Understanding the Cherenkov Signals at FLASH2

Nicoleta Baboi, MDI

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HELMHOLTZ

FLASH.
Free-Electron Laser FLASH

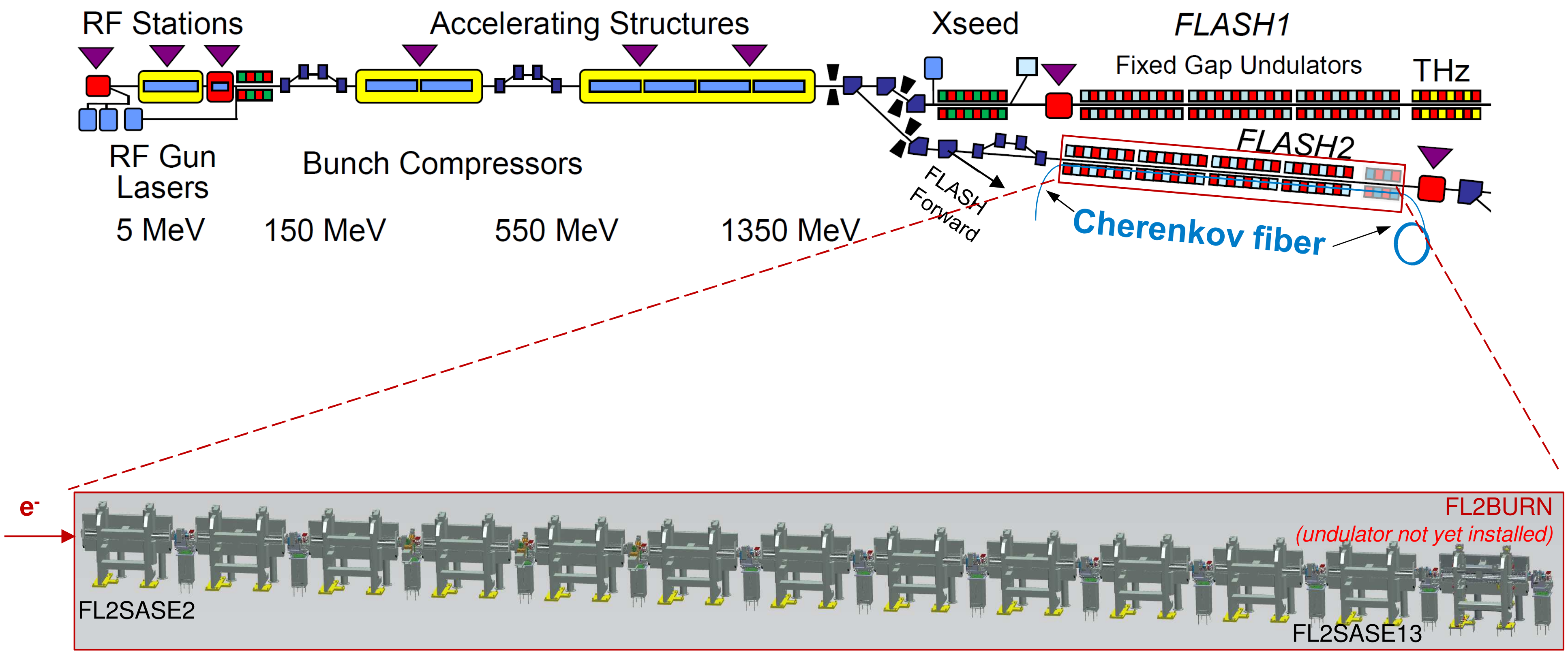
DESY.

Outline

- Cherenkov System at FLASH2
- Calibration of Signal Time into Loss Position
- Comparison to BLM and BPM data
- Understanding the Reflected Signal
- Conclusion?

Cherenkov-System in FLASH2

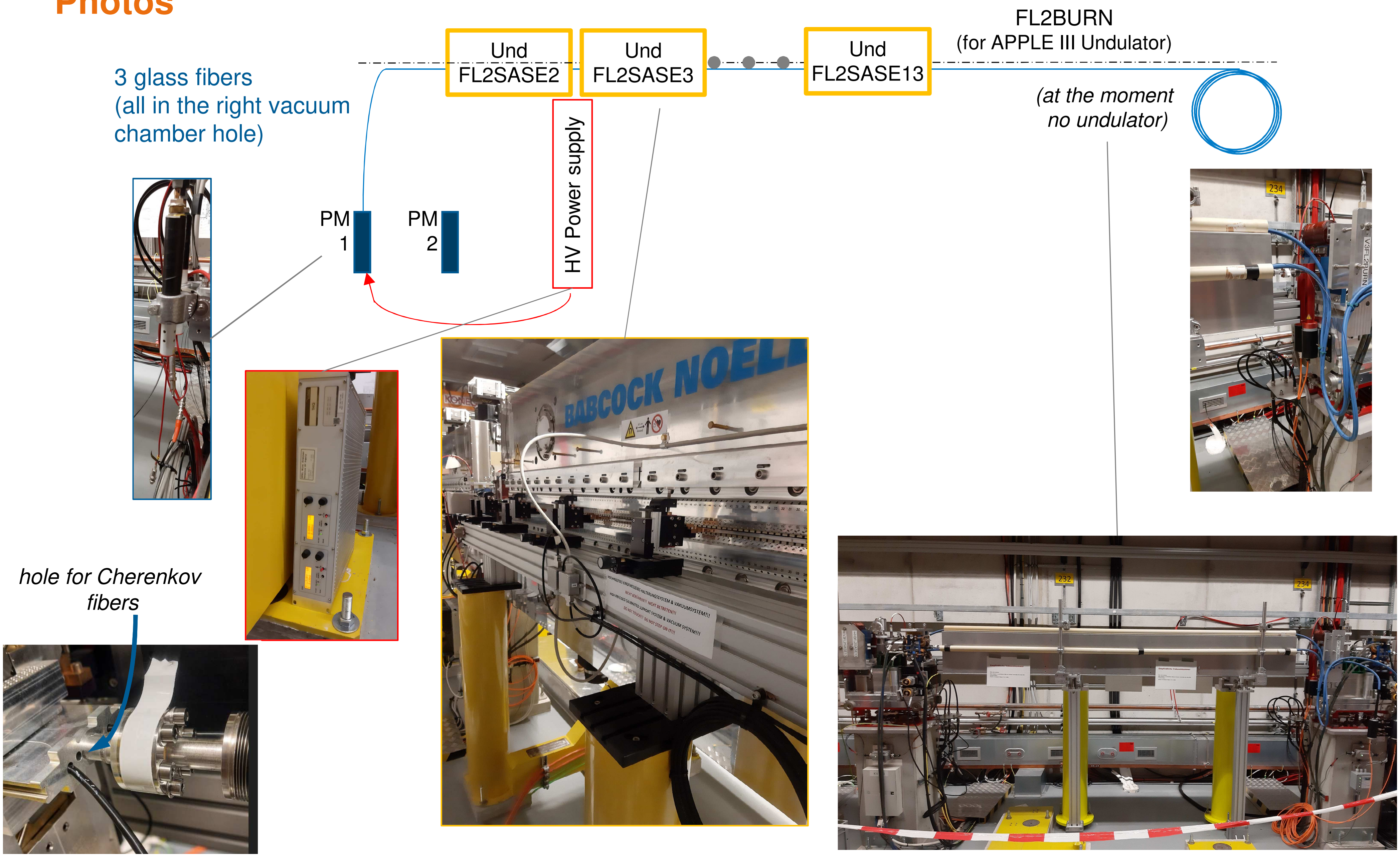
Overview



Each undulator section is 3.3m long

Cherenkov-System in FLASH2

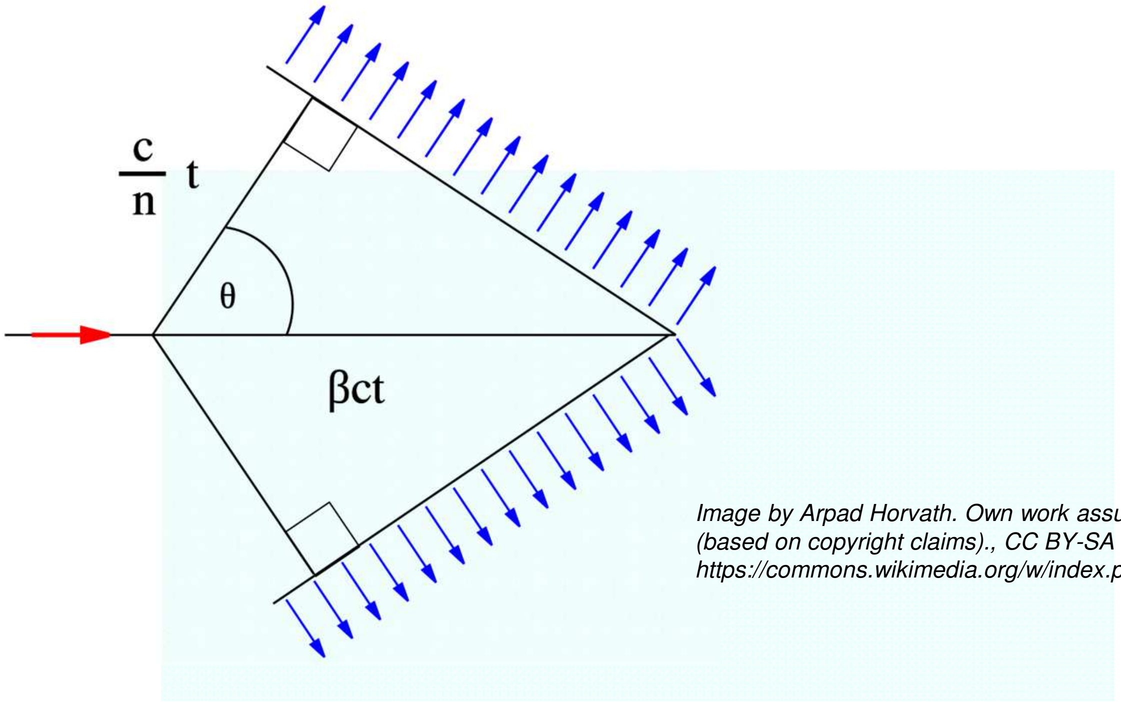
Photos



Cherenkov-System in FLASH2

Cherenkov Radiation very briefly

- Or Vavilov–Cherenkov radiation
  (or Tscherenkov)
- Generated when **an electron** (or another charged particle) **travels** in a medium **faster than light** in that medium



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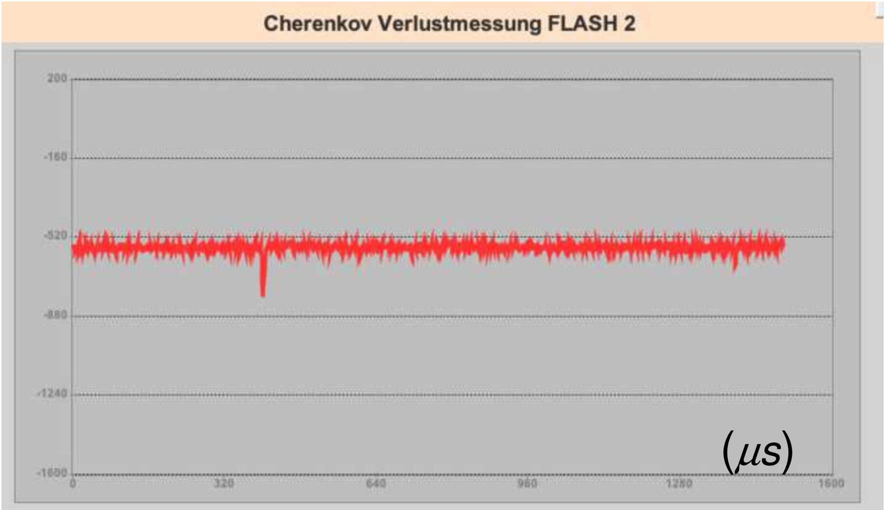
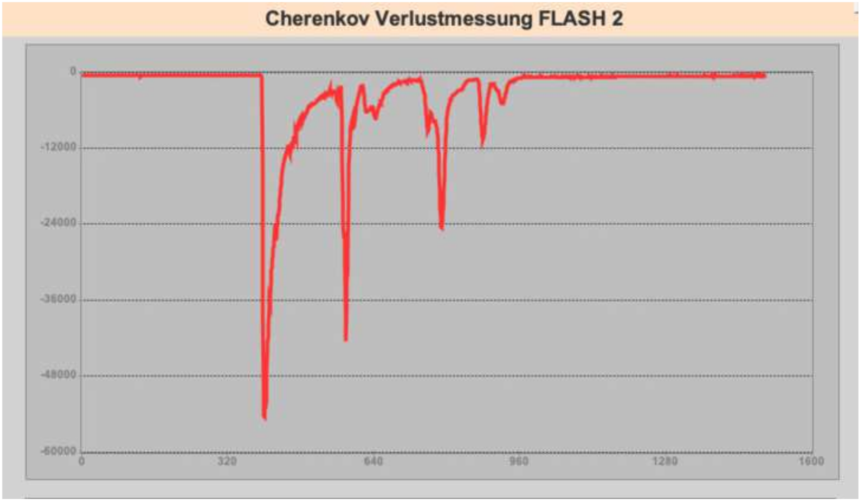
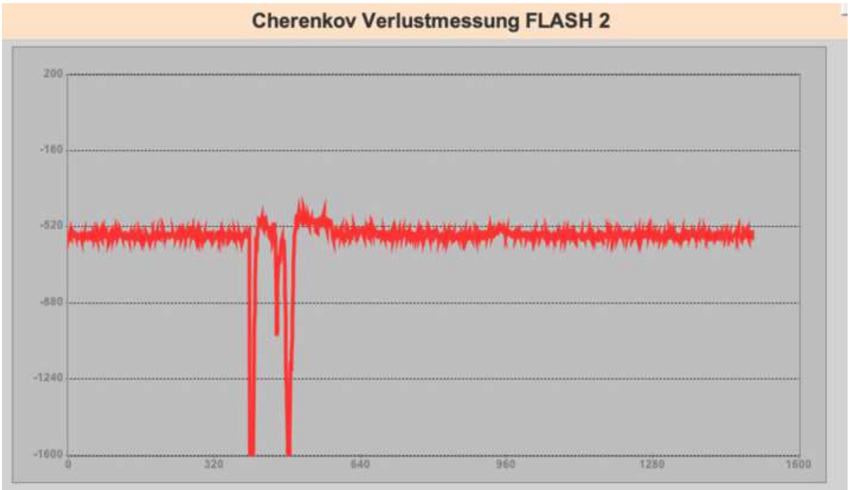
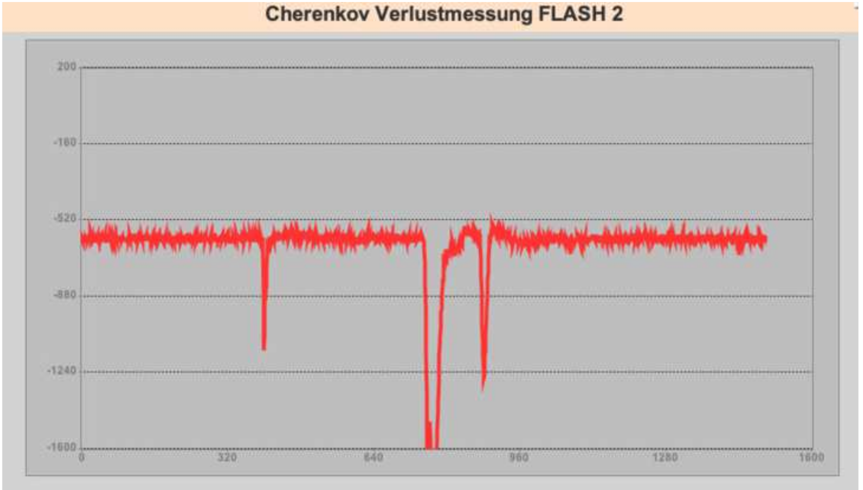
Calibration of Signal Time into Loss Position

Examples of Measured Signals



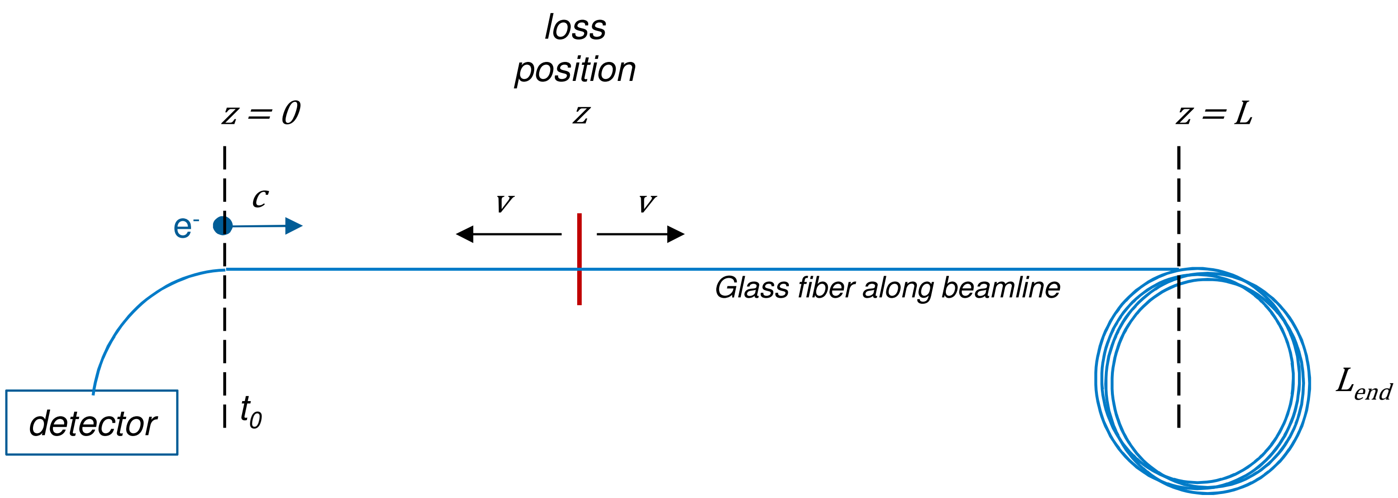






Calibration of Signal Time into Loss Position

Conversion Factor



- Timing of signal from loss at position z (from beginning of fiber in beamline)

$$t = \frac{z}{c} + \frac{z}{v} = z \cdot \left(\frac{1}{c} + \frac{1}{v}\right), \quad \text{wrt } t_0$$

  - t_0 = time when the bunch is at beginning of fiber
- From literature: $v = c/n \approx 2/3c \;\Rightarrow$ factor $1/c+1/v \sim= 8.3$ ns/m
- $\Rightarrow$ $\quad \mathbf{z_{loss}[m] = \frac{t[ns]}{8.3[ns/m]}}$
- The beamline from FL2SASE2 till incl. FL2BURN: ca. 43.25m $\Leftrightarrow$ ~ 357ns

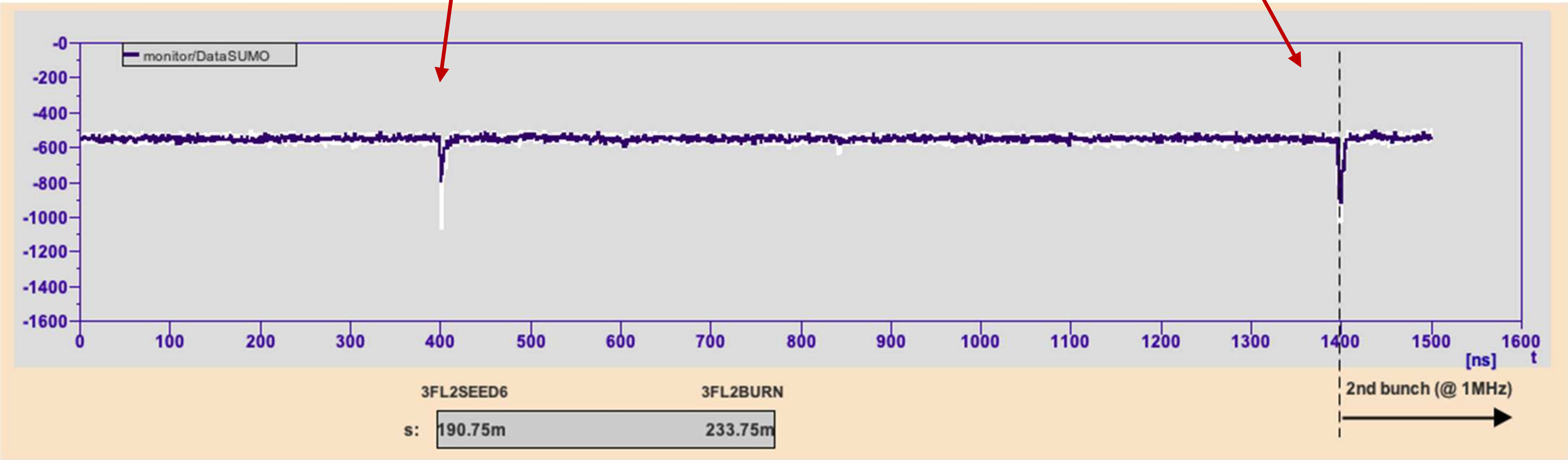
Calibration of Signal Time into Loss Position

Losses at Beginning of Beamline Section

- $z_{loss}[m] = \frac{t[ns]}{8.3[ns/m]}$

Earliest signal
(when steering the beam before the undulator section)

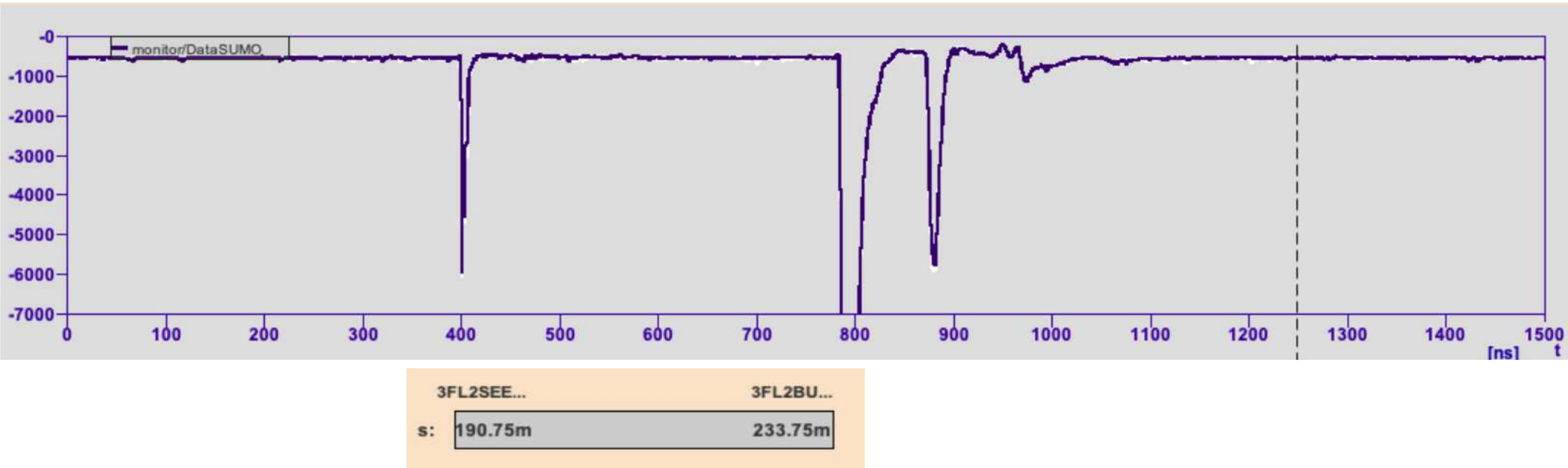
2nd bunch



Calibration of Signal Time into Loss Position

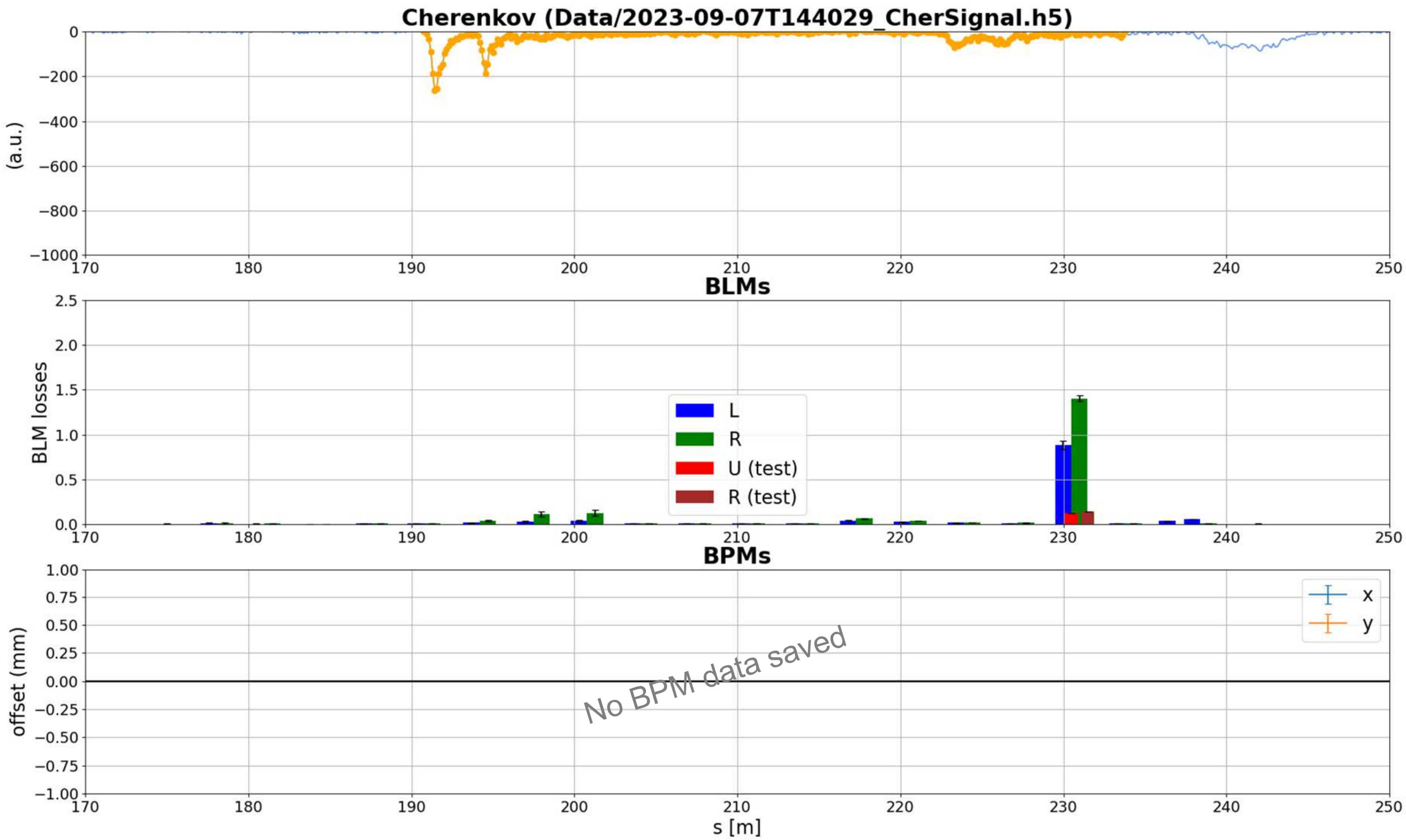
Losses at End of Beamline Section

Loss caused by steerer before FL2BURN section



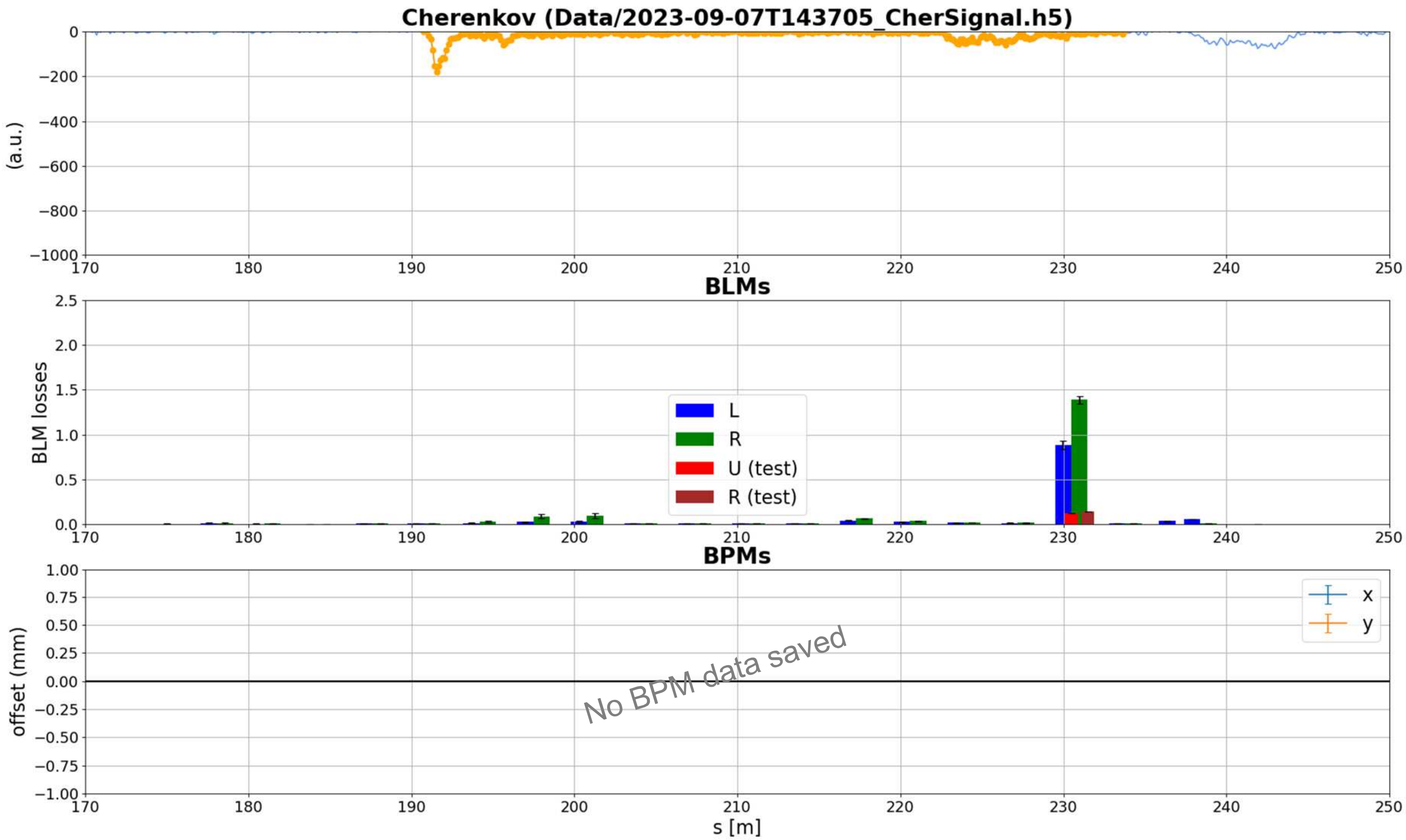
Comparison to BLM and BPM data

Example 1



Comparison to BLM and BPM data

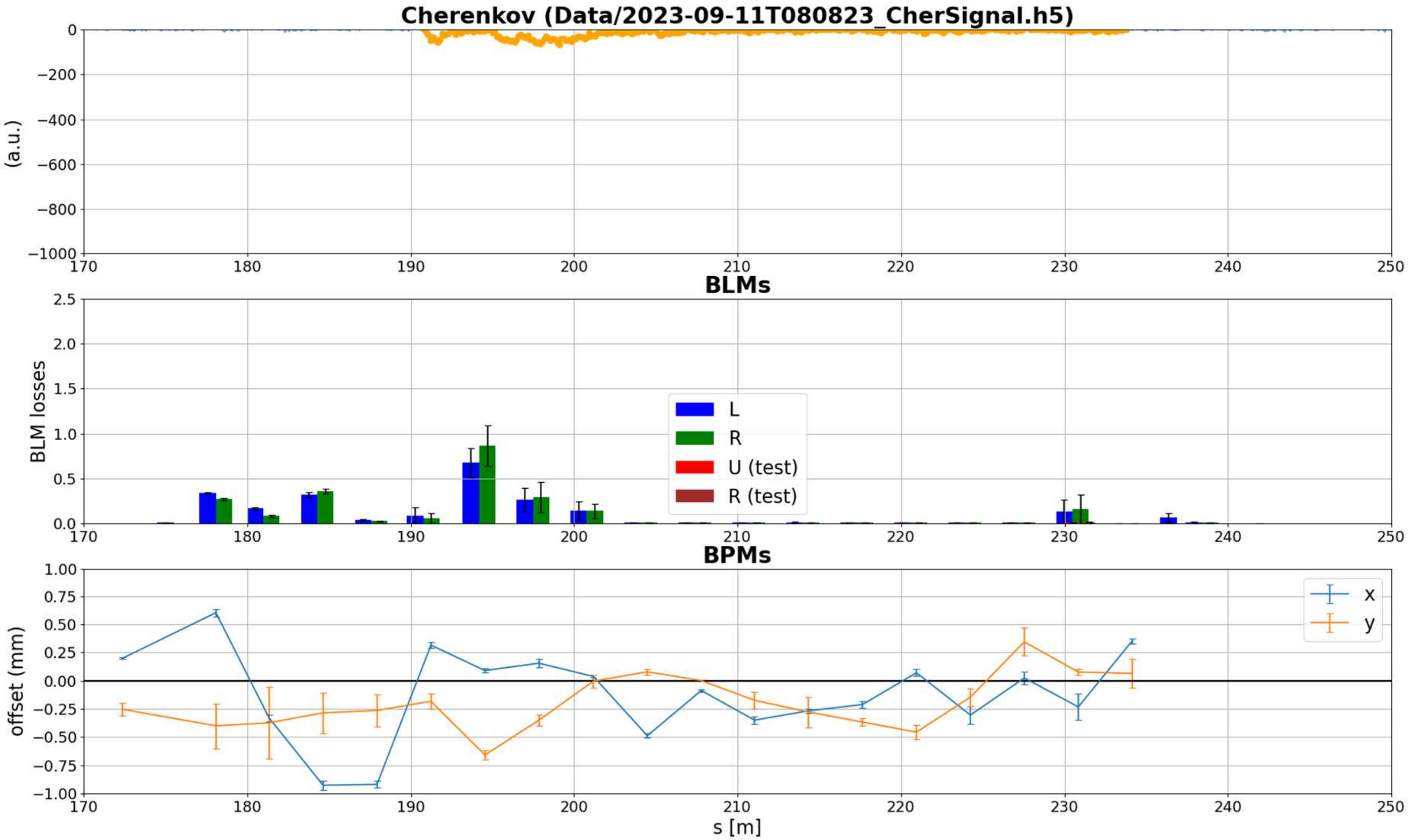
Example 2



Almost same as previous; slight correlation between Cherenkov and BLM signals

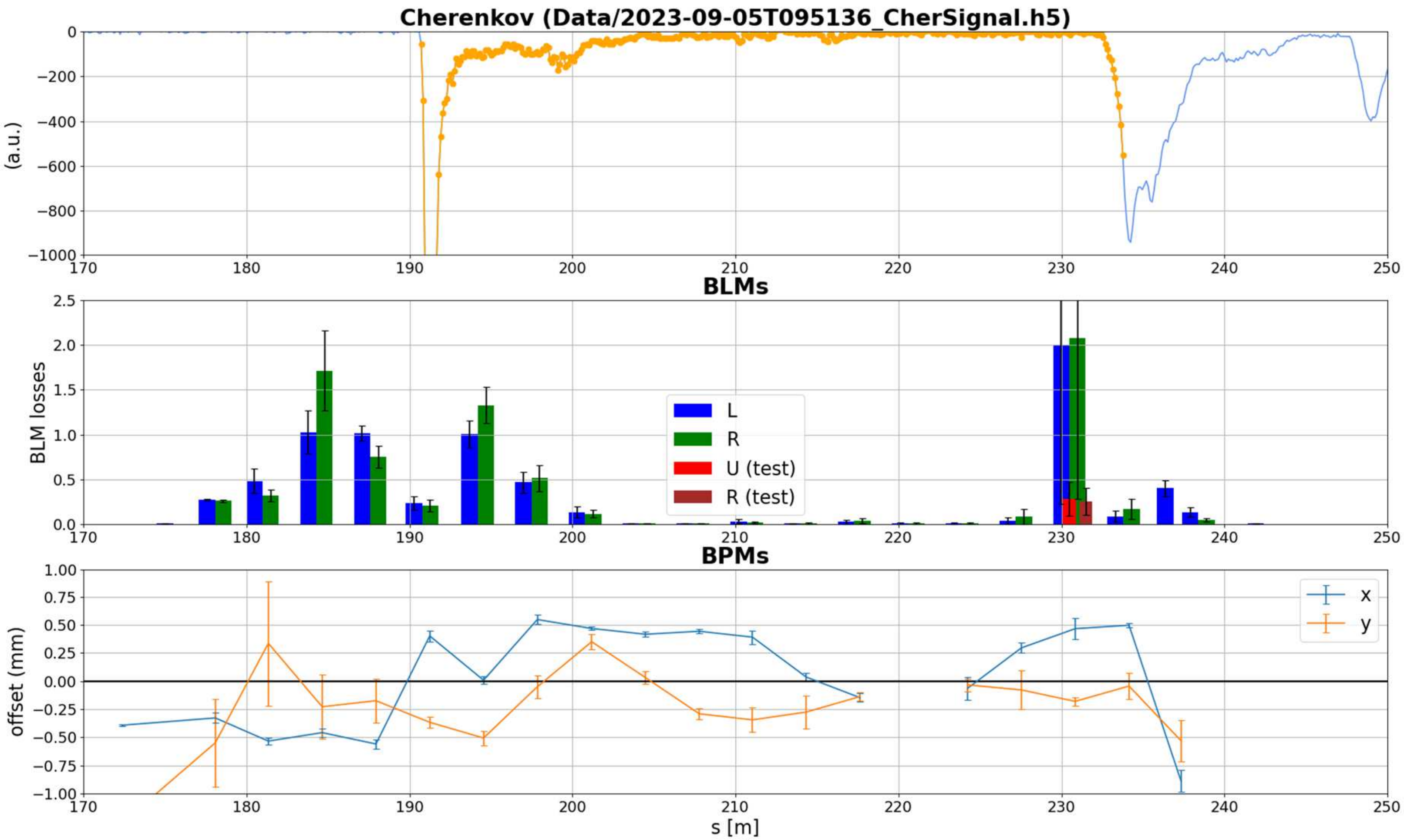
Comparison to BLM and BPM data

Example 3



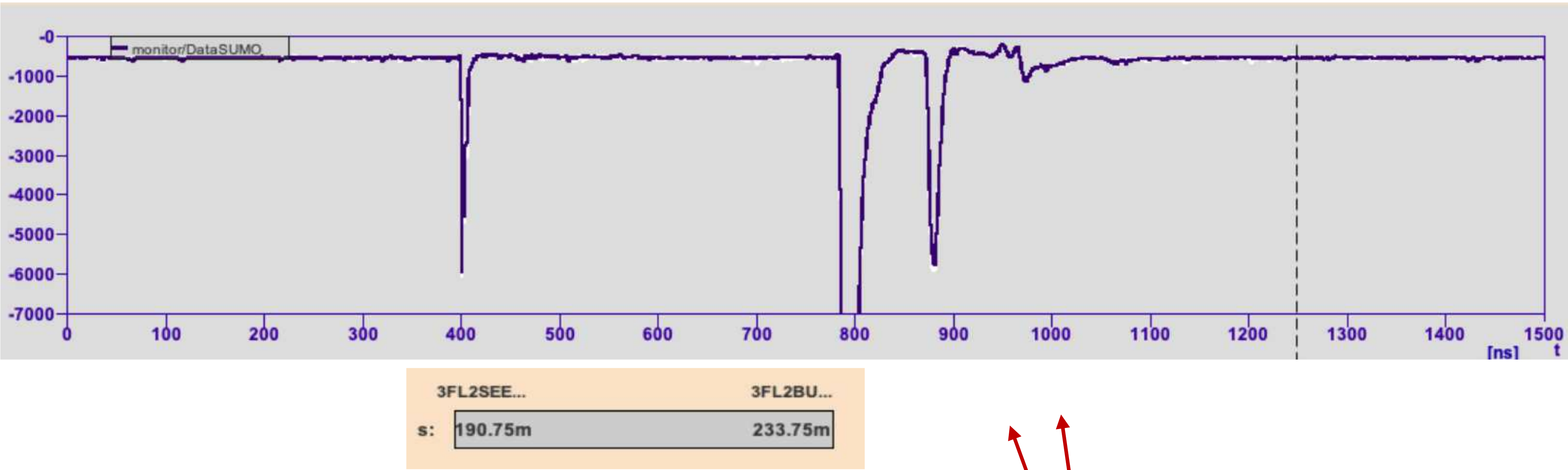
Comparison to BLM and BPM data

Example 4



Understanding the Reflected Signal

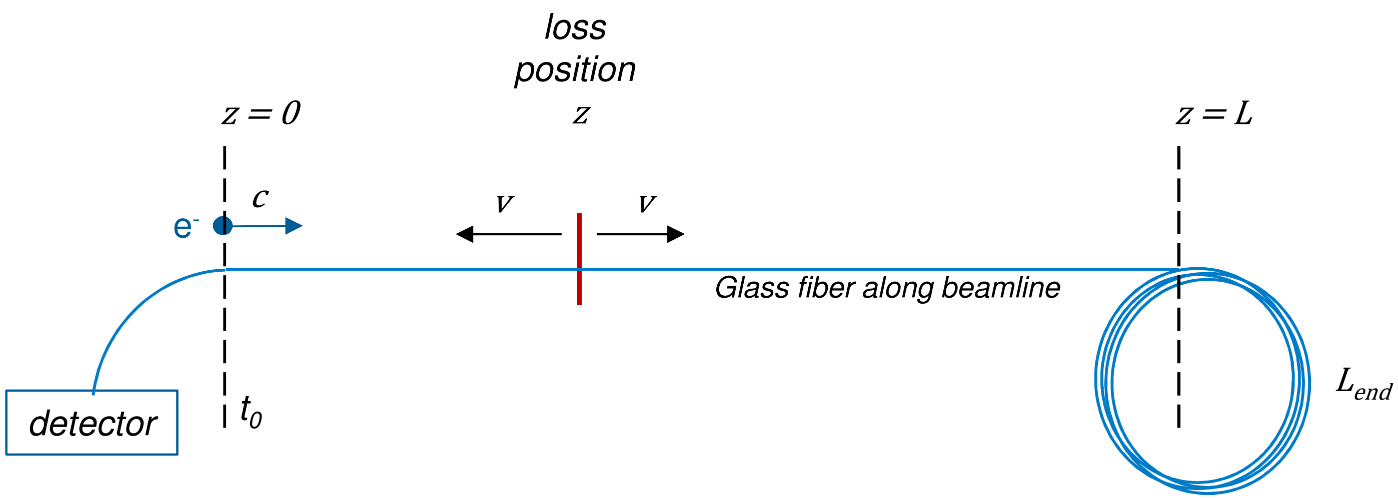
Loss caused by steerer before FL2BURN section



Are these reflexions?

Understanding the Reflected Signal

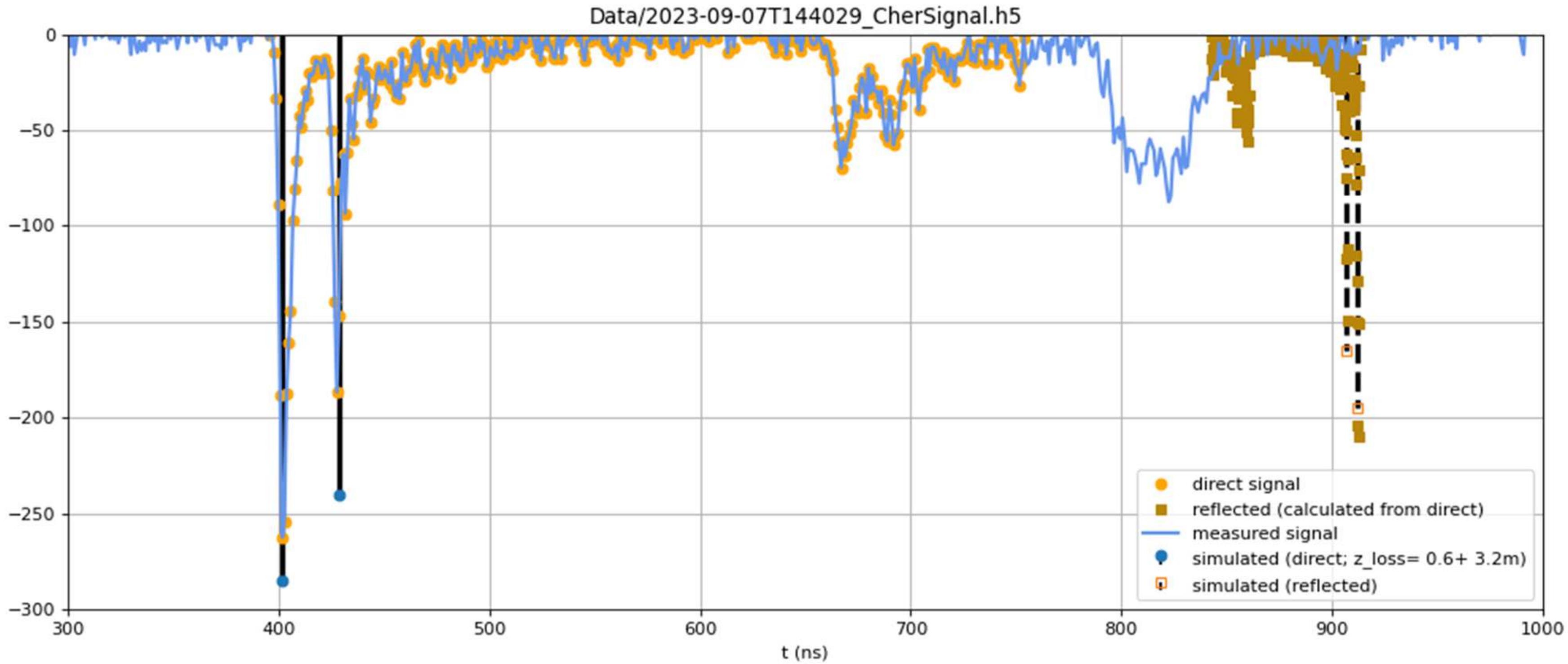
Calculation of reflected signal time



- Time of reflected signal
  - $t_{refl} = z \cdot \left(\frac{1}{c} - \frac{1}{v}\right) + 2 \cdot \frac{L+L_{end}}{v} + t_0$
- Difference to direct signal
  - $t_{refl} - t = \frac{2 \cdot (L+L_{end}) - z}{v}$

Understanding the Reflected Signal

Measured versus Calculated: Losses at the beginning

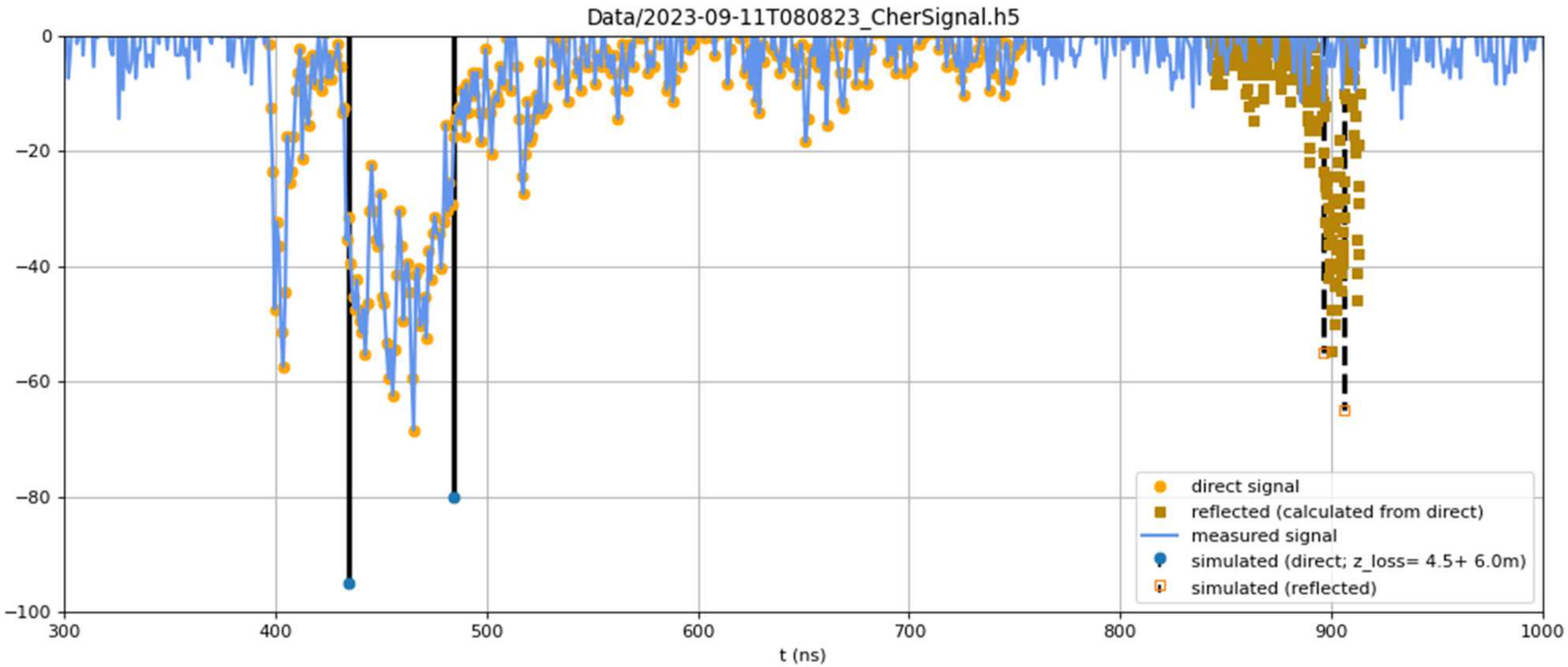


(example 1)

- There seems to be no reflection for losses at the beginning of section
- May be fully attenuated?

Understanding the Reflected Signal

Measured versus Calculated: Losses at the beginning (2)

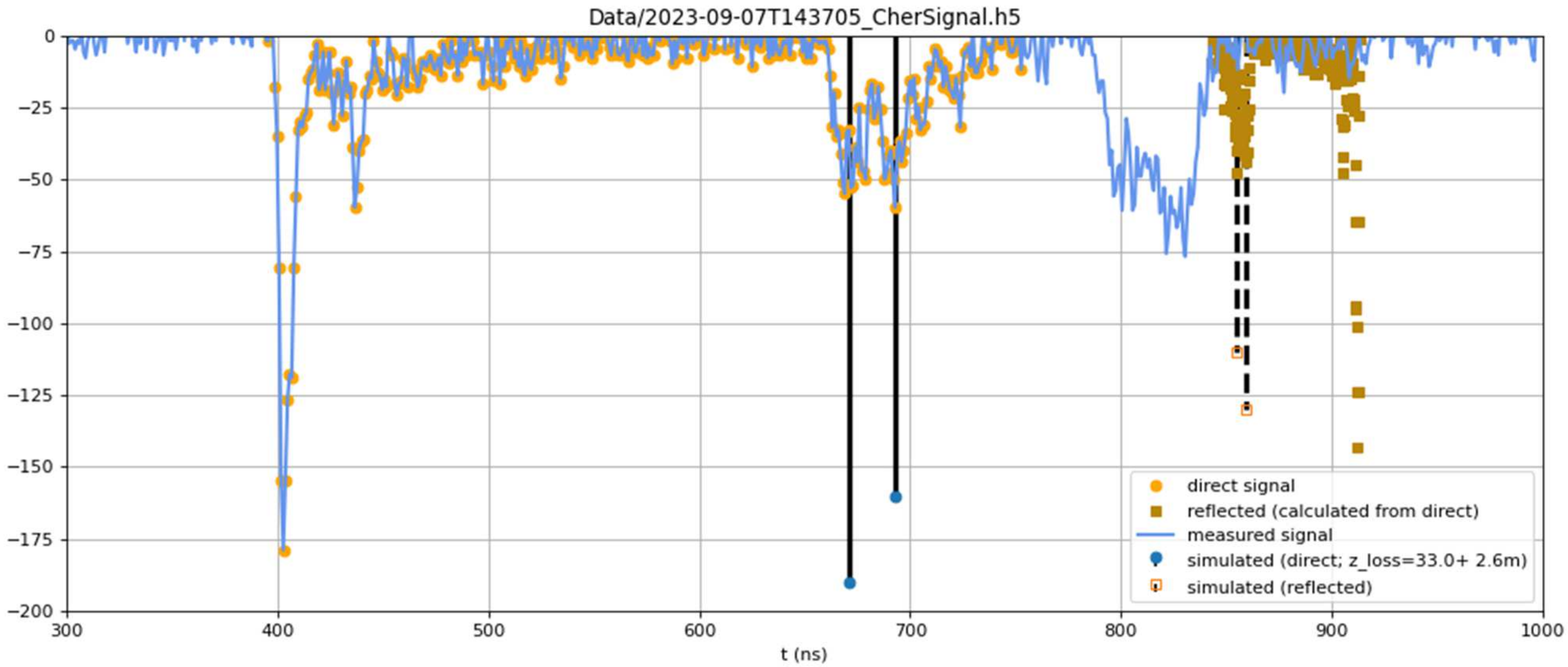


(example 3)

- There seems to be no reflection for losses at the beginning of section

Understanding the Reflected Signal

Measured versus Calculated: Losses towards the end

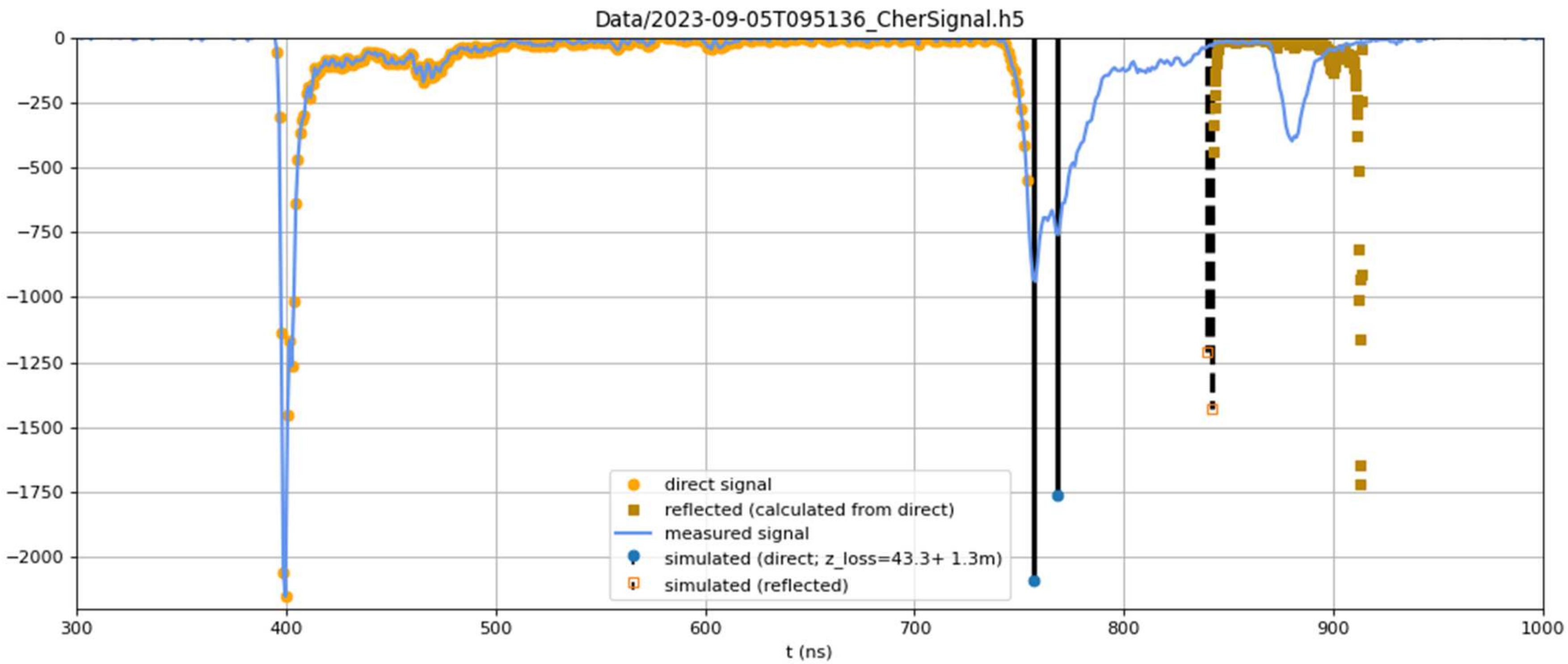


(example 2)

- Reflection seems to be earlier than expected
- The signal looks much wider than expected, and the amplitude is higher than direct signal
  - If this is not a reflection, what is it?

Understanding the Reflected Signal

Measured versus Calculated: Losses towards the end (2)



(example 4)

- Reflection seems to be later than expected
- Also, the signal looks much wider than expected,
  - If this is not a reflection, what is it?

Understanding the Reflected Signal

Question Marks

- Reflection does not fit expectations!
- What is wrong?

- Calculation of reflection (Reminder)
  - Time of reflected signal: $t_{refl} = z \cdot \left(\frac{1}{c} - \frac{1}{v}\right) + 2 \cdot \frac{L+L_{end}}{v} + t_0$
  - Difference to direct signal: $t_{refl} - t = \frac{2 \cdot (L+L_{end}) - z}{v}$

- The reflection depends only on the
  - speed of light in the fiber *v*
  - the fiber length *L*
  - the additional fiber length L_{end}
  - and the loss position *z*

Understanding the Reflected Signal

Width of Reflected vs. Width of Direct Signal

- Assume two losses at z_1 and z_2
- $t_{1,2} = z_{1,2} \cdot \left(\frac{1}{c} + \frac{1}{v}\right) + t_0 \quad \Longrightarrow \quad \Delta t = \Delta z \cdot \left(\frac{1}{c} + \frac{1}{v}\right)$
- $t_{refl,1,2} = z_{1,2} \cdot \left(\frac{1}{c} - \frac{1}{v}\right) + 2 \cdot \frac{L+L_{end}}{v} + t_0 \Rightarrow \Delta t_{refl} = \Delta z \cdot \left(\frac{1}{c} - \frac{1}{v}\right)$
- $\Rightarrow \quad \frac{\Delta t_{refl}}{\Delta t} = \frac{\frac{1}{c} - \frac{1}{v}}{\frac{1}{c} + \frac{1}{v}} = \frac{\frac{v}{c} - 1}{\frac{v}{c} + 1} \cong \mathbf{-0.2} \qquad (v/c \cong 2/3)$
- $\Rightarrow$ The ratio of the reflection width to the direct signal width depends only on the light velocity in the fiber!
- For a ratio of 0.5, one would need a velocity of

Understanding the Reflected Signal

Speed of Light in the Fiber

- $v = c/n$
  - $n \approx 1.5 \Rightarrow v \approx 0.67\,c$

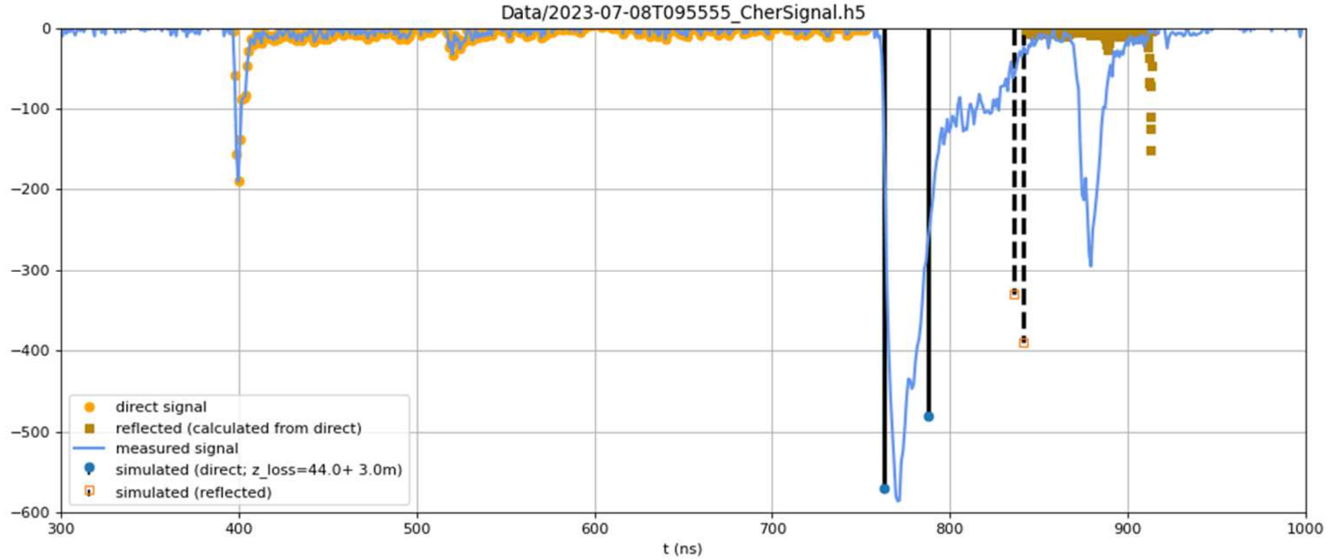
- Does the light travel straight?
  Is there a slow down by reflections at the fiber walls?

- Estimated the effective light speed in the fiber for the path of a ray at the critical angle of ca. 82deg
  $\Rightarrow v_{eff} = 0.99v$ (with $v \approx 2/3c$ = light speed in the fiber)

- This does not explain the measured signals

Understanding the Reflected Signal

Calculate z_{loss} from Position of Direct and Reflected Signals



- $t = z \cdot \left(\frac{1}{c} + \frac{1}{v}\right) + t_0$ and $t_{refl} = z \cdot \left(\frac{1}{c} - \frac{1}{v}\right) + 2 \cdot \frac{L+L_{end}}{v} + t_0$
  - $t \sim= 770ns$
  - $t_{refl} = 879ns$
- => z = 44.9m
  and L_fiber = 41m (= L+L_end)

- **It cannot be that L+L_end < z**

Conclusion

?

- Any ideas?