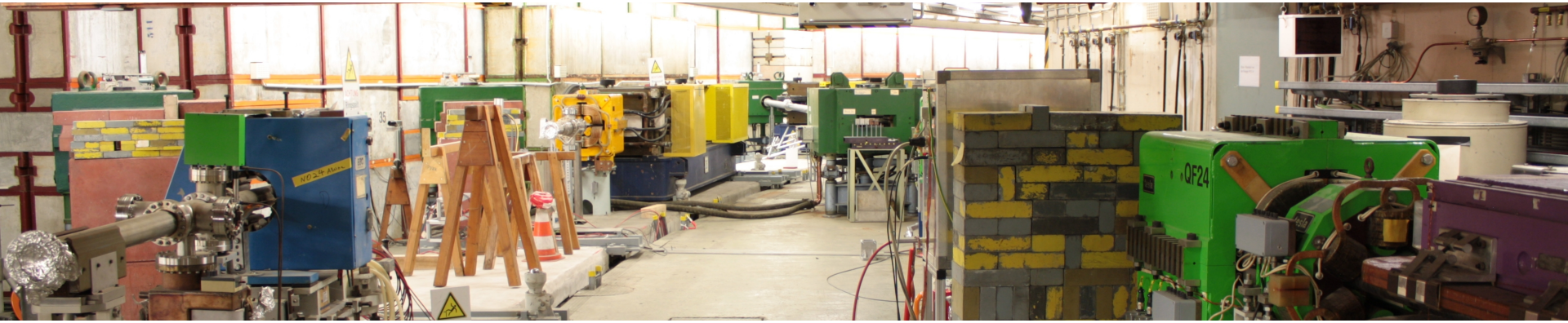
Simulation of Particle Fluxes at the DESY-II Test Beam Facility



Master's thesis

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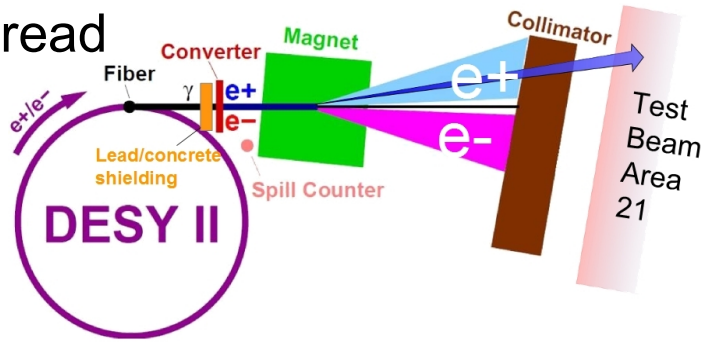
Supervisors:
Eckhard Elsen
Marcel Stanitzki

Hamburg, 20 January 2015

Karlsruher Institut für Technologie

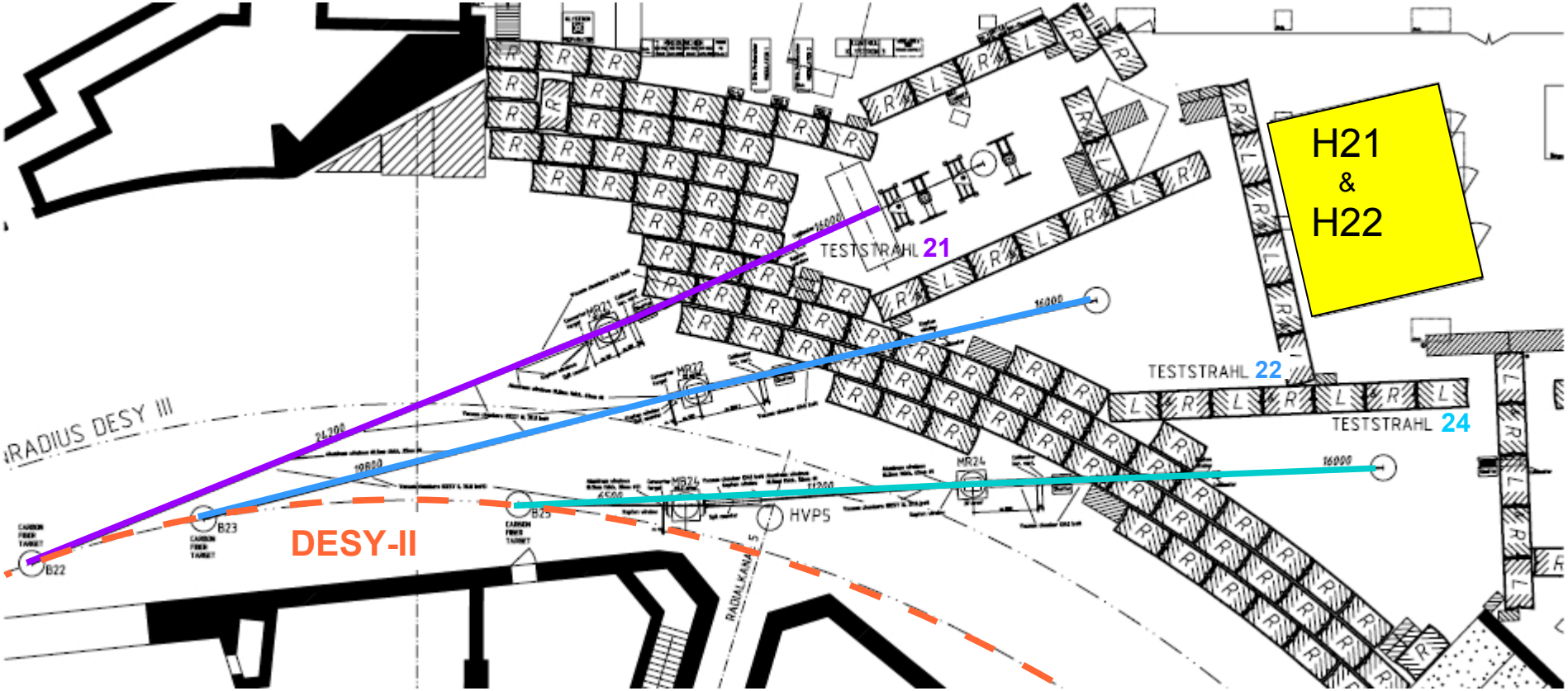
Motivation: Simulation

- More detailed knowledge about the test beam lines is necessary:
  - The beam generation
  - The beam attributes:
    - Beam energy and its spread
    - Beam purity
    - Particle fluxes



- Simulation of all components of the test beam lines
  - Geometry description in GDML format
  - SLIC with Geant4 toolkit → simulated data in LCIO format
- Key input for future beam line improvements

Test Beam Facility: DESY-II tunnel and TB areas



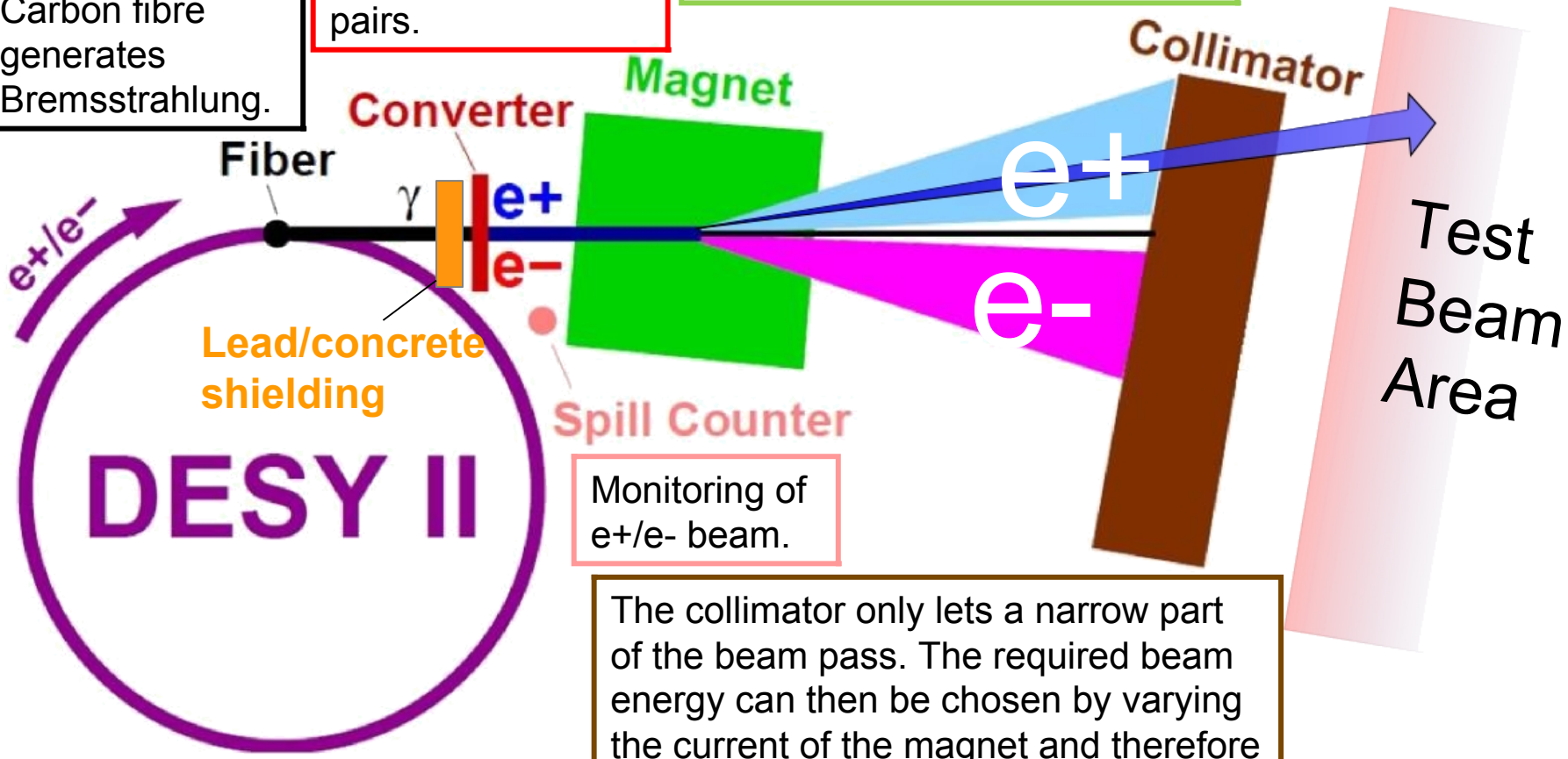
DESY-II:
e+/e- synchrotron
Preaccelerator for PETRA

Test Beam generation

Carbon fibre generates Bremsstrahlung.

Aluminium/ copper plate converts photons to e+/e- pairs.

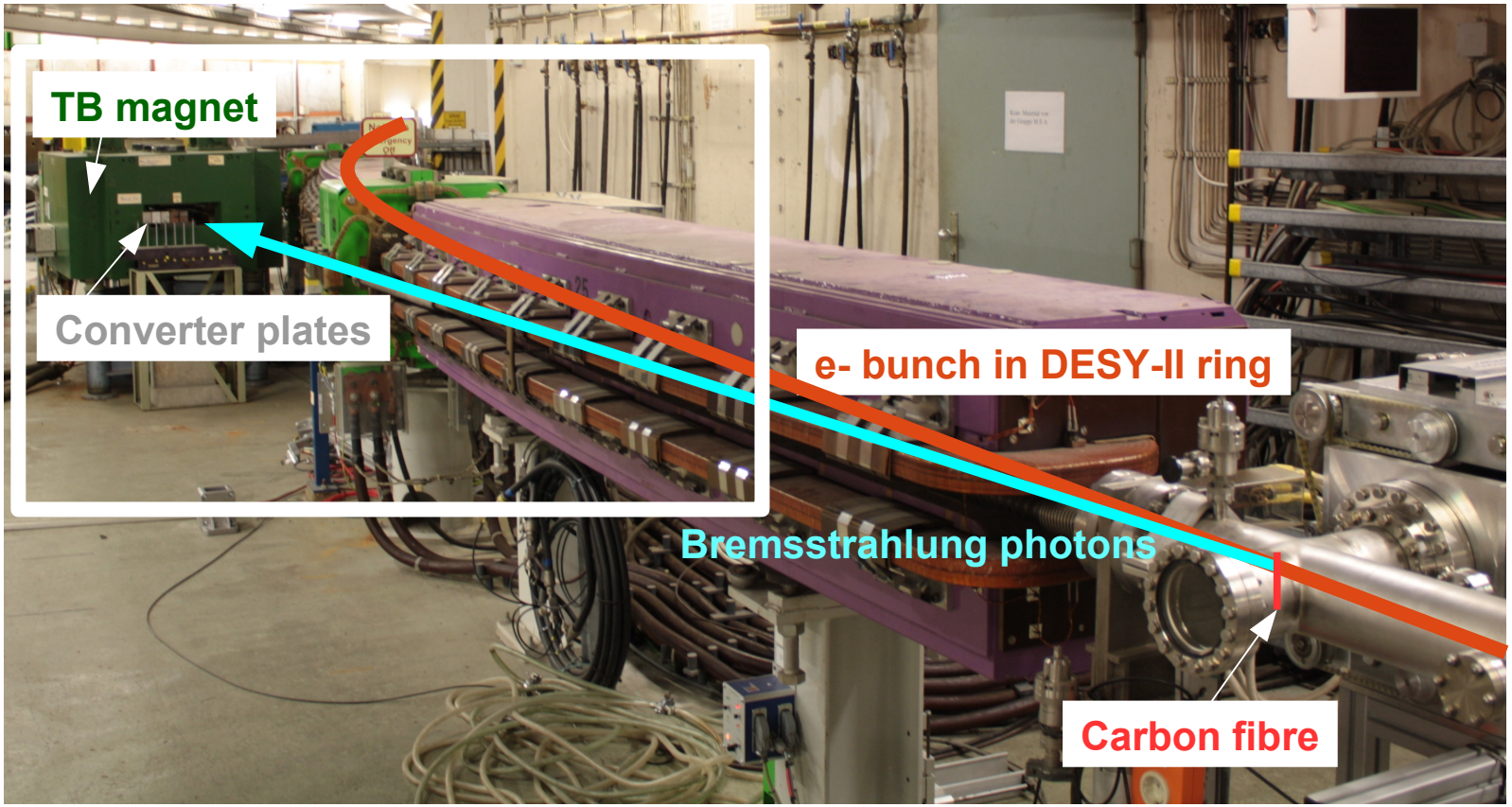
The magnetic field spreads the beam due to:
- Different charges of particles
- Energy distribution



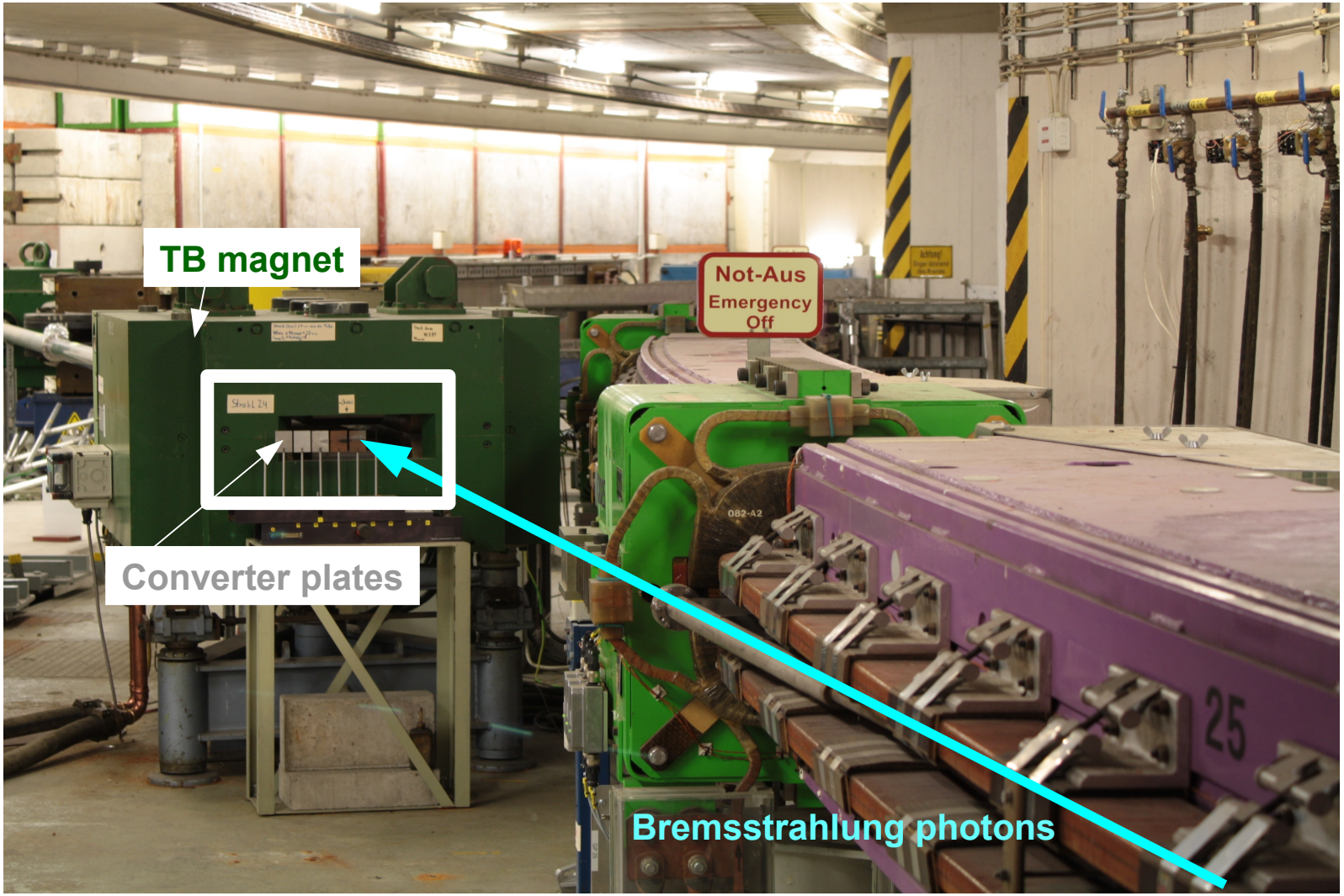
Monitoring of e+/e- beam.

The collimator only lets a narrow part of the beam pass. The required beam energy can then be chosen by varying the current of the magnet and therefore the deflection.

DESY-II ring - carbon fibre - converter plates - TB magnet

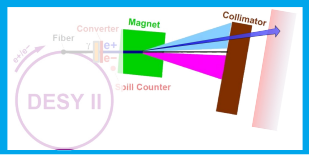


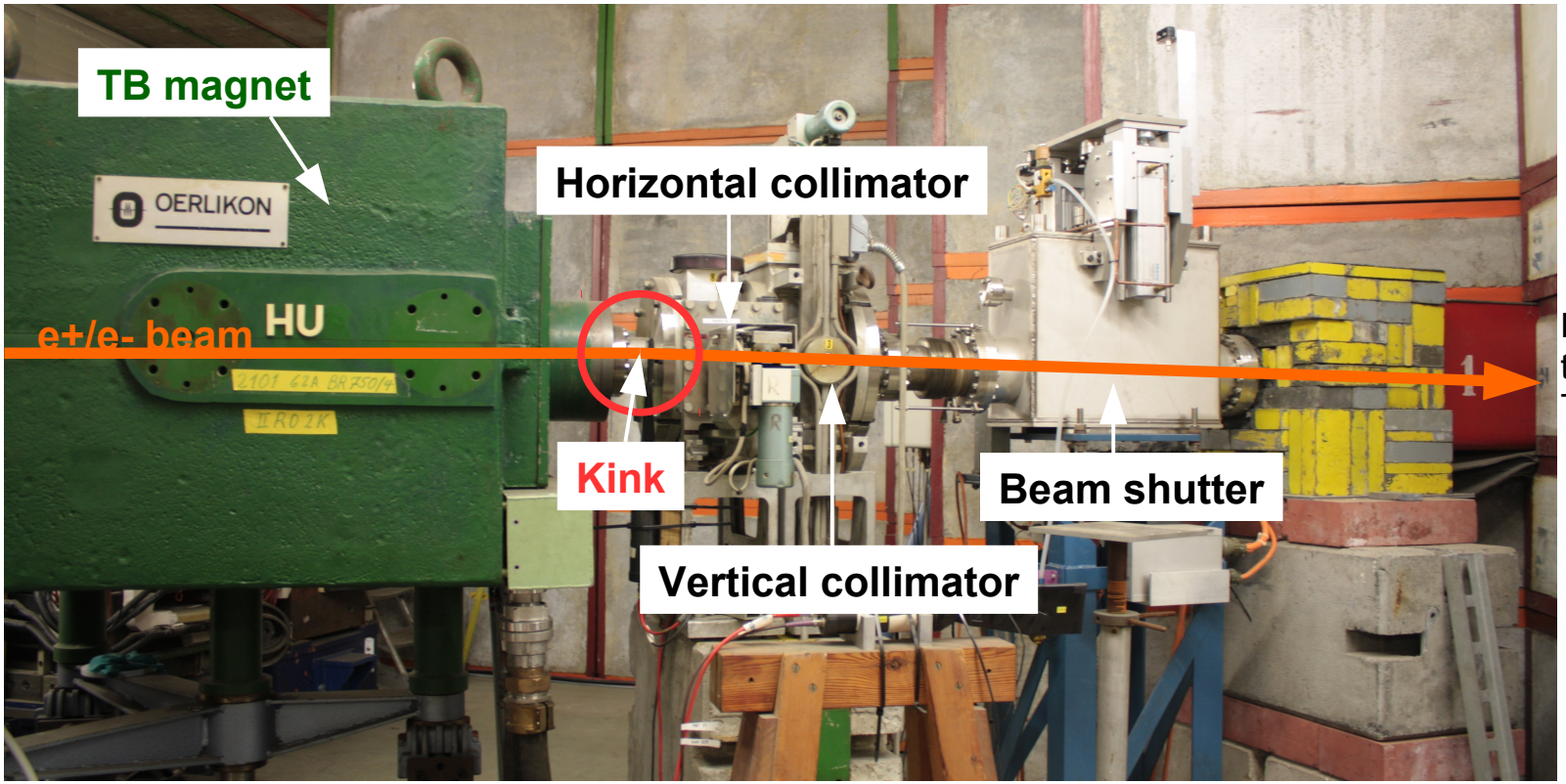
DESY-II ring - converter plates - TB magnet



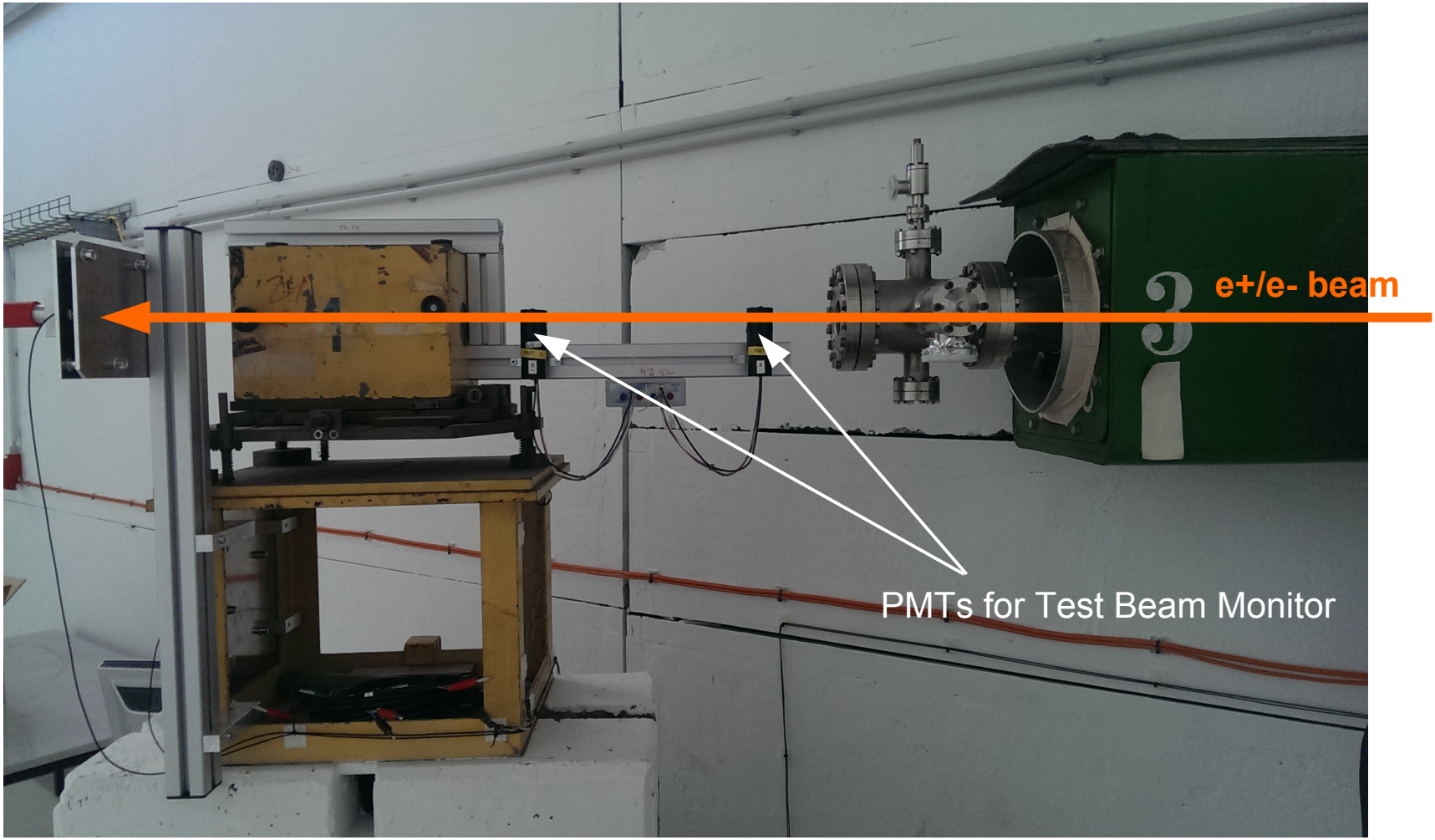
Converter plates - TB magnet

TB magnet – horizontal and vertical collimators

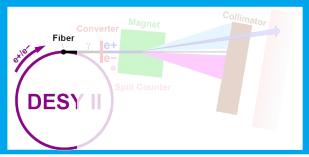




TB area: Final collimation and beam monitoring



Simulation: DESY-II beam bunch



- DESY-II bunch:
  - $1*10^{10}$ electrons with 6.3 GeV
  - $\sigma_E/E = 9.8*10^{-4}$
  - beam sizes:

    $\sigma_x = 1.53$ mm

    $\sigma_y = 0.753$ mm

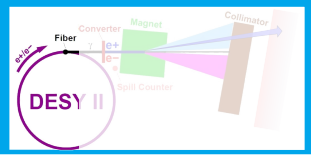
- Slic macro:

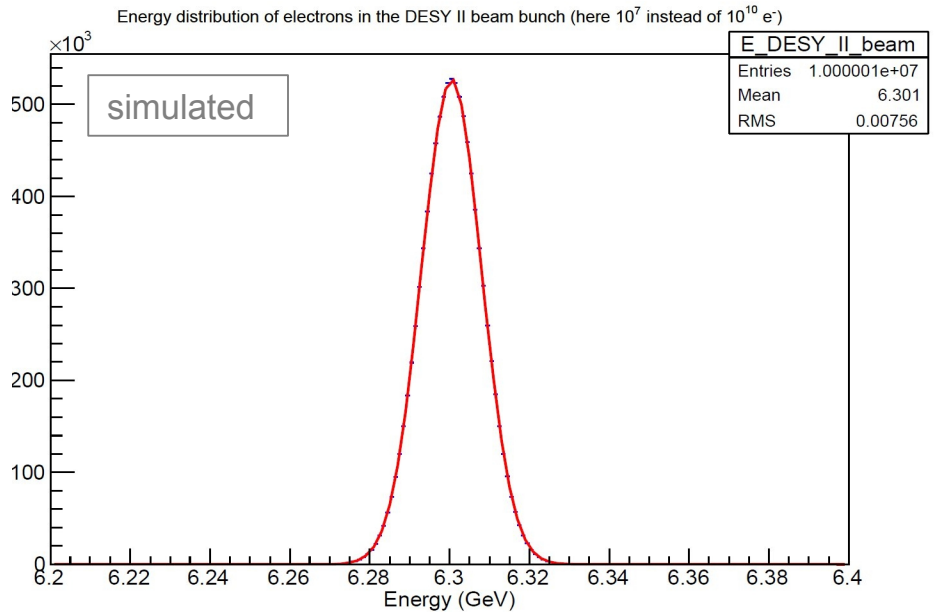
```
/run/initialize

/generator/select gps
/gps/particle e-
/gps/pos/type Beam
/gps/pos/sigma_x 1.53 mm
/gps/pos/sigma_y 0.753 mm
/gps/pos/centre 0 0 0 cm
/gps/direction 0. 0. 1.
/gps/ene/type Gauss
/gps/ene/mono 6.3 GeV
/gps/ene/sigma 6.17249 MeV

/random/seed
/run/beamOn 10000000000
```

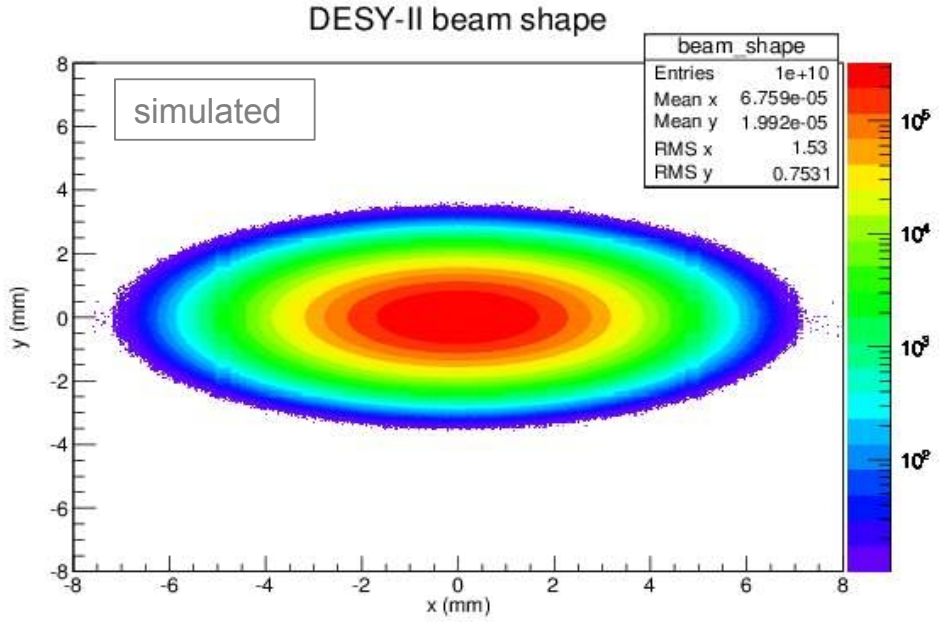
[Heiko Ehrlichmann,

DESY-II machine coordinator]

Simulation: DESY-II beam bunch



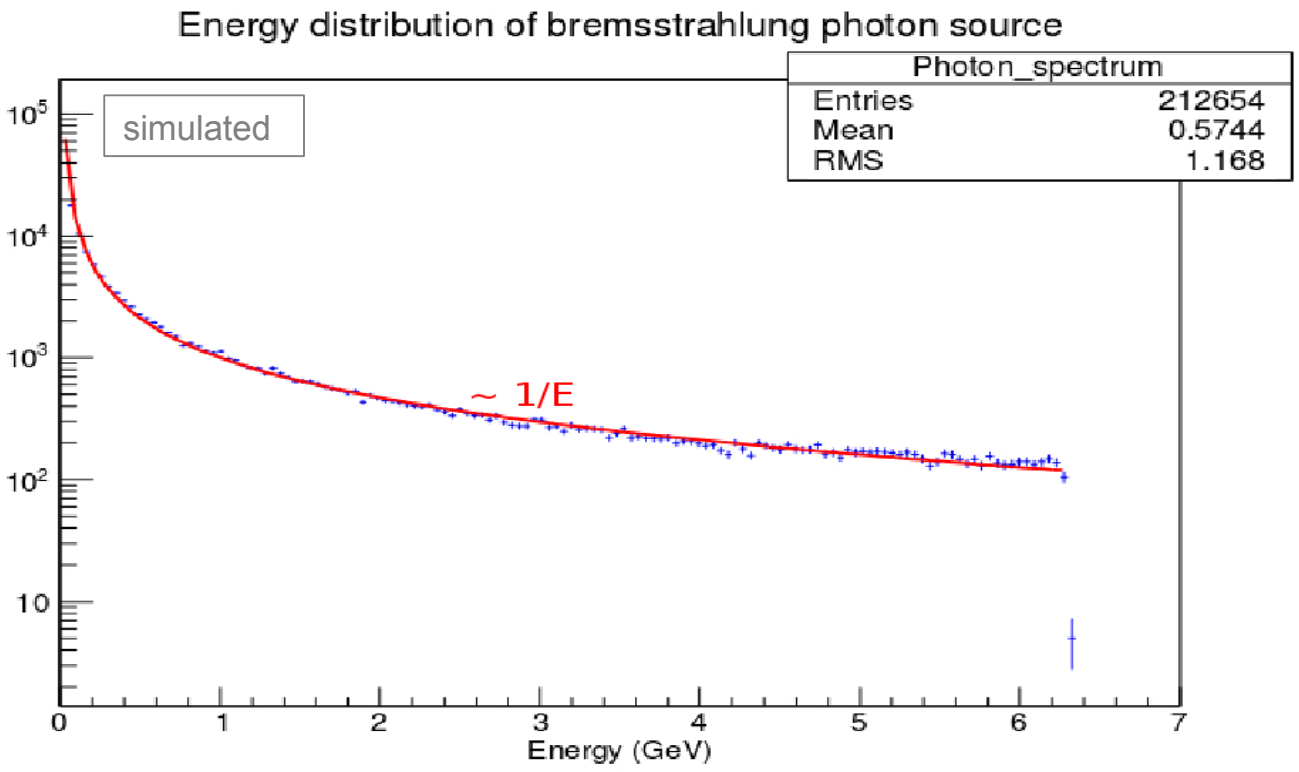




→ Simulation of the beam bunch is input for the simulations of further test beam line components

Simulation: Primary target

- $2.1*10^5$ bremsstrahlung photons
- Typical bremsstrahlung spectrum dependency on 1/E



Simulation: Lead/concrete shielding

- Lead and concrete shielding
  - Lead shielding for stopping e+/e-, primary photons (deviating from the beam path) and synchroton radiation from entering the magnet
  - Concrete shielding for stopping proton and neutron fluxes
- Where to put new scintillators (old ones were slowly fried)
- Where to put our neutron counters (ThermoLuminescent Dosimeters)

Simulation: Lead/concrete shielding

- gdml geometry description:

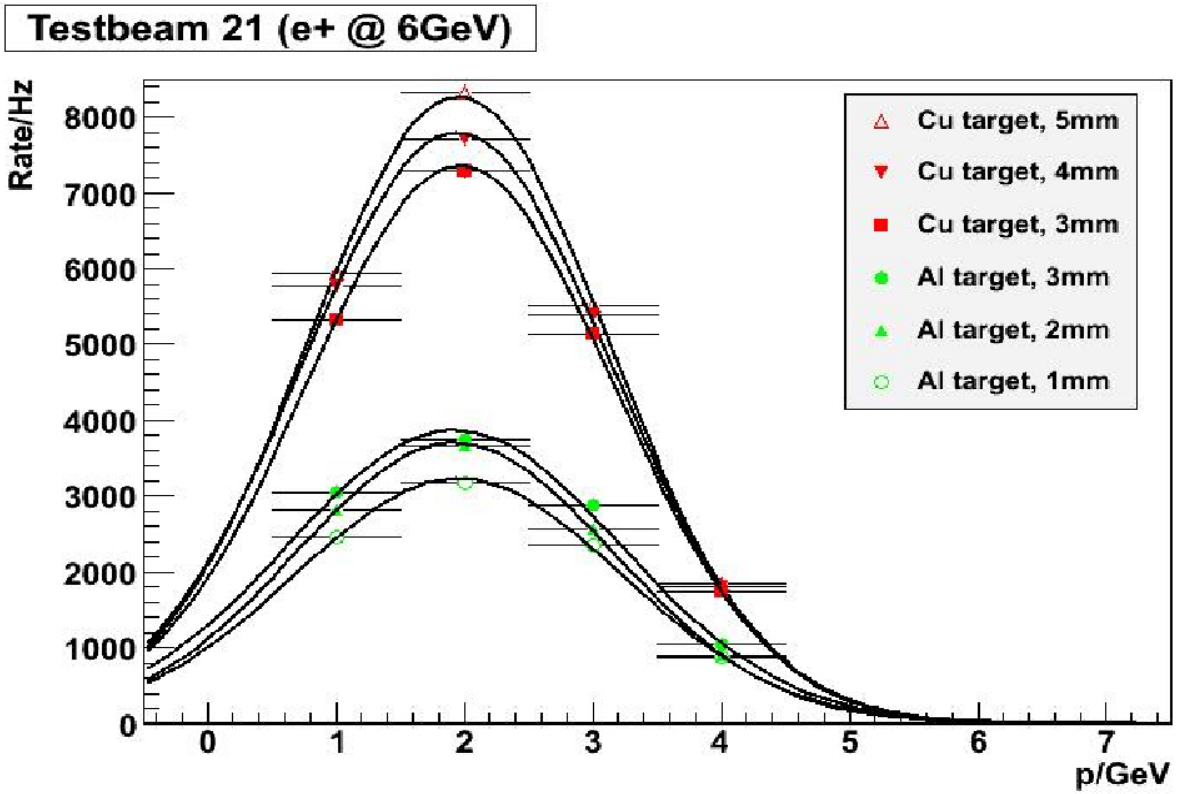
```
<gdml>
  <define>
     Constants, positions,...
  </define>
  <materials>
     <material name="heavyConcrete">
        ...
  </material>
  <solids>
        <!--  Lead Shielding  -->
     <box lunit="mm" name="ShieldingBox"  x="800." y="275." z="200."/>
     <box lunit="mm" name="ShieldingHole" x="50."  y="75."  z="200."/>
     <subtraction name="LeadShieldingWall">
        <first ref="ShieldingBox"/>
        <second ref="ShieldingHole"/>
        <positionref ref="Position_of_ShieldingHole"/>
     </subtraction>
        ...
  </solids>
        ...
```

Simulation: Lead/concrete shielding

```
      ...
  <structure>
     <volume name="LeadShielding_vol">
        <materialref ref="Lead"/>
        <solidref ref="LeadShieldingWall"/>
     </volume>
        …
     <volume name="testbeam_volume">
        <materialref ref="Air"/>
        <solidref ref="WorldBox"/>
        <physvol>
               <volumeref ref="LeadShielding_vol"/>
               <position name="LeadShielding_vol_position"
                                              x="-100." y="75." z="100."/>
        </physvol>
     </volume>
  </structure>
  <setup name="Default" version="1.0">
        <world ref="testbeam_volume"/>
  </setup>
</gdml>
```

Simulation: Secondary target

- Pair production to electron/positron pairs
- Converter plates of different materials and thicknesses
- Different rates of final test beam



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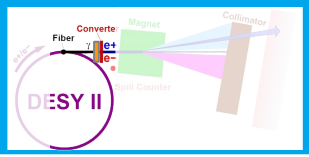
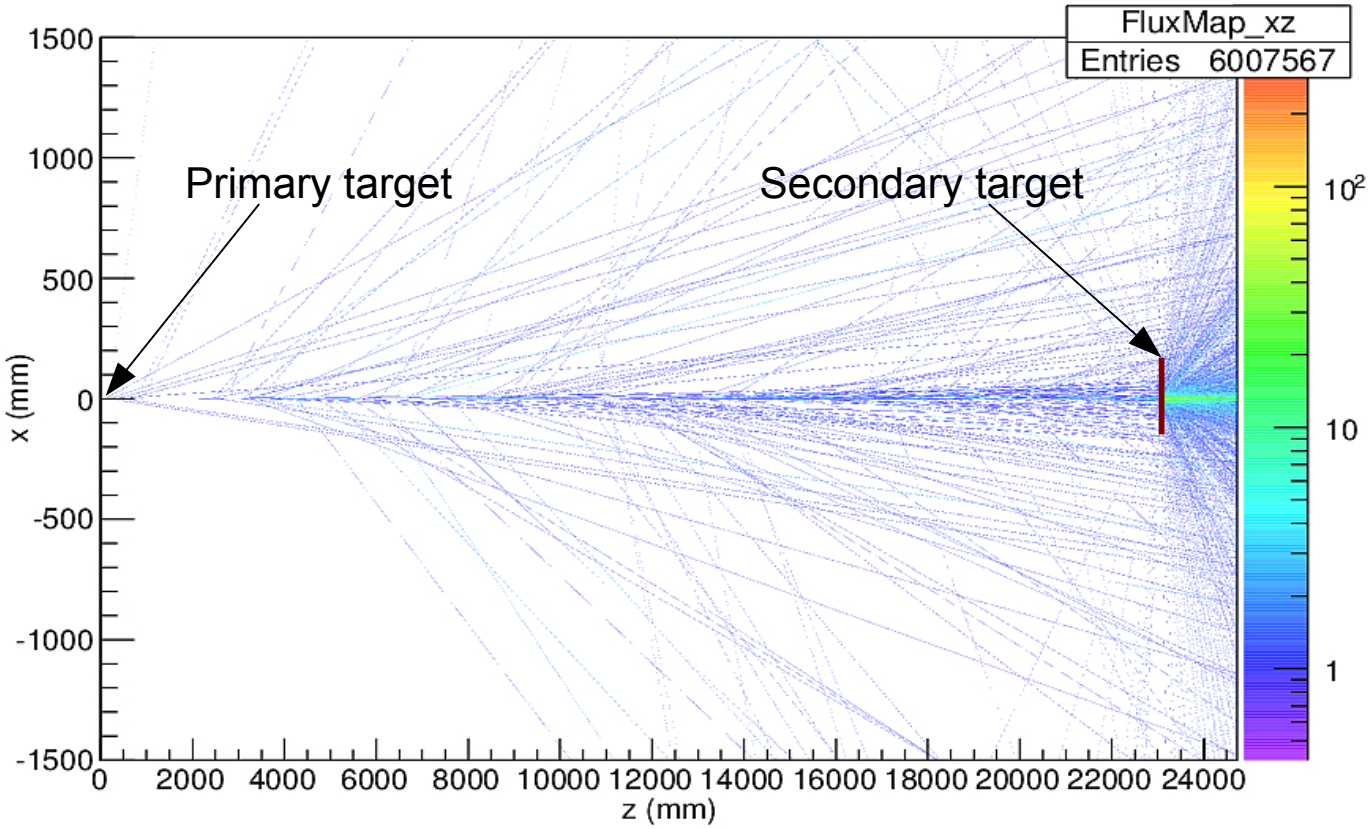
Map of particle trajectories

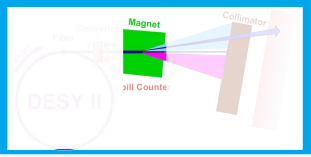


- Two dimensional histogram of particle trajectories in the DESY-II tunnel
- For specific particle type(s)

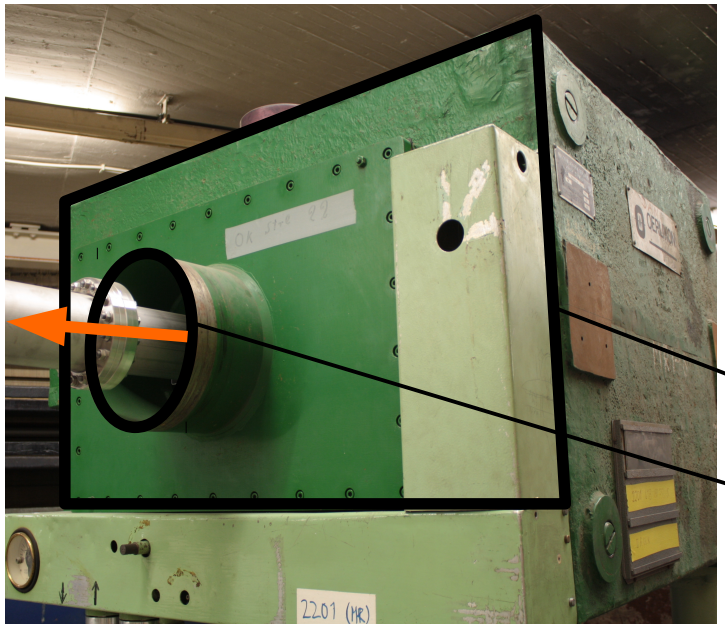
Map of simulated electron trajectories along the TB line

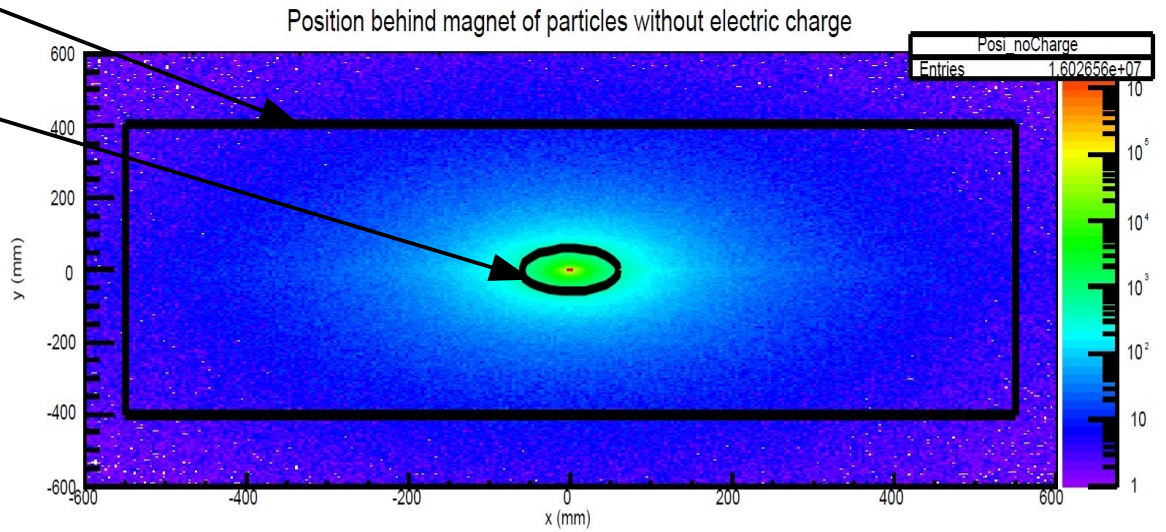


Simulation: TB dipole magnet

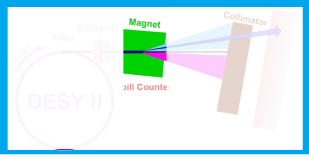


- Magnetic field over an length of 104cm
- Adjustable current to vary the magnetic field strength

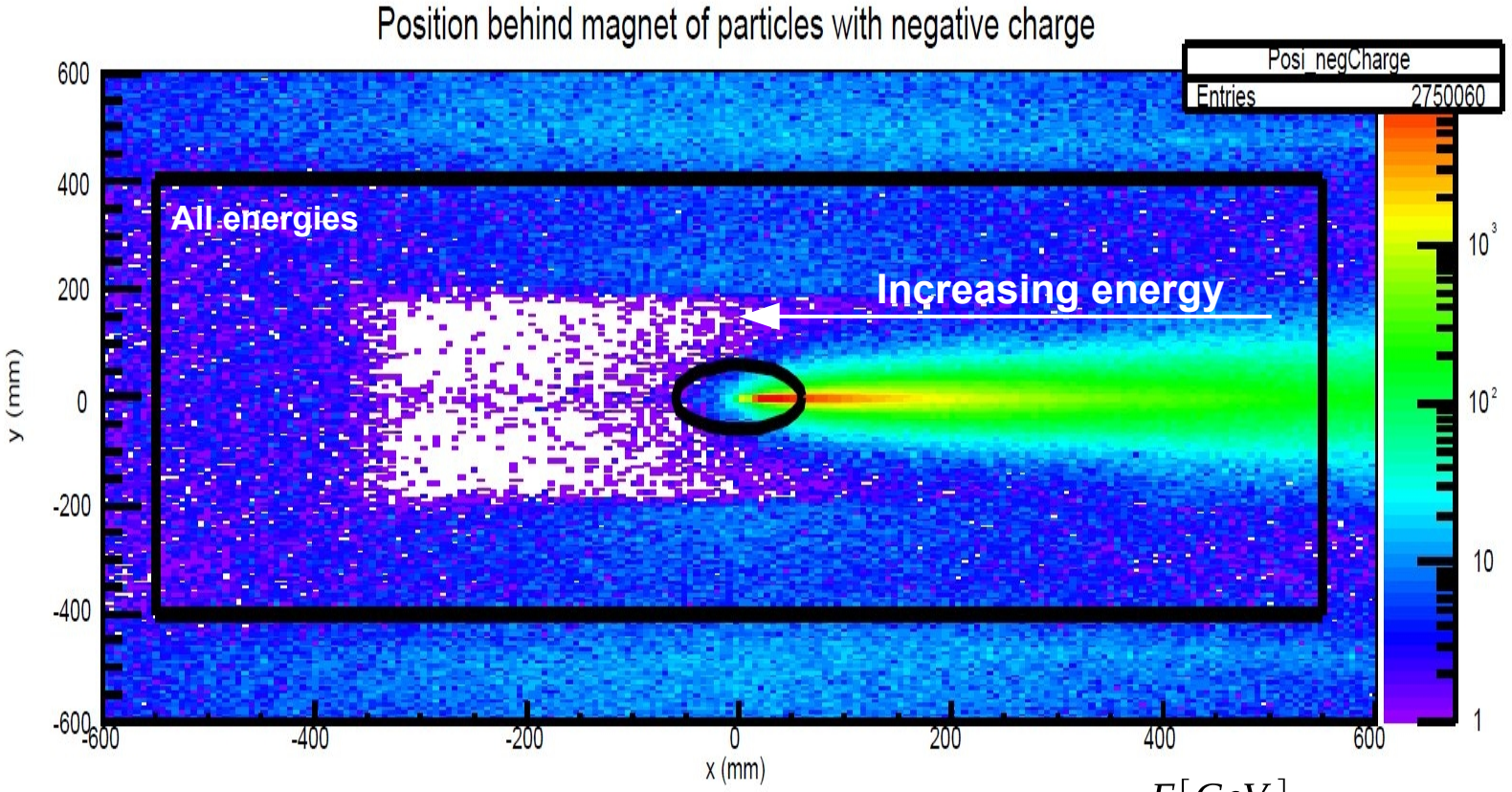




TB magnets: deflection of negatively charged particles



B=0.5T

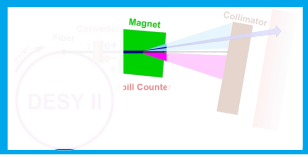


The higher the particle energy, the smaller the deflection in a homogeneous magnetic field.

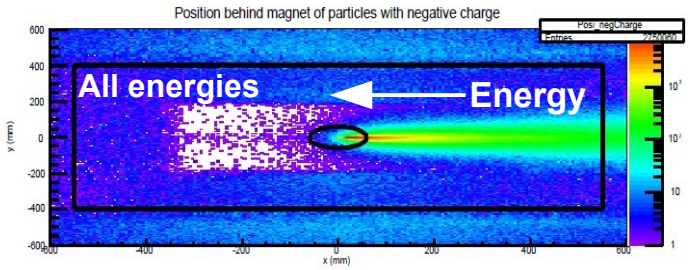
$$r\,[m] \approx \frac{E\,[GeV]}{0.3 \cdot B\,[T]}$$

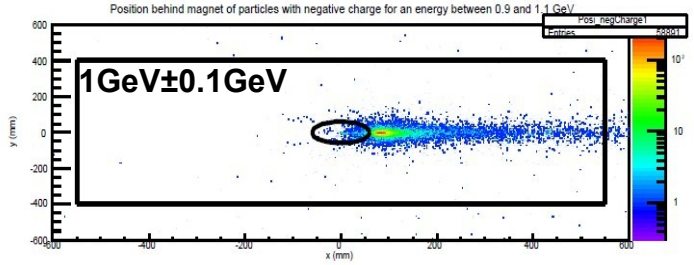
$$theta\,[Radians] = \frac{1}{2}\arcsin\left(\frac{d \cdot 0.3 B\,[T]}{E\,[GeV]}\right)$$

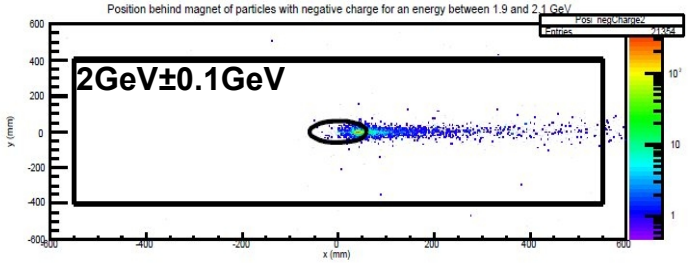
TB magnets: deflection of negatively charged particles

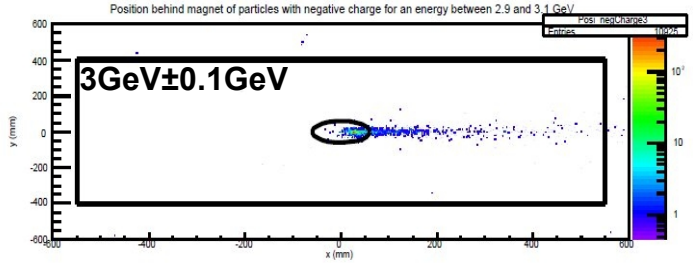


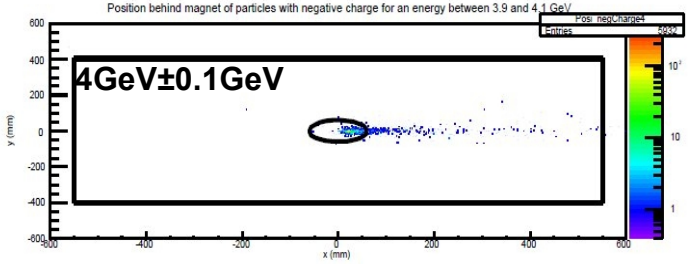
B=0.5T

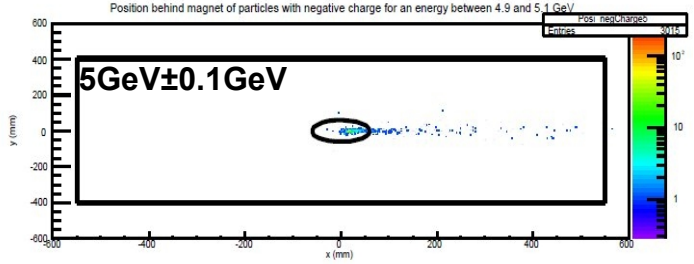


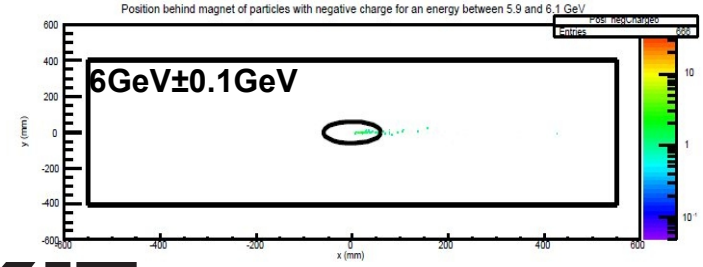


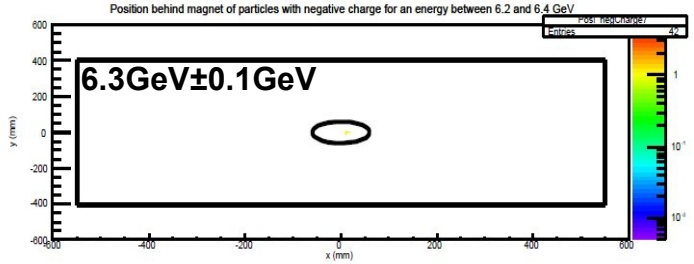








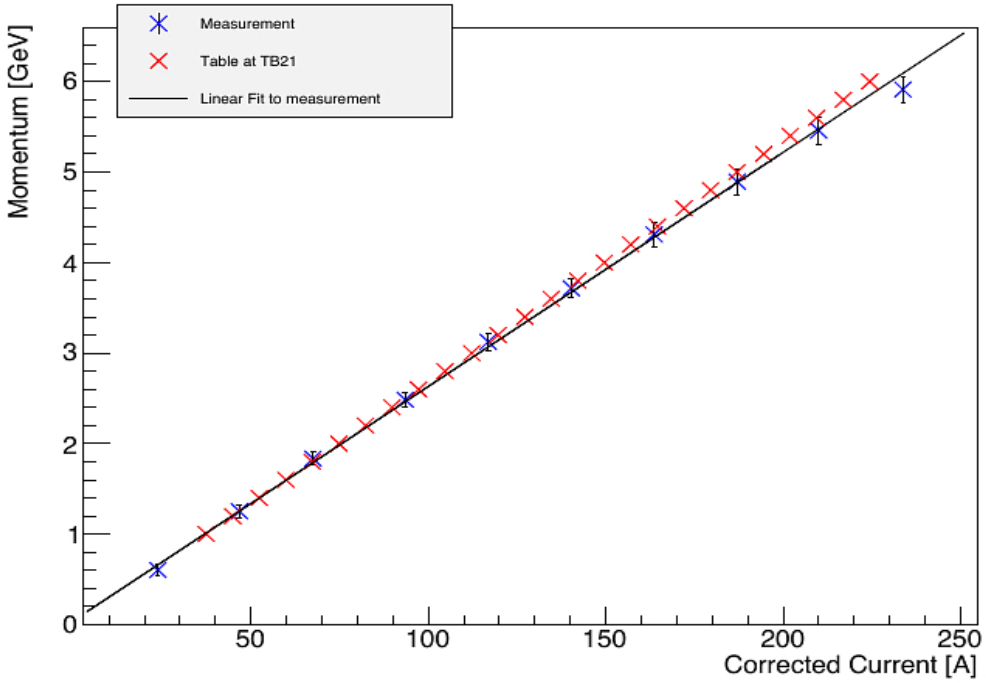




The higher the particle energy, the smaller the deflection in a homogeneous magnetic field.

Final steps

- Beam pipe kink – collimation – final collimation in the TB area
- Better understanding of beam composition
  - Behind magnet and beam pipe kink no photons, neutrons and low energy pions and protons left → pure e^+/e^- beam
- Plot of test beam energy and energy spread



Summer student project 2013: Paul Schütze

Summary and conclusion

- Geant4 simulation of the DESY test beam generation
  - gdml geometry description of all components of the test beam lines
- Better understanding of beam composition
  - Synchrotron radiation and neutron flux reduced due to shielding
  - Pure e^+/e^- beam behind test beam magnet and kink
- Plots of test beam energy and energy spread
  - Better understanding of dependency between particle momentum and current through test beam magnet

  → **Improvement of the test beam operation for users**

Thank you for your attention!

Dankeschön!

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DESY

Backup

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DESY

Simulating an homogeneous magnetic field

- Magnetic field over an length of 100cm
- Particle deflection:

$$r[m] \approx \frac{E[GeV]}{0.3 \cdot B[T]}$$

$$theta[Radians] = \frac{1}{2}\arcsin\left(\frac{d \cdot 0.3\mathrm{B}[T]}{E[GeV]}\right)$$