
Muon Conversion with high-Z target at HIMB

Andreas Knecht
Paul Scherrer Institute

8. 4. 2021
HIMB Physics Case Workshop
Zoom

SINDRUM II experiment

- ▶ Measurement of muon conversion on gold
- ▶ Removal of pions from beam through degrader and subsequent transport solenoid
- ▶ Some residual background events from pions observed through timing (mostly from degrader)

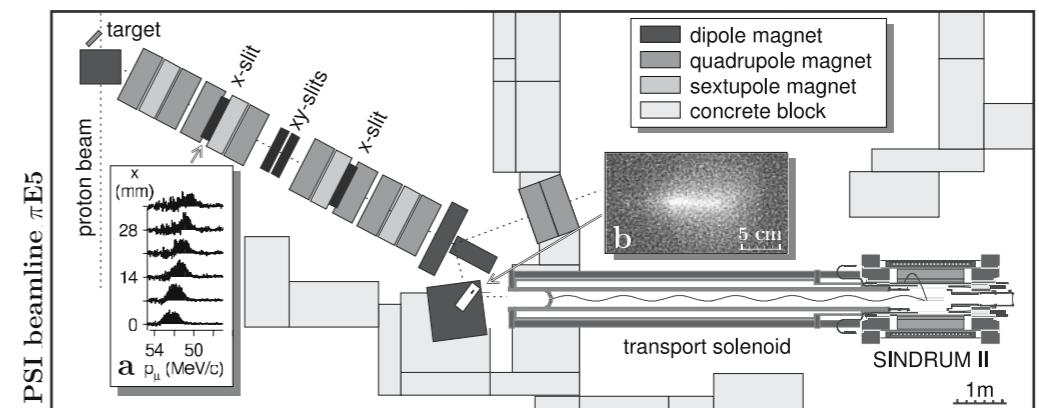


Fig. 2. Plan view of the experiment. The 1 MW 590 MeV proton beam extracted from the PSI ring cyclotron hits the 40 mm carbon production target (top left of the figure). The π E5 beam line transports secondary particles (π, μ, e) emitted in the backward direction to a degrader situated at the entrance of a transport solenoid connected axially to the SINDRUM II spectrometer. *Inset a*) shows the momentum dispersion measured at the position of the first slit system. The momentum was calculated from the flight time through the channel and the distributions show the increase when opening one side of the slit. *Inset b*) shows a cross section of the beam observed at the position of the beam focus

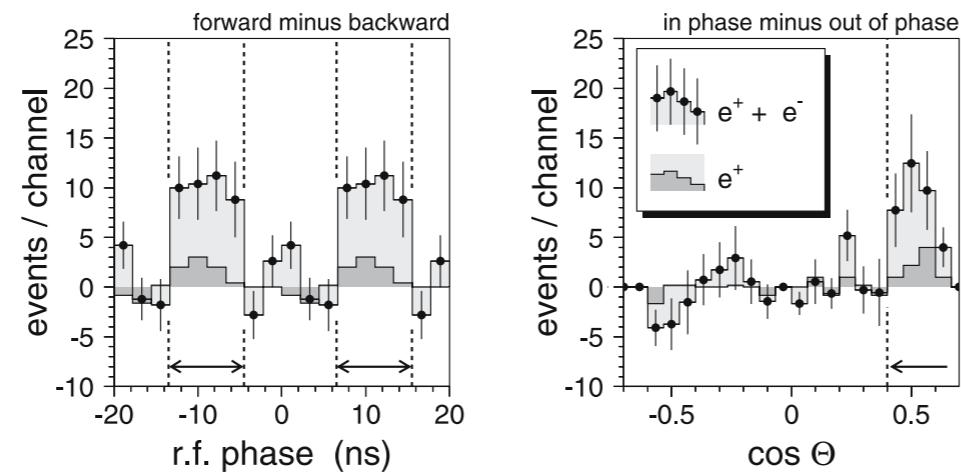


Fig. 10. Prompt beam induced background. Electron and positron events were selected with total momentum above 87 MeV/c but outside the main signal region 92.5–95.5 MeV/c. *Panel a*): spectrometer timing relative to the 50.6 MHz cyclotron rf signal. Time differences with respect to both the previous and the next rf bucket are incremented. Shown is the difference between the distributions with $\cos \theta > 0.4$ and $\cos \theta < -0.4$. *Panel b*): $\cos \theta$ distribution. Shown is the distribution corresponding to the phase enhancement by the pion induced events. The arrows indicate the region populated by pion induced events. See the text for a discussion of the nature of these events

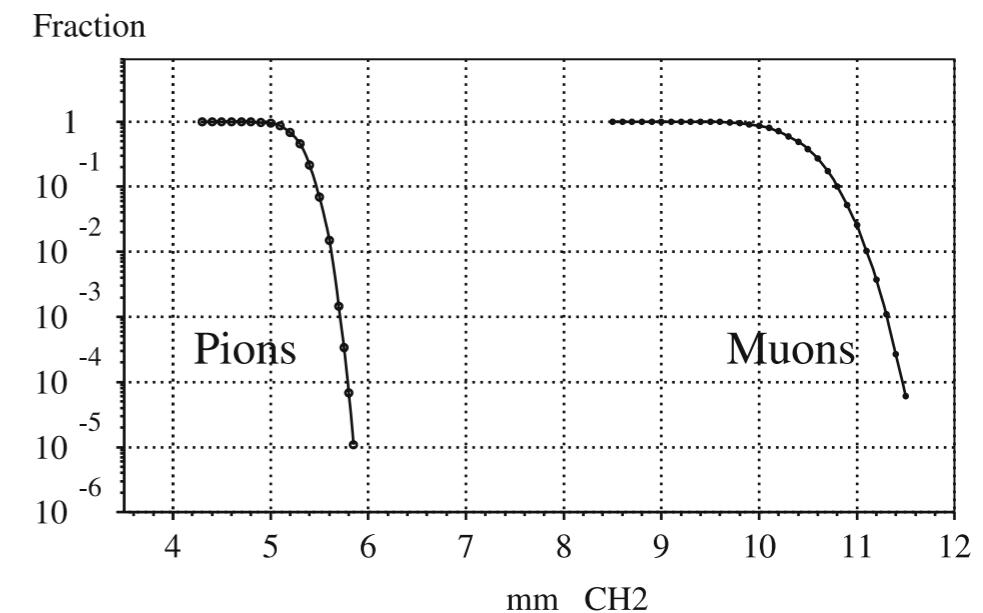


Fig. 1. Fraction of pions and muons with a momentum of 52 MeV/c that cross a CH_2 moderator as a function of the moderator thickness. GEANT [23] simulation

SINDRUM II experiment

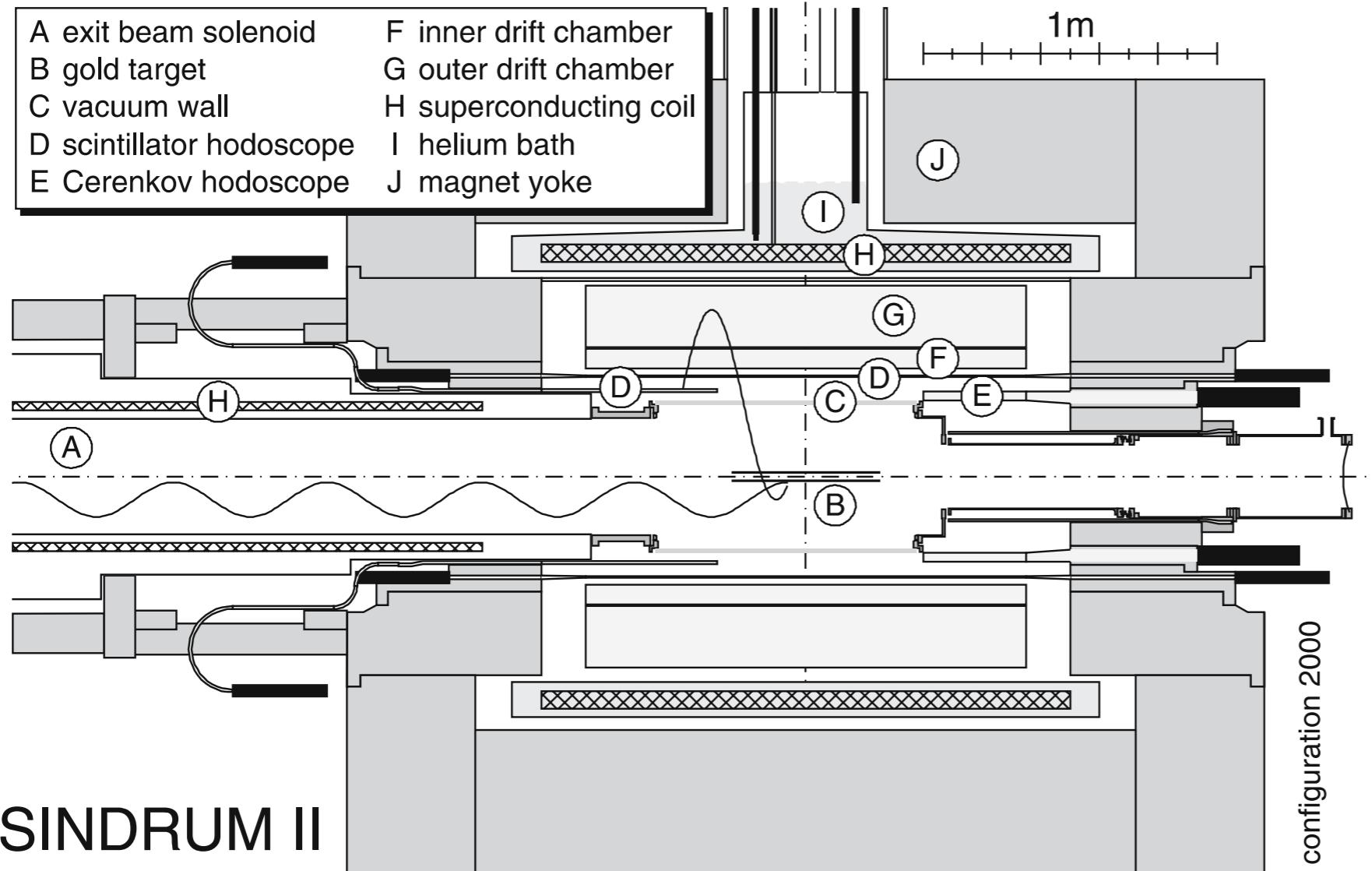
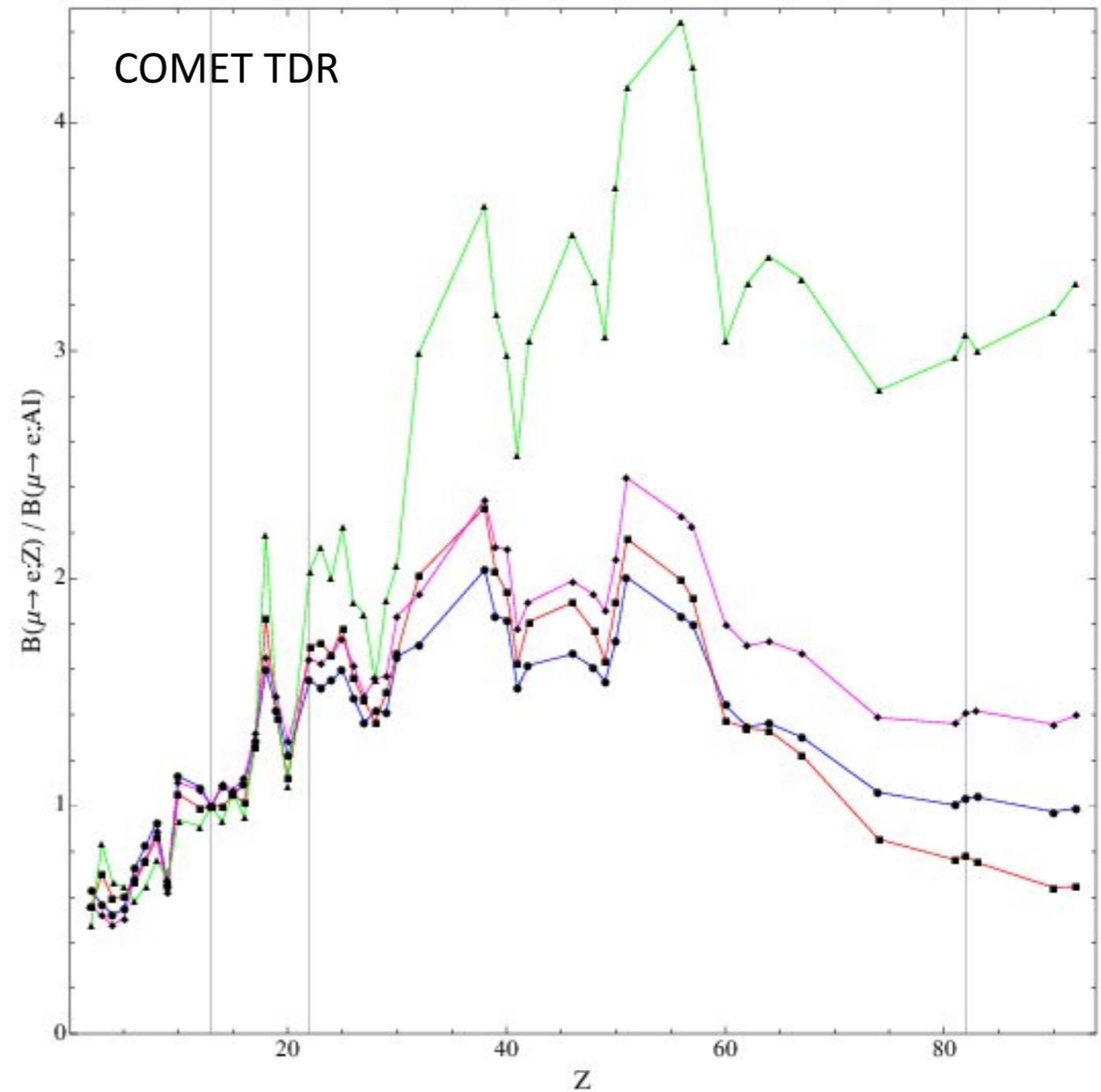


Fig. 3. The SINDRUM II spectrometer. Typical trajectories of a beam muon and a hypothetical conversion electron are indicated

Eur. Phys. J. C 47, 337–346 (2006)

Why high-Z?

- ▶ Scaling of branching ratio of muon conversion as a function of Z differs depending on underlying physics
-> allows to understand underlying physics in the case of a discovery
- ▶ High-Z atoms not ideal for pulsed beams due to short lifetimes



Muon conversion at HIMB

- ▶ Muon rates:
 - ▶ SINDRUM II: $\sim 2 \times 10^6 \mu^-/\text{s}$ at 52 MeV/c (not written explicitly, but estimated from beam power at that time and given muon stops on target)
 - ▶ HIMB: $\sim 1 \times 10^8 \mu^-/\text{s}$ at 40 MeV/c (highest momentum with good transport efficiency)
- ▶ Sensitivity:
 - ▶ SINDRUM II: $B_{\mu e}^{\text{Au}} < 7 \times 10^{-13}$ 90% C.L.
 - ▶ HIMB: Can increase the sensitivity by a factor 100 if backgrounds can be reduced accordingly

Muon conversion at HIMB

► Pion contamination:

- HIMB: Can also use degrader at 40 MeV/c (less efficient compared to 50 MeV/c, but due to lower momentum ~ 10 x less pions in the beam)
- Add bend in transport section after degrader to reduce backgrounds coming from moderator
- With better detector, active target, and the above background reduction, can probably keep pion backgrounds low enough to capitalise on higher muon rate

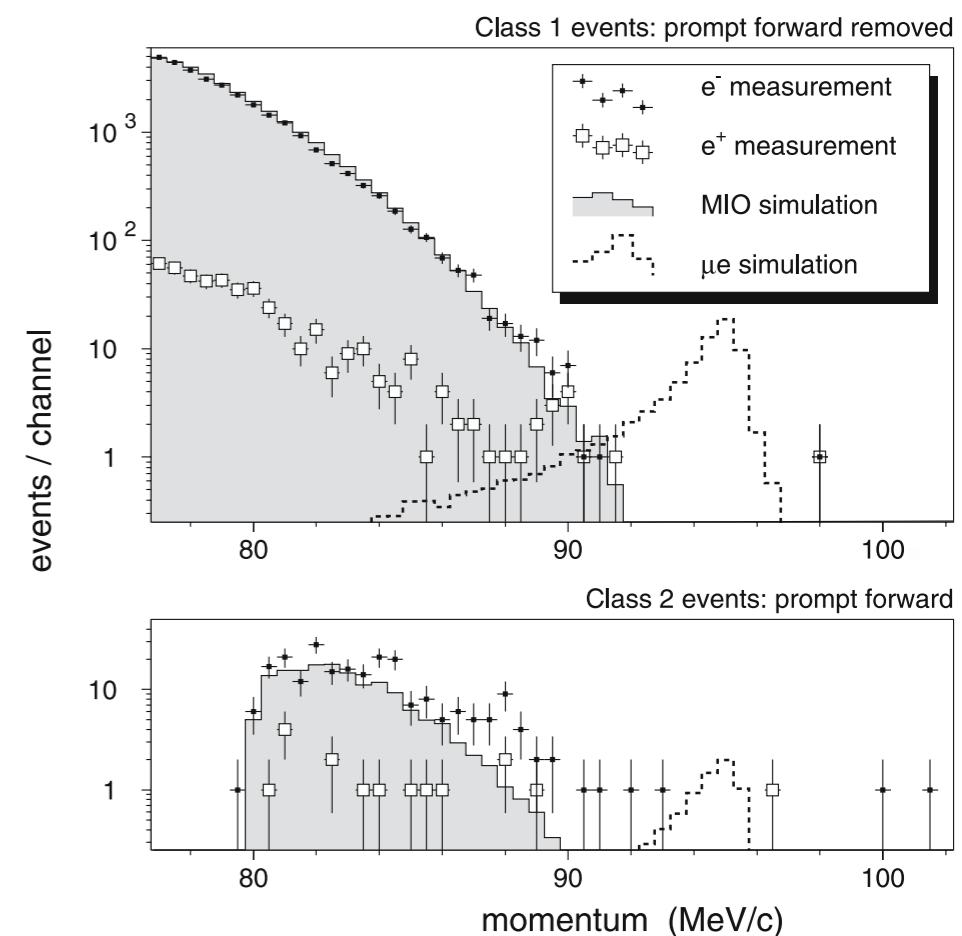
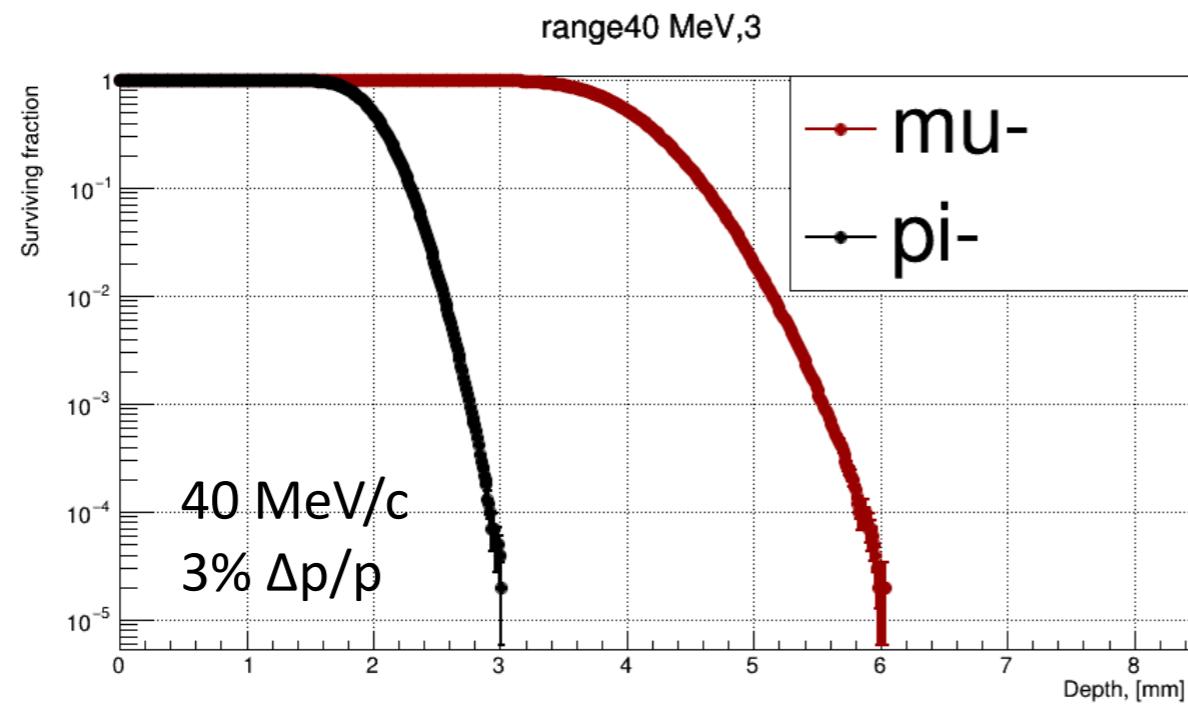


Fig. 11. Momentum distributions of electrons and positrons for the two event classes. Measured distributions are compared with the results of simulations of muon decay in orbit and $\mu - e$ conversion

Eur. Phys. J. C 47, 337–346 (2006)

Mu2e/COMET

- ▶ Mu2e and COMET will perform their measurements with expected muon rates of around $1\text{e}10 \mu/\text{s}$
- ▶ They will improve the sensitivity over SINDRUM II by a factor 10^4
- ▶ Changes in expected branching ratio as a function of Z are on the level of <4
- ▶ Conclusion:
 - ▶ It is probably not worthwhile to pursue a muon conversion experiment at HIMB, if Mu2e and COMET reach their targeted sensitivity
 - ▶ However, if a signal is observed by either Mu2e or COMET at a relatively high branching ratio such a measurement at PSI might become again attractive