Calibration of the DE-TOF detector: position and energy dependence in the plastic scintillator bars

FOOT meeting

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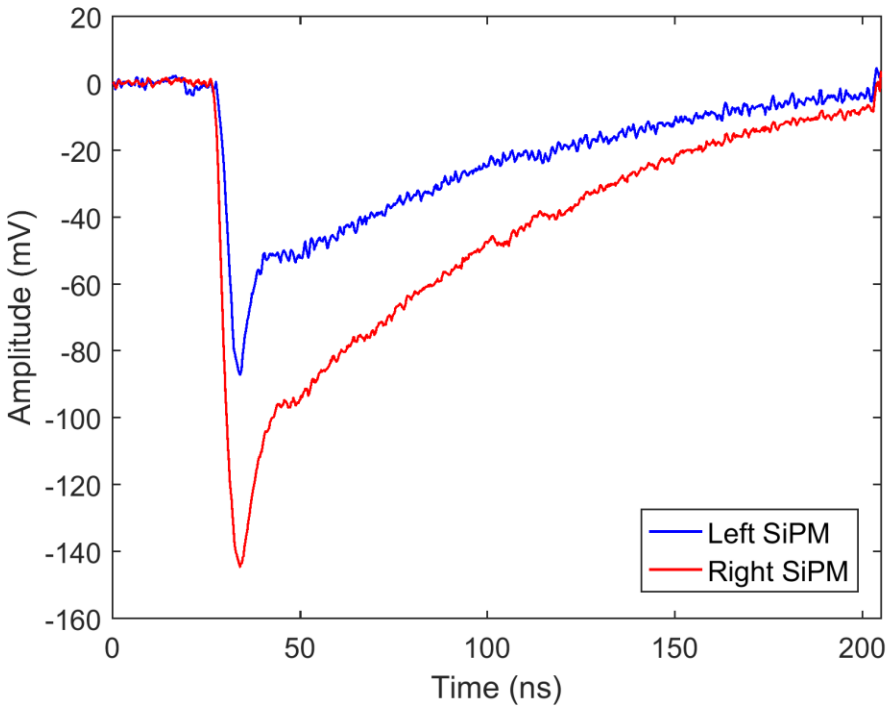
Objectives

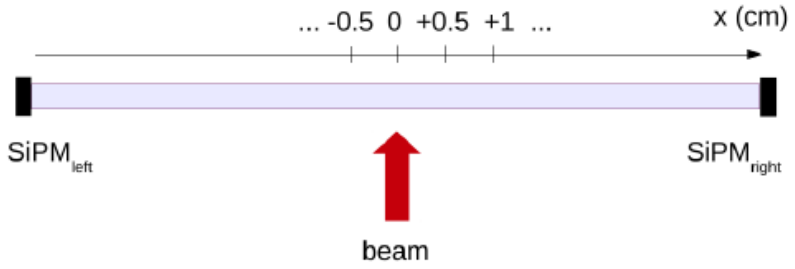
• To define the dependence of the Energy resolution and of the Time resolution of the ΔE-TOF detector on the energy and on the interaction position of the ion

• To model the response of the ΔE-TOF detector, to add it to the simulation of the FOOT experiment

• To obtain information for the development of the next prototype

System set-up

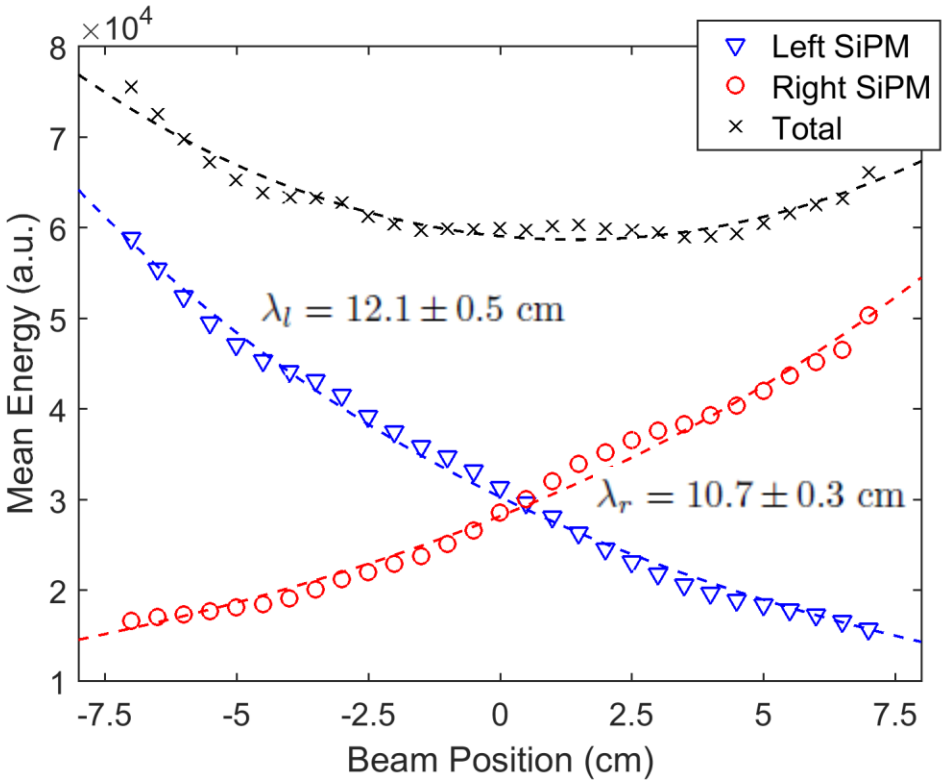




Scan	Beam position (cm)	Beam energy (MeV)
Beam position	[-7,+7], 0.5 cm steps	170
Beam energy	0	70-230

200 x 20 x 2 mm^3 bar coupled to 2 SiPMs on each side.
Signal sampled at 5 GSamples/s

Light Collection



•Exponential light attenuation in the bar → collected energy can be described as:

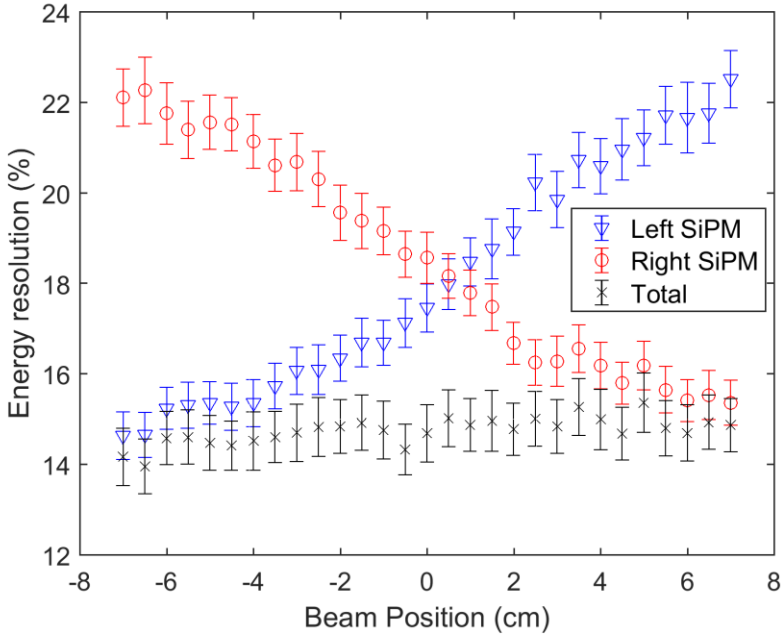
$$E_l = A_l \exp\left(-\frac{L/2 + x}{\lambda}\right)$$

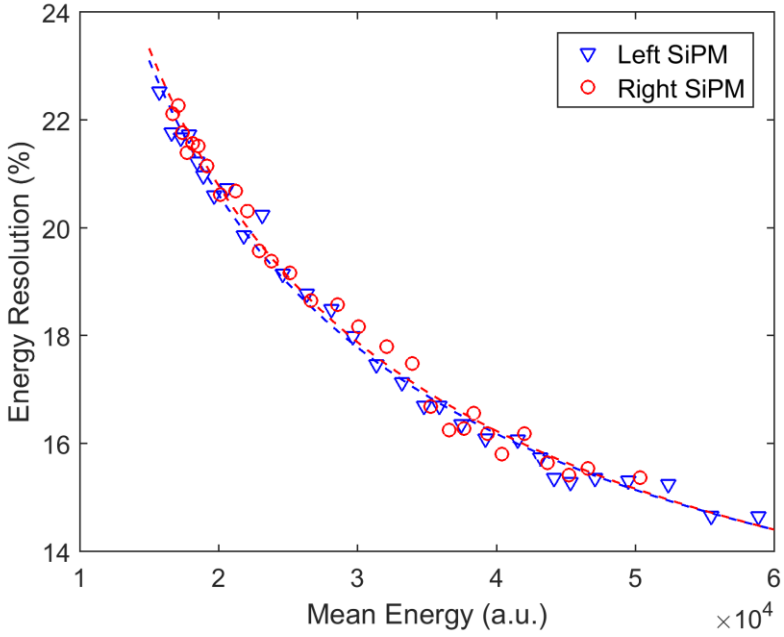
$$E_r = A_r \exp\left(-\frac{L/2 - x}{\lambda}\right)$$

•The two attenuation lengths should be equal

• Attenuation length is maybe affected by hand-made wrapping

Energy resolution vs. beam position





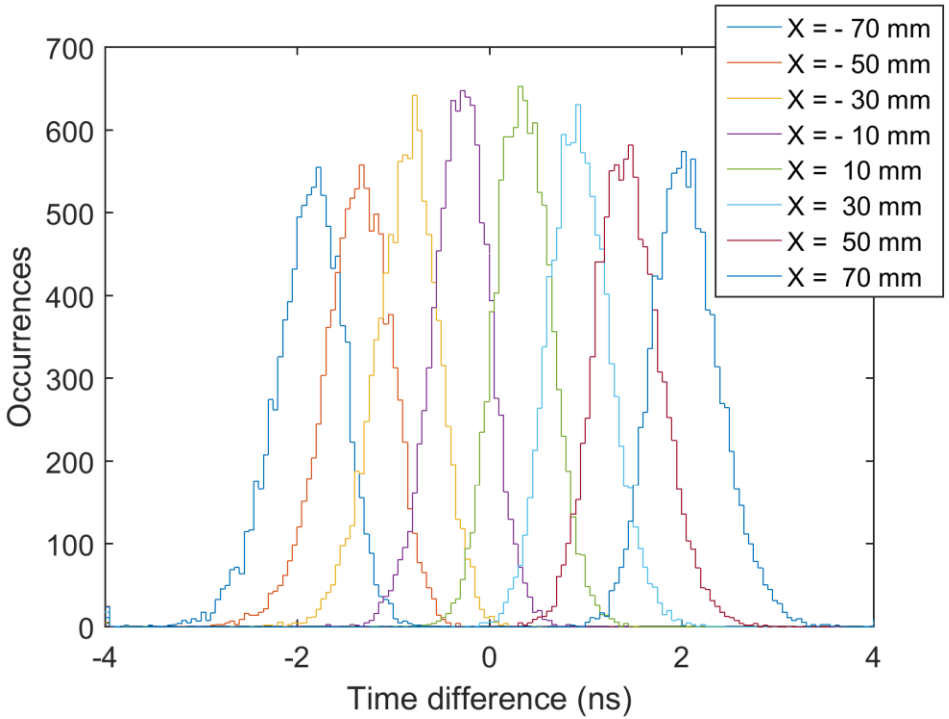
- The total energy resolution is constant along the bar (14 – 15 % with 170 MeV protons)
- The Landau contribution was not subtracted

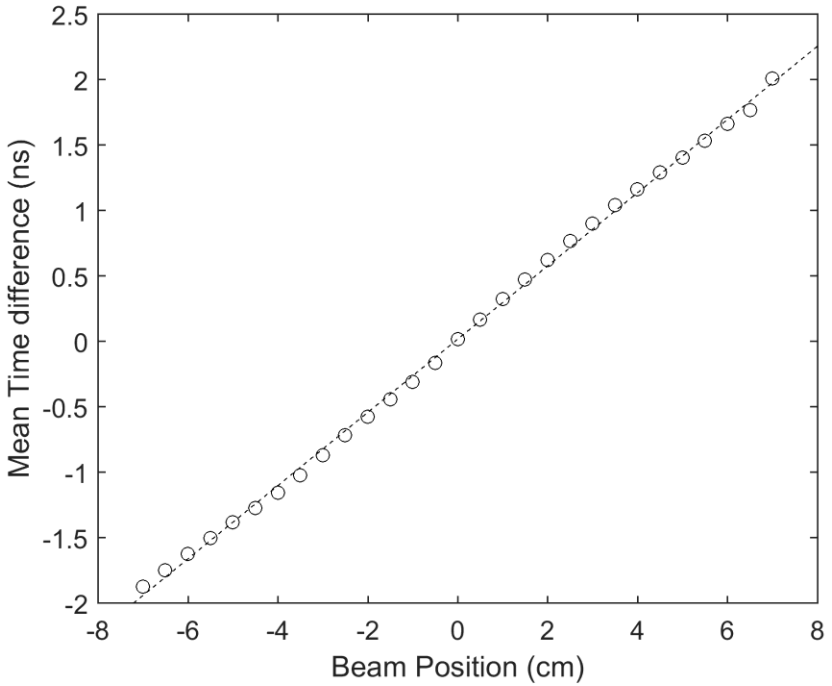
$$ER \propto \sqrt{1/E + C^2}$$

Statistical contribution

constant

Light propagation in the bar



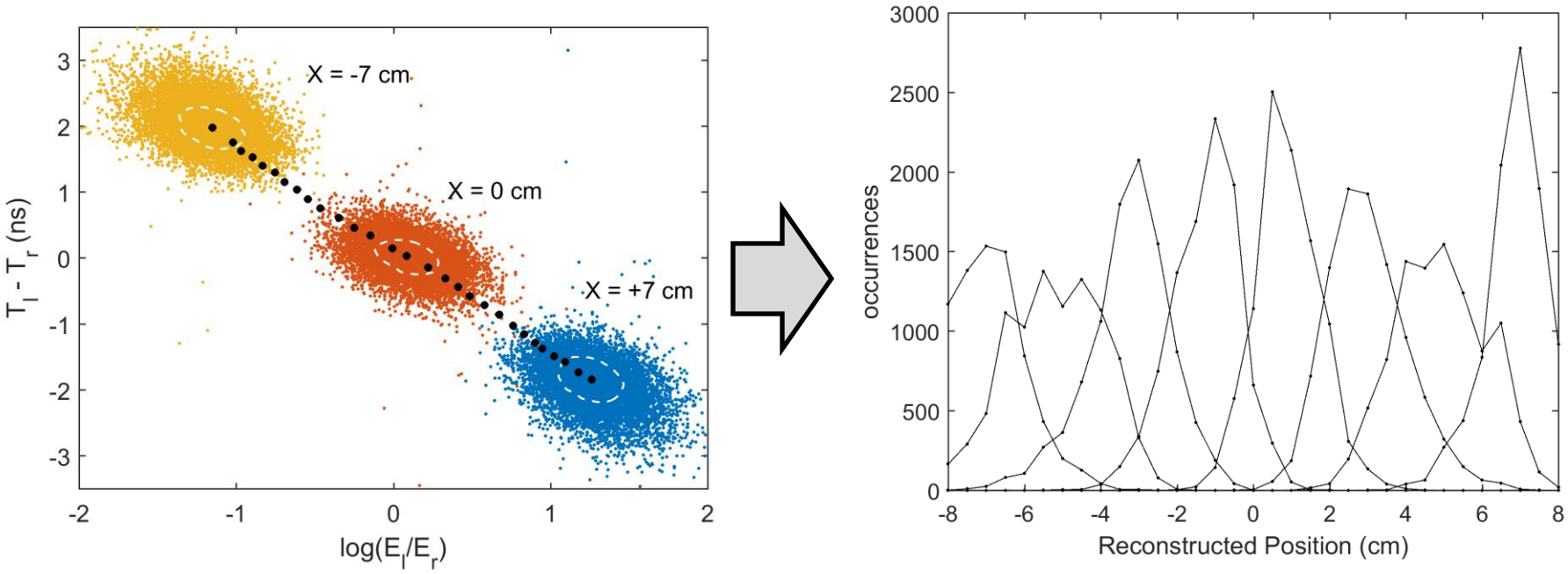


•Photon arrival time at the photo-detector (timestamp) depends on the scintillation position

• The difference between the timestamps at the two sides is linear with the beam interaction position

• Differences range between -2 ns and 2 ns for a 14 cm shift

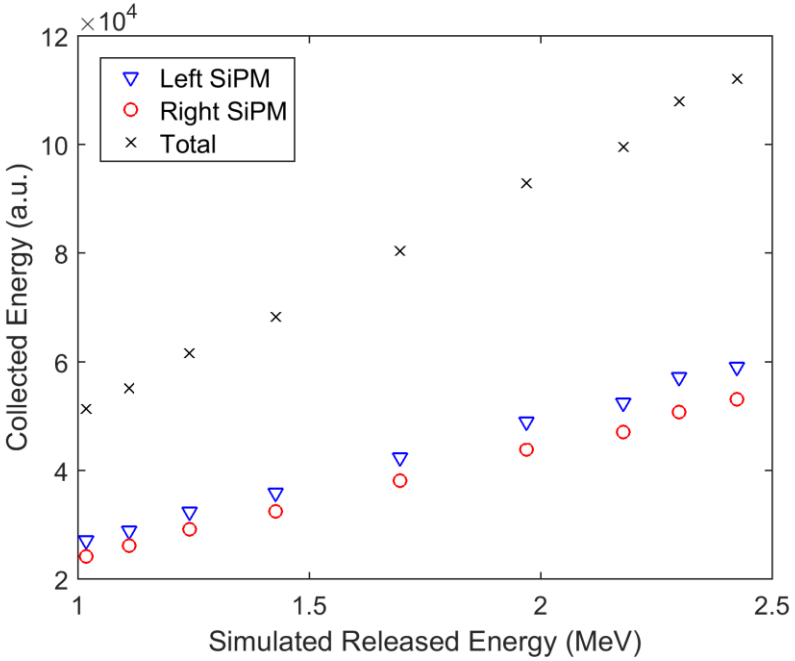
Interaction Position Determination

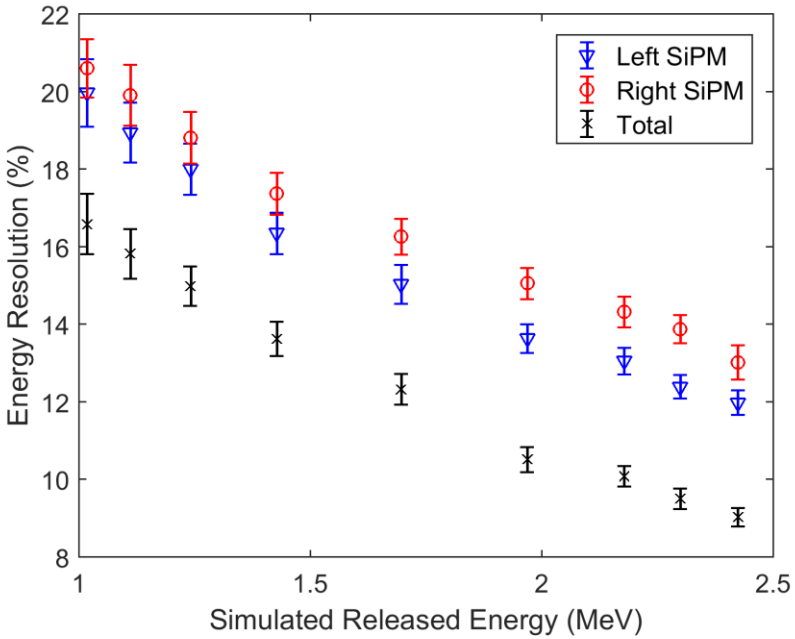


- The interaction position can be determined by using:
  - the difference between the timestamps at the two sides
  - the logarithm of the ratio of the energies collected at the two sides

- Position is determined with a resolution of 1.8 cm, about the lateral size of the bar.

Dependence on beam energy

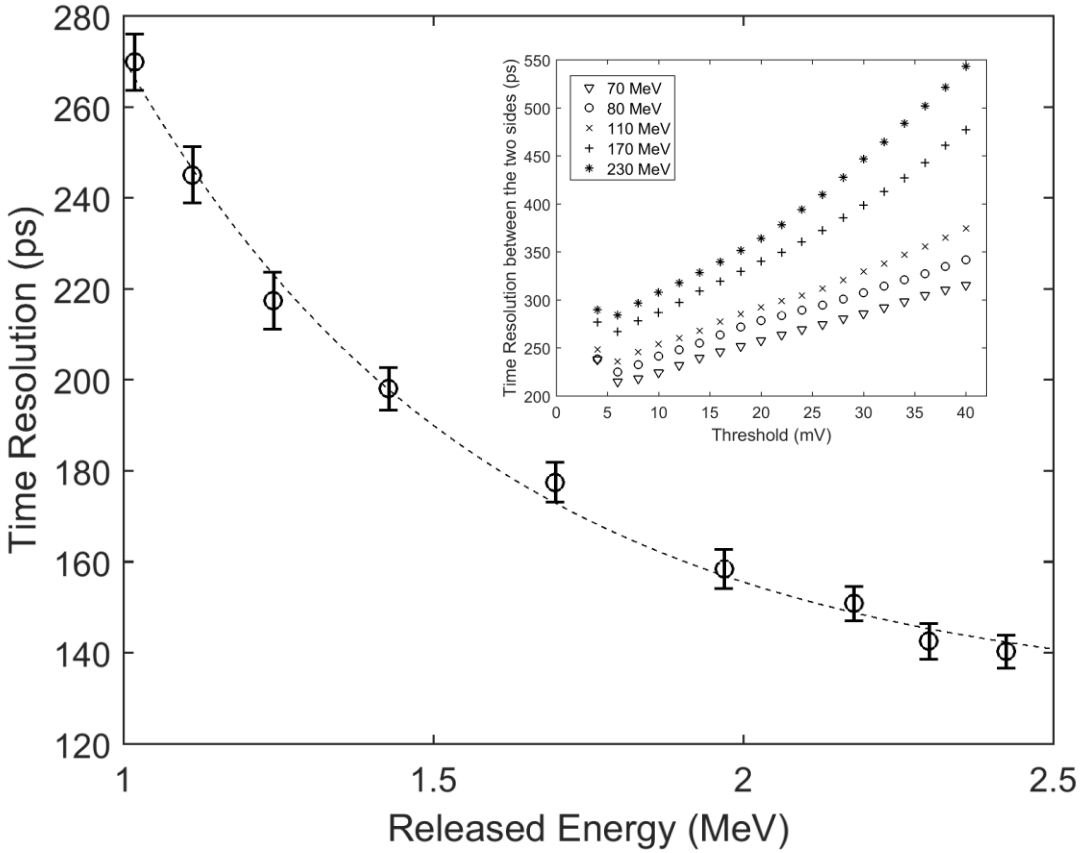




- The collected energy depends linearly on the released energy
- No saturation effects were observed

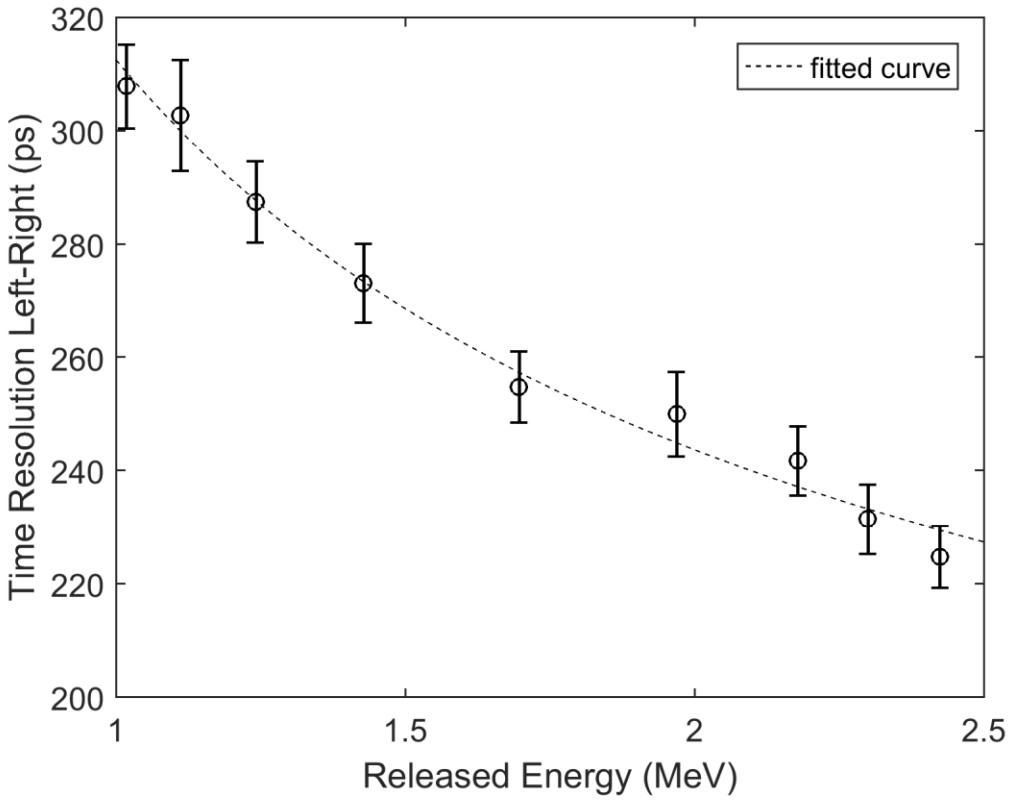
- Energy resolution improves with the released energy
- After subtraction of the Landau contribution we should observe the analytical dependence

Time Resolution



- Time resolution is due to a *constant* and a *statistical* contribution
- The contribution of the reference detector (thick plastic scint. Coupled to a PMT) has to be subtracted
- The best threshold for time evaluation was chosen (6 mV)

Time Resolution Left-vs-Right



- The Left-vs-Right resolution was fitted with a 1/sqrt(E) contribution and a constant contribution
- The constant contribution is about 145 ps

Summary

• The total collected energy depends on the interaction position, but it can be modeled analytically

•The energy response of the detector is linear, so the integral of the collected signal can be calibrated in terms of released energy (using the FLUKA simulation)

• The interaction position can be reconstructed with a resolution of about 2 cm, so events with multiple fragments inside the FOOT acceptance cone can be discriminated.

Next Steps

- 2 + 2 new bars arrived in Pisa (400 mm x 20 mm, 2 - 3 mm thick)
- Different kind of SiPMs are being tested (Hamamatsu, 25 µm and 50 µm, and AdvanSiD 40 µm), 6 x 6 mm^2 SiPMs were also purchased to investigate their time resolution in case that thicker bars would be adopted
- New SiPM board hosting 4 sensors are being developed (a configuration of a parallel of 2 series or a single series can be selected with jumpers)
- Radiation hardness tests will be conducted to investigate the change in the I-V curves that was seen in the previous tests
- Geant4 simulations of the optical transport are ongoing and will be tested using the new bars