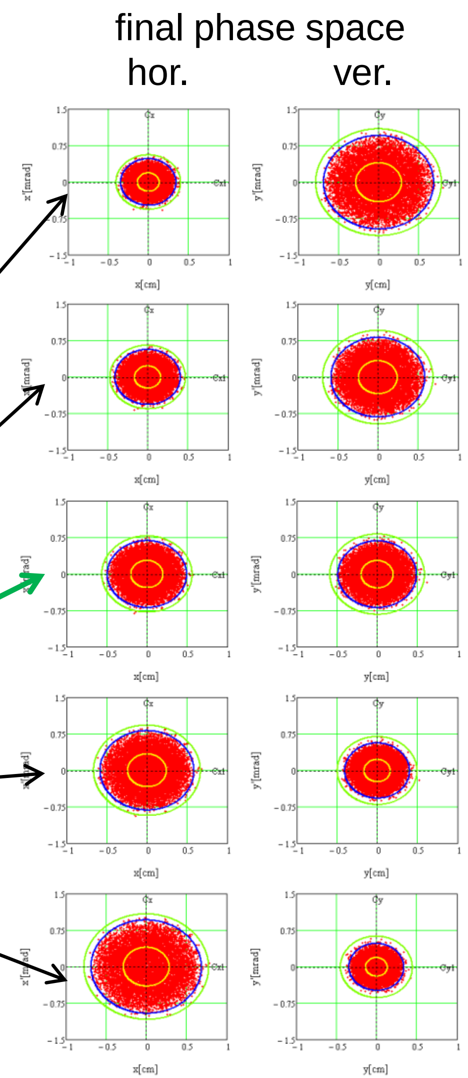
from C. Xiao, PRST-AB 2013



applying innovative 4d-envelope model first published in PRL 2013
H. Qin, Princeton University
M. Chung, Fermilab

This is EmTEx - a one-knob tool for emittance partitioning

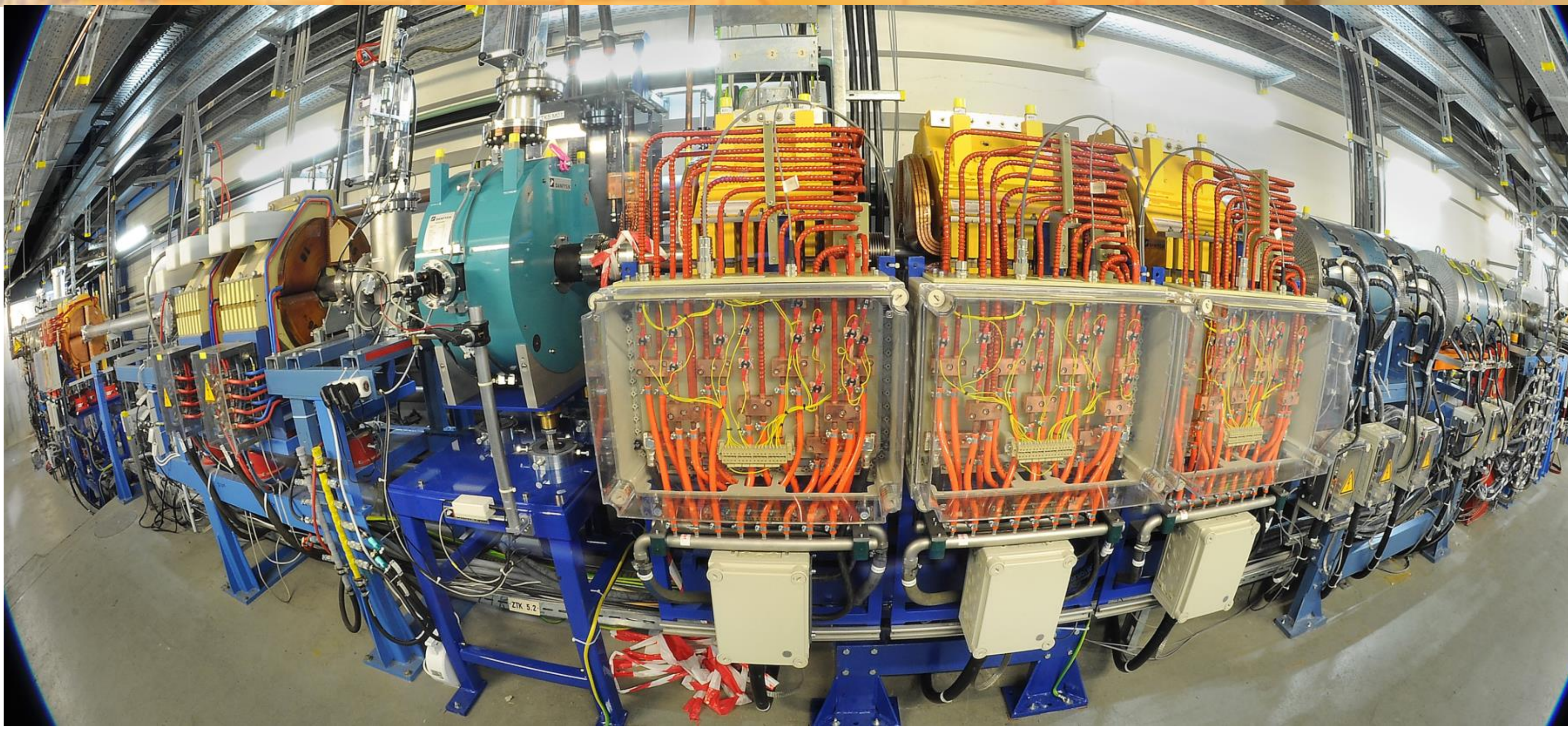




only the solenoid field is varied !

Transfer channel section TK5 in Nov 2013

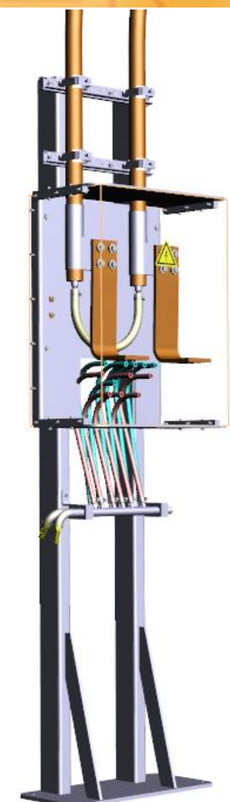
EmTEx beam line on June 6th, 2014

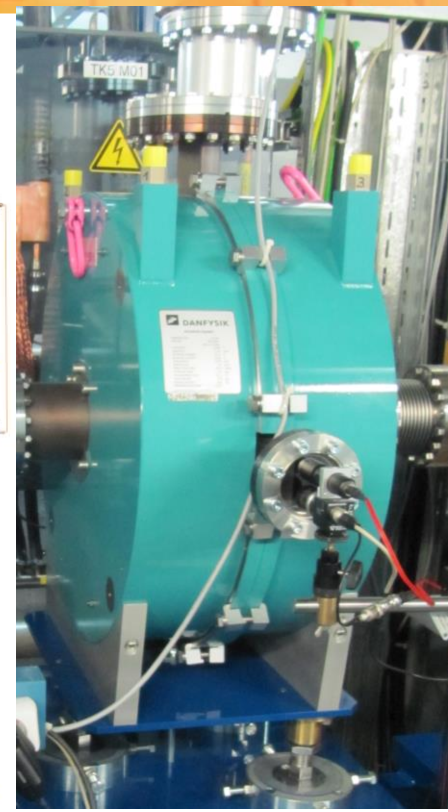


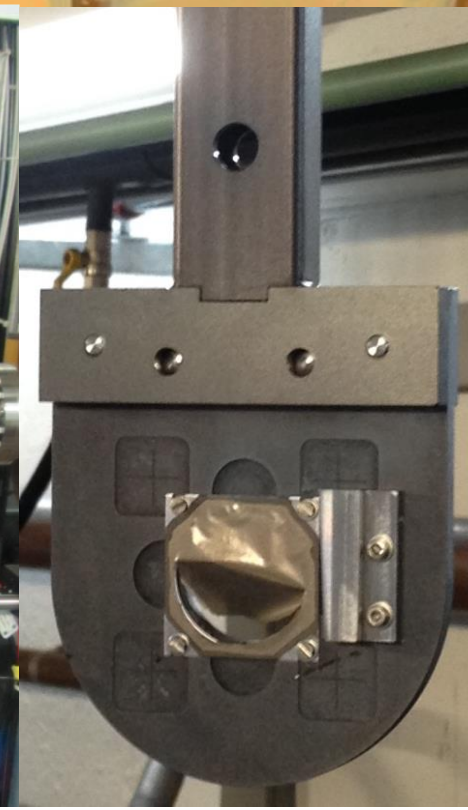
The split solenoid and its components

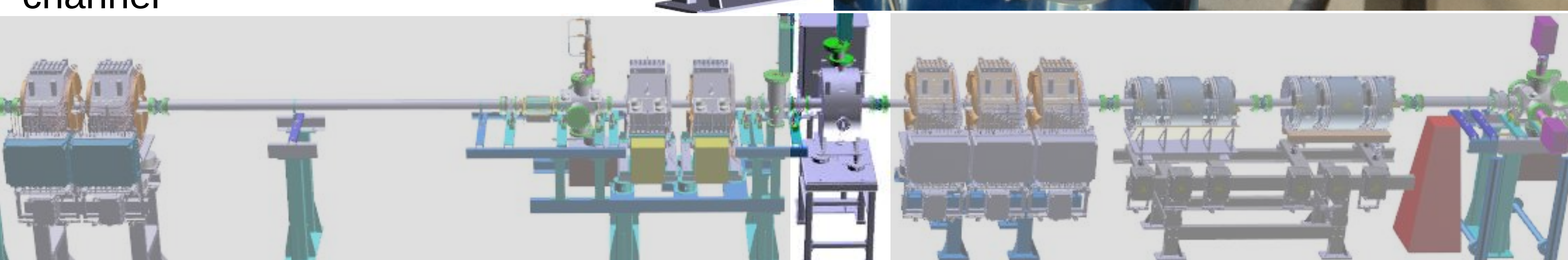
The split solenoid (center) and the 20 µg/cm^2 carbon foil mounted on the support arm (right). The whole chamber and foil support has been blackened to avoid reflections for online observation of the foil.

Also shown (left) the special connection box that had to be constructed to fit the 90 cm bending radius of the water cooled power cable with 55 mm diameter inside the transfer channel



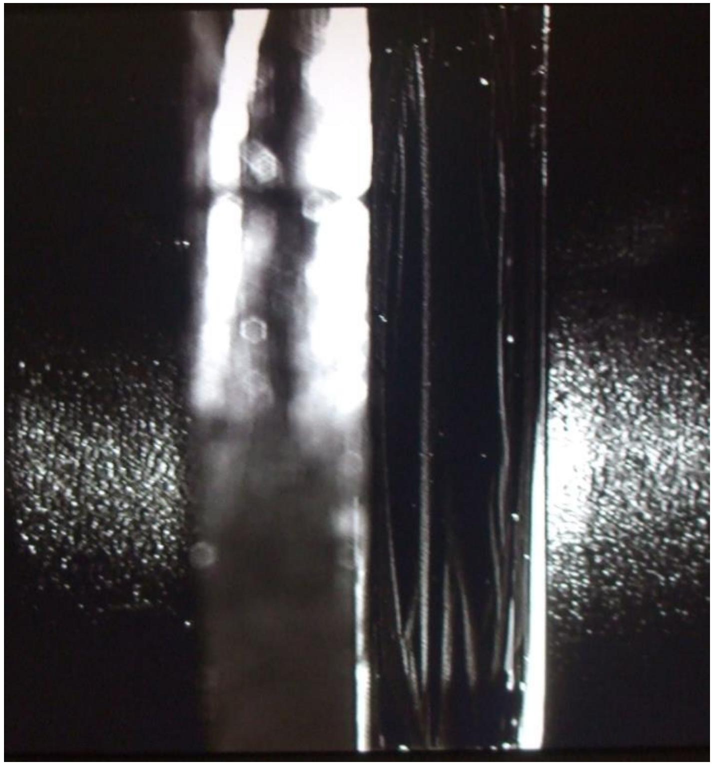






First commissioning results of the solenoid and its components

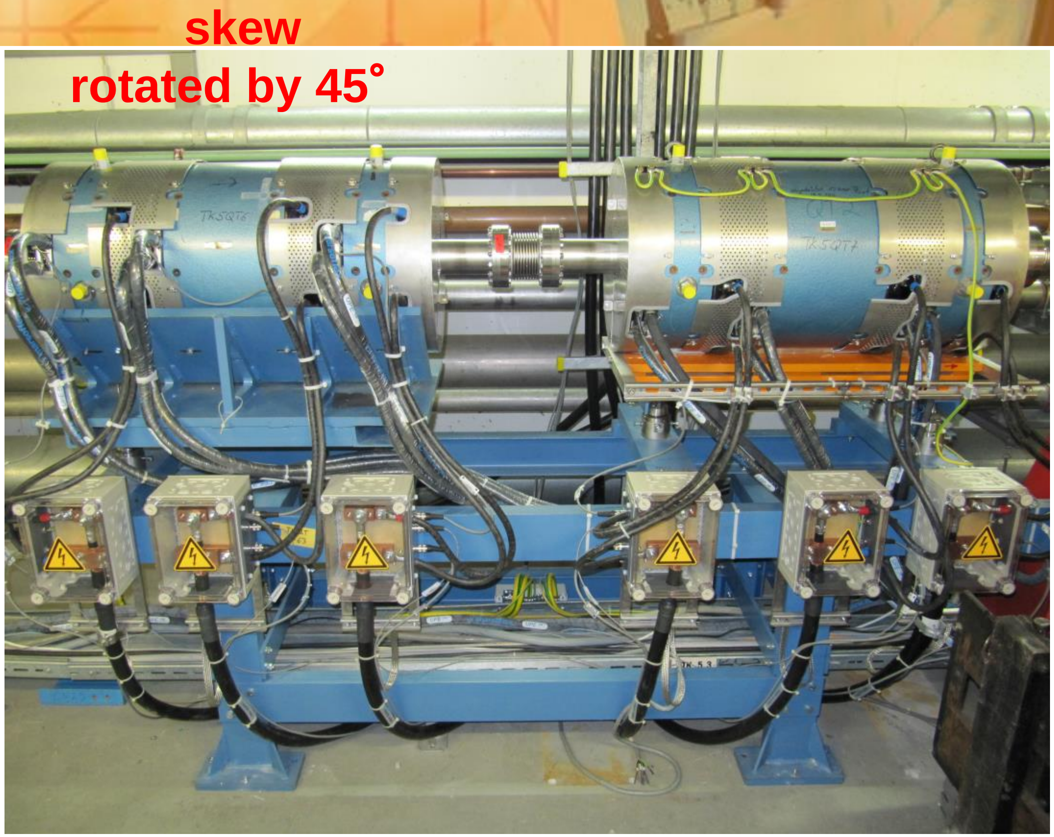
The solenoid was installed before the first beam time block in 2014 and therefore tested with beam. The focussing effect for the $^{40}Ar^{8+}$ beam was as expected. In an independent test both camera systems to observe the stripping foil have been commissioned successfully.

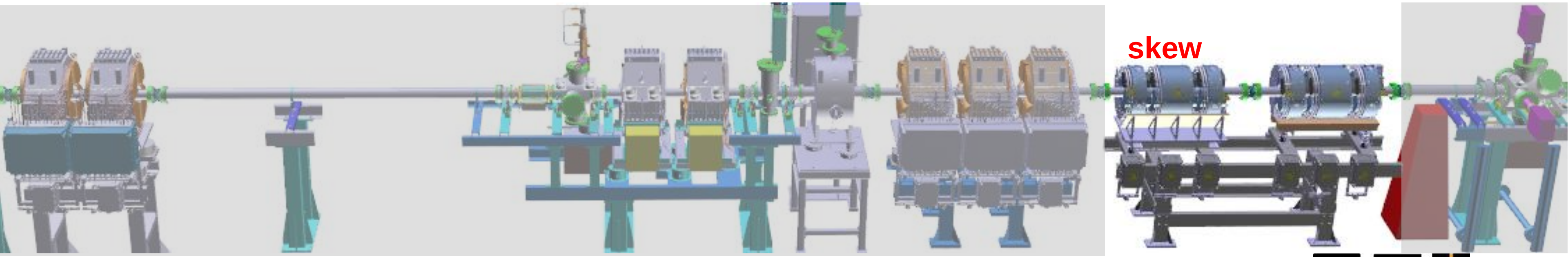


Non-destructive (left) and destructive (right) observation of the c-foil

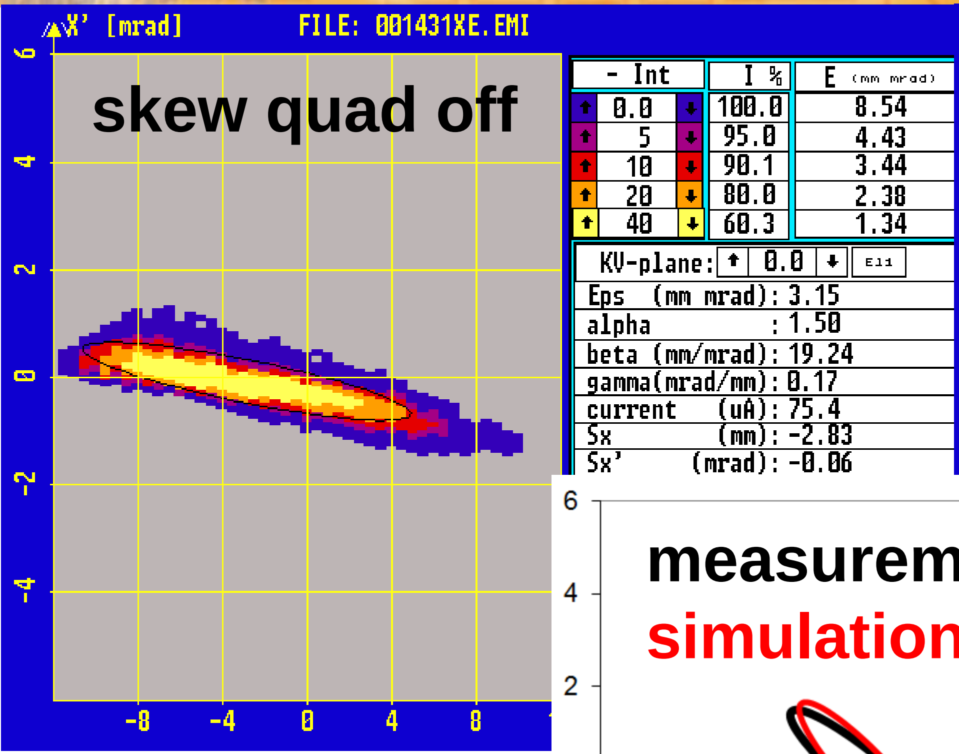
Decoupling & Re-matching Section

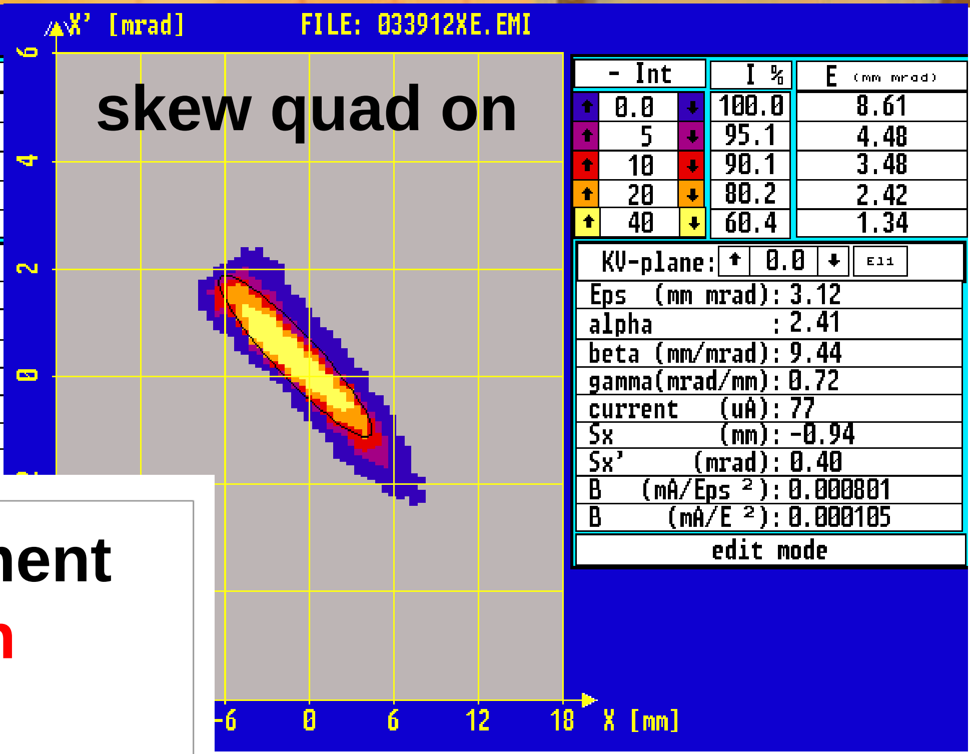
Stored in the basement (lower)
Overhauled, installed and ready to use for EmTEx (right)

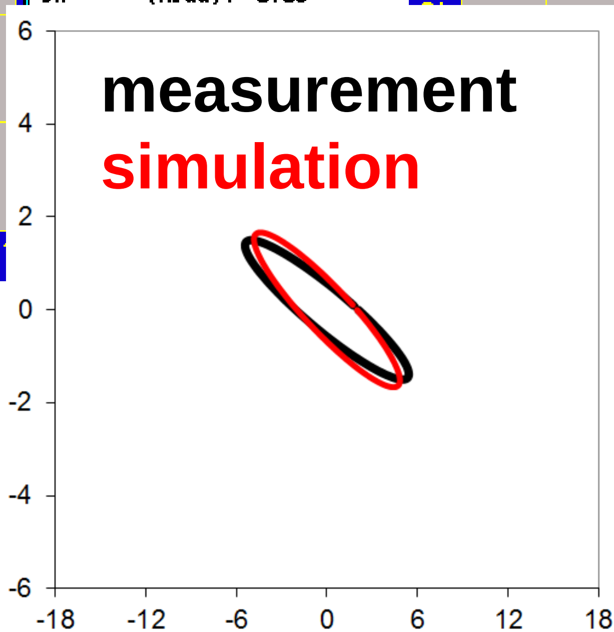




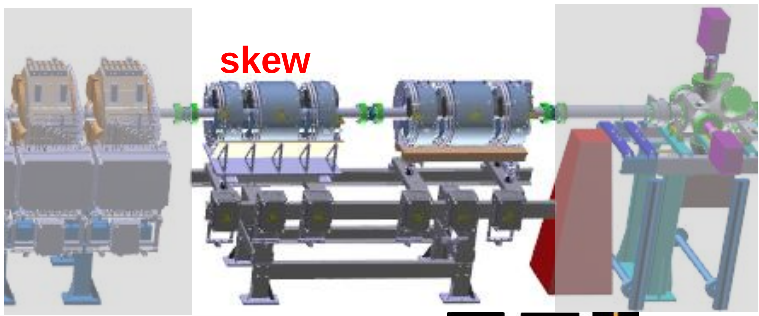
Skew quadrupole test with beam







As the two triplets at the end of the beam line were already available in house, they were the first to be installed in the beam line and used in the first beam time block in 2014.



Conclusion

- So far testing promises that an emittance transfer on ion beams is possible

  - next week we may know! -

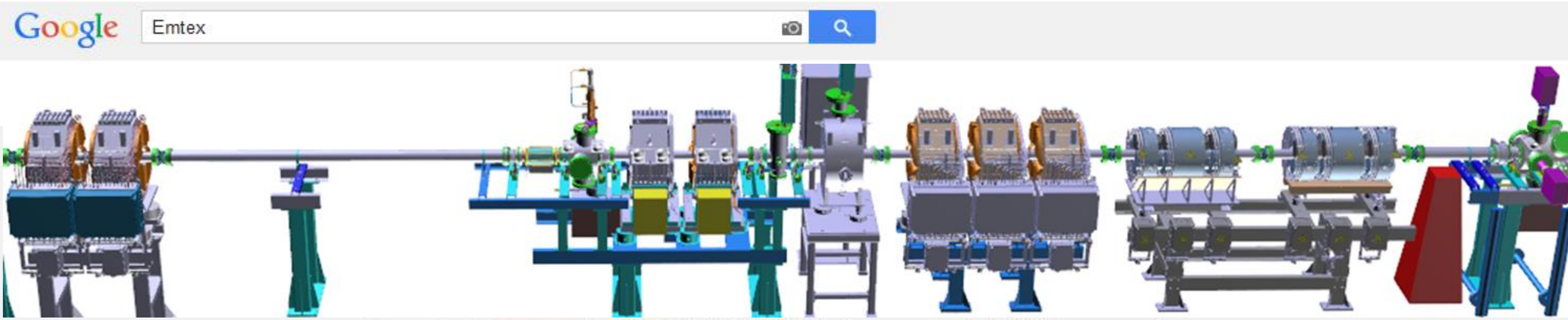
- Experiment will use:
  - An 11.4 MeV/u molecular D_6^+ beam stripped to $3D_2^+$ inside the solenoid
  - low space charge, no charge state spectrum, low momentum spread

- If this experimental proof-of-principle is successful, it might be envisaged to apply the technique to an intense uranium beam in a new linac* that could replace the existing Alvarez DTL.

- First simulations for emittance transfer on $U^{4+} \rightarrow U^{28+}$ including charge state spectrum, momentum spread and space charge, delivered promising results.

*** A. Orzhekhovskaya et al., THPME005 IPAC14**

Thank you for your attention



My special gratitude to my GSI colleagues of:

- ENMA - magnets & alignment
- ENMD - mechanical design
- ENMI - mechanical integration
- MWS - mechanical workshop
- CSTI - transport & installation
- LOEP - electric power systems
- LOBI - beam instrumentation
- All my colleagues briefing me in 4d beam dynamics
- and especially all forgotten