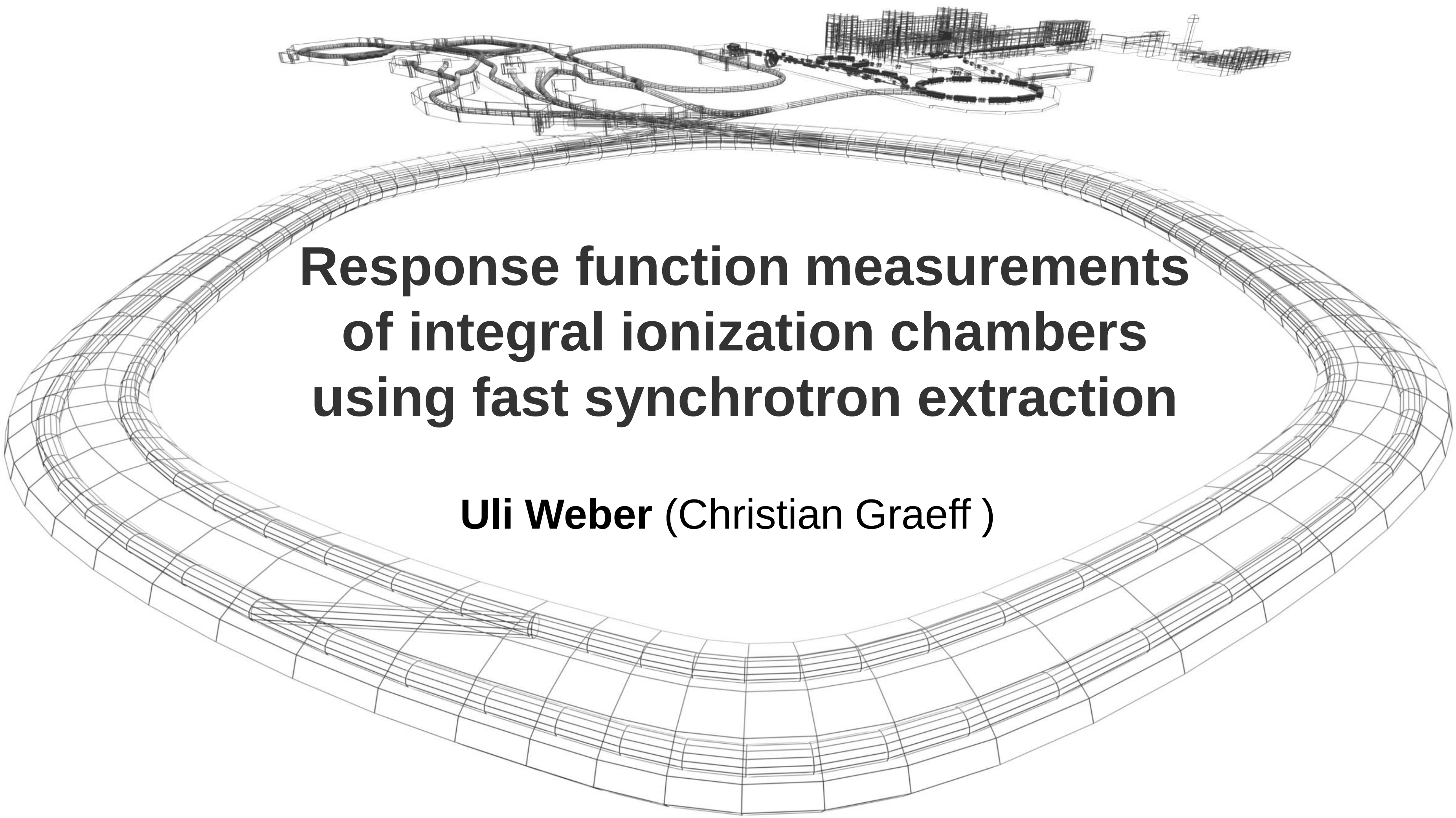
Response function measurements of integral ionization chambers using fast synchrotron extraction



Uli Weber (Christian Graeff)

New Scanning System @ GSI

- GSI Biophysics plans upgrade of Cave M scanning system
- Scanning / delivery speed shall be increased
- Main research item: 4D-delivery often with more, smaller spots (e.g. rescanning)
- Facility will enable research at the scanning system unrestricted by Medical Product regulations
- Cooperation with CNAO for fast control system

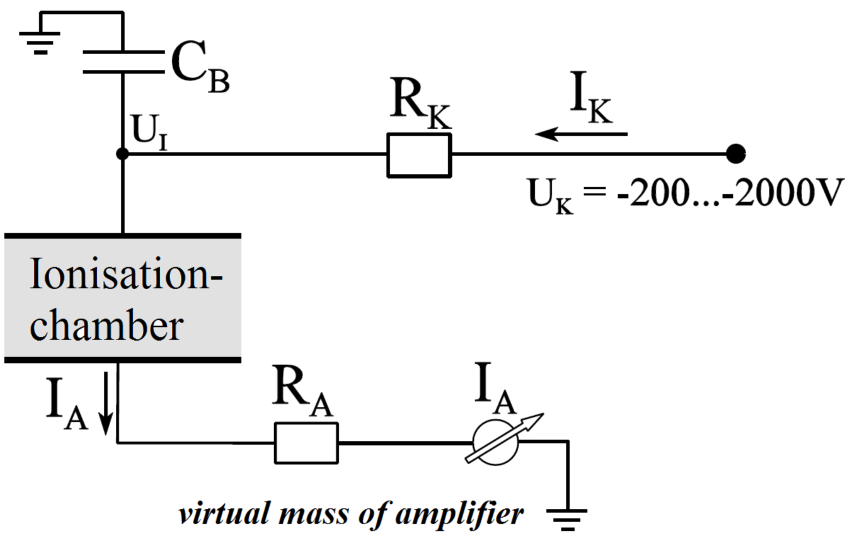
New Scanning System @ GSI

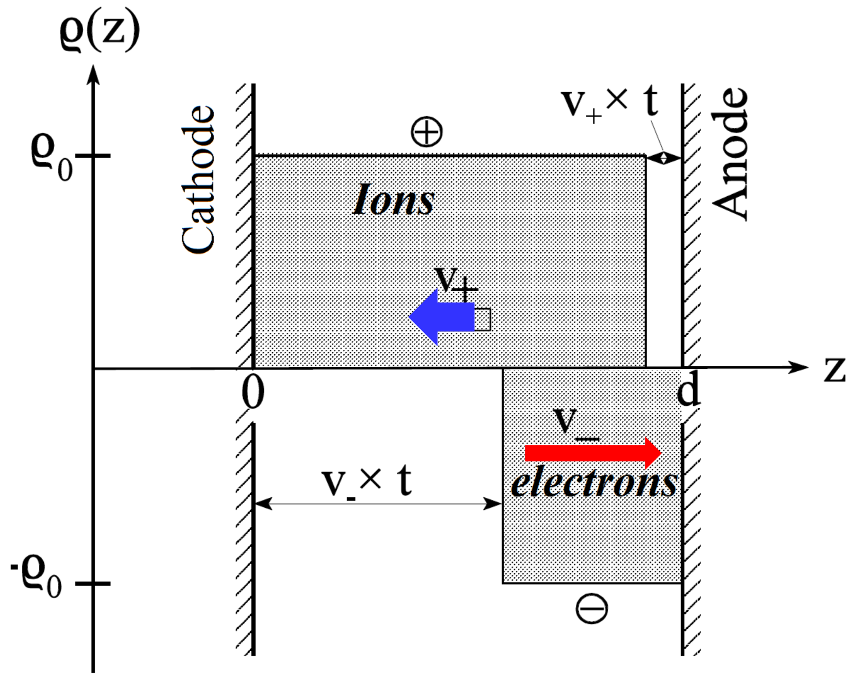
Beam monitoring is the predominant bottle neck for faster scanning

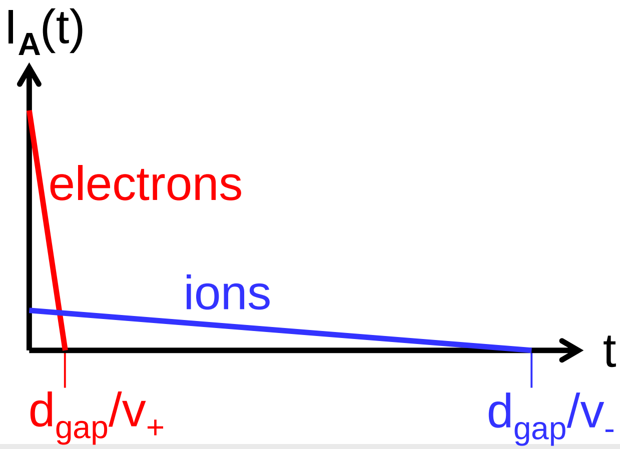
- Beam intensity detectors (Parallel plate ionization chambers)
- Position sensitive detectors (MWPC / strip chambers)

Main reason is the signal delay caused by slowly drifting positive ions, that give ca. 50% of the signal

Delay by drift time   (response for a short beam pulse)

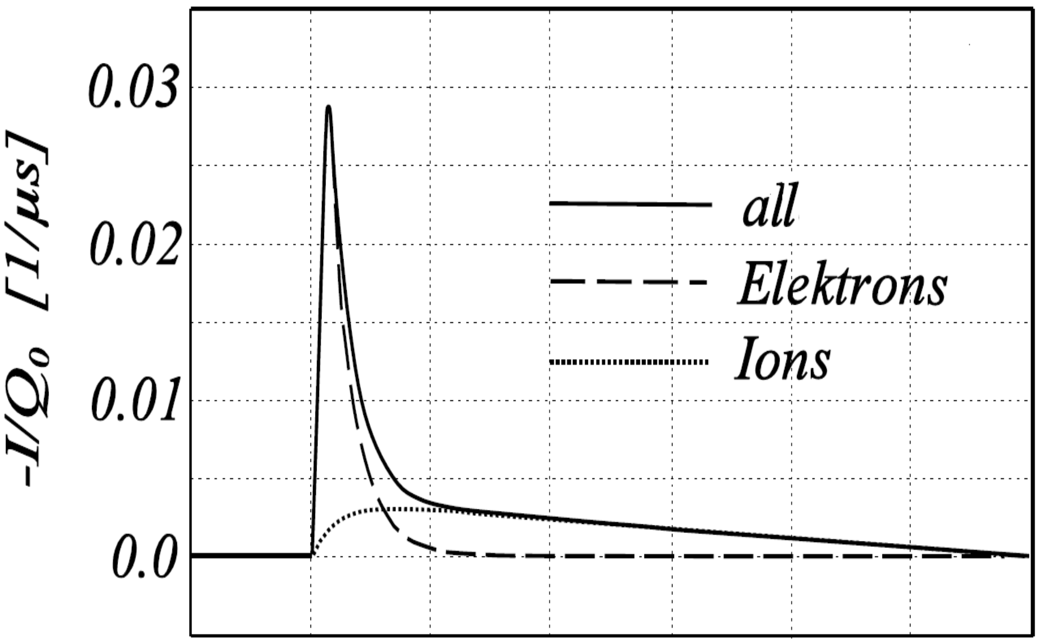




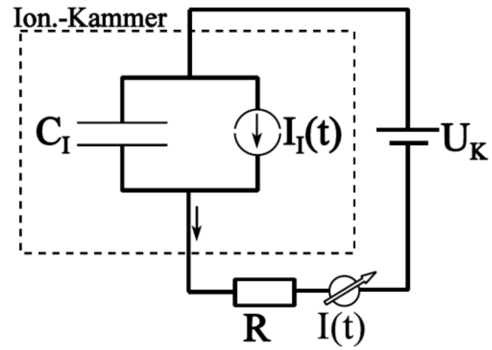


Delay by drift time (response for a short beam pulse)

Theoretical time response



RC=10µs, d=5mm, U_K=-500V, Gas=Ar,
⇒v_+=1.7cm/ms, v_-=600cm/ms.



$$I(t) = -\frac{Q_0}{d^2}\left[H_+(t)\,v_+(d-v_+t) + H_-(t)\,v_-(d-v_-t)\right] - \frac{Q_0}{d^2}\left[\left(G_+(t)v_+^2 + G_-(t)v_-^2\right)RC_I\right] + \frac{Q_0}{d^2}\left[\exp(-t/RC_I)\left(v_+(d+v_+RC_I) + v_-(d+v_-RC_I)\right)\right]$$

$$G_+(t) = \begin{cases} 1 & : \quad t \le \frac{d}{v_+} \\ \exp\left(-\frac{t-d/v_+}{RC_I}\right) & : \quad t > \frac{d}{v_+} \end{cases}$$

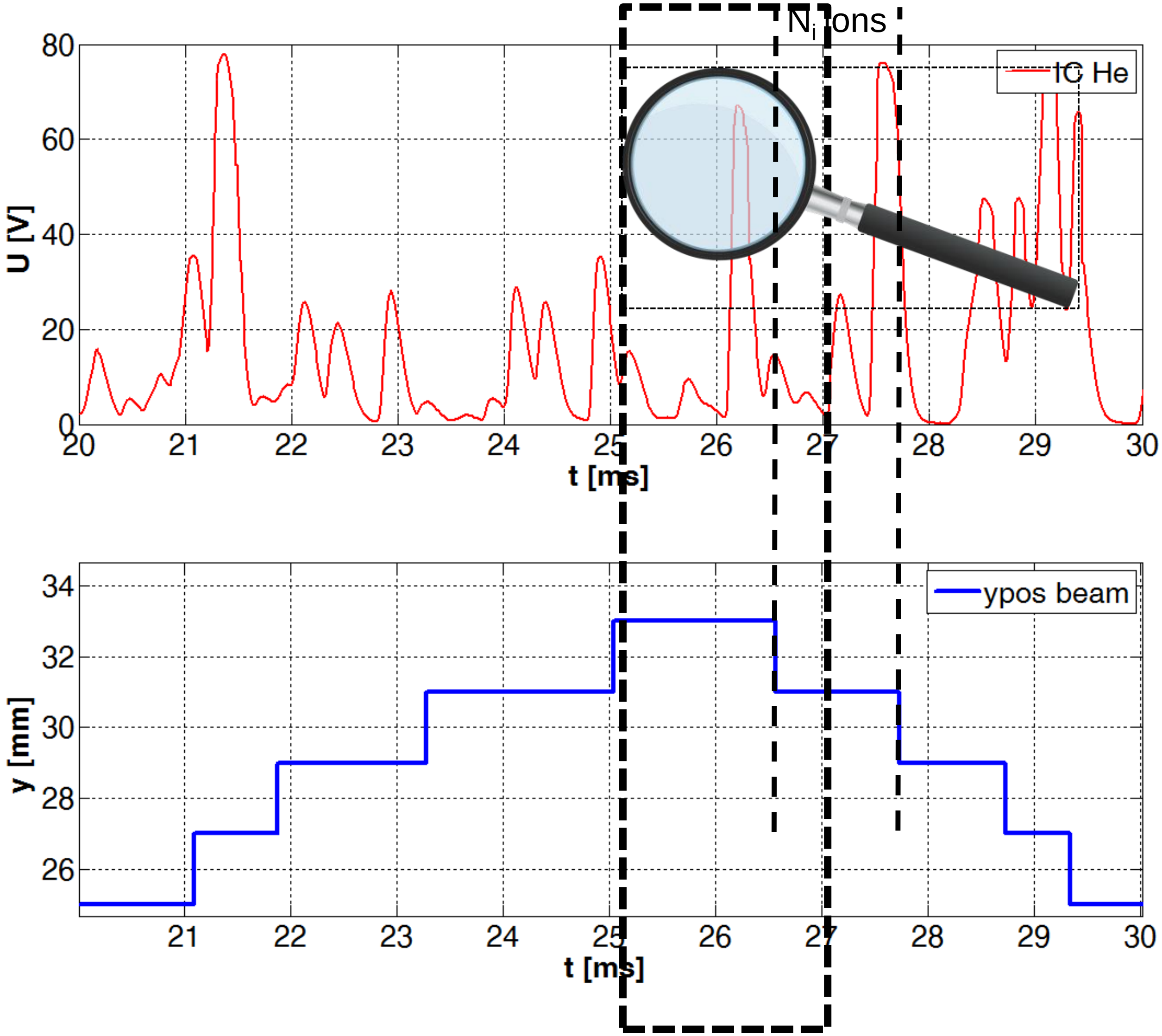
$G_-(t)$ *analog*

$$H_+(t) = \begin{cases} 1: & t \le \frac{d}{v_+} \\ 0: & t > \frac{d}{v_+} \end{cases}$$

$H_-(t)$ *analog*

Intensity controlled scanning

^{12}C, 300 MeV/u



IC signals from short ion-beam pulses

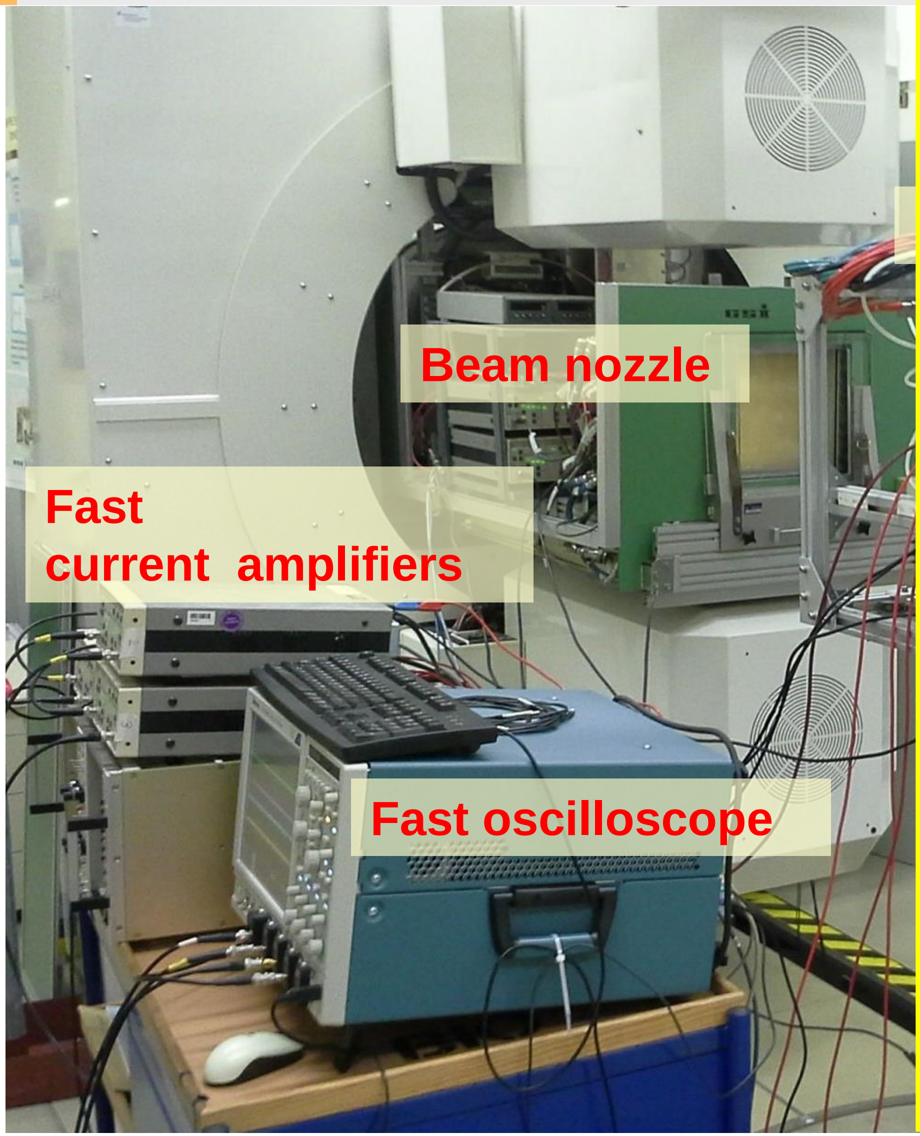
Beam parameters:

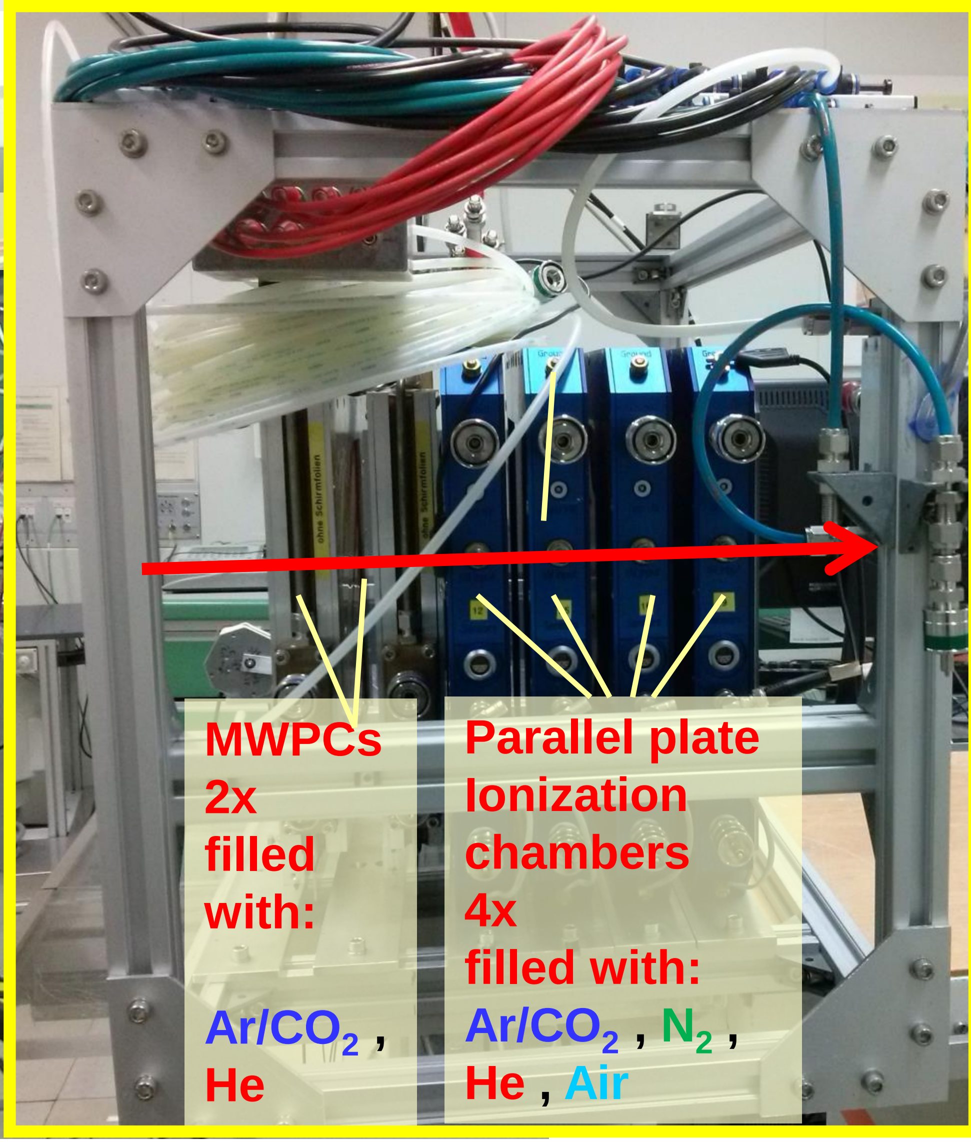
- GSI Synchrotron ; Cave M
- Fast extraction (Kicker) ; beam pulse < 1 µs
- ^{12}C , 300 MeV/u ; ≈10^6 ions

Detectors:

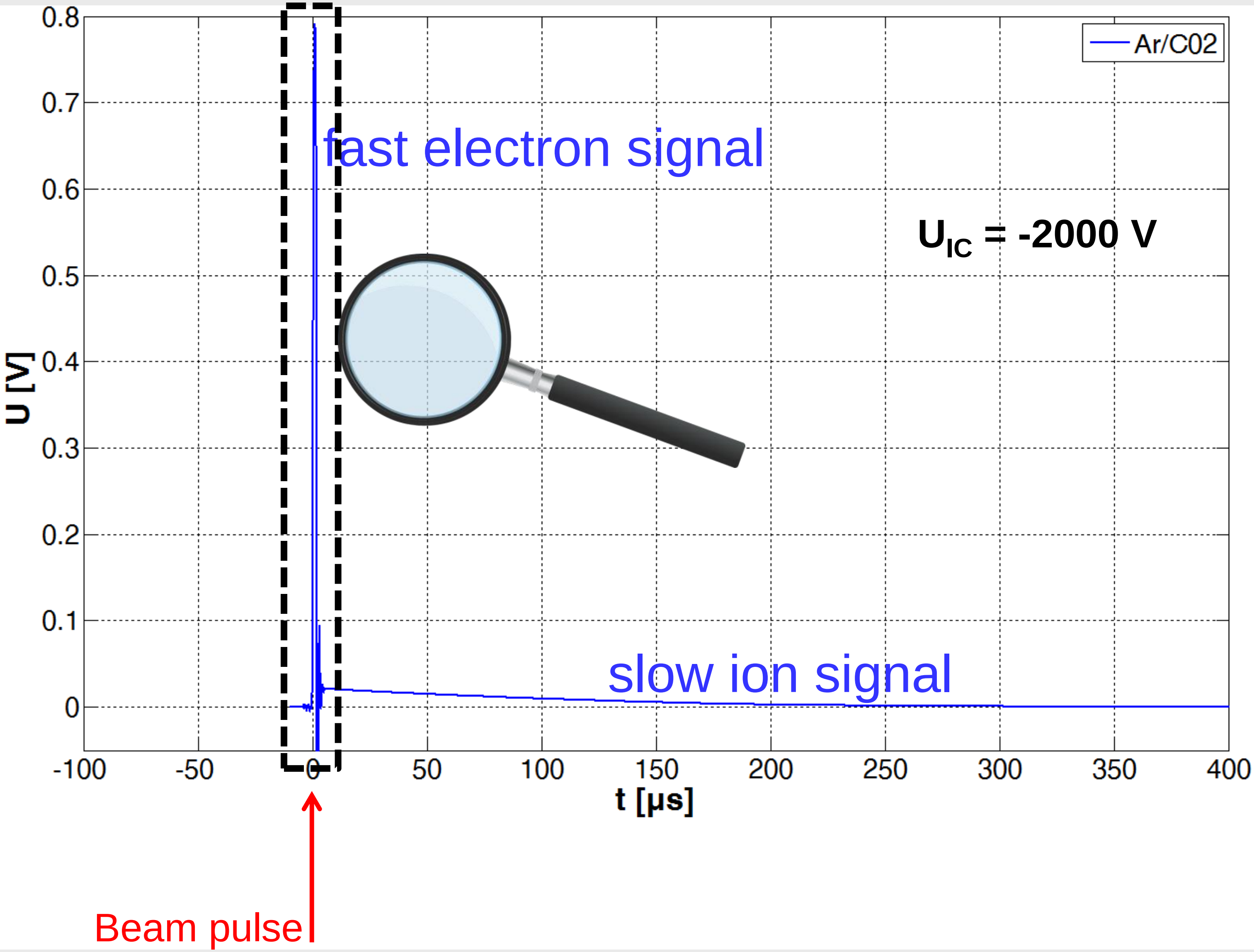
- 4 parallel plate ionization chambers
  - Ar-CO_2 (80-20%)
  - Helium
  - Air
  - N_2
- 2 MWPCs
  - Ar-CO_2 (80-20%)
  - Helium
- Stanford-Instruments fast current amplifiers (10^4 - 10^7 V/A)

Detector Test Setup in Cave M

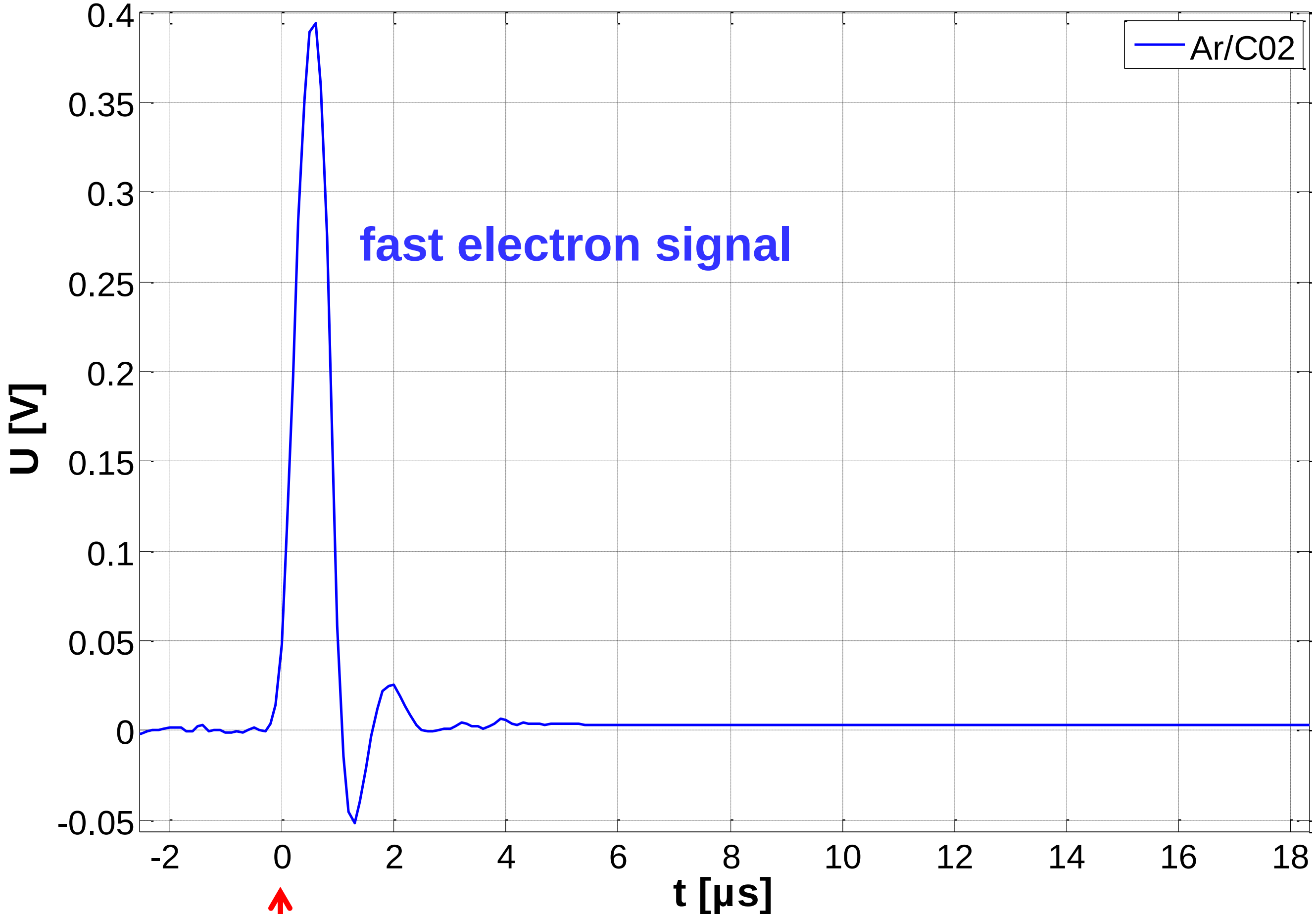




Response function for a short beam pulse (fast beam extraction: t < 1 μs)



Response function for a short beam pulse (fast beam extraction: t < 1 µs)

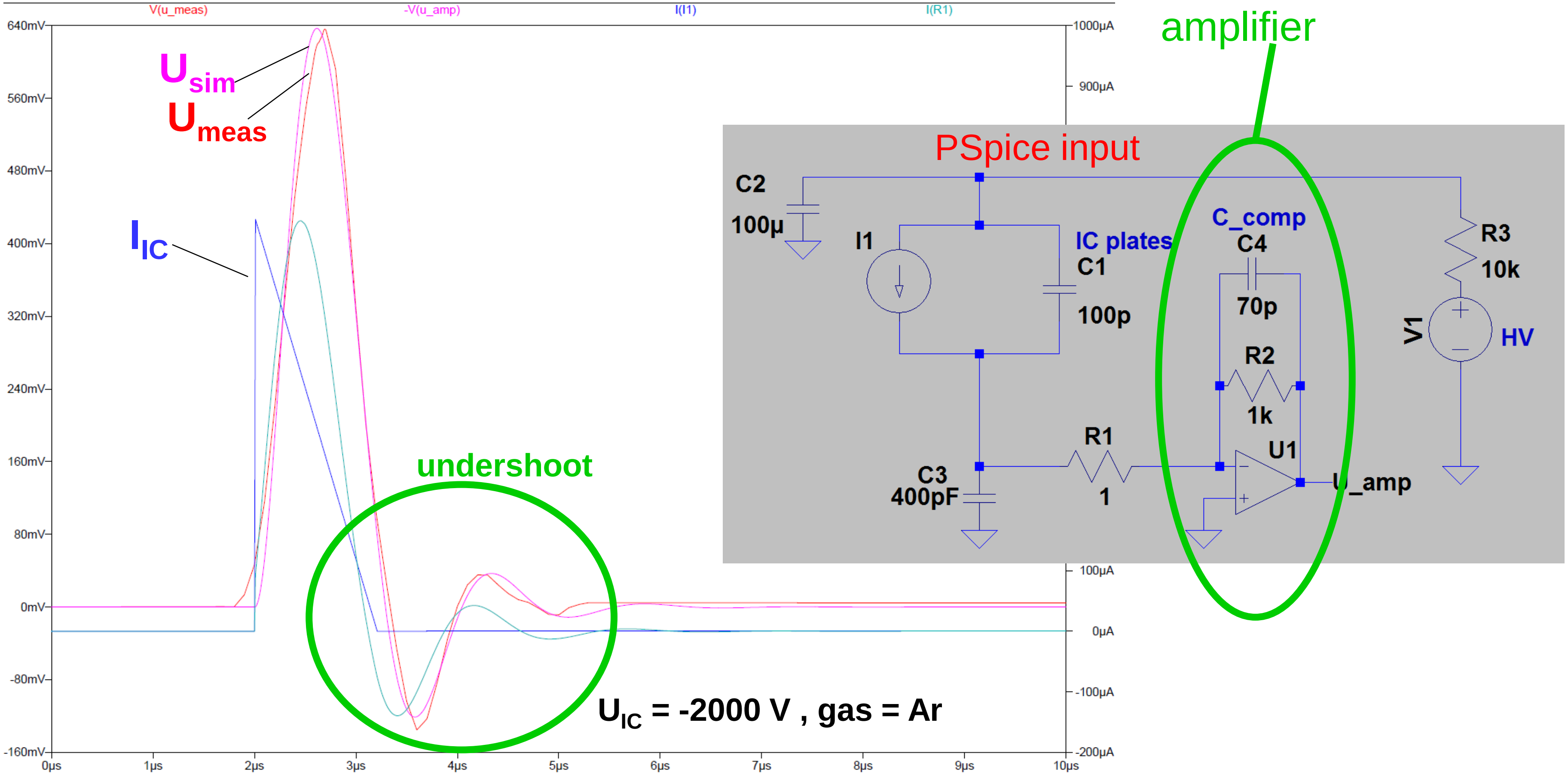


U_{IC} = -500 V

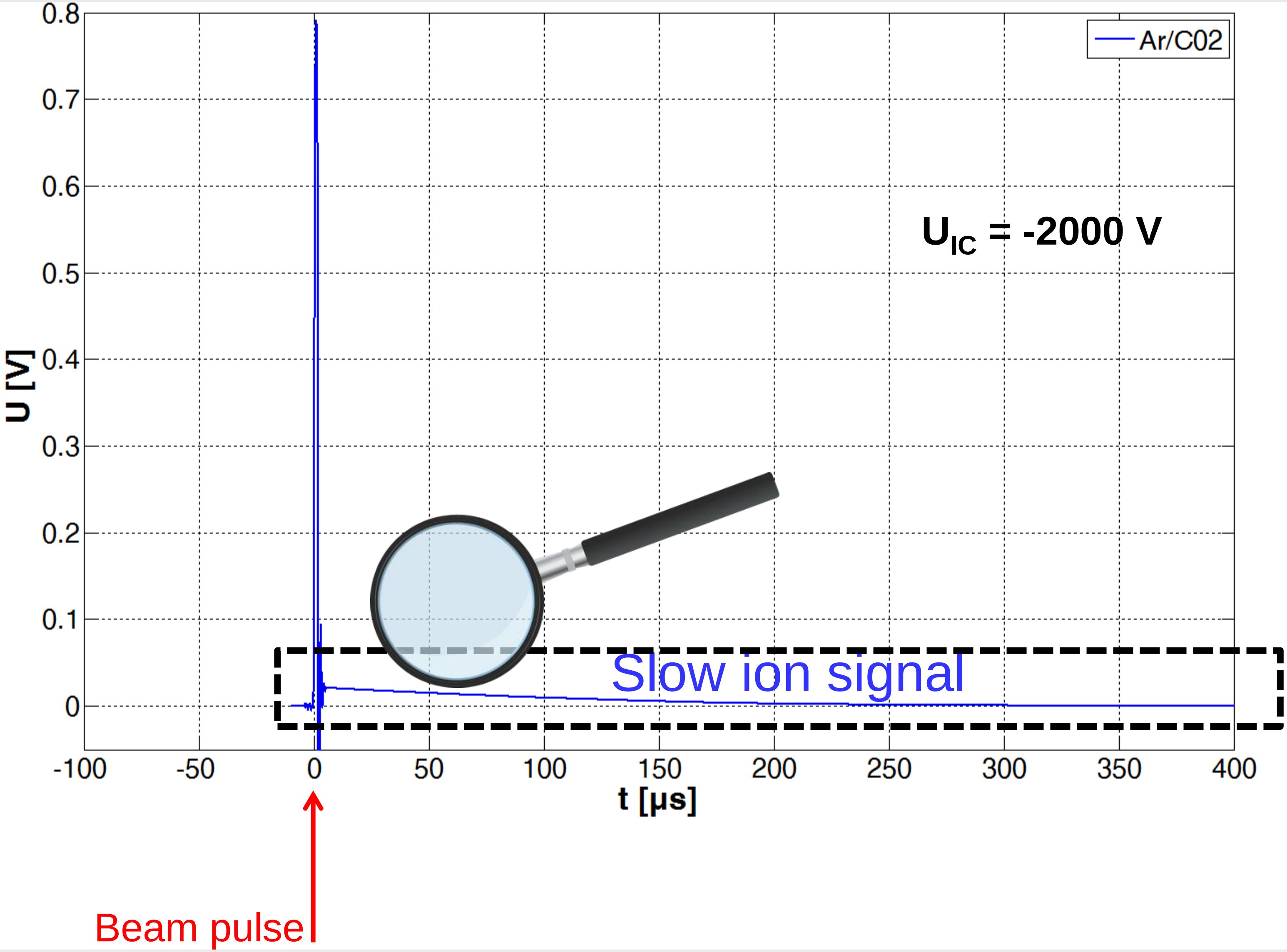
Beam pulse

Simulation (PSpice) of the fast electron pulse

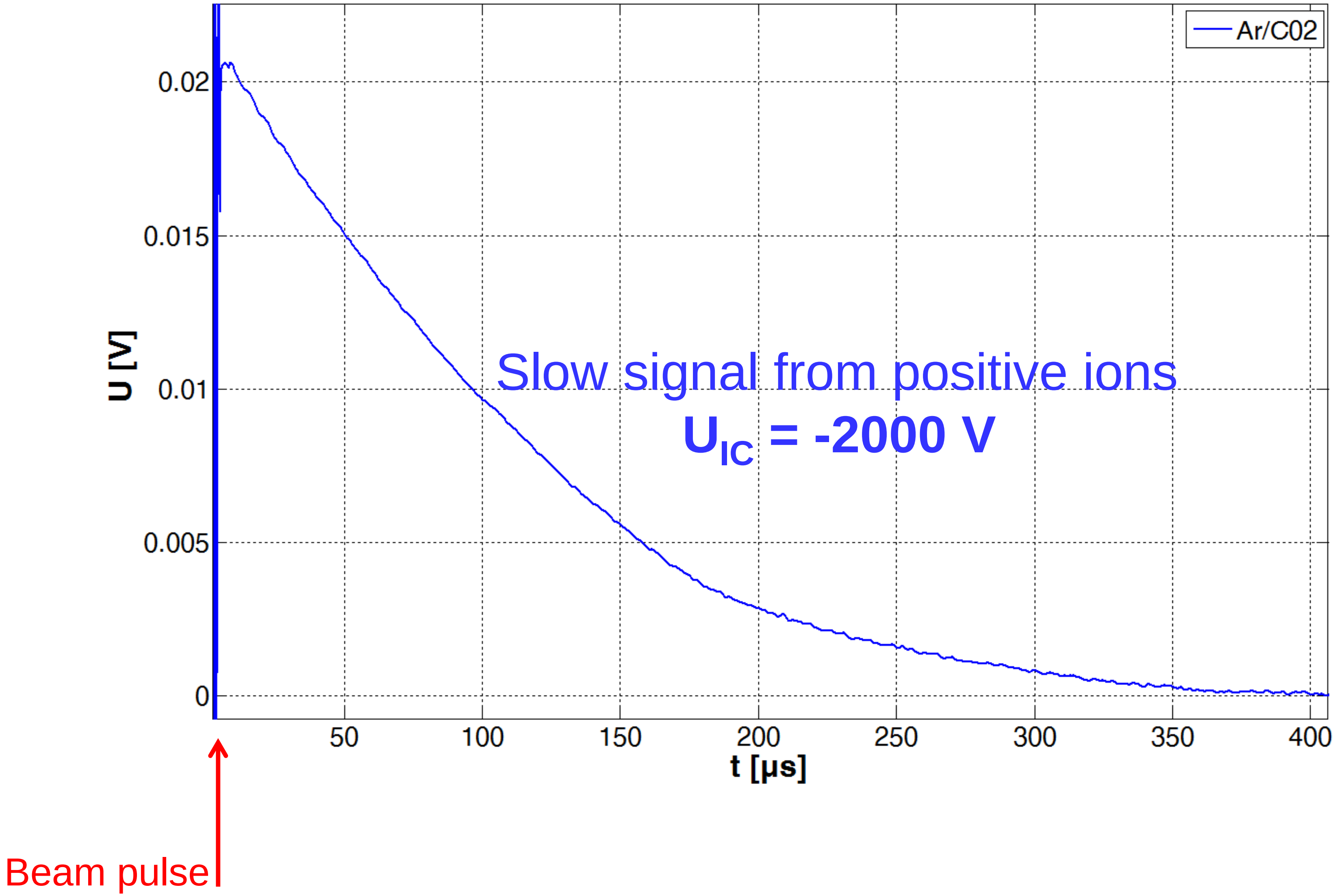
Consideration of the time-response from the amplifier



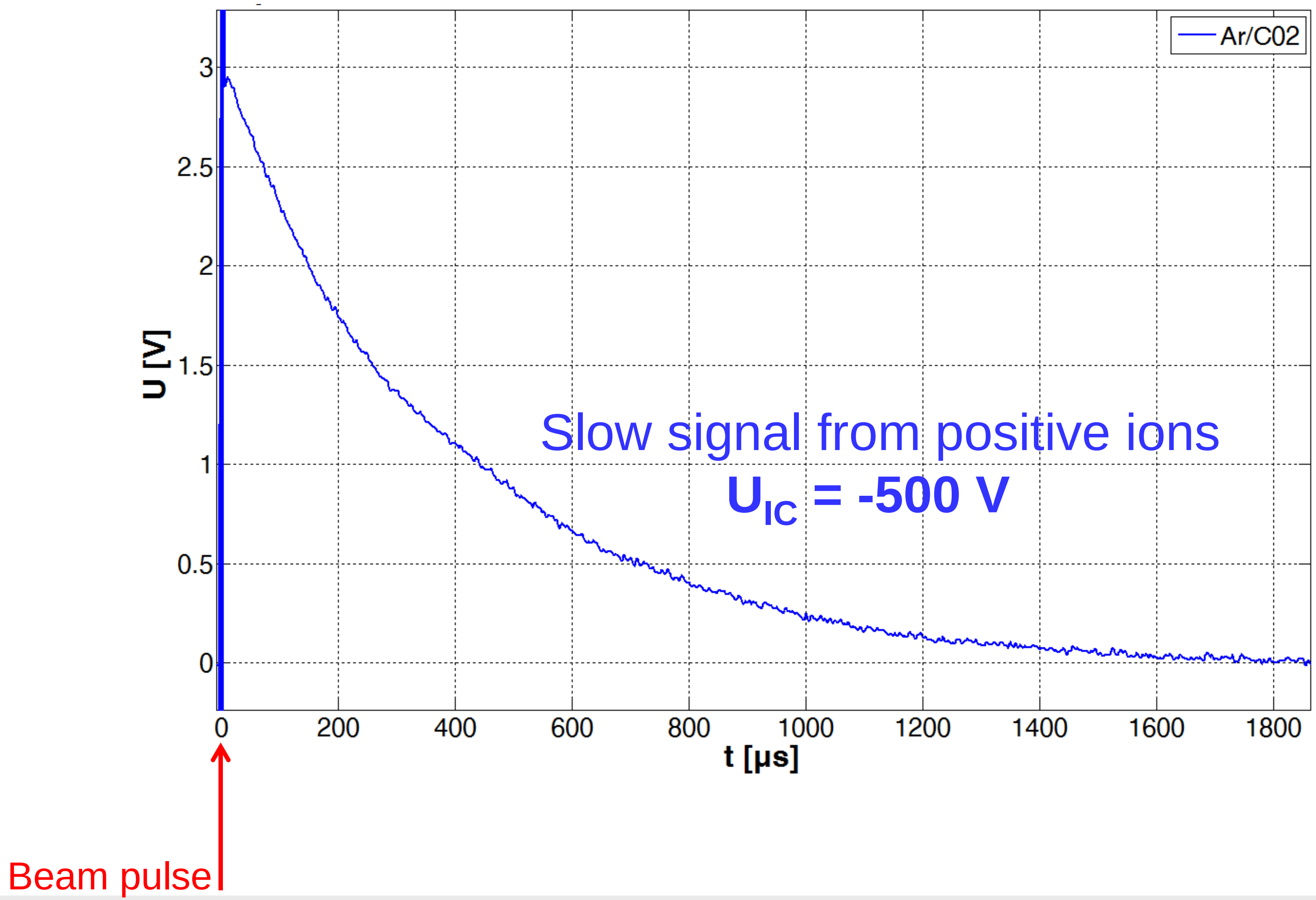
Response function for a short beam pulse (fast beam extraction: t < 1 µs, ^{12}C, 300 MeV/u)



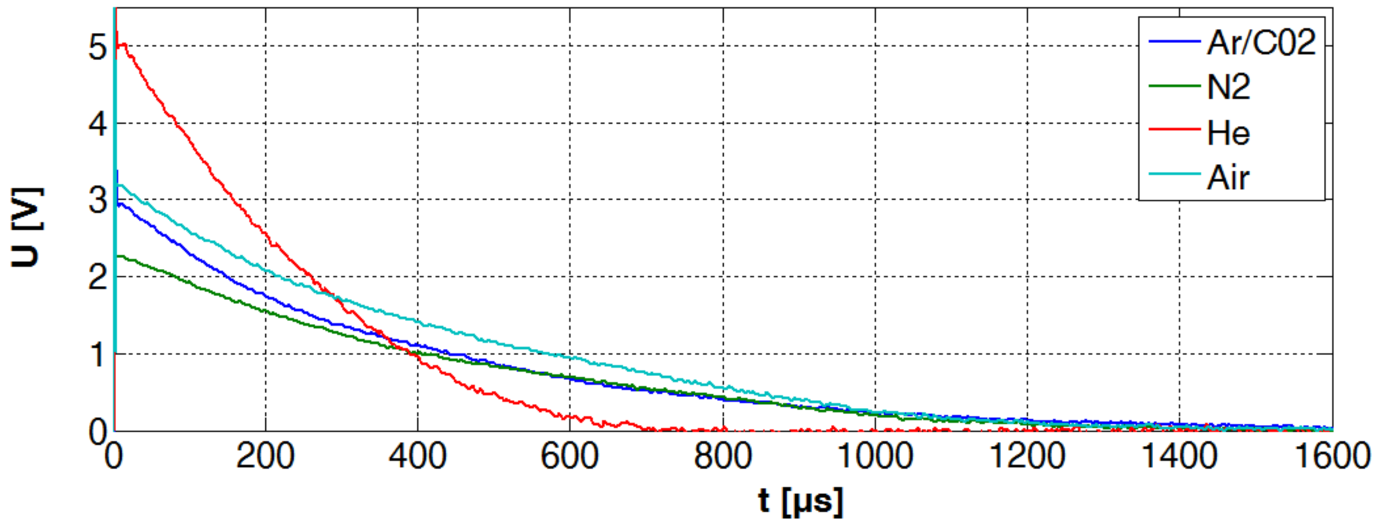
Response function for a short beam pulse (fast beam extraction: t < 1 μs, ^{12}C, 300 MeV/u)



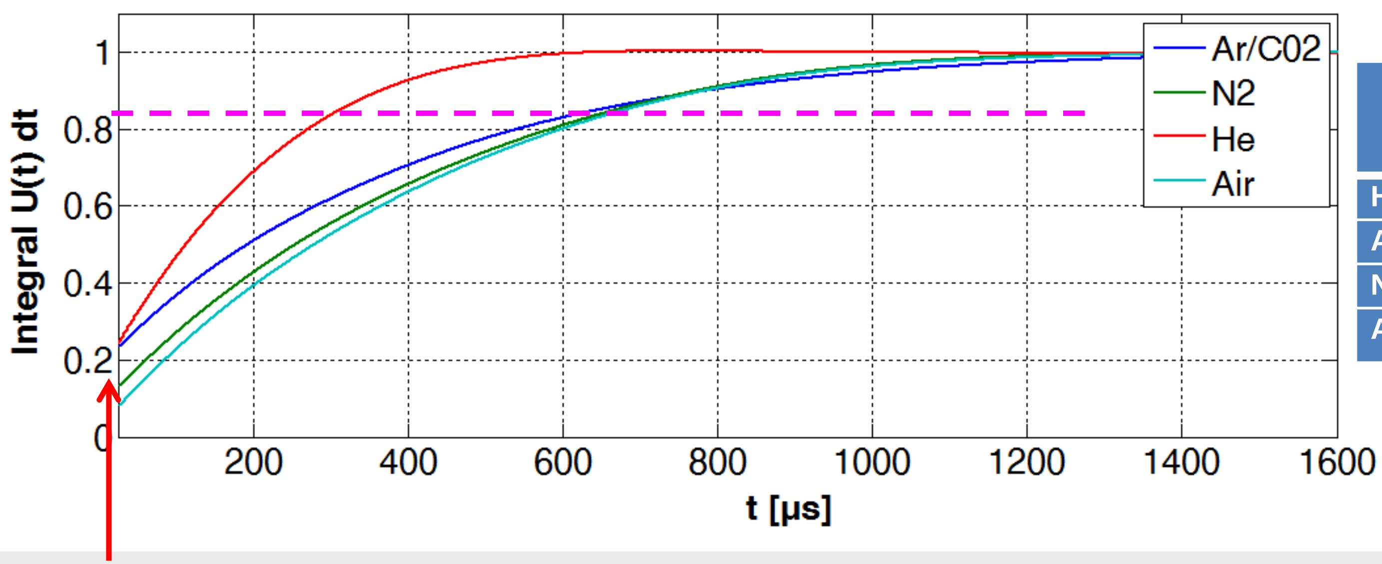
Response function for a short beam pulse (fast beam extraction: t < 1 μs, ^{12}C, 300 MeV/u)



Response function for a short beam pulse for 4 different gasses (Ar/CO_2 , N_2 , He , Air)

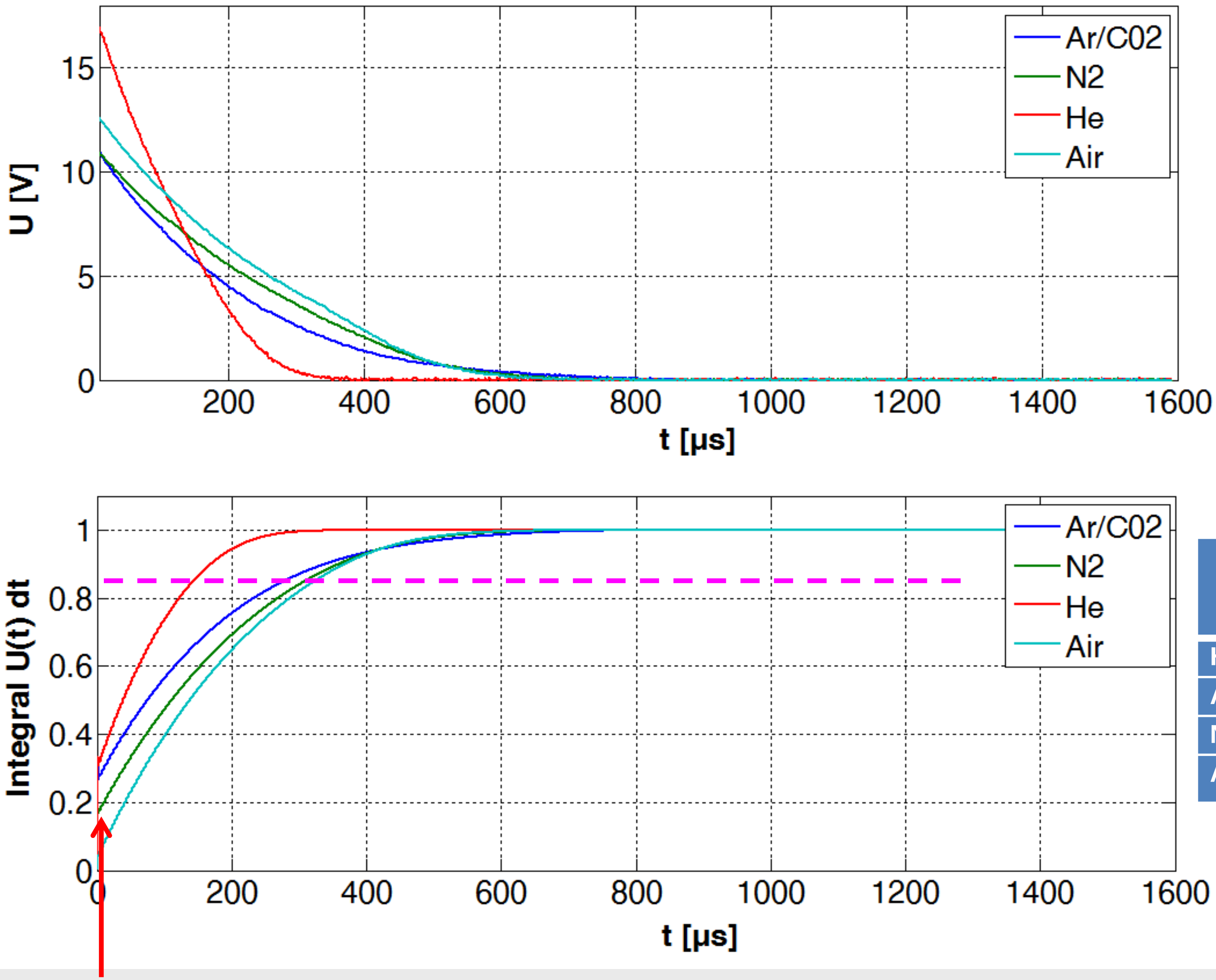


U_{IC} = -500 V



	t - 80% [µs]	t - 80% normalized to Helium
He	271 µs	100%
Ar-CO_2	542 µs	200%
N_2	585 µs	215%
Air	599 µs	221%

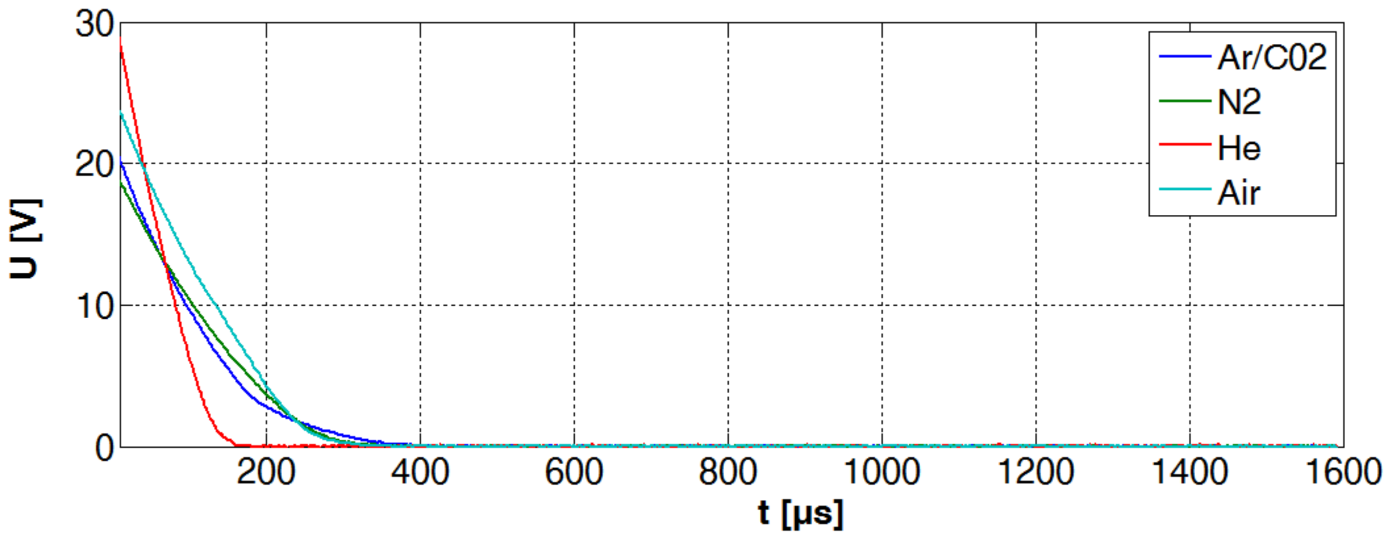
Response function for a short beam pulse for 4 different gasses (Ar/CO_2 , N_2 , He , Air)



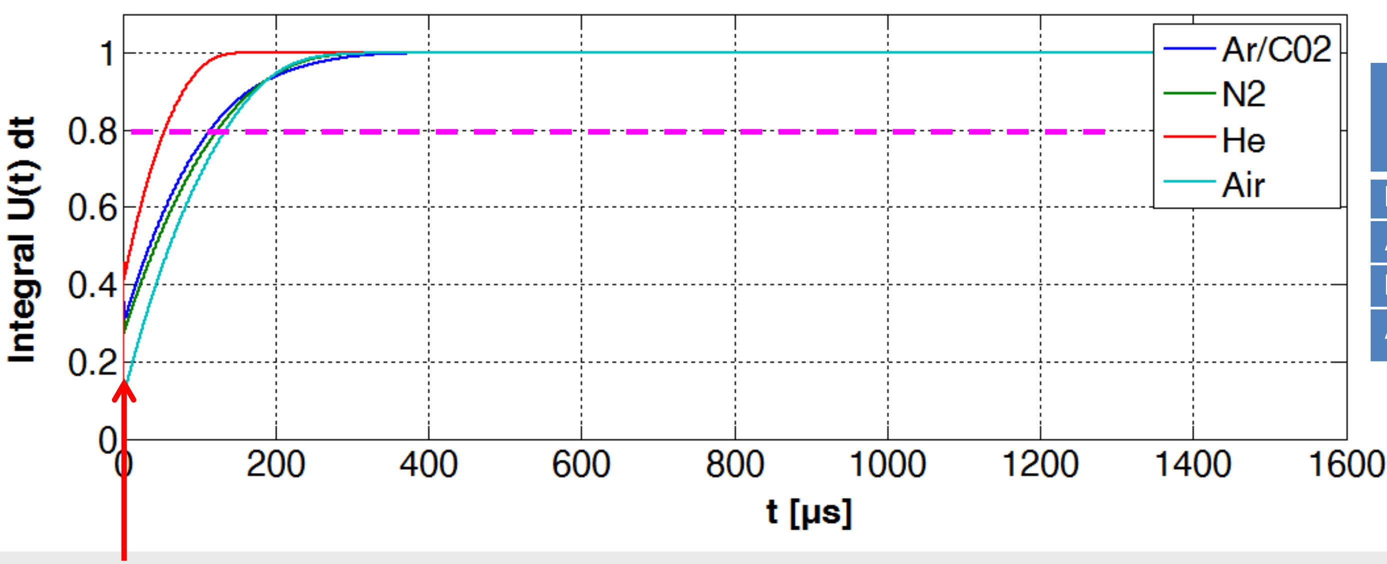
U_{IC} = -1000 V

	t - 80% [µs]	t - 80% normalized to Helium
He	122 µs	100%
$Ar\text{-}CO_2$	232 µs	190%
N_2	269 µs	220%
Air	286 µs	234%

Response function for a short beam pulse for 4 different gasses (Ar/CO_2 , N_2 , He , Air)

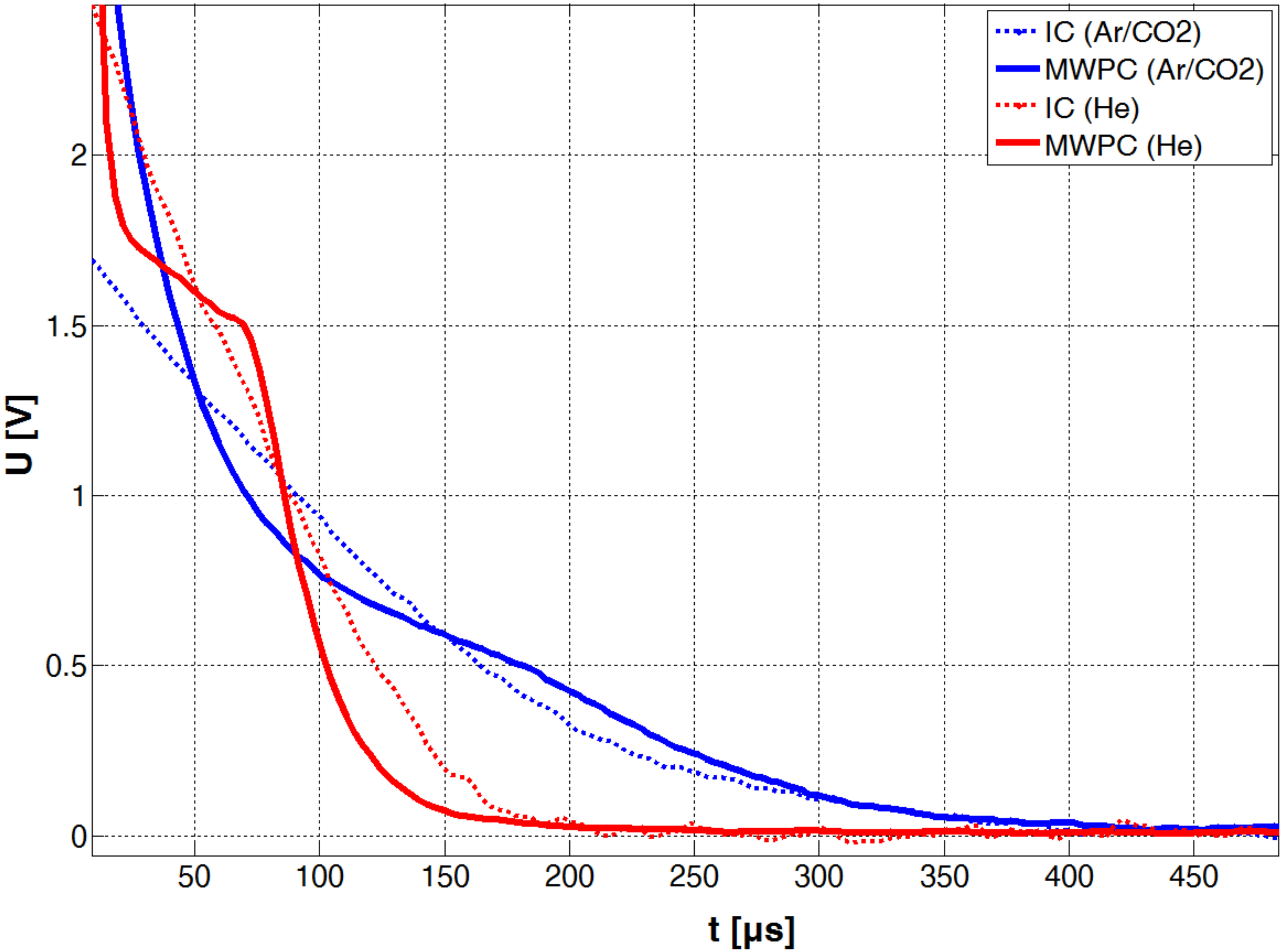


U_{IC} = -2000 V



	t - 80% [µs]	t - 80% normalized to Helium
He	55 µs	100%
$Ar\text{-}CO_2$	114 µs	207%
N_2	124 µs	225%
Air	135 µs	245%

Response function of the MWPC for 2 different gases (Ar/CO_2 and He)



U_{IC} = -1750 V

IC signals from Photon LINAC pulses

Beam parameters:

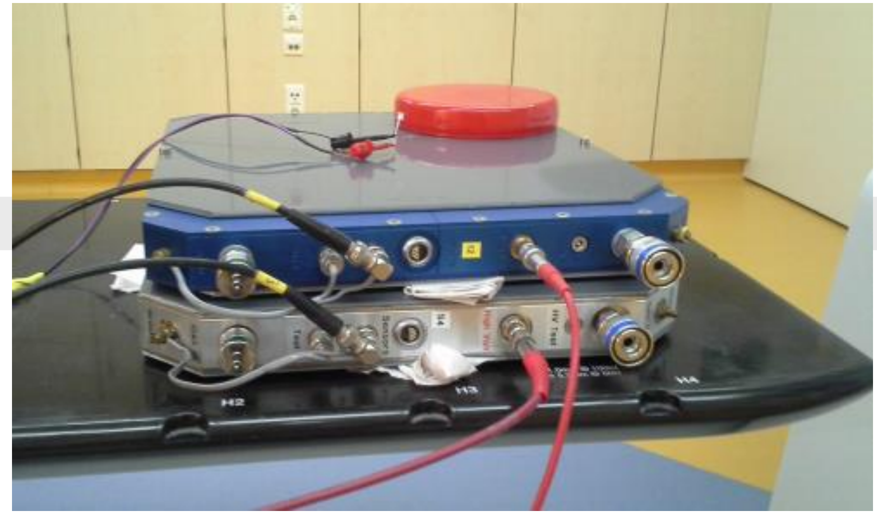
- Varian 6 MeV LINAC,
- short beam pulses < 1 µs
- field size 10 x 10 cm

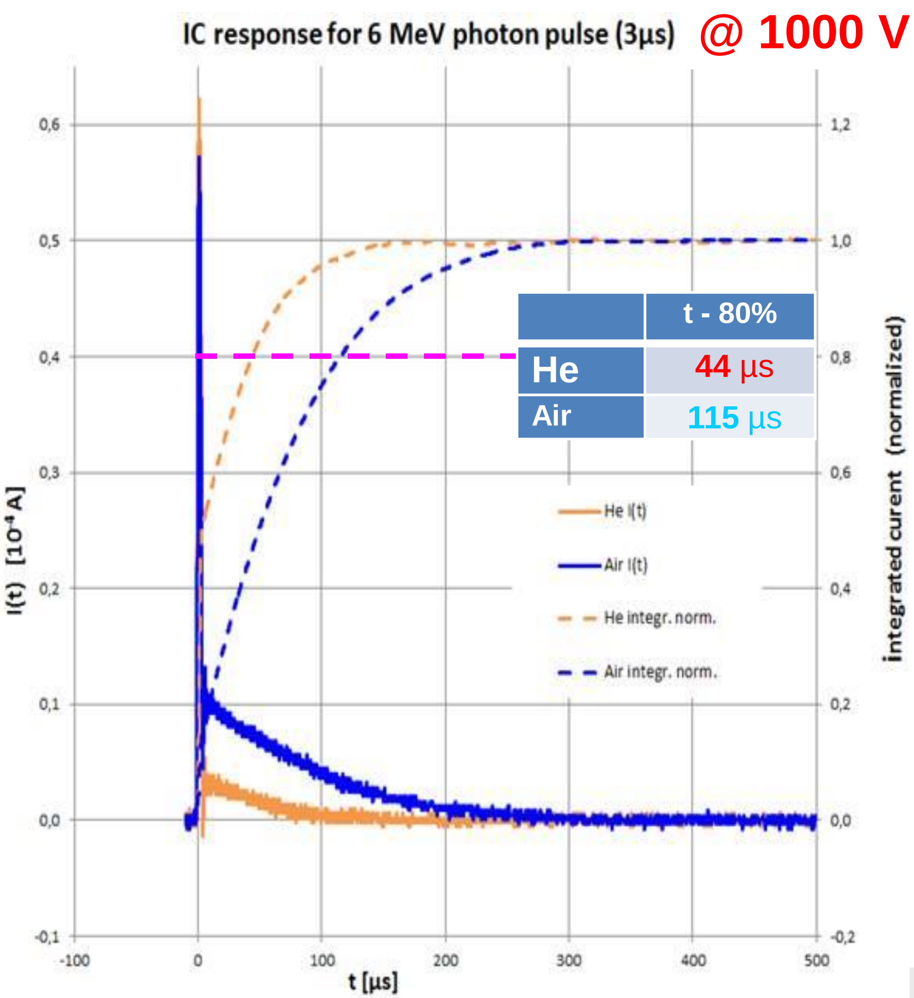
Detectors:

- 2 parallel plate ionization chambers
  - ArCO2
  - Helium
- 1 fast silicon PIN diode as trigger
- Keithley fast current (Modell 428) Amplifiers (10^4 - 10^6 V/A)

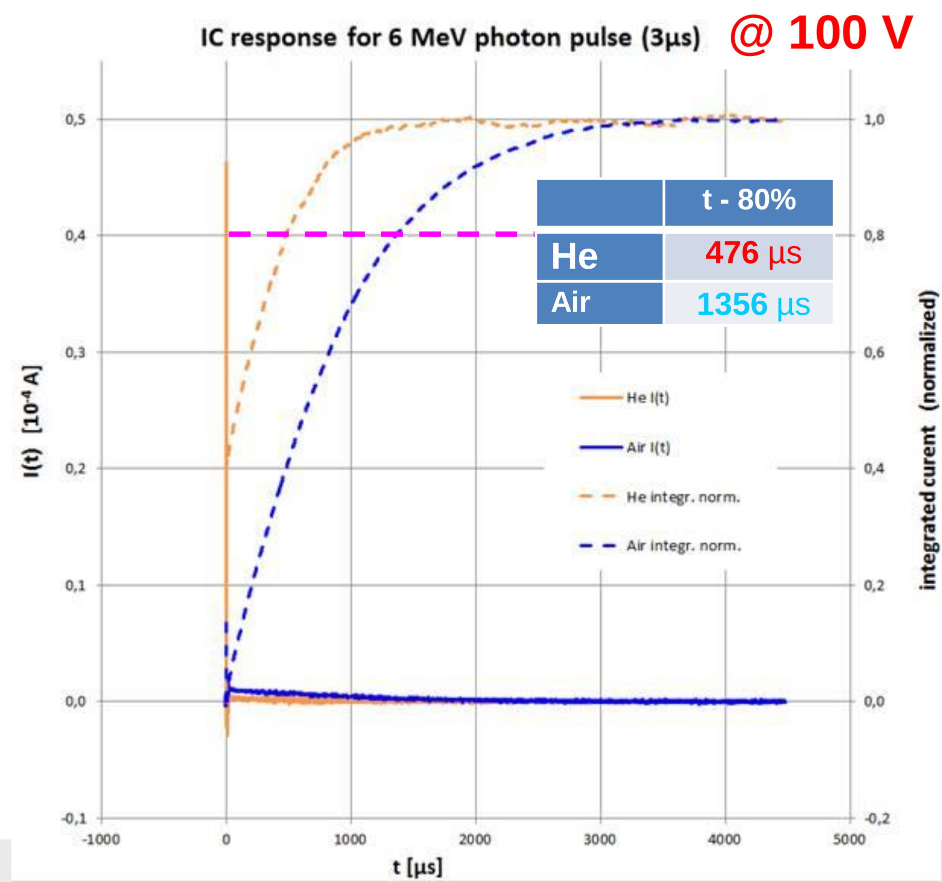
IC signals from Photon LINAC pulses

Helium vs. Air





	t - 80%
He	44 μs
Air	115 μs



	t - 80%
He	476 μs
Air	1356 μs

Discussion

- Helium > 2 times faster than $ArCO_2$
  - drawback: considerably lower signal – sufficient for small spots?
- Higher Voltage decreases the delay: t_{delay} ~ 1 / Voltage
- He @ 2kV – 80% of signal available after ~ 50 µs

- Better understanding of detector time behavior could improve fast position control

- Complete redesign and upgrade of the GSI Cave-M Scanning-System is ongoing

Thank you …

Reserve …