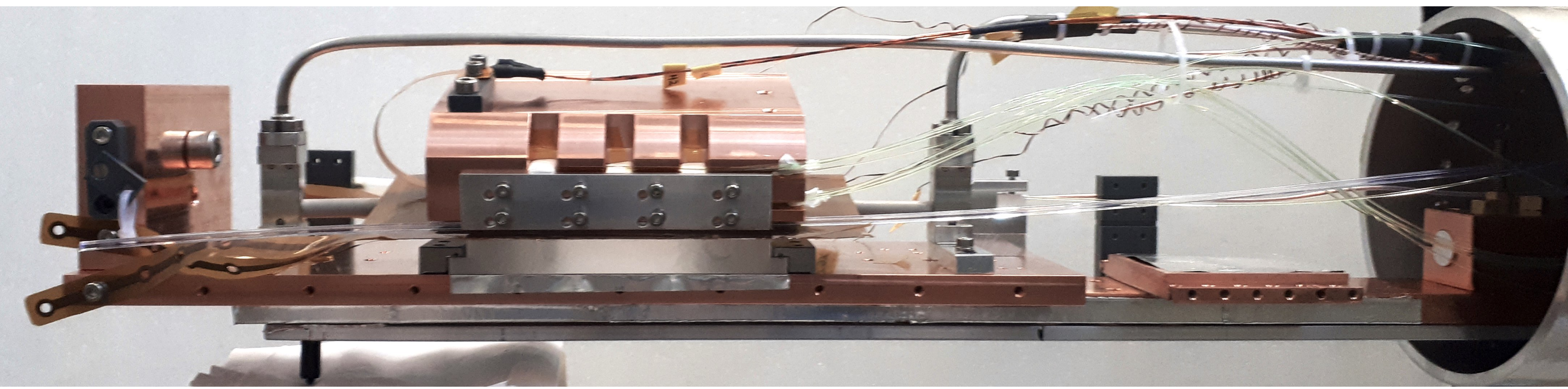
ETH zürich

PAUL SCHERRER INSTITUT

muCool : Development of ultra-cold high-brightness positive muon beam line



Ryoto Iwai (ETHZ)

On behalf of muCool collaboration

Goal

- Build a device to compress phase space of a standard muon beam by 10 order of magnitude

- Add-on to existing surface muon beam lines
    - E_μ : 4.1 MeV → <1 eV
    - Beam size : 10 mm → <1 mm
    - Conserve initial polarisation
    - Efficiency ~ 10^{-3}

- Muons are reaccelerated to keV energy and sent to experiments

Motivation

Particle physics experiments

- Improved injection into magnetic systems

  ➡ muon g-2/EDM

- High quality Mu beam

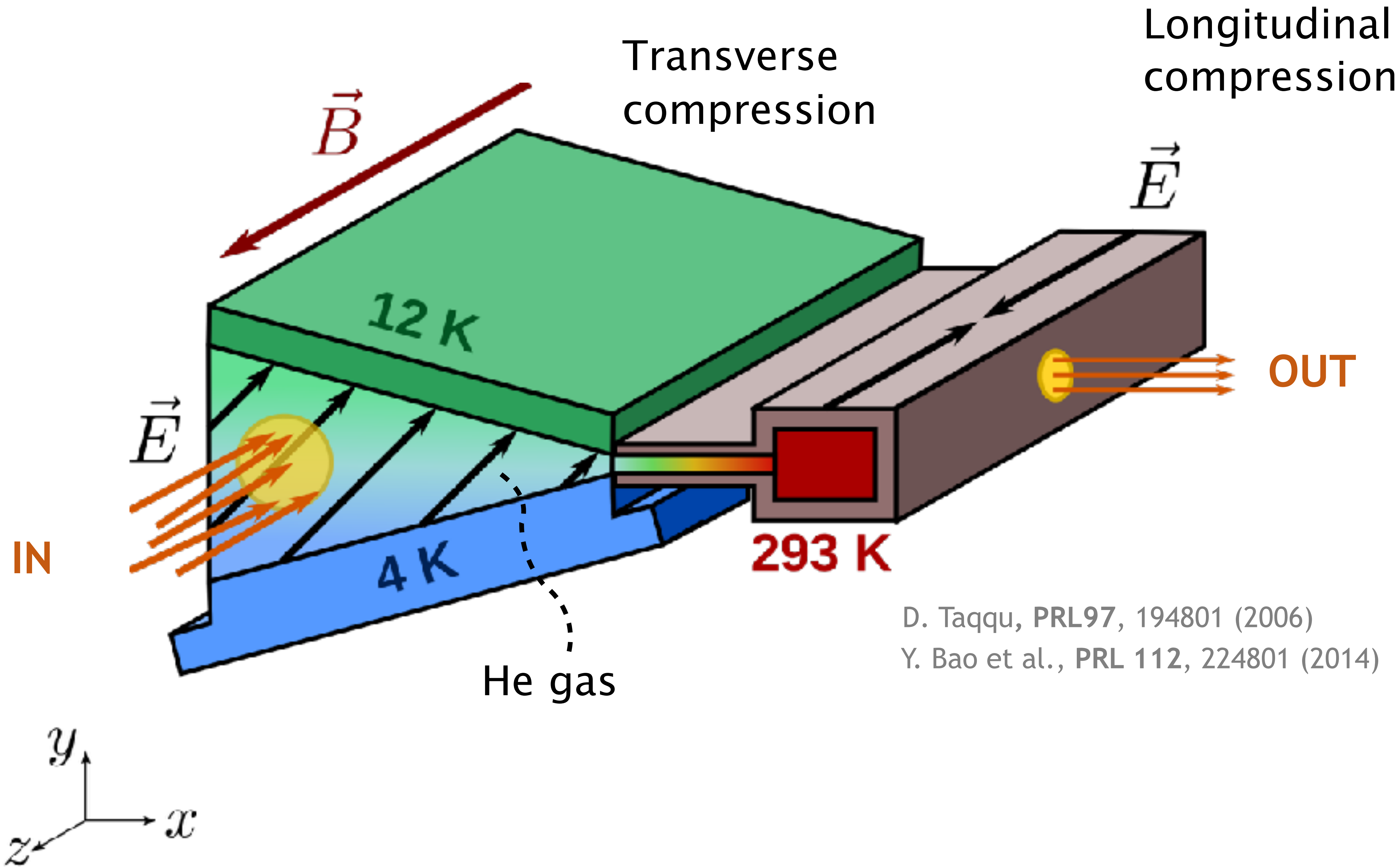
  ➡ test anti-matter gravity

  ➡ Mu 1S-2S spectroscopy

μSR applications

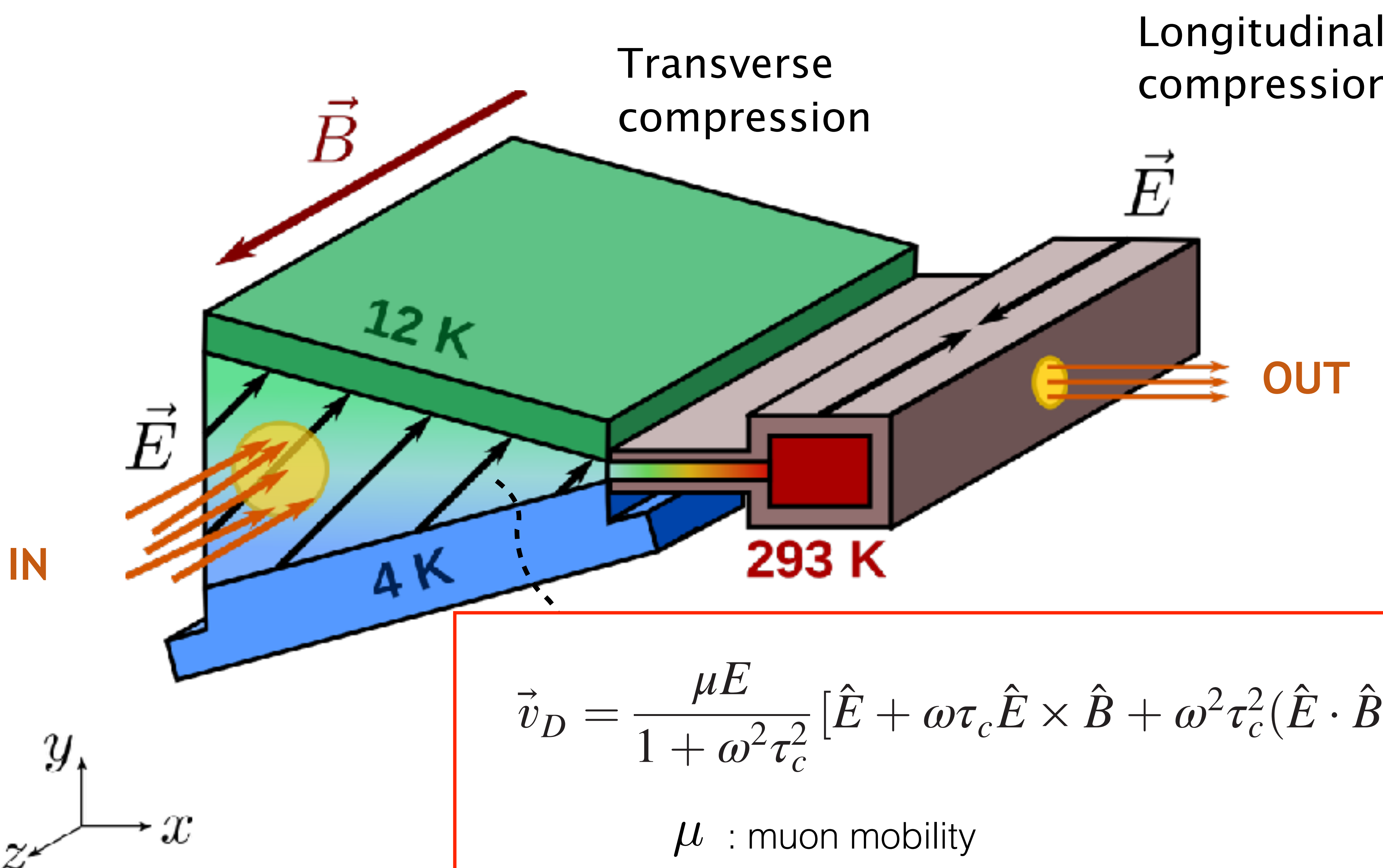
- Study thin material, small sample

Working principle



D. Taqqu, **PRL97**, 194801 (2006)
Y. Bao et al., **PRL 112**, 224801 (2014)

Working principle



$$\vec{v}_D = \frac{\mu E}{1+\omega^2\tau_c^2}\left[\hat{E} + \omega\tau_c \hat{E}\times\hat{B} + \omega^2\tau_c^2(\hat{E}\cdot\hat{B})\hat{B}\right]$$

μ : muon mobility

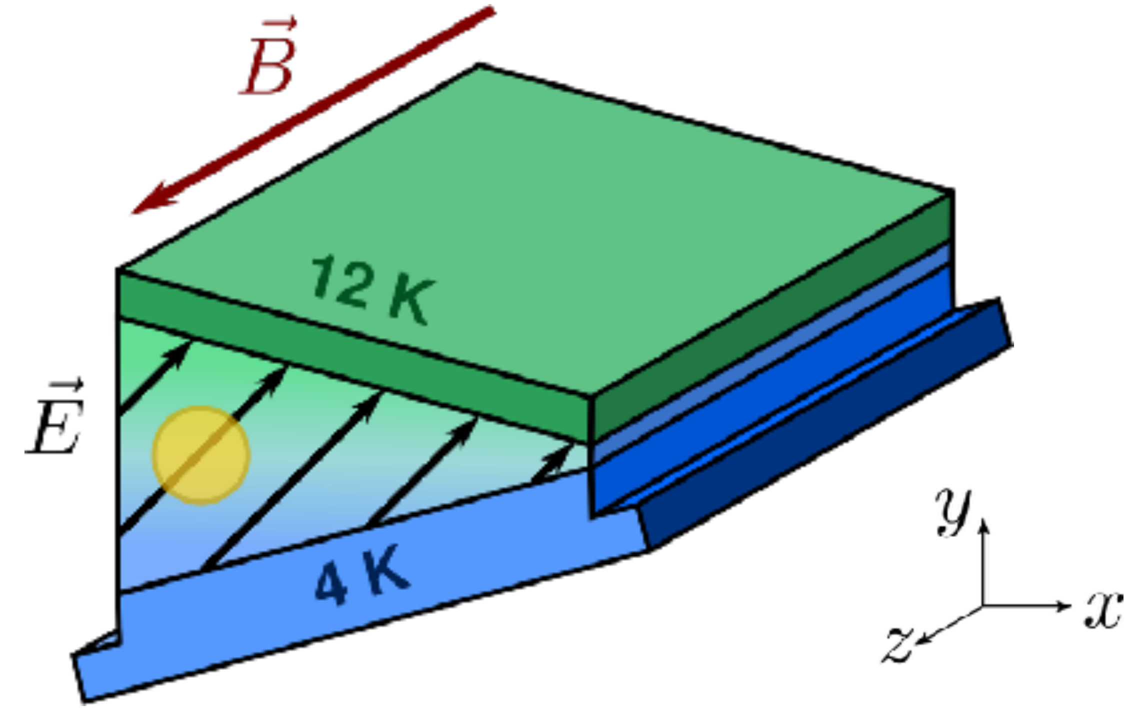
ω : cyclotron frequency

τ_c : mean time between collisions

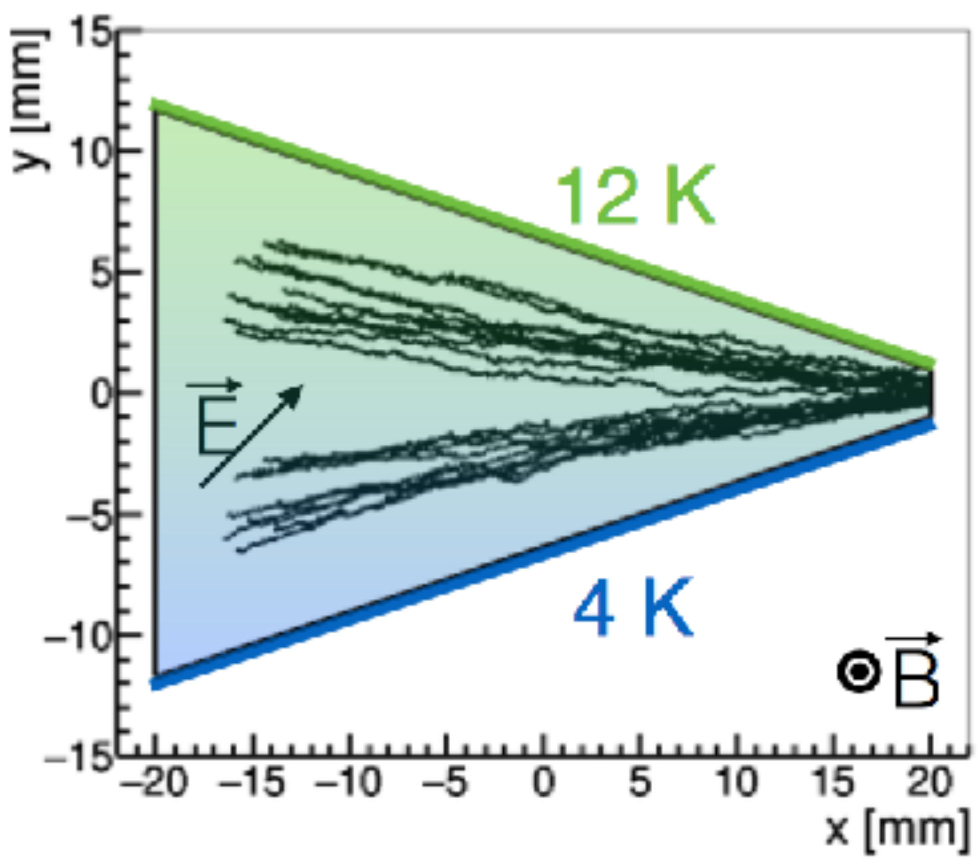
Transverse compression

- 5 mbar He gas
- Cryogenic temperature
- Temperature gradient
- Crossed E- and B-field

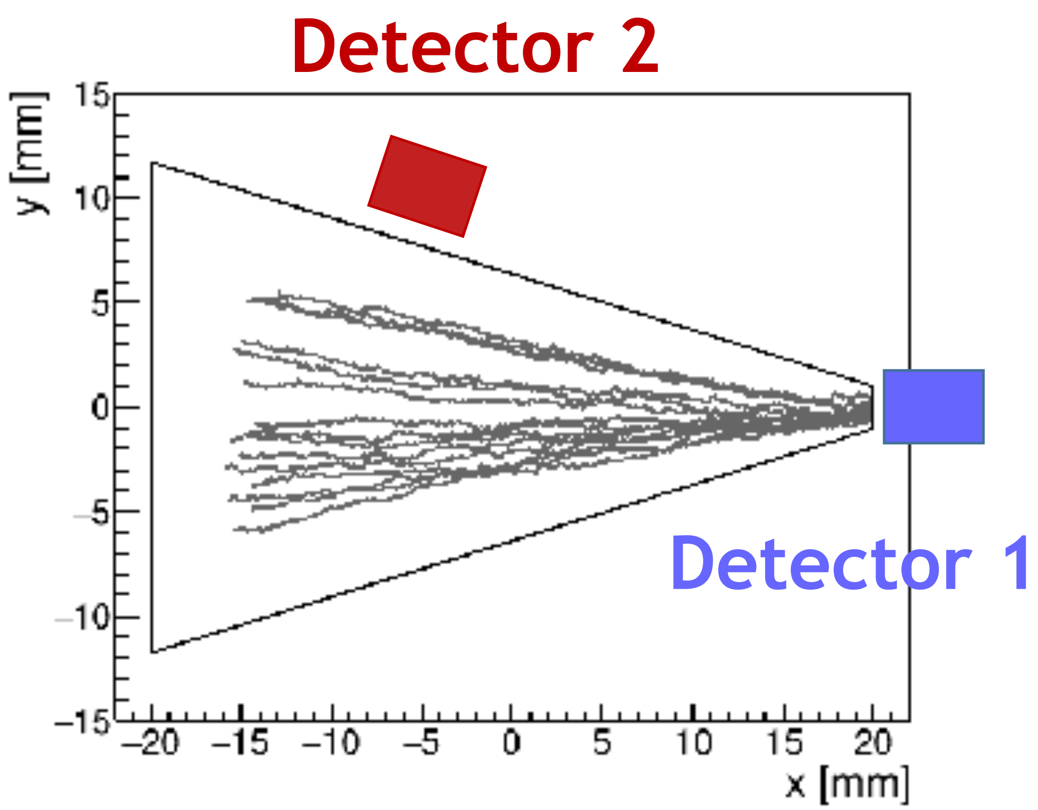
$$|\vec{E}| = \ 3.0\,\mathrm{kV/cm}$$
$$|\vec{B}| = 5\ \mathrm{T}$$

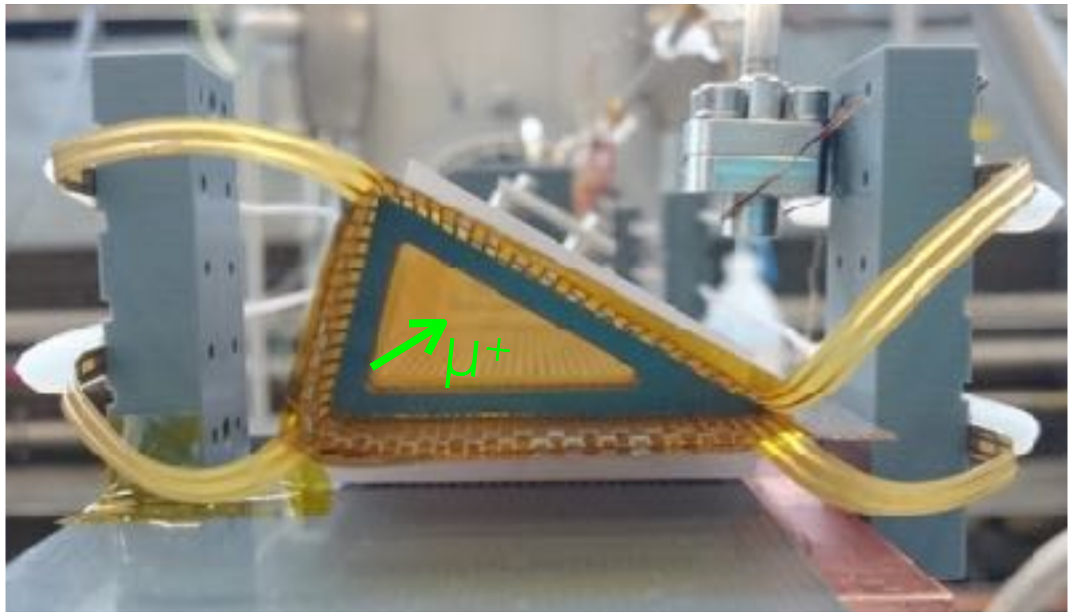


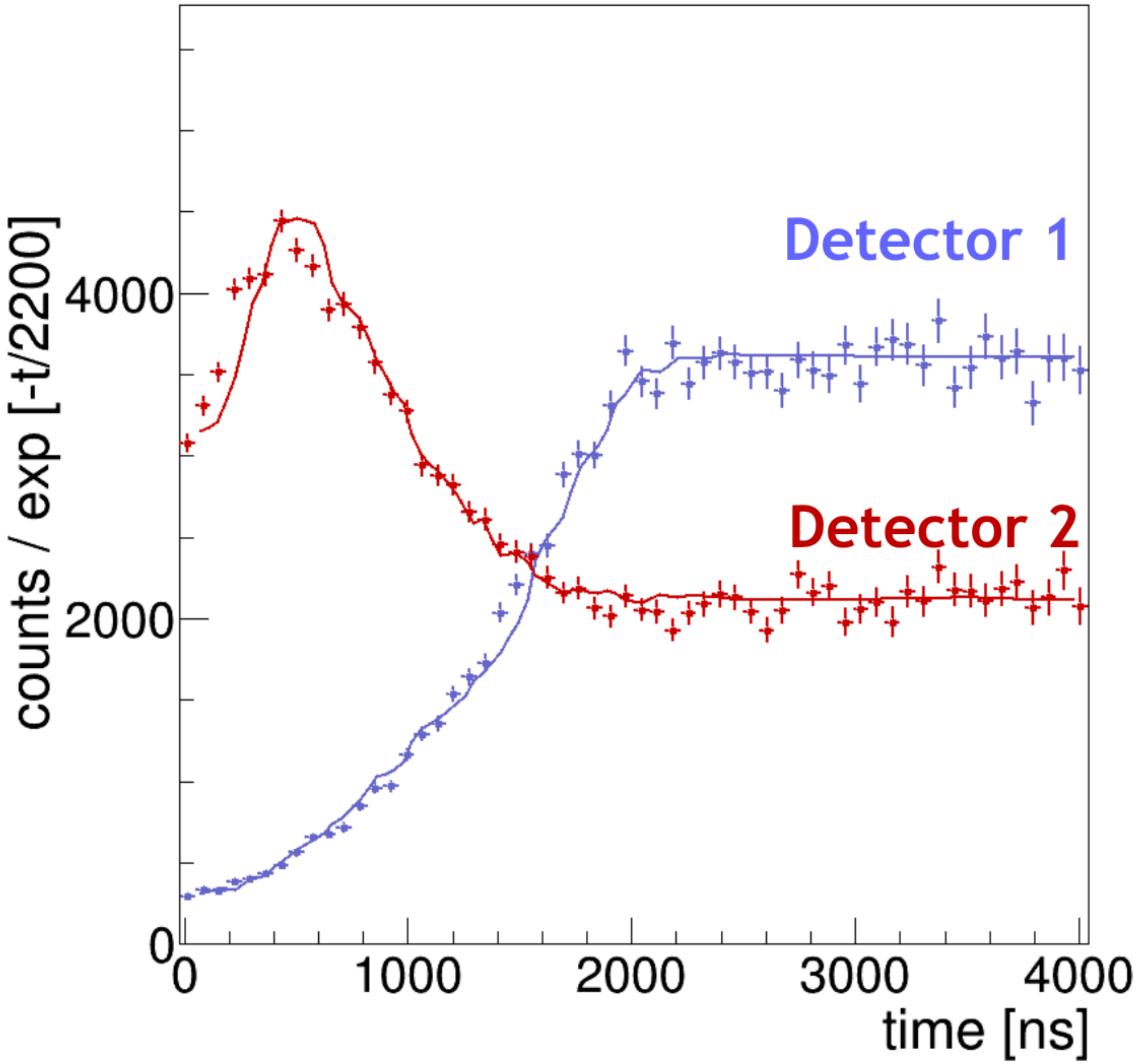
$$\vec{v}_D = \frac{\mu E}{1+\omega^2\tau_c^2}\left[\boxed{\hat{E} + \omega\tau_c \hat{E}\times\hat{B}} + \omega^2\tau_c^2(\hat{E}\cdot\hat{B})\hat{B}\right]$$



Demonstration of trans. comp.







I. Belosevic, Joint annual meeting of
Swiss and Austrian Physical Societies 2017

Longitudinal compression

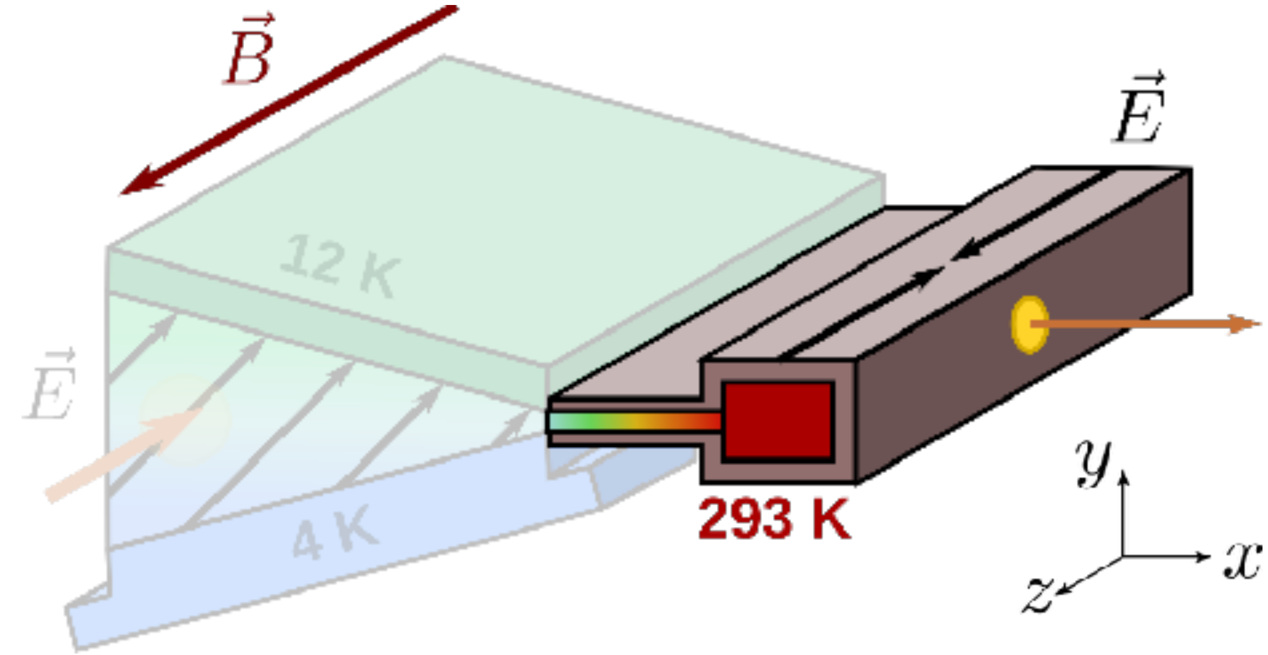
- 5 mbar He gas
- Room temperature
- Parallel E- and B-field

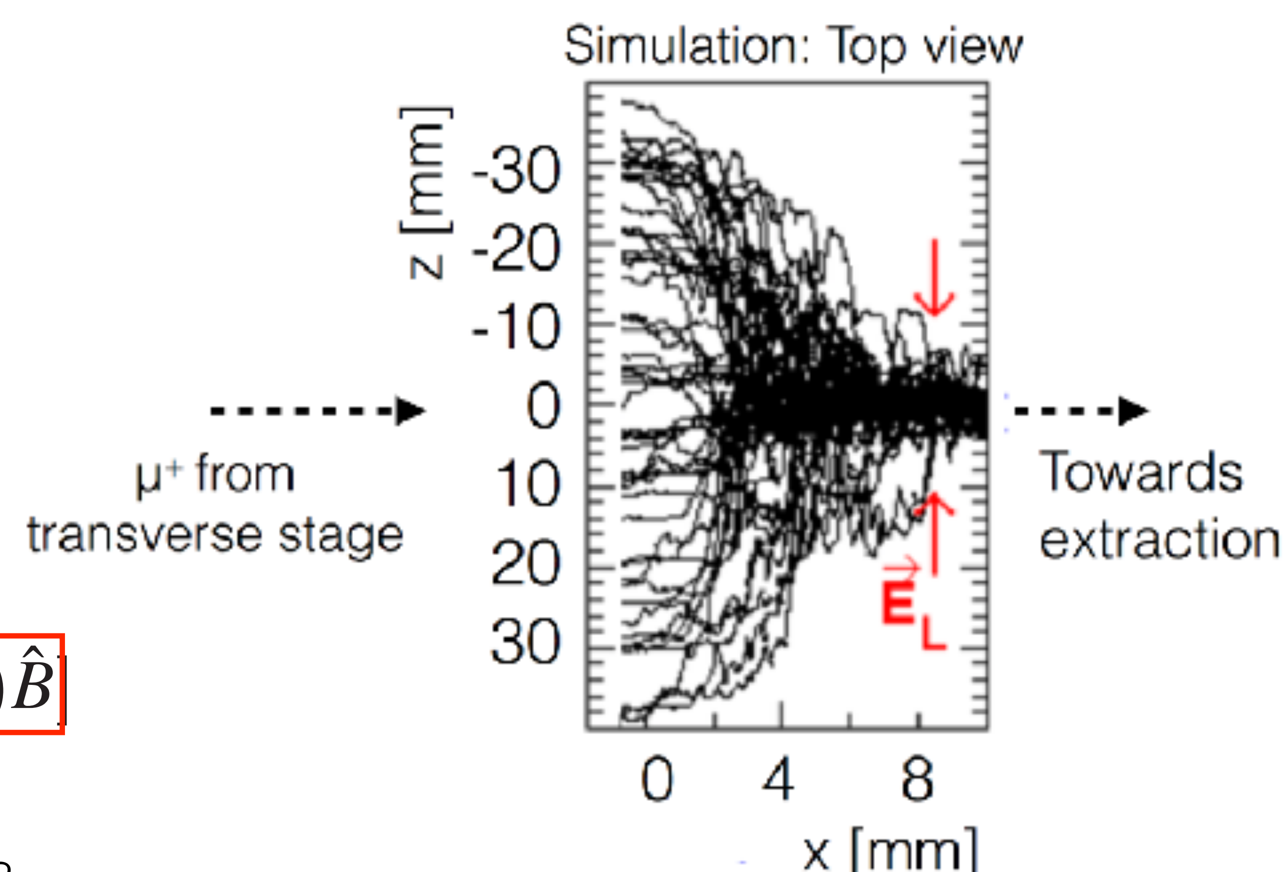
$$|\vec{E}| \sim 60\ \mathrm{V/cm}$$

$$|\vec{B}| = 5\ \mathrm{T}$$

- Demonstrated in 2011

Y. Bao et al., **PRL 112**, 224801 (2014)

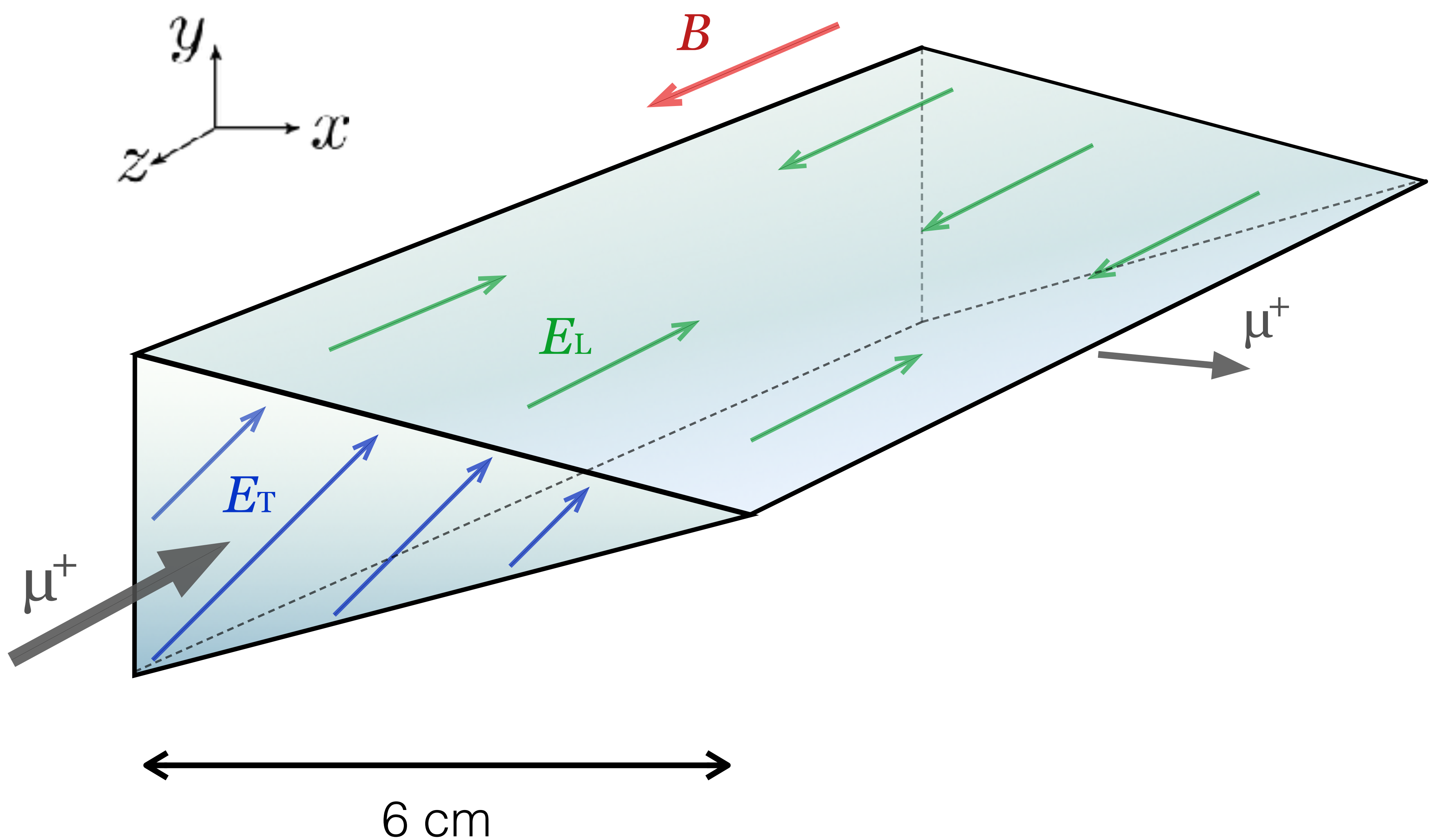




$$\vec{v}_D = \frac{\mu E}{1+\omega^2\tau_c^2}[\hat{E} + \omega\tau_c\hat{E}\times\hat{B} + \boxed{\omega^2\tau_c^2(\hat{E}\cdot\hat{B})\hat{B}}]$$

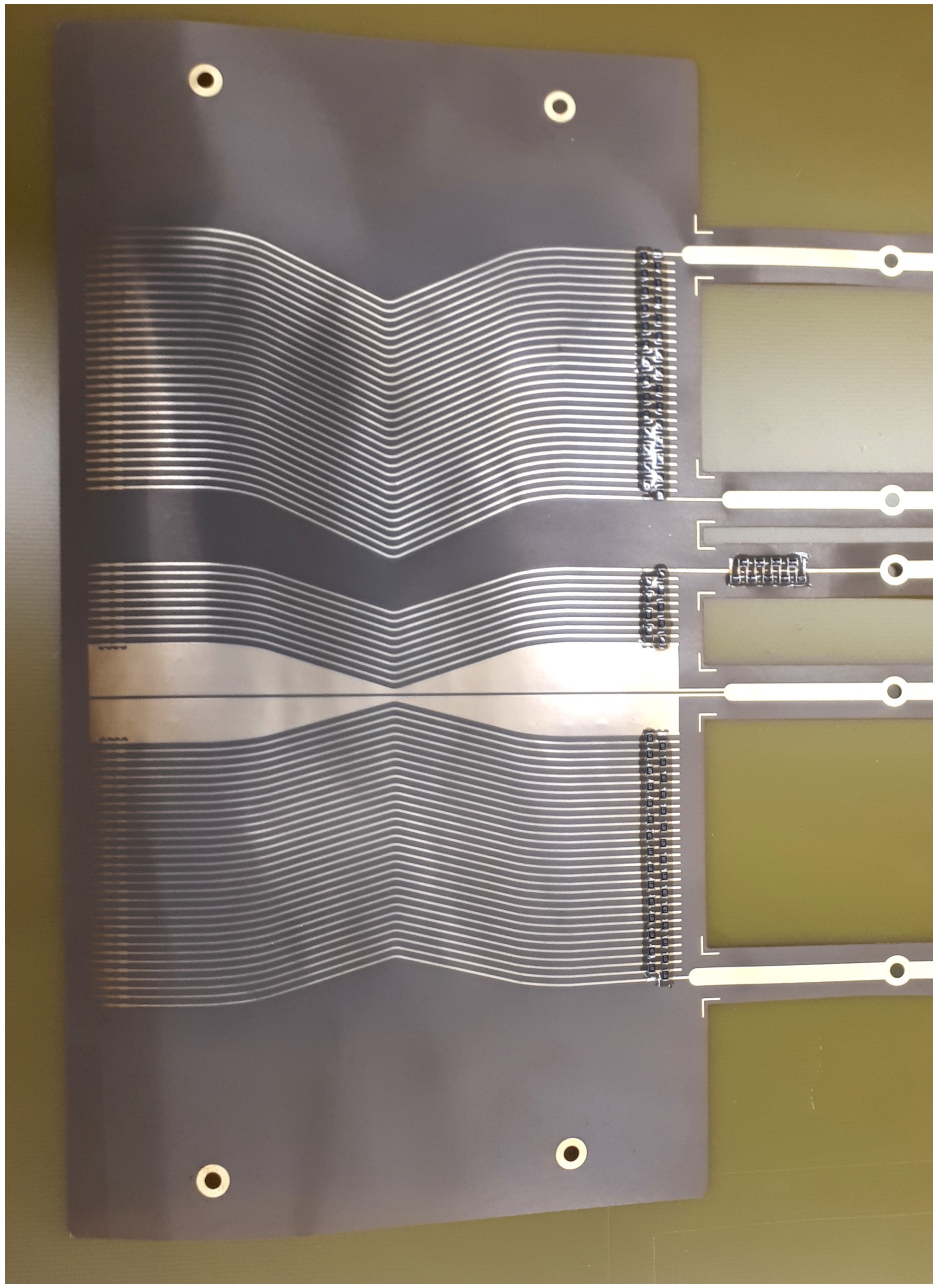
New scheme

- Mixed transverse & longitudinal compression
- Single stage at cryogenic temperature

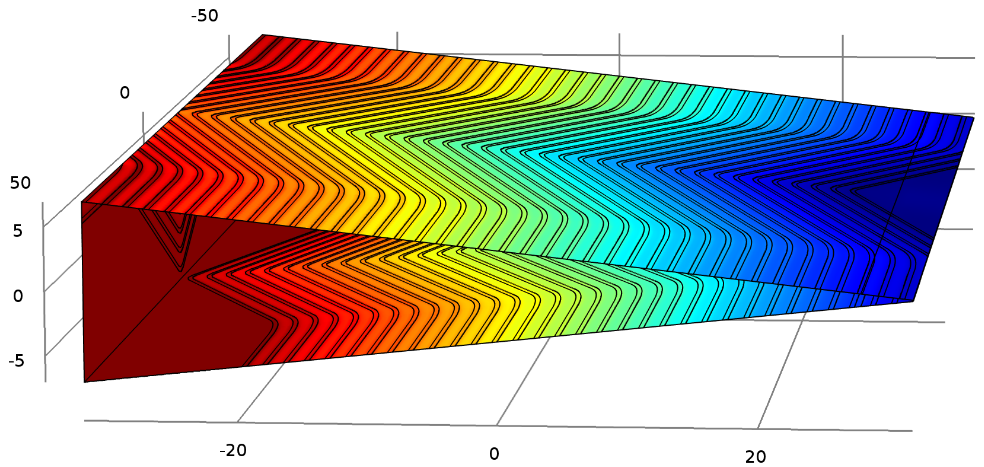


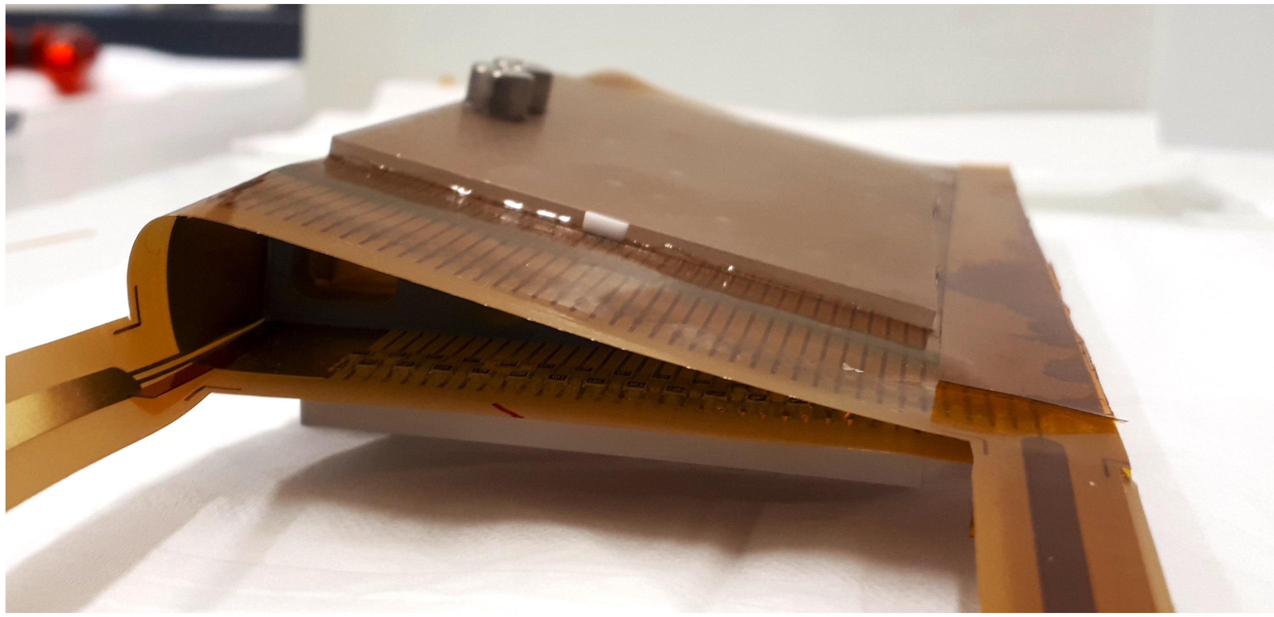
Target construction

- Kapton foil + electrodes with SMD resistors
- Sapphire plates to define temperature



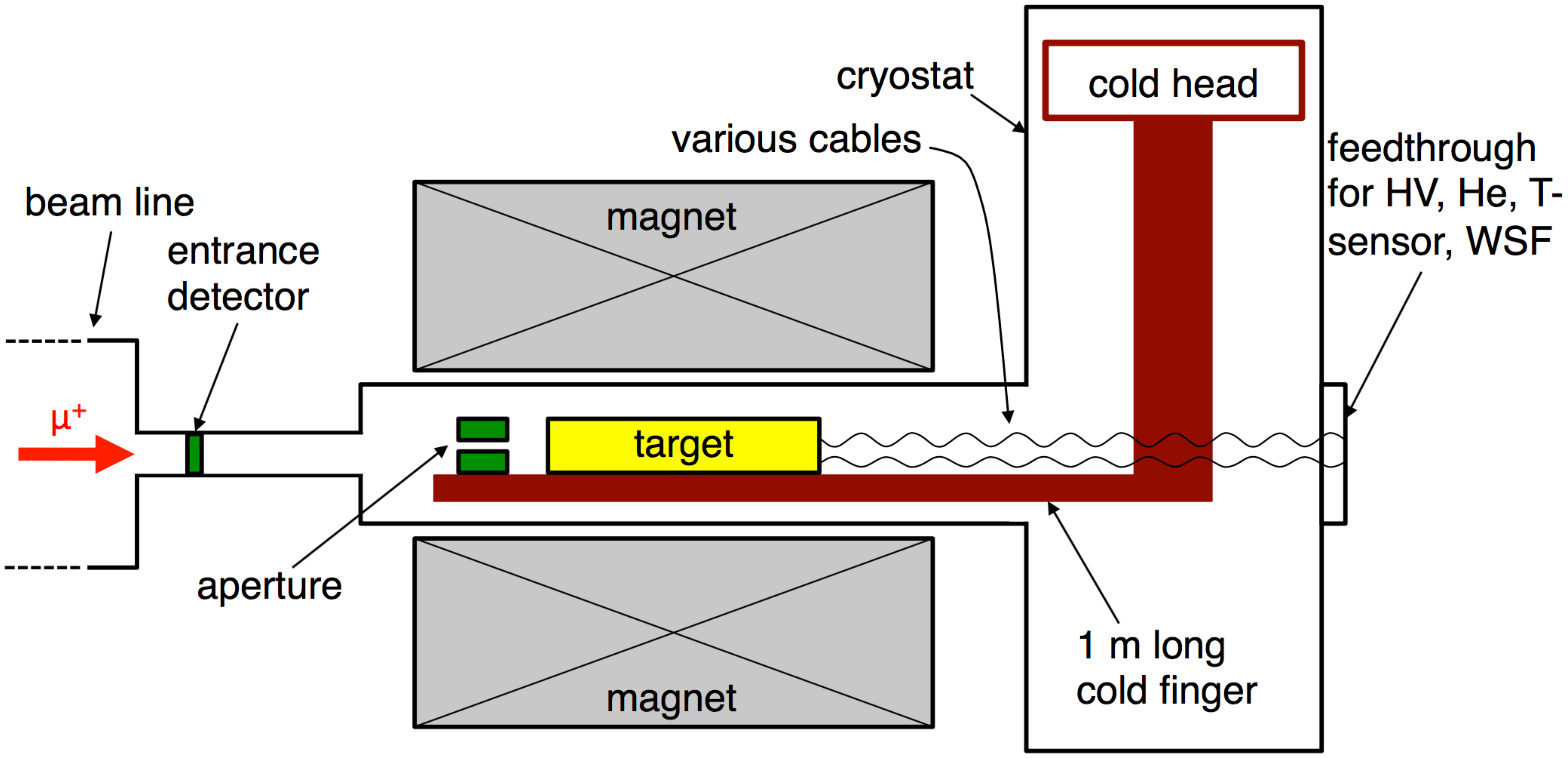
Potential at wall



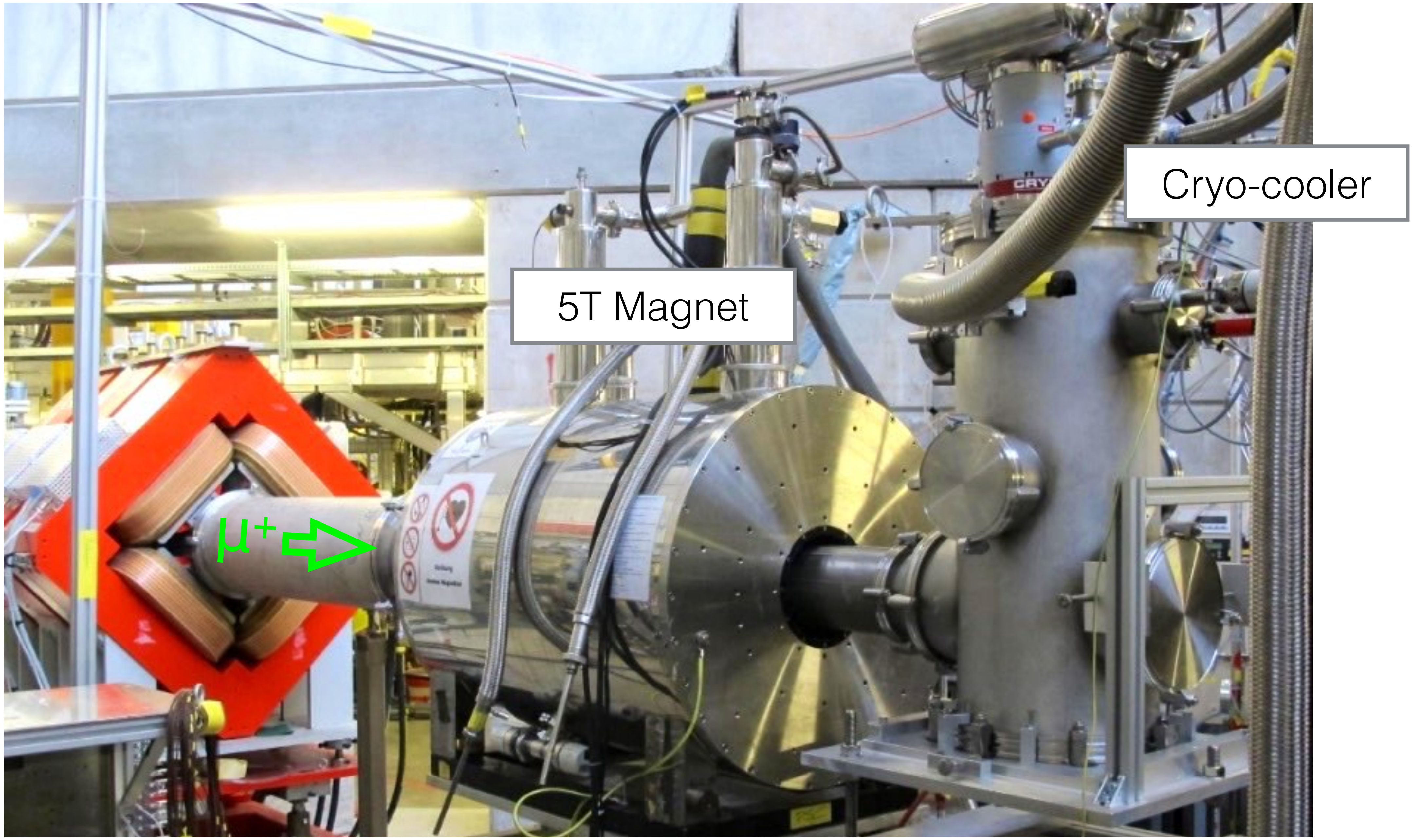


Beam test in 2017

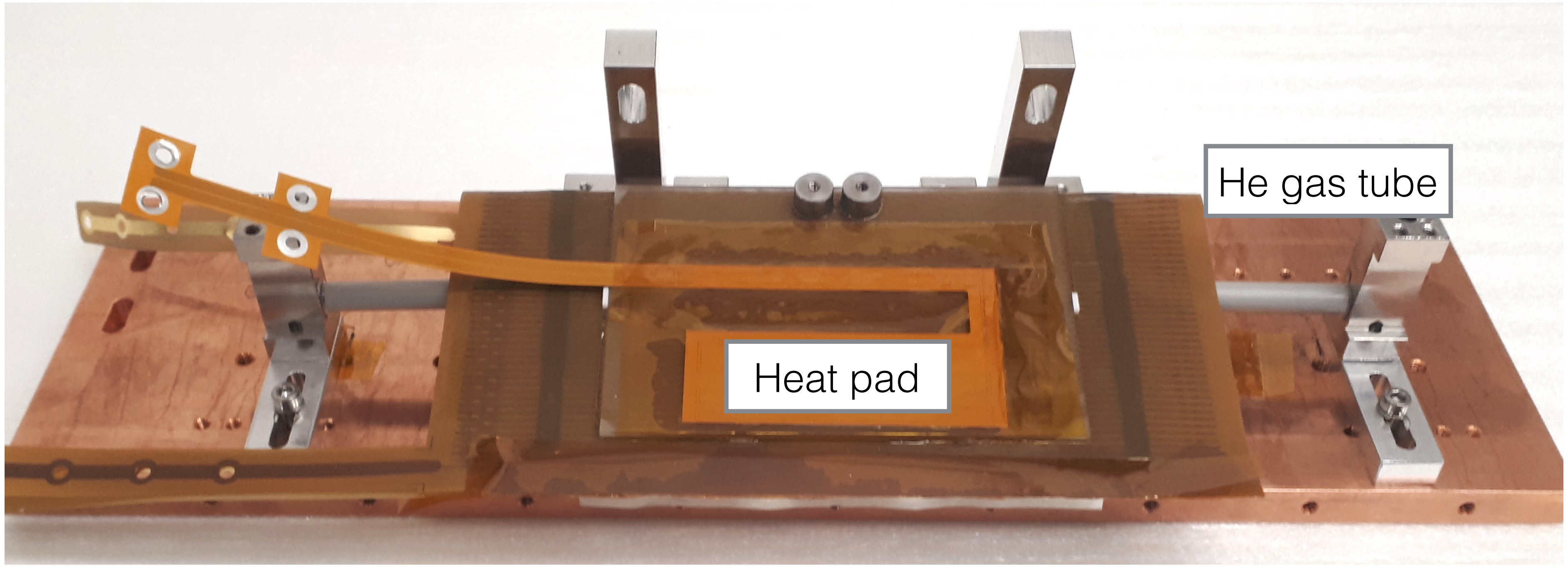
- Goal : demonstrate mixed compression
- Setup

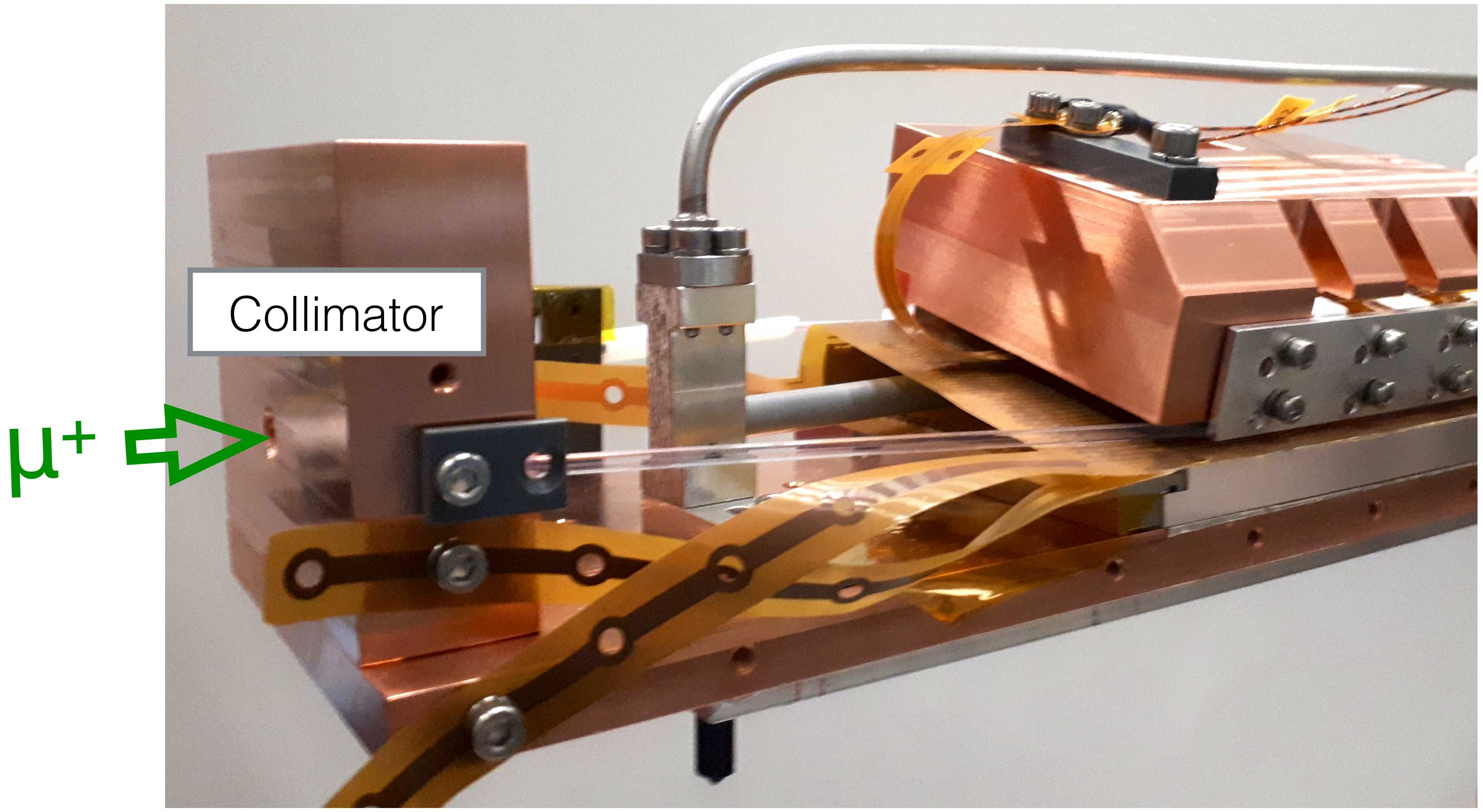


- @PiE1 beam line in PSI

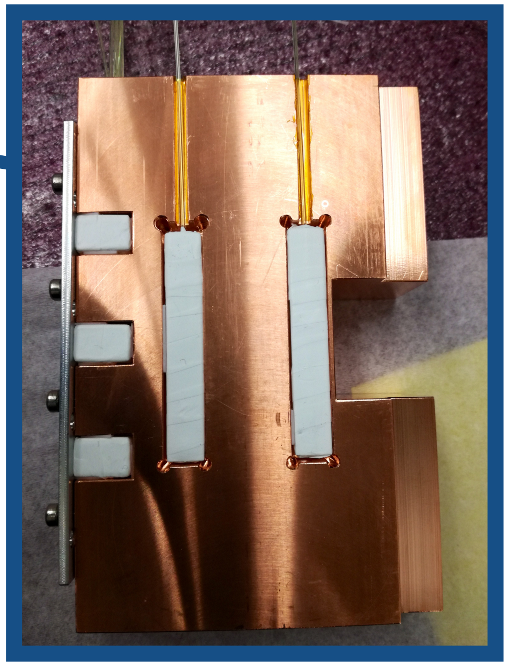


Target installation





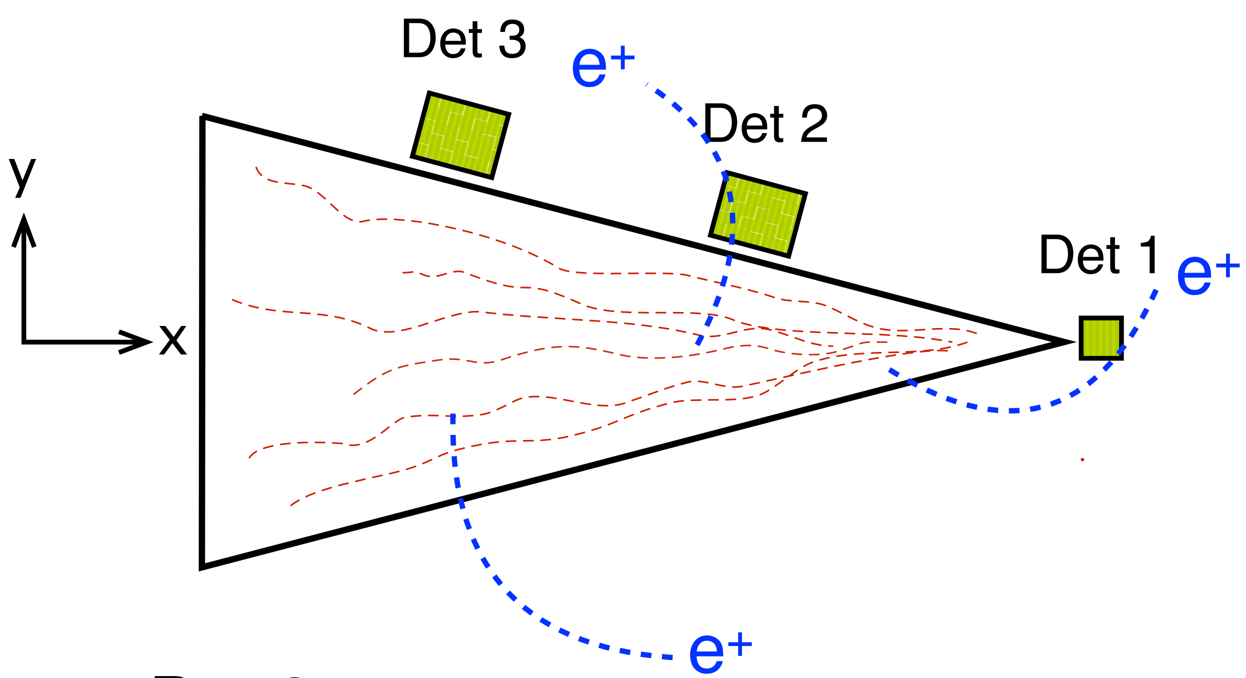
Detector



scintillator
+
WLS
+
SiPM (outside cryo)

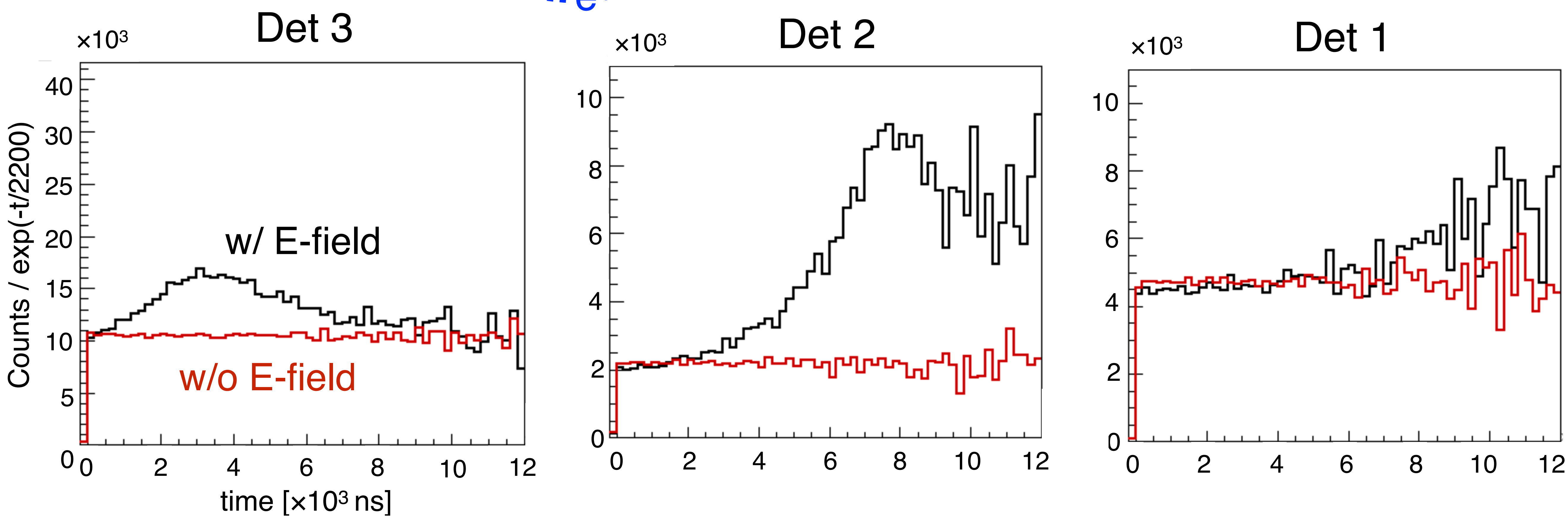
Time spectra of Michel e+

- Drift in x-y direction

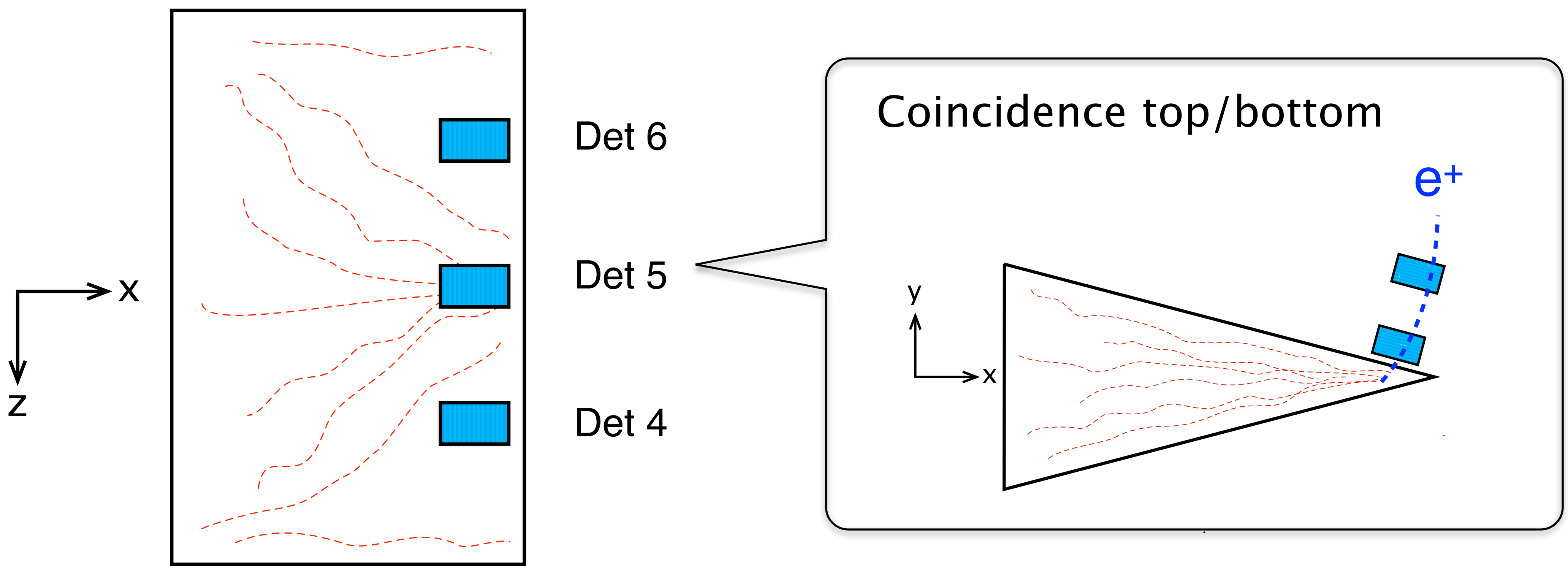


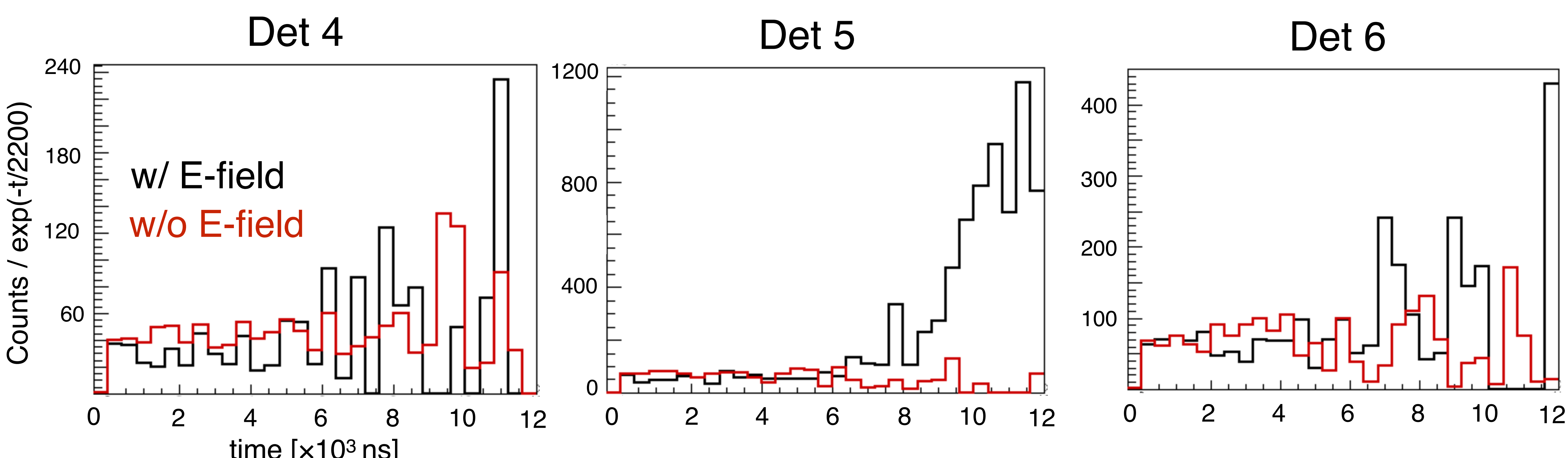
Target condition

$\|E\|$	3.25 kV/cm
$\|B\|$	5 T
E_T/E_L	3.5
T_{top}	30.8 K
T_{bottom}	9.2 K



- Drift in x-z direction

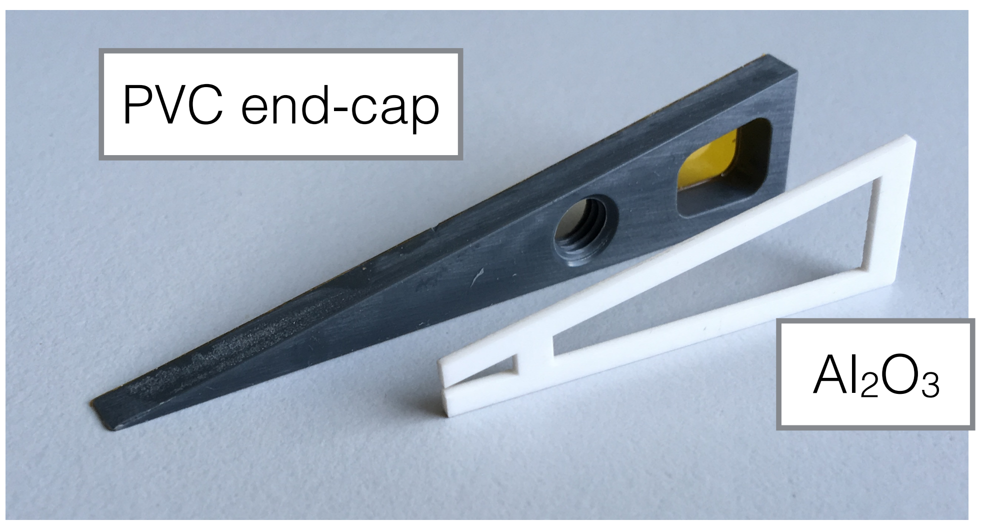




Short term goal

- Improve mixed transverse-longitudinal compression
- E-field strength limited by discharging in He gas

➡ eliminate mechanical support inside target



➡ improve E-field design, investigation of material, ..

Summary

- A device to compress standard muon beam is under development

- Efficient longitudinal / transverse compressions demonstrated separately

- A new scheme with mixed compression partially worked

- Next step : Improve strength of E-field

  Muon extraction from gas into vacuum & acceleration

Backup