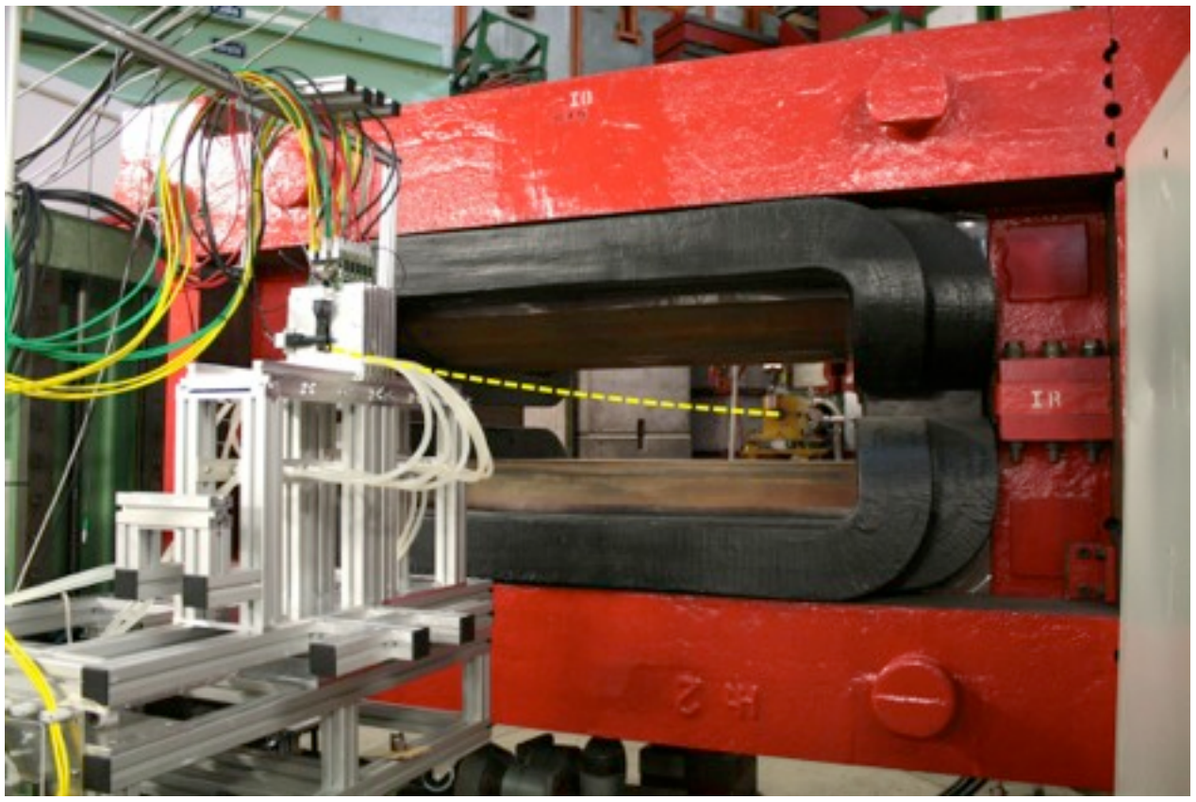
Energy Calibration of the DESY Test Beam in Beamline 21.

Measuring the particles momentum due to deflection in a magnetic field



Paul Schütze
CMS
Summer Student Session
5 September 2013

HELMHOLTZ ASSOCIATION

Karlsruhe Institute of Technology

DESY

Outline

- DESY Test Beam Facility
- Energy Measurement
- Simulation
- Results

DESY Test Beam Facility

> What is a Test Beam Facility?

- The DESY Test Beam provides electron or positron beams of certain energies from 1 to 6 GeV.
- Only a handful of Test Beam Facilities exist worldwide.

> How does the DESY Test Beam work?

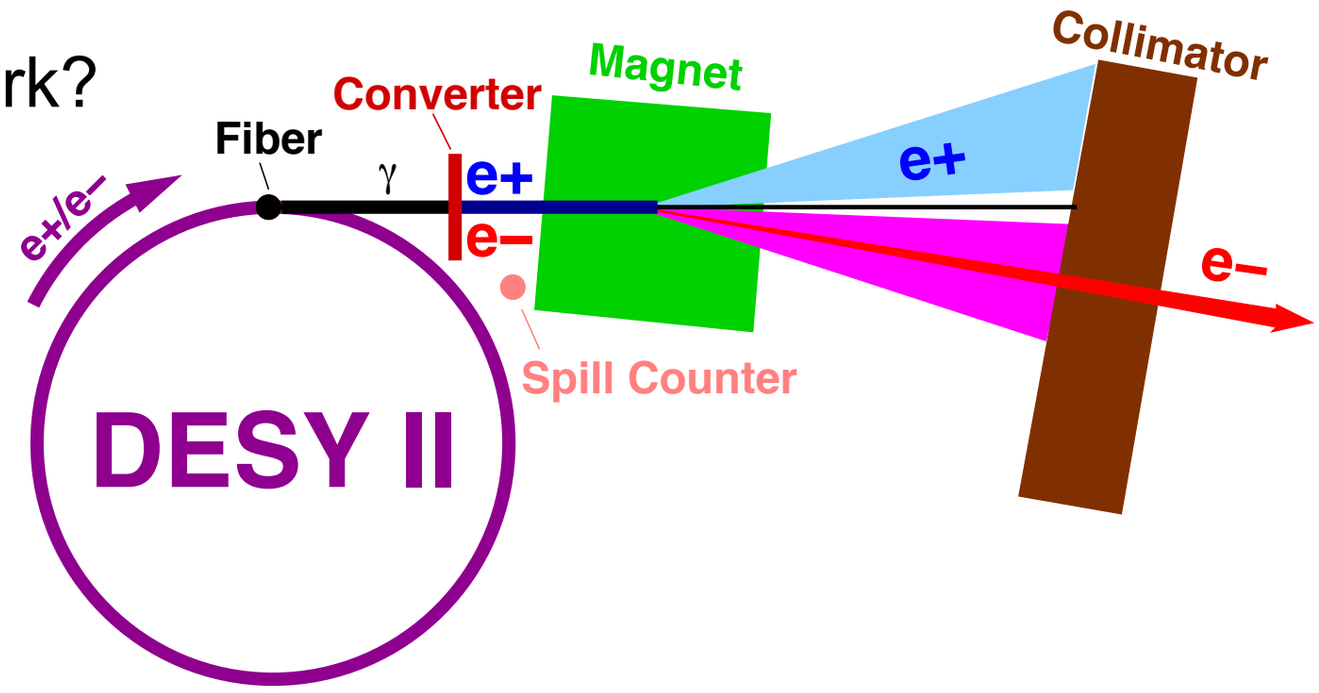
- A carbon fibre is placed inside DESY II

➡ 6.3 GeV bremsstrahlung

➡ Photons hit a conversion target

➡ Electron-positron pair with p≤6.3 GeV

➡ „Green magnet“ separates beam by momentum



DESY Test Beam Facility

> Why do I need a Test Beam?

- Test Beam areas are frequently used for the development and testing procedures of particle detector prototypes and their readout systems.

> How do I know which energy my beam has?

- Good question, no one knows...

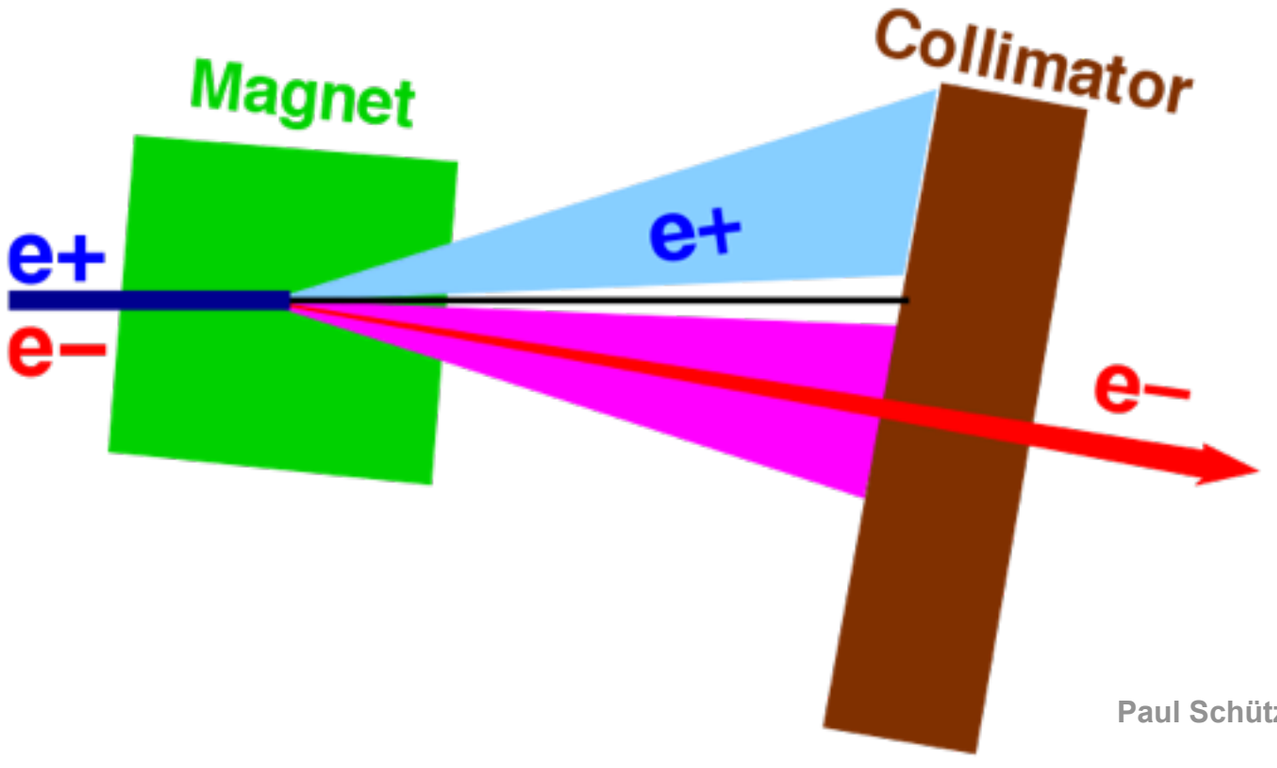
DESY Test Beam Facility

> Why do I need a Test Beam?

- Test Beam areas are frequently used for the development and testing procedures of particle detector prototypes and their readout systems.

> How do I know which energy my beam has?

- Okay, this is not entirely true.
- The momentum of the beam depends on the current of the „Green Magnet“, there are theoretical predictions



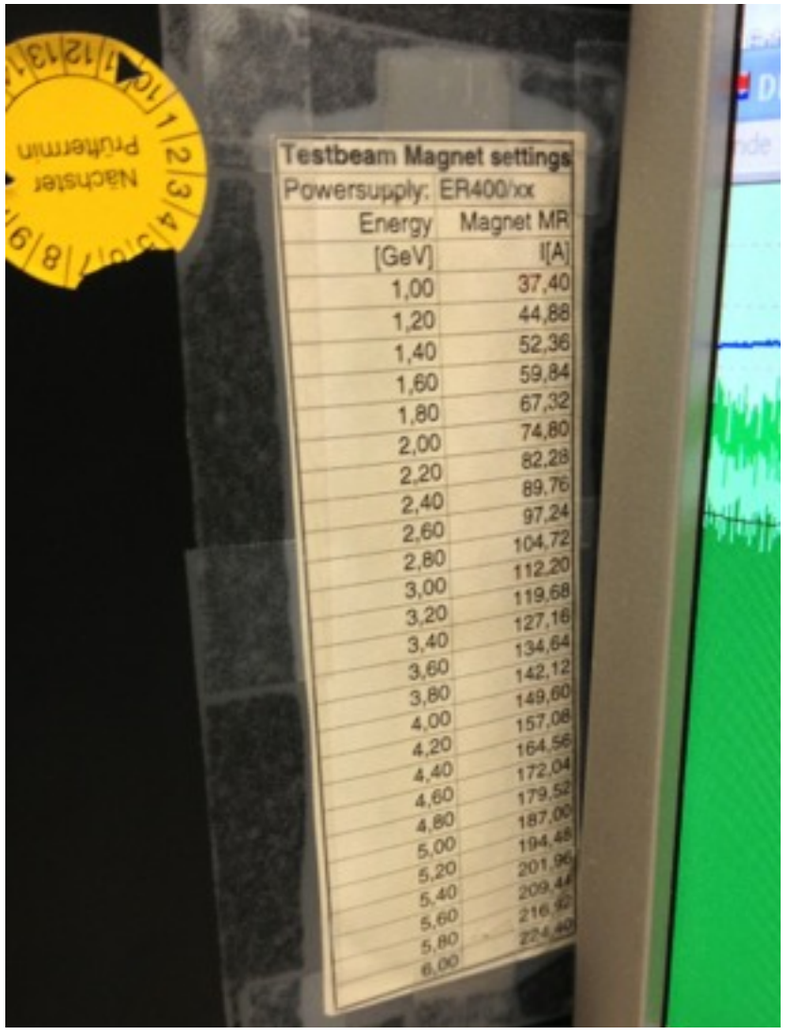
DESY Test Beam Facility

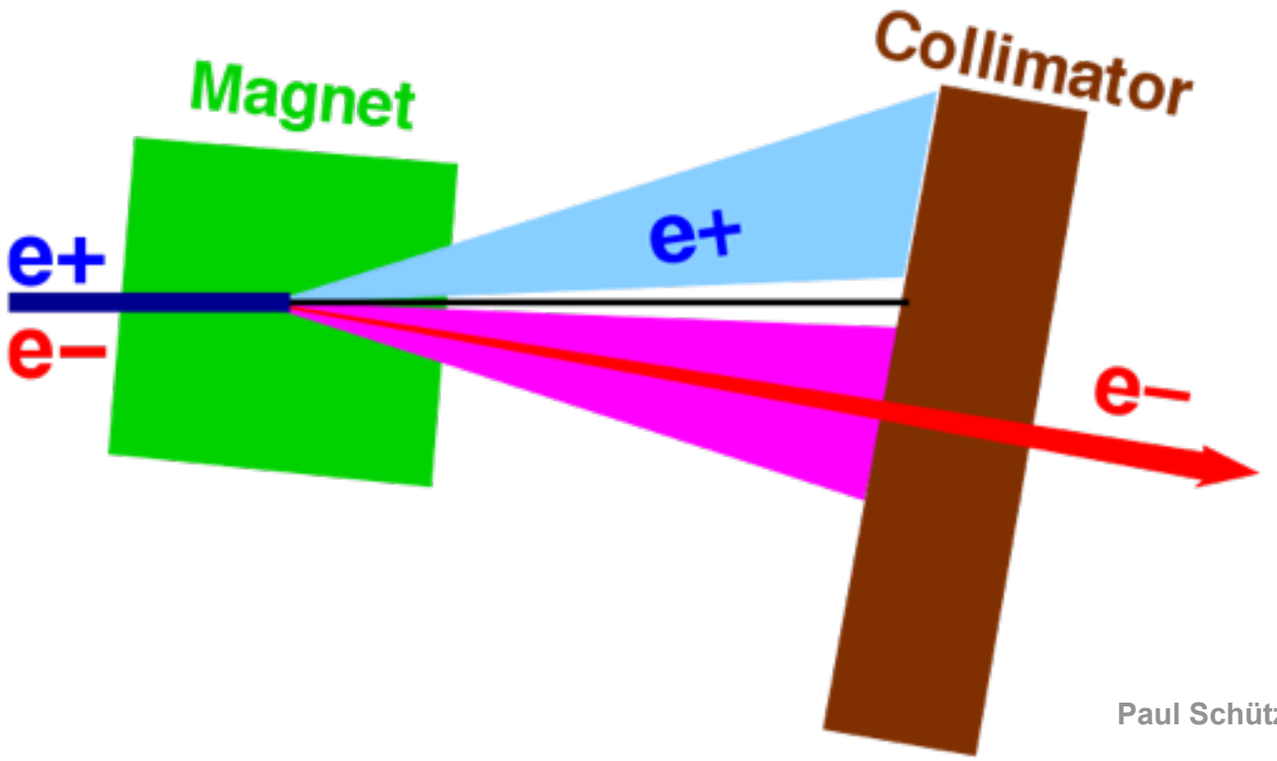
> Why do I need a Test Beam?

- Test Beam areas are frequently used for the development and testing procedures of particle detector prototypes and their readout systems.

> How do I know which energy my beam has?

- Okay, this is not entirely true.
- The momentum of the beam depends on the current of the „Green Magnet“, there are theoretical predictions





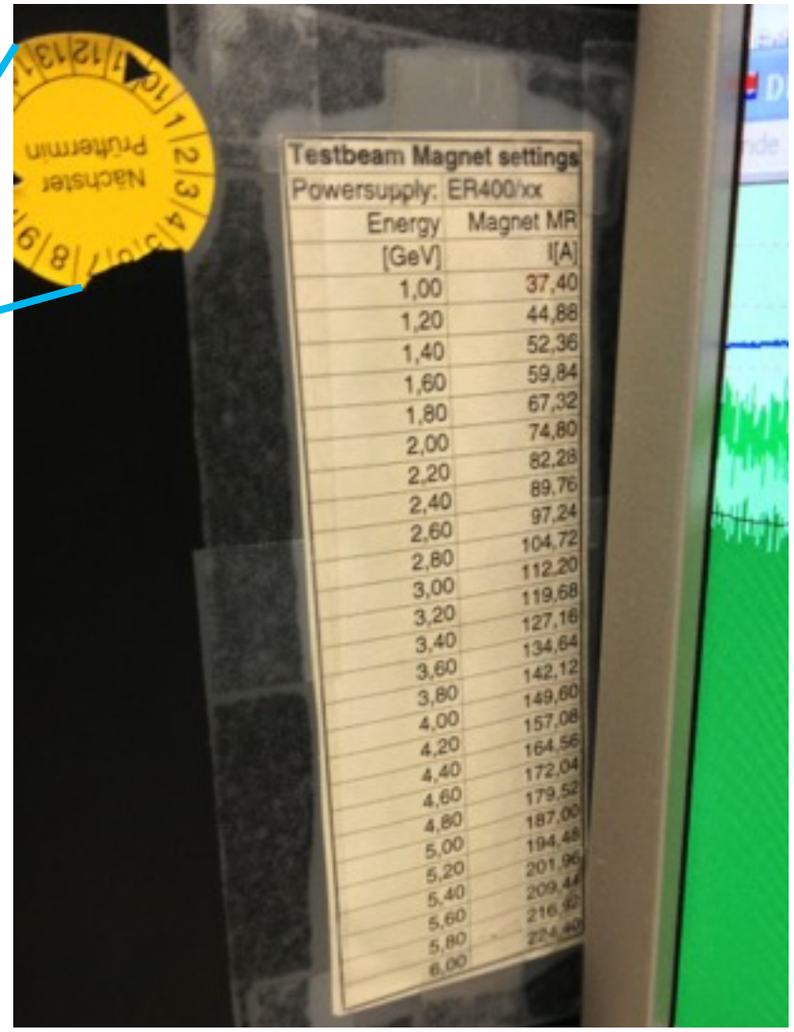
DESY Test Beam Facility

> Why do I need a Test Beam?

- Test Beam areas are frequently used for the development and testing procedures of particle detector prototypes and their readout systems.

> How do I know which energy my beam has?

- Okay, this is not entirely true.
- The momentum of the beam depends on the current of the „Green Magnet“, there are theoretical predictions



„Next examination date: Nov 2011“

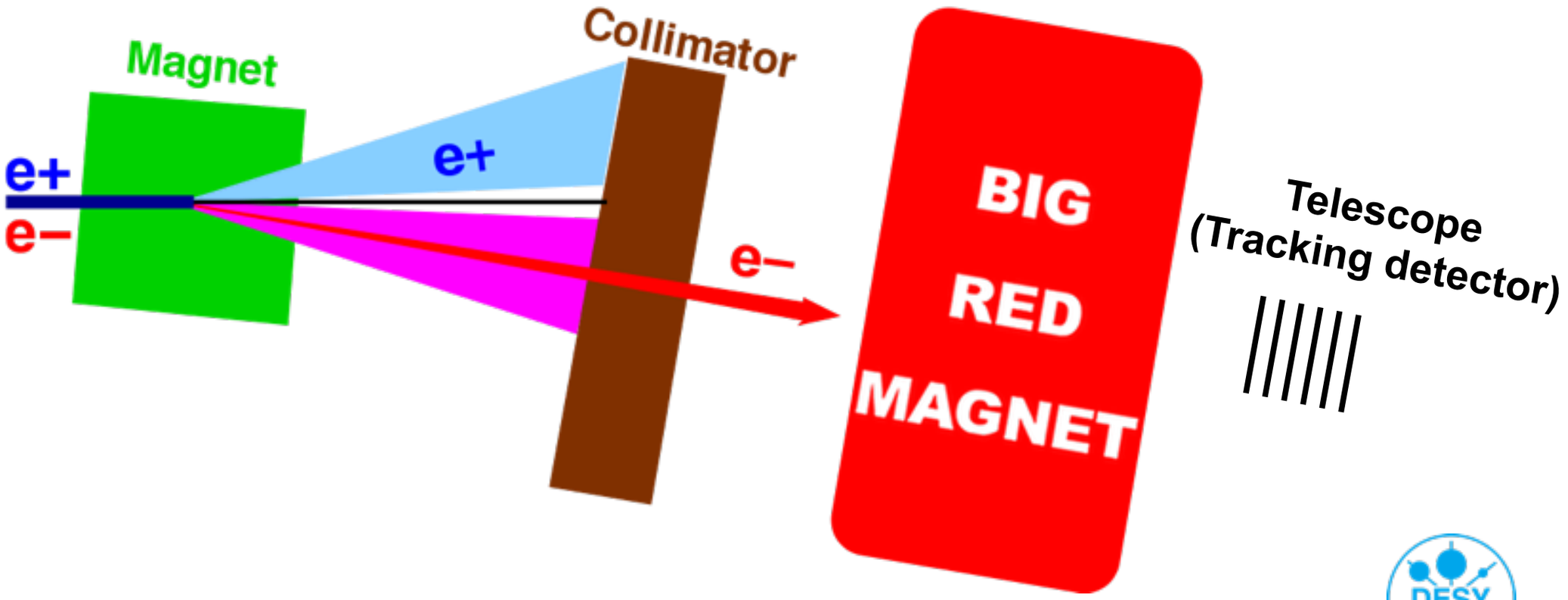
Measuring the deflection angle

- In order to verify this table a measurement was planned and executed by four summer students and two supervisors of ATLAS and CMS

Thank you guys :-)

- We used the Big Red Magnet (BRM) in TB21 to deflect the positron beam

- Measuring the deflection angle gives information on the particles momenta

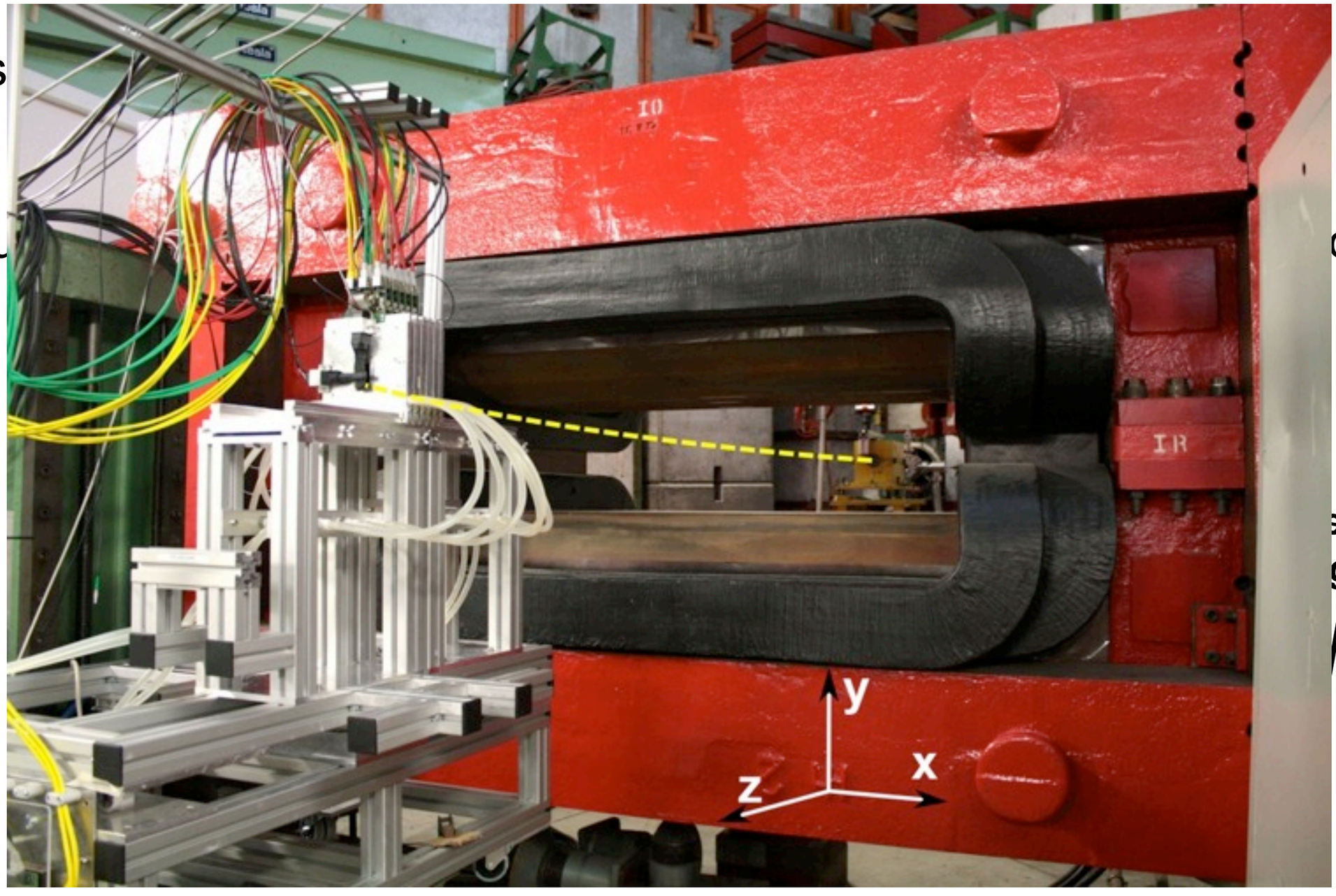


Measuring the deflection angle

- In order to verify this table a measurement was planned and executed by four summer students and two supervisors of ATLAS and CMS

Thank you guys :-)

- We us beam
- Measu omenta



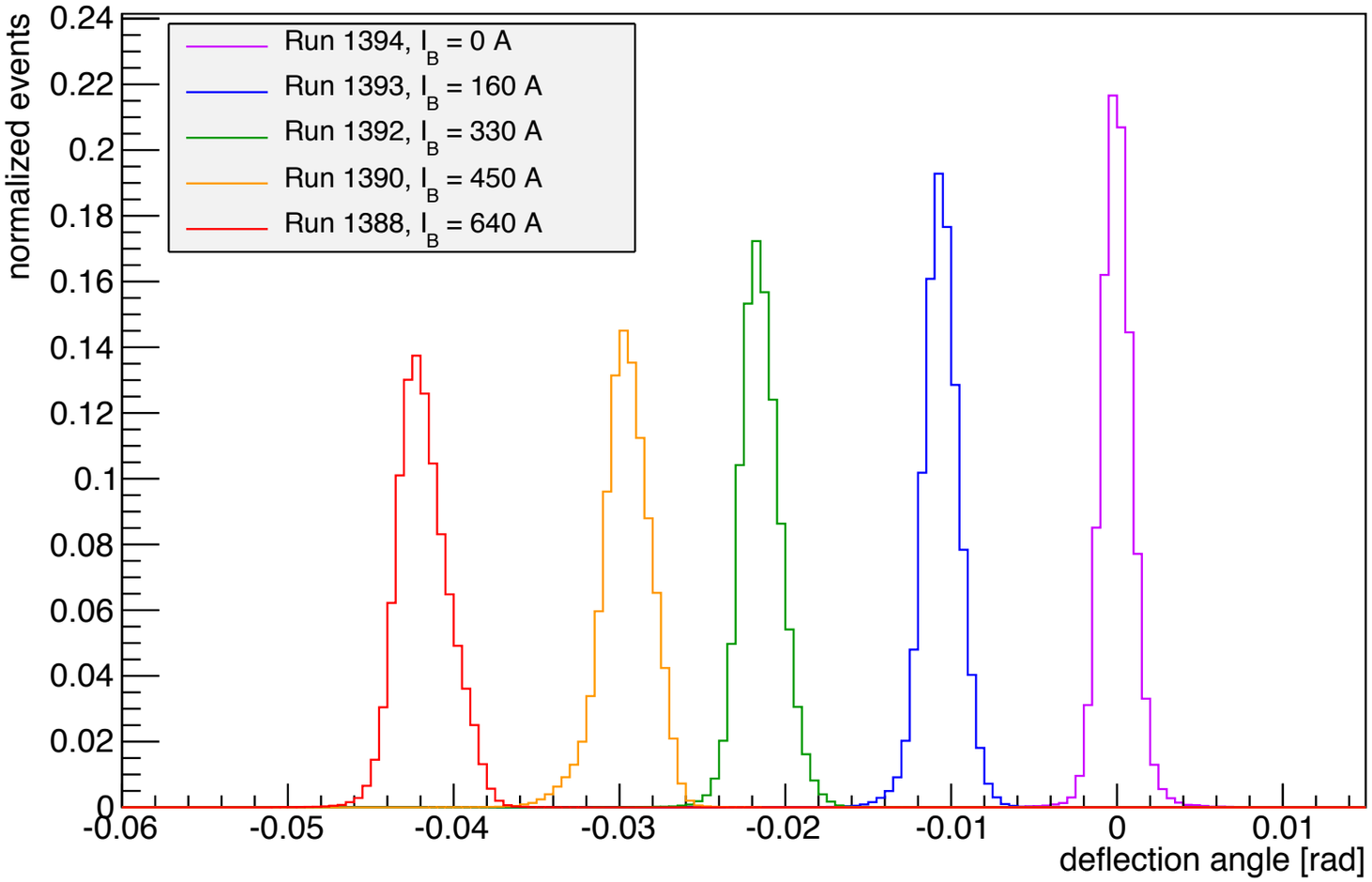
escope
g detector)

Measuring the deflection angle - facts

- Measurement executed by three summer students from ATLAS and one from CMS together with two supervisors
- 8 days of measurement (> 70 hrs)
- 283 runs taken with a total event count of >25 Million
- 5 GB of data
- ~500 cookies eaten

Measuring the deflection angle

- For a run containing several tens of thousands of events the angular distribution is plotted

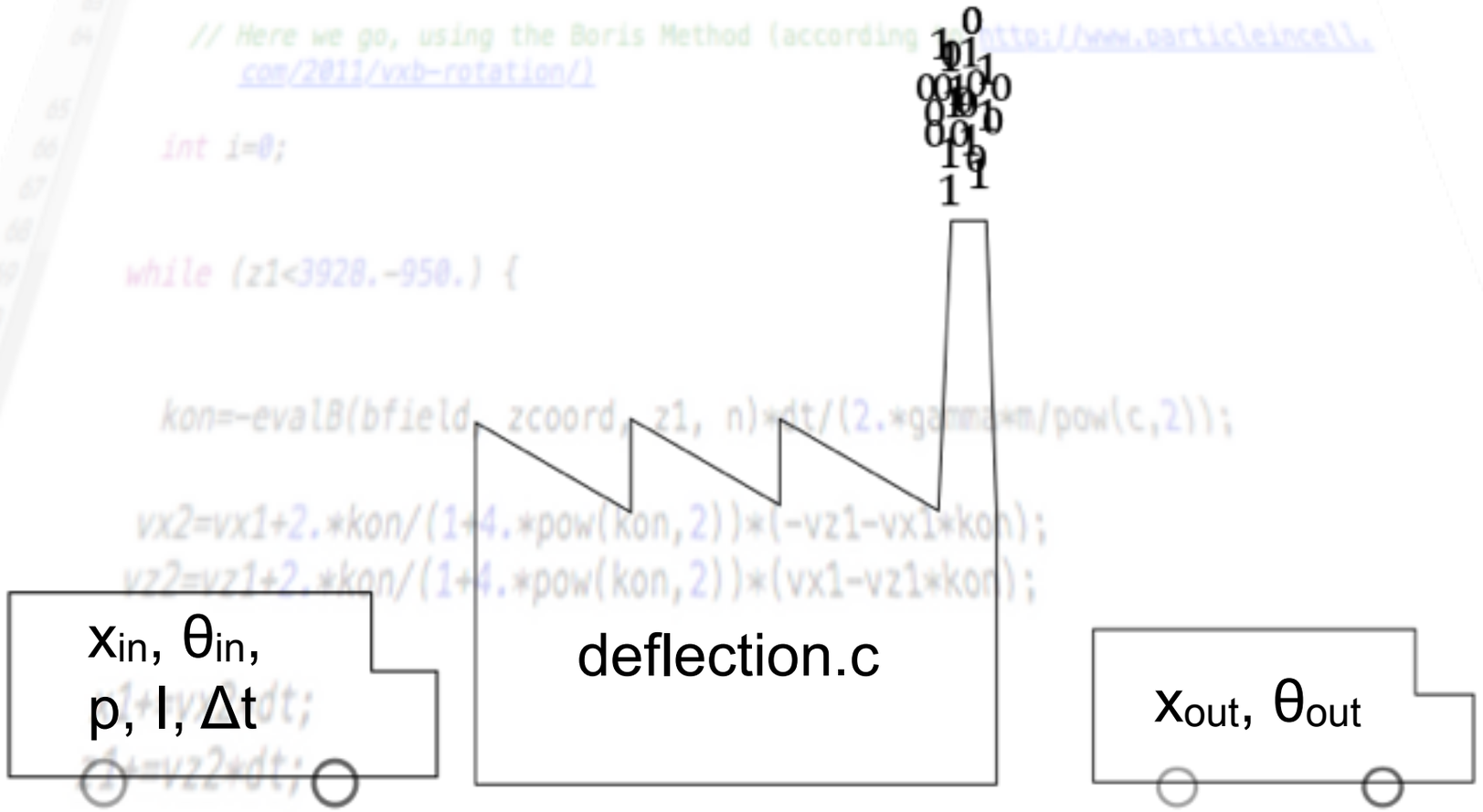


- In order to get information on the particles momentum out of the angle, the deflection has to be simulated for the magnetic field we used

Simulating the particles track in a magnetic field

- Analytical approaches fail due to the inhomogeneity of the magnetic field, they only give rough estimations of the actual deflection

- A simulation of the particles trajectory can use any magnetic field and is more flexible to specific initial parameters (e. g. incoming angle)



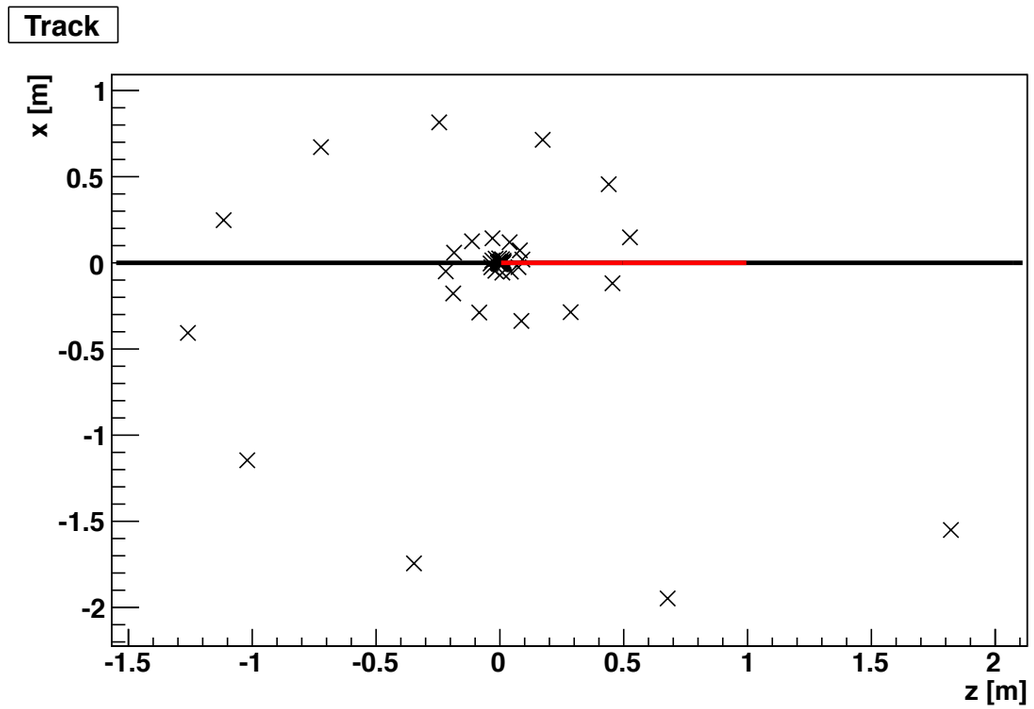
Simulating the particles track in a magnetic field

> First approach: Simple discretisation of the equation of motion

$$\frac{F}{\gamma m} = \frac{d\vec{v}}{dt} = \frac{e}{\gamma m}\vec{v} \times \vec{B}$$

$$\frac{v_x^{n+1} - v_x^n}{\Delta t} = \frac{e}{\gamma m} v_z^n B$$

$$x^{n+1} = x^n + v_x^n \Delta t$$



> Test in a constant magnetic field did not yield circular motion

Simulating the particles track in a magnetic field

- Second approach: CYLRAD* method, slightly more complex

$$\frac{\vec{v}^{n+1} - \vec{v}^{n}}{\Delta t} = \left(\vec{v}^{n} + \vec{v}^{n} \times \vec{t}\right) \times \vec{t} \cdot \frac{2}{1 + t^2} \qquad \vec{t} = \frac{e\Delta t}{2\gamma m}\vec{B}$$

*: See e.g. http://www.particleincell.com/2011/vxb-rotation/

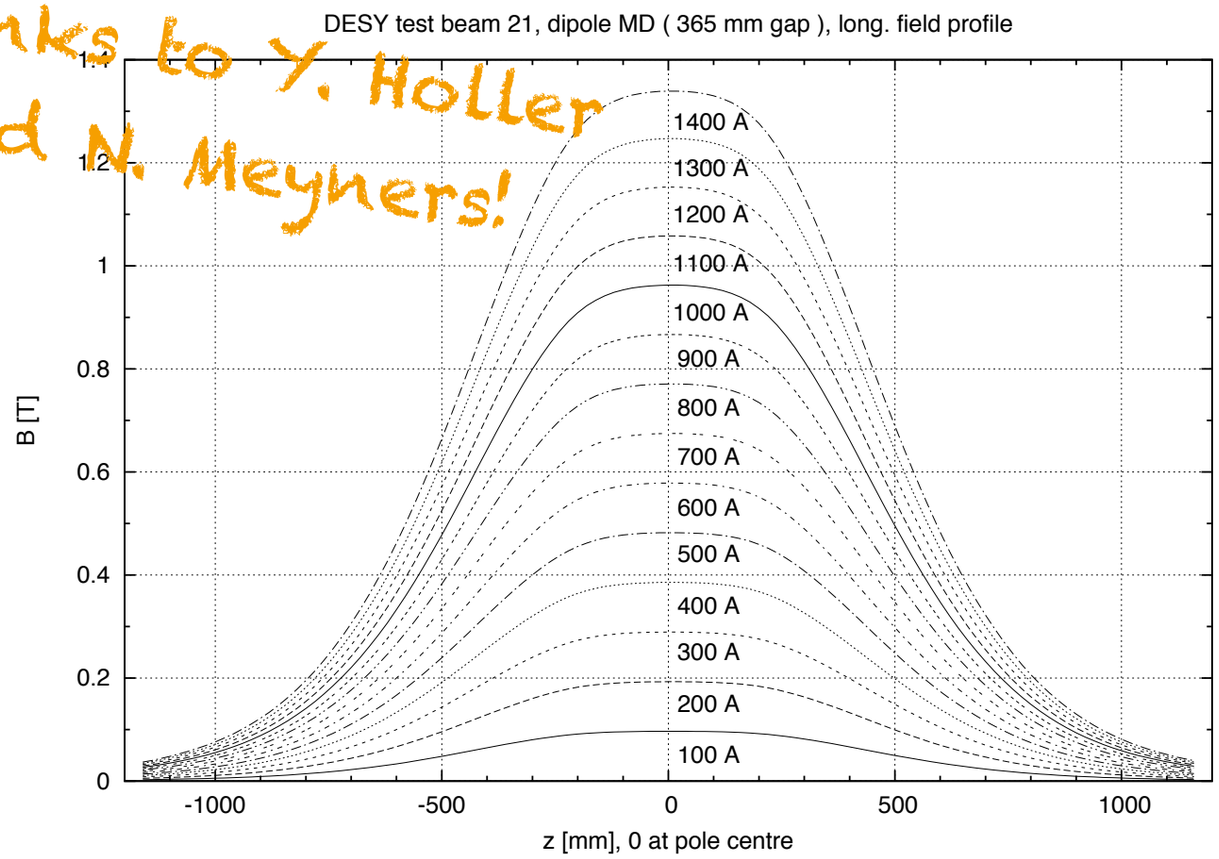
Simulating the particles track in a magnetic field

- Second approach: CYLRAD* method, slightly more complex

$$\frac{\vec{v}^{n+1} - \vec{v}^{n}}{\Delta t} = \left(\vec{v}^{n} + \vec{v}^{n} \times \vec{t}\right) \times \vec{t} \cdot \frac{2}{1 + t^2} \qquad \vec{t} = \frac{e\Delta t}{2\gamma m}\vec{B}$$

- Measurements of the magnetic field of the red magnet from 1985 have been used in order to evaluate the magnetic field for every single timestep

Thanks to Y. Holler and N. Meyners!

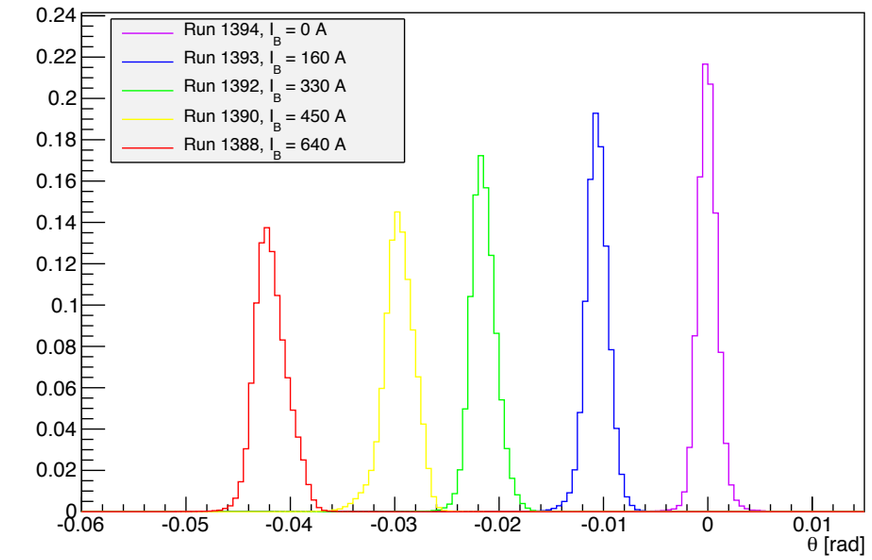


- Checked that measurement quickly with a Hall probe, ...
  - because it‘s older than i am
  - because the beam axis and the axis along which the measurement was taken are displaced by ~7 cm

*: See e.g. http://www.particleincell.com/2011/vxb-rotation/

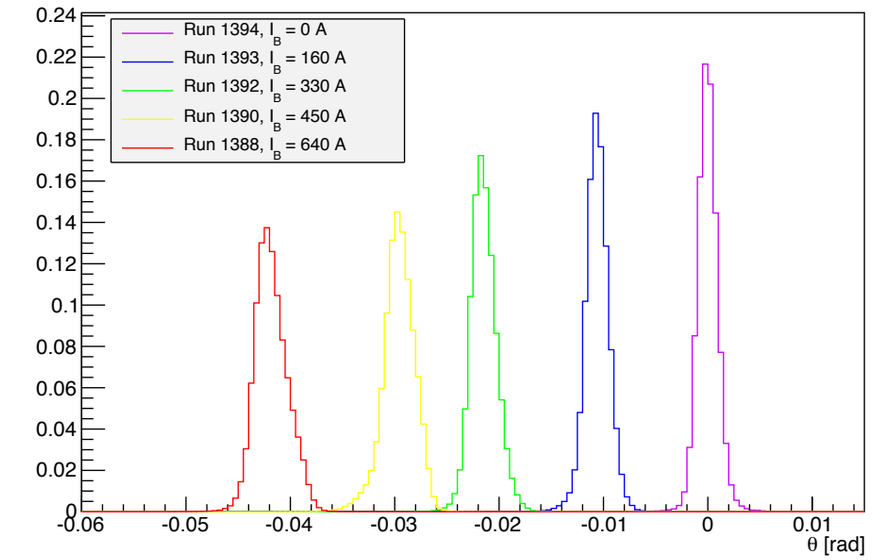
Results

- To get the mean particle momentum of a single run, the input momentum of the simulation is adjusted, so that the simulated angle equals the mean angle of the measurement



Results

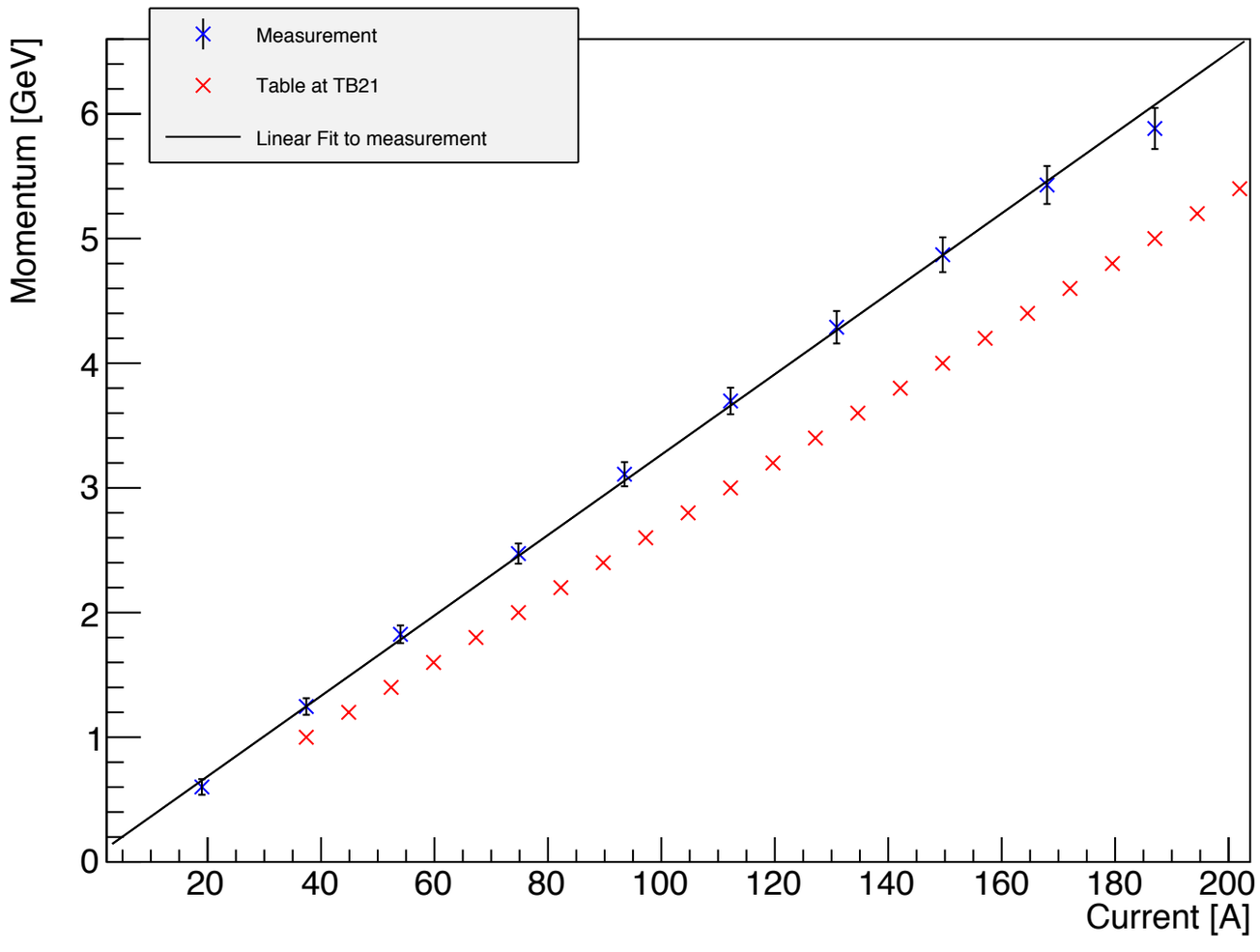
- To get the mean particle momentum of a single run, the input momentum of the simulation is adjusted, so that the simulated angle equals the mean angle of the measurement



- This is done for every run, scanning certain currents set to the green magnet

- Deviation of measurement and the table in TB21:

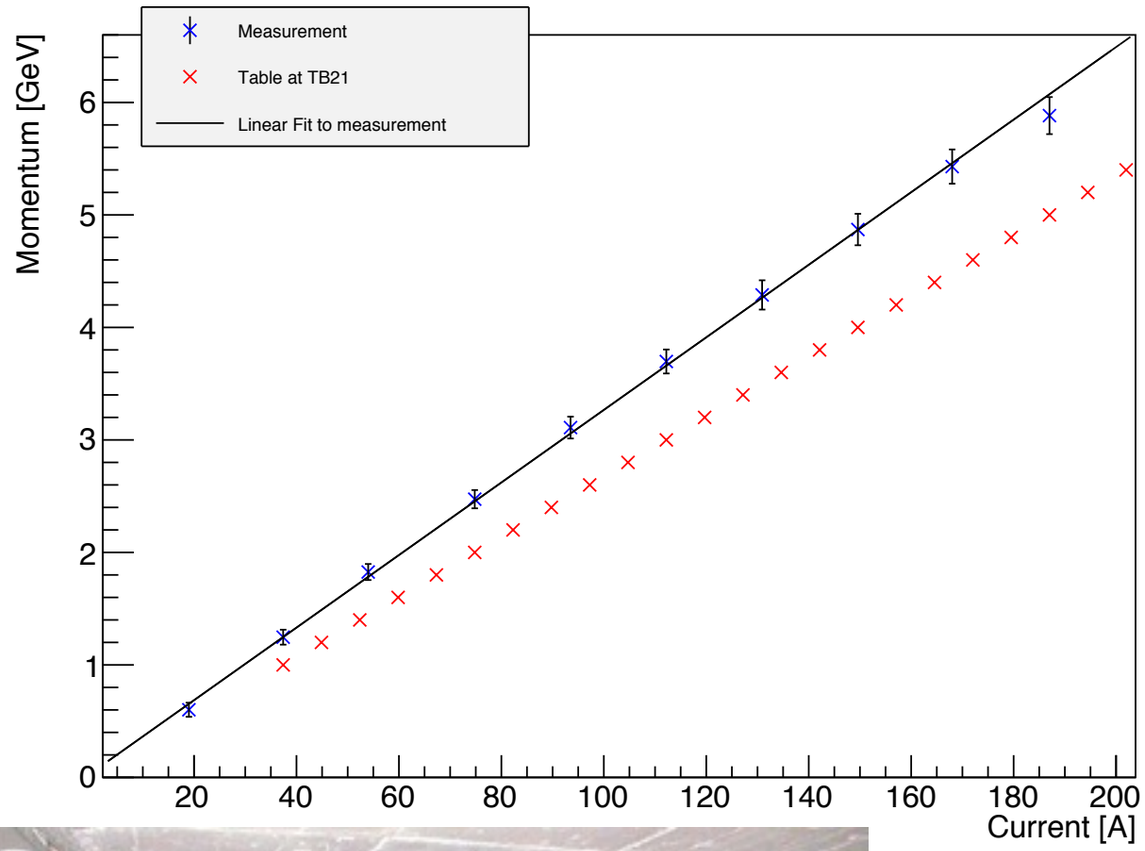
≈ 20%



Summary (as it would have been 48 hours ago)

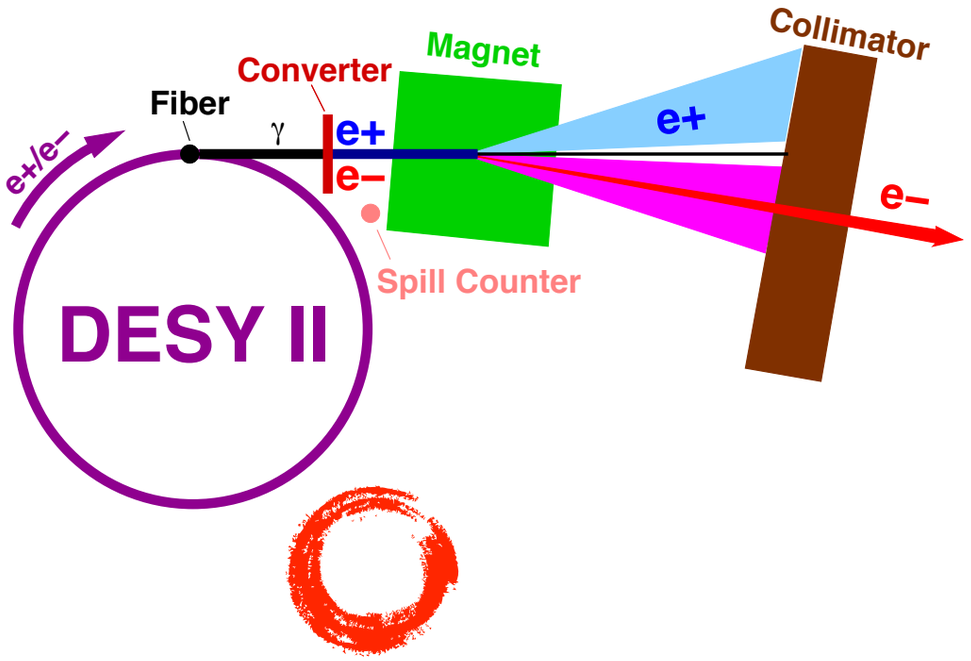
- The table in TB 21 predicting the beam energy from the magnet current might have to be changed

- Before this is done, a few reviews have to be taken into account
  - During the DESY II Shutdown this week the green magnet will be examimed
  - Additionally an analysis of radiation length measurements performed in test beam area 21 is awaited, which also yields information on the beam energy



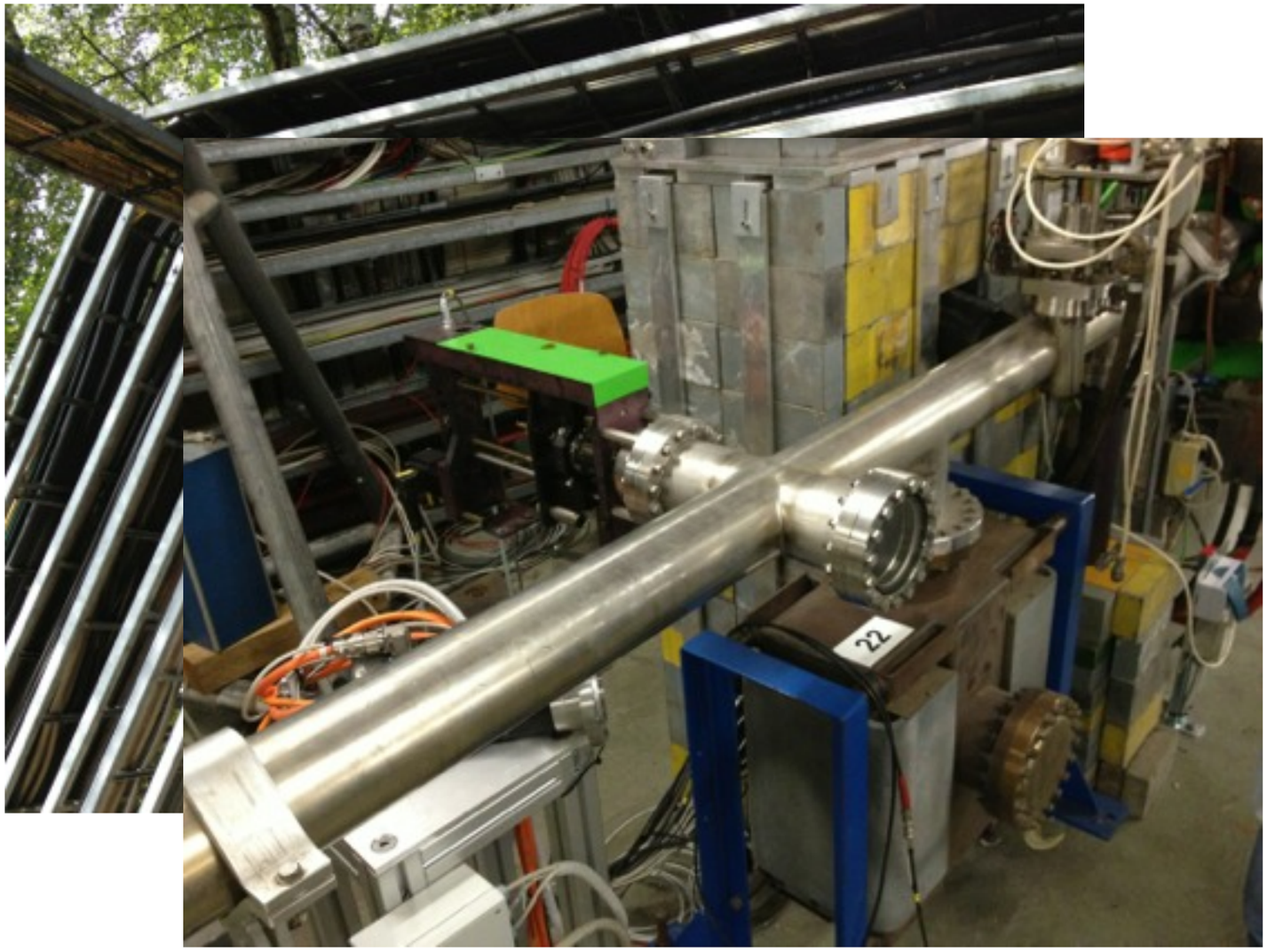
Further investigations

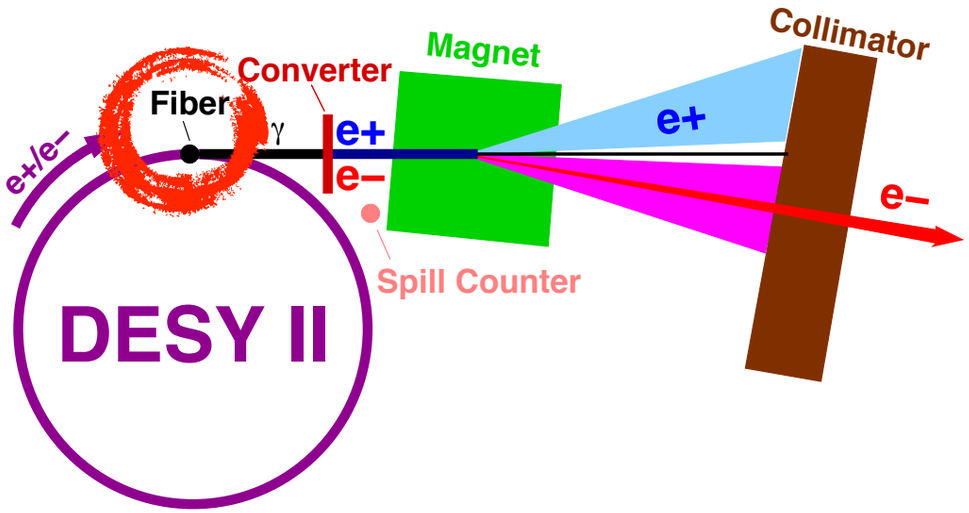
> DESY II is shut down this week - Let‘s go inside



Further investigations

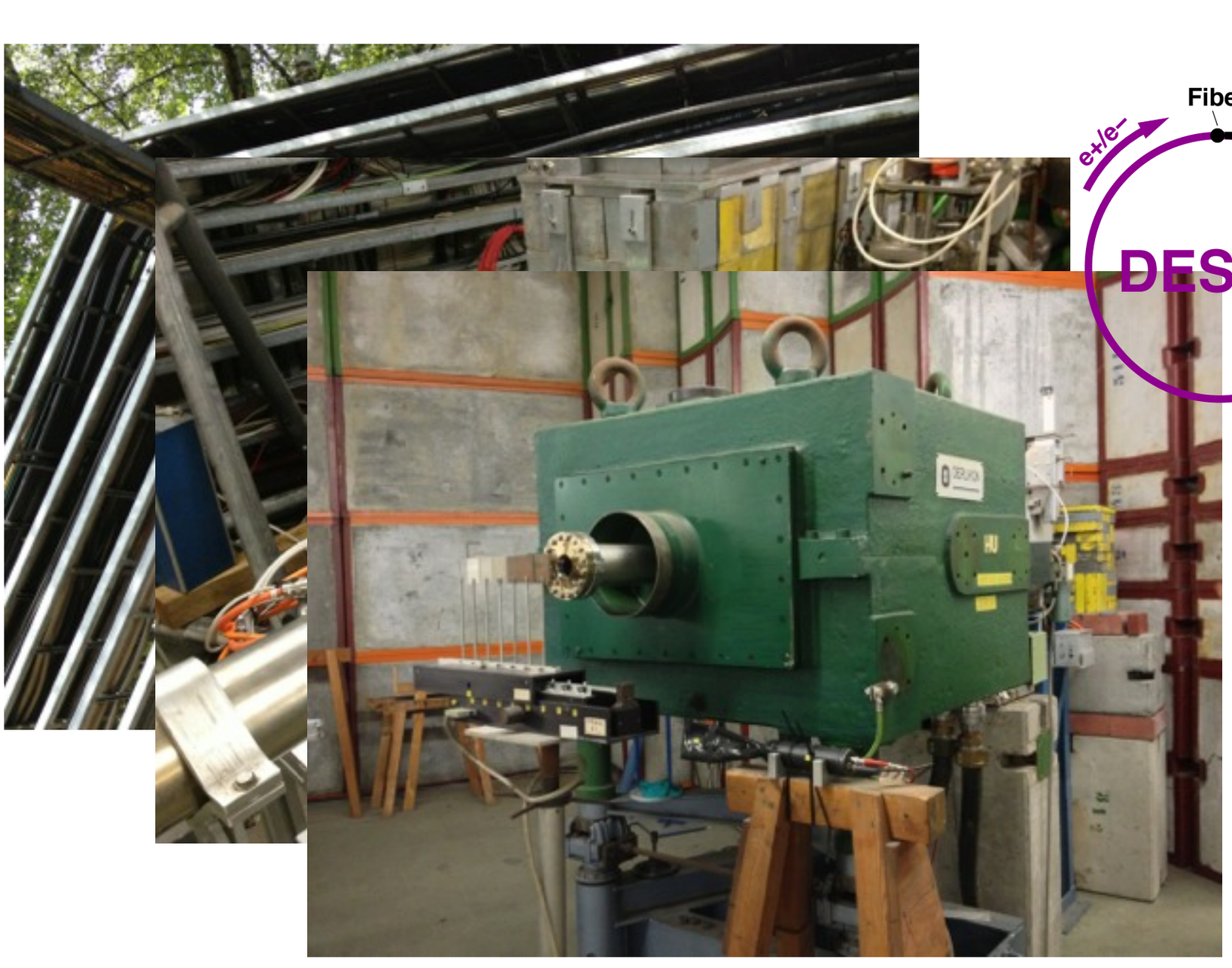
- DESY II is shut down this week - Let‘s go inside

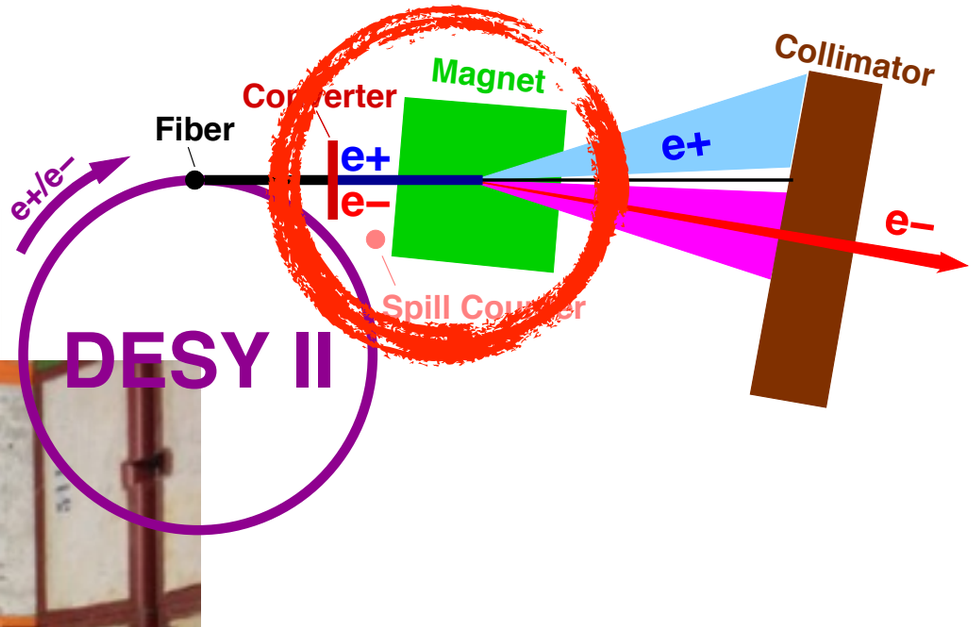




Further investigations

- DESY II is shut down this week - Let‘s go inside

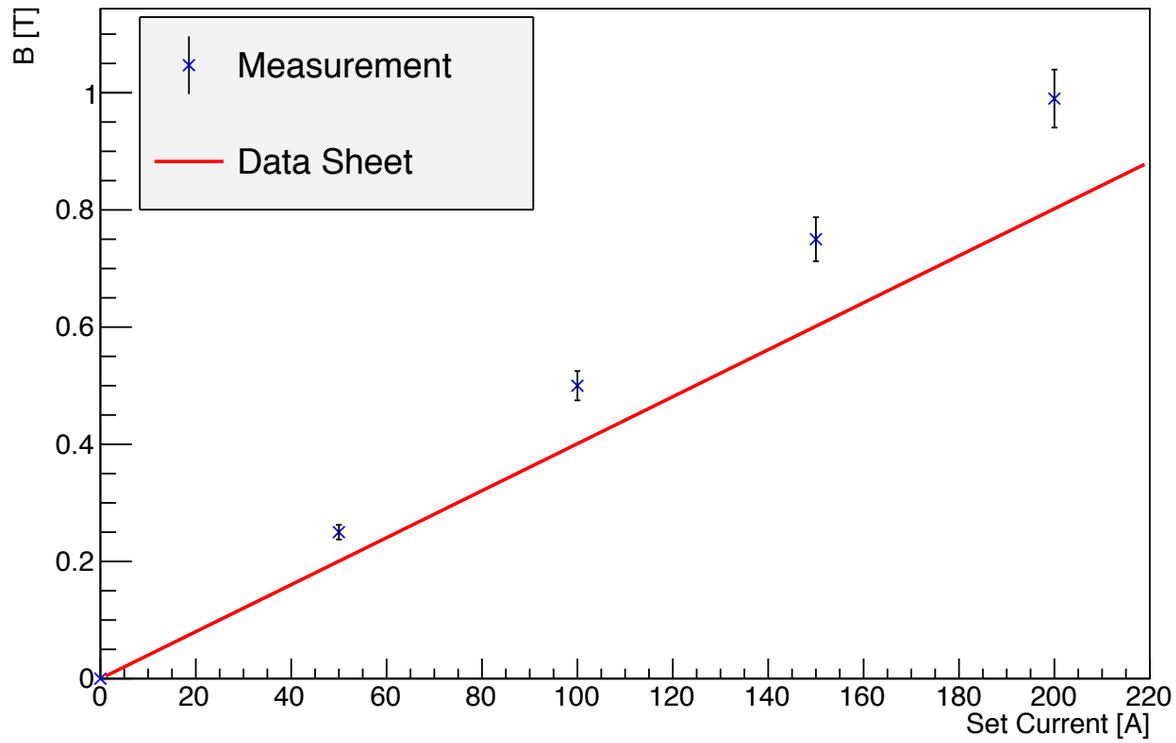




Further investigations - Tuesday

- The magnetic field of the green magnet was measured using a Hall Probe depending on the set current

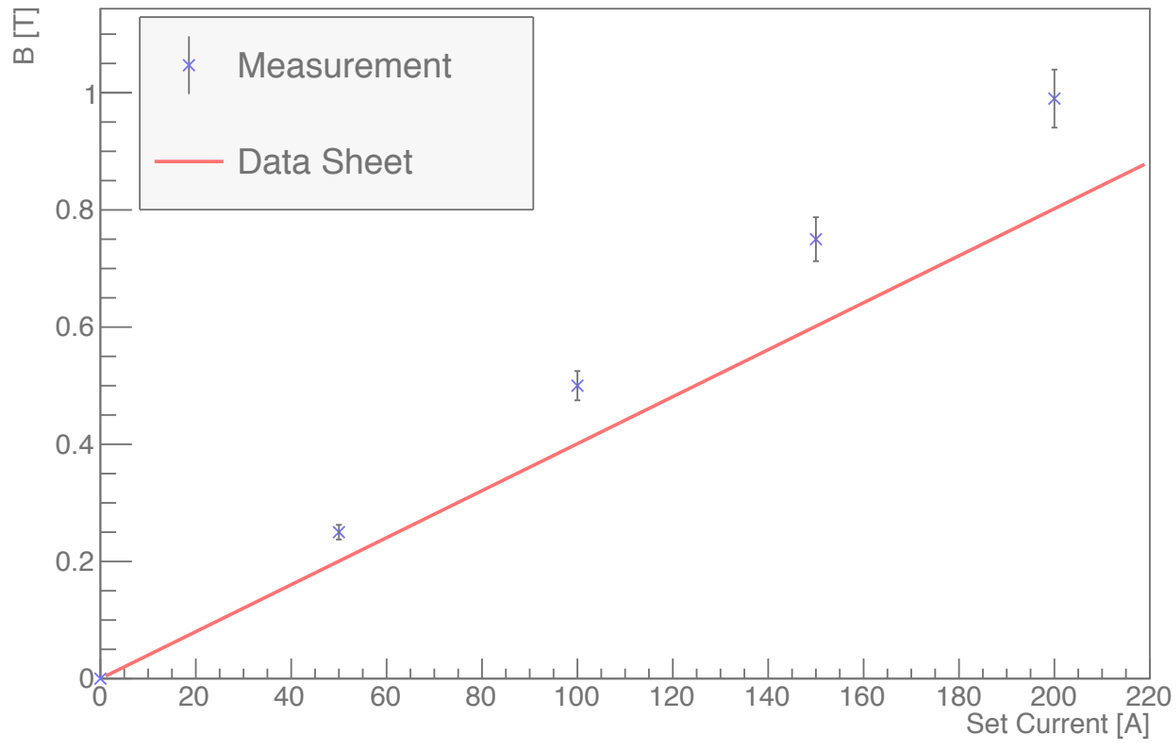
- The magnetic field measured was ~25% higher than noted on the data sheet



Further investigations - Wednesday

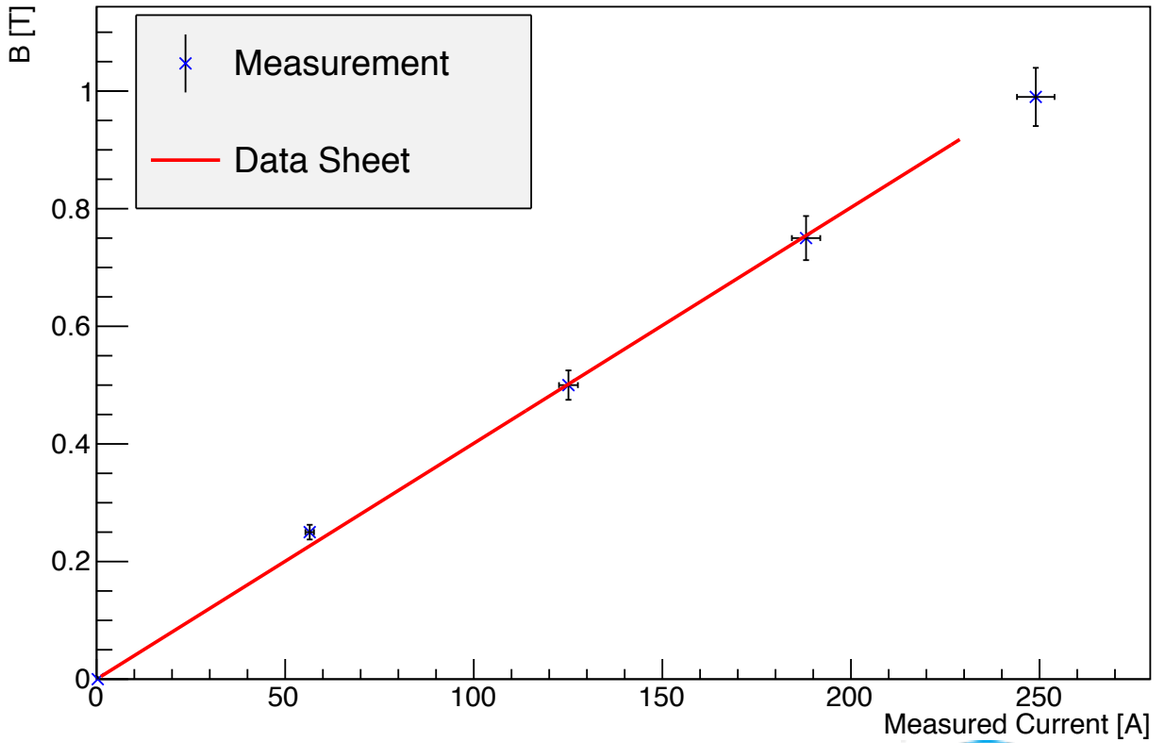
- The magnetic field of the green magnet was measured using a Hall Probe depending on the set current

- The magnetic field measured was ~25% higher than noted on the data sheet



- The actual current at the magnet was measured using a current clamp

- The measured current was ~25% higher than the current set via the control panel ➔ Rescale the plot



Further investigations - Wednesday

- As the magnet is proved to be fine, the error was the discrepancy of the set current to the actual measured current of the green magnet.

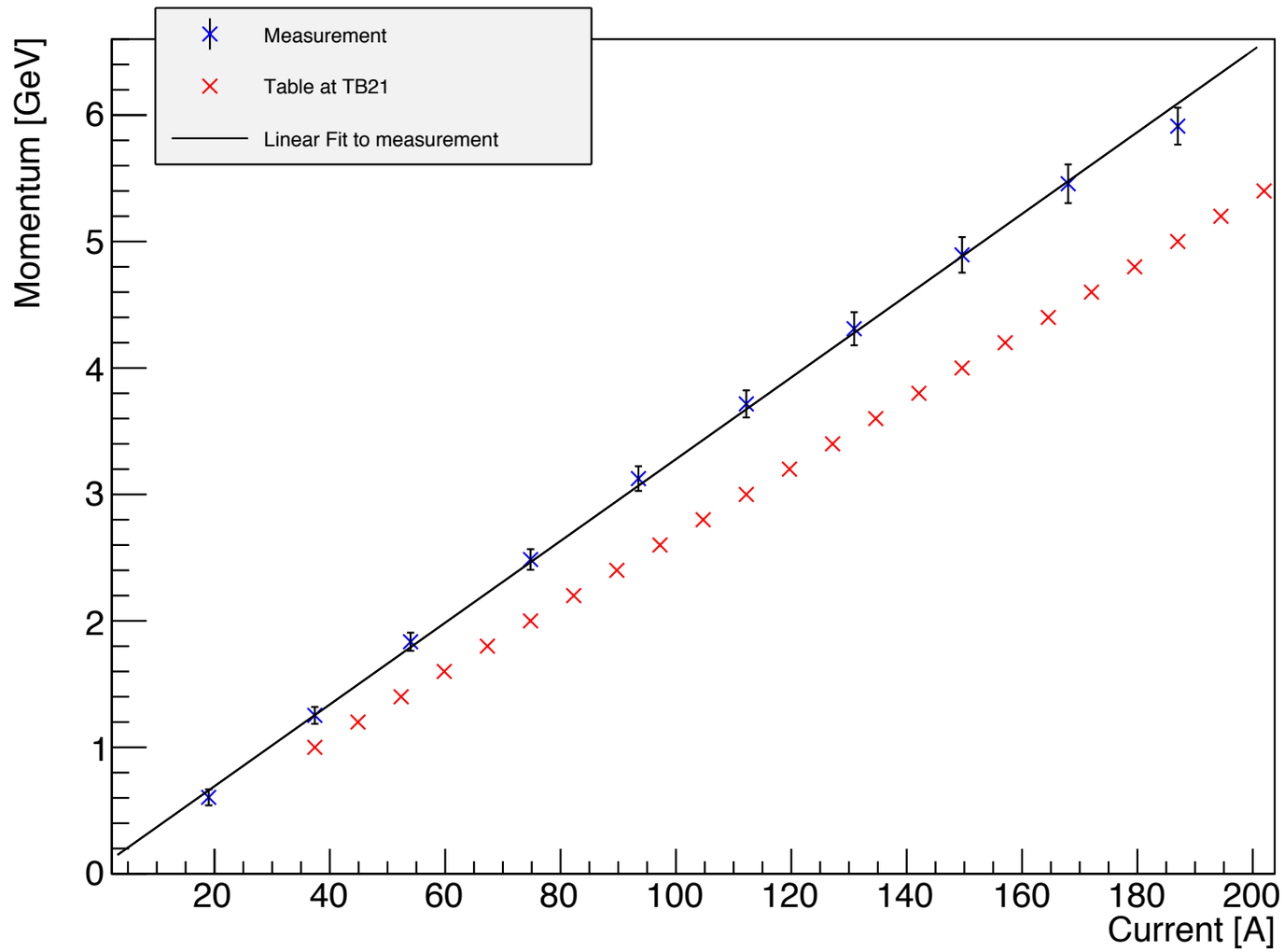
- We* found the reason to be a miscalibration of the power supply control

- The calibration is now corrected

*: N. Meyners, Y. Holler and S. Spannagel

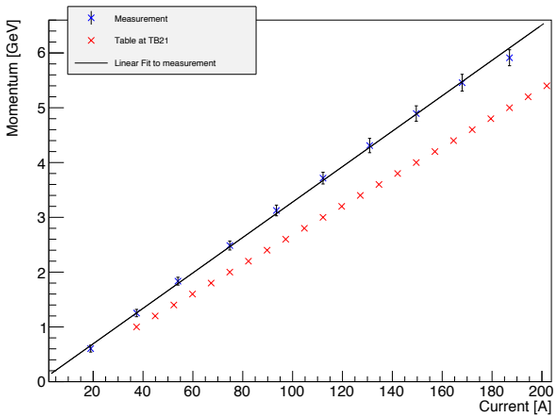
Further investigations - Wednesday, about midnight

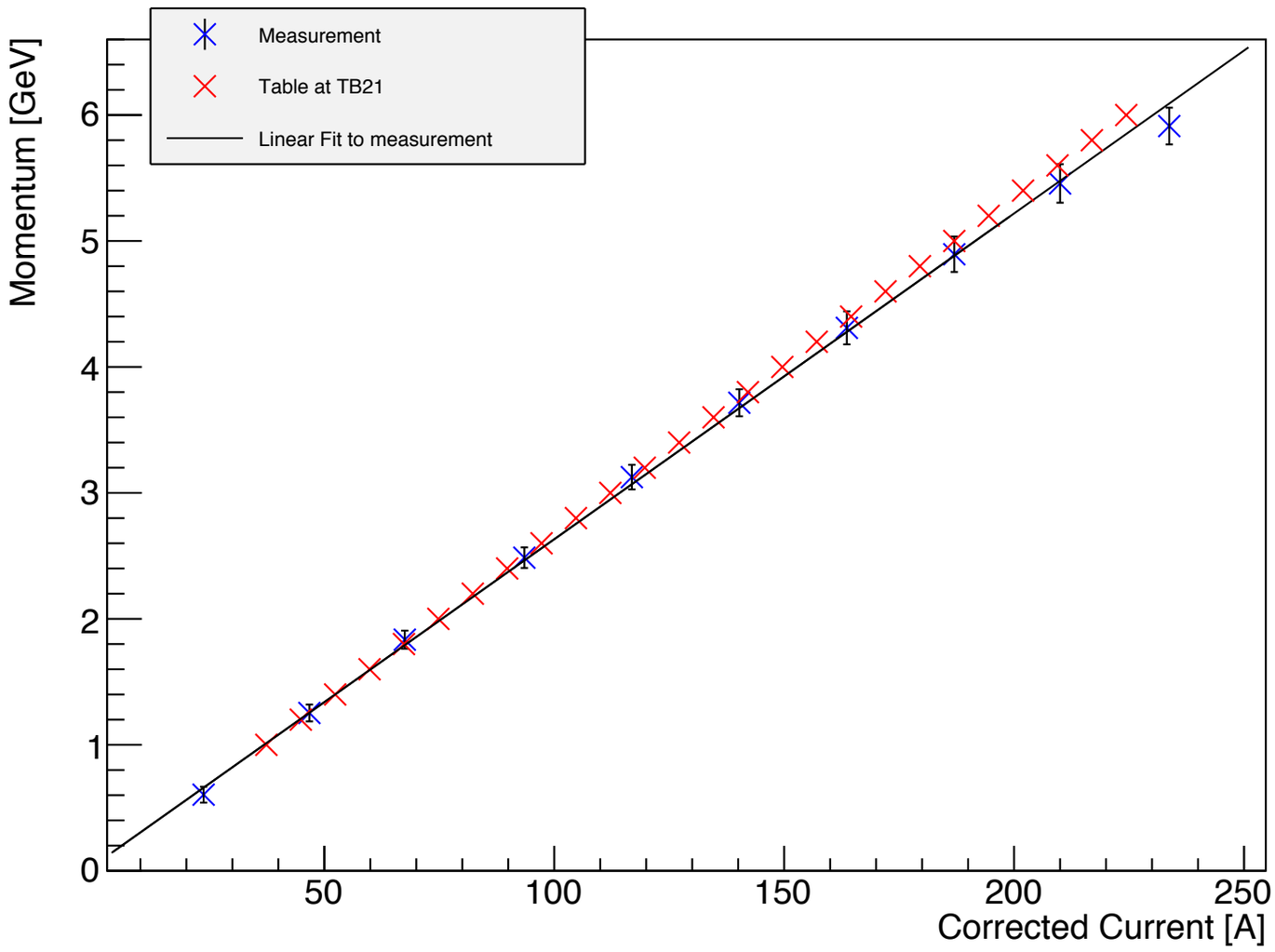
- The result of the energy measurement could easily be corrected by the same factor as the calibration of the power supply



Further investigations - Wednesday, about midnight

- The result of the energy measurement could easily be corrected by the same factor as the calibration of the power supply



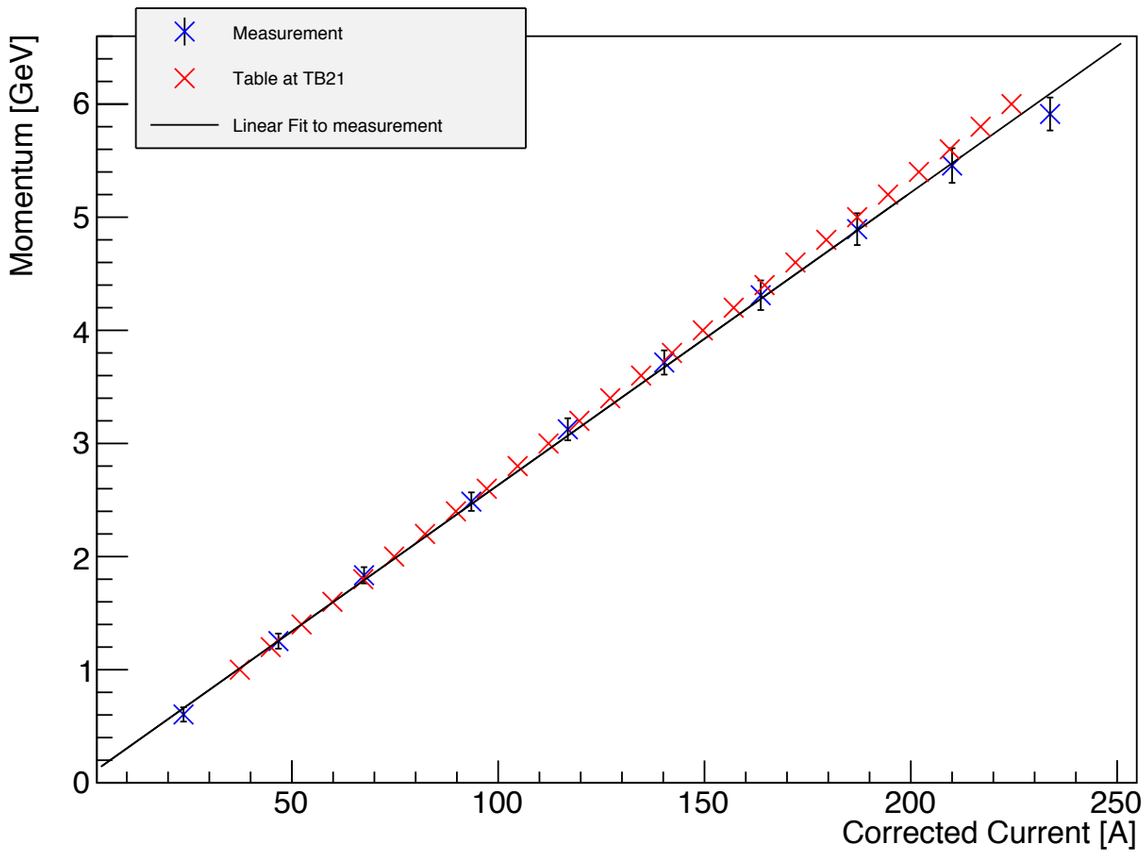


- Good consistency of measurement and prediction

Summary

- After the recalibration the theoretical prediction for the beam energy in test beam area 21 could be confirmed

- The recalibration of the power supply was very important for future experiments at the DESY test beam area 21



- Possible further investigations:
  - Error studies on the measurement and simulation
  - Investigation of the energy spread, basically possible with my code and data

The End.

> Thank you for your attention!

> Are there any questions?