Development of a high-brightness low-energy muon beamline

Ivana Belosevic

on behalf of the muCool collaboration

Motivation

Goal: develop a novel tertiary μ^+ beamline with following properties

- sub-eV μ^+
- beam diameter $< 1\ \mathrm{mm}$

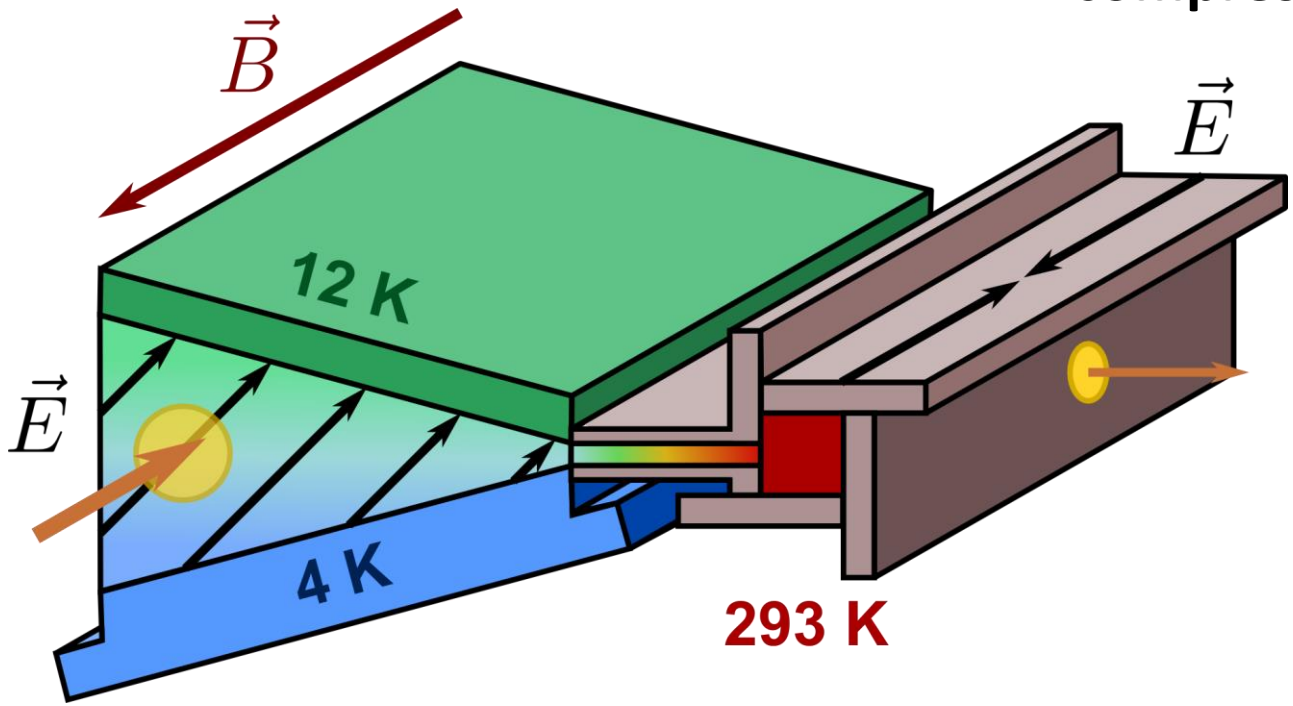
Applications:

- BSM search with μ^+
- Mu ($\mu^+ e^-$) spectroscopy
- micro beam for μSR applications

Working principle

Transverse compression

Longitudinal compression



IN: Secondary μ^+
energy: 4 MeV
diameter: 10 mm

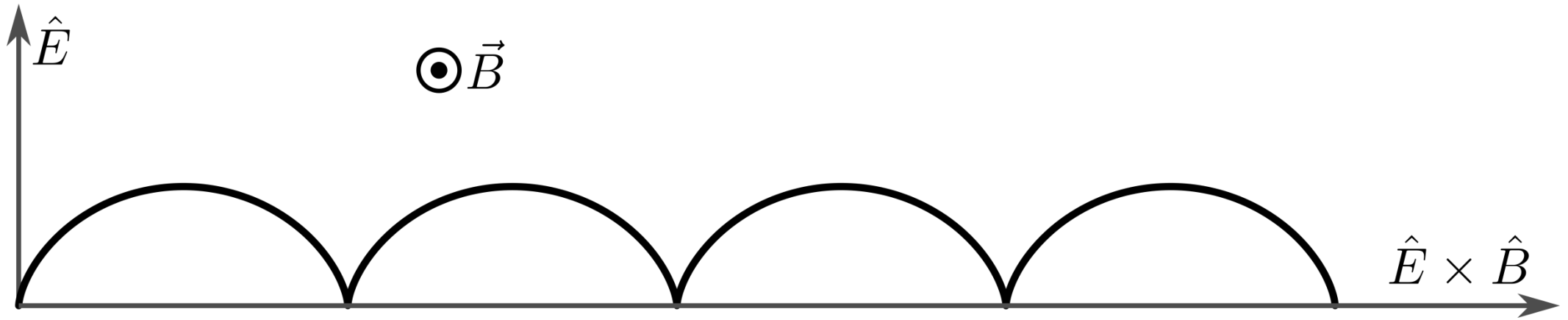
OUT: Tertiary μ^+
energy: <1 eV
diameter: <1 mm

→ Transforms standard μ^+ beam into high-brightness low-energy μ^+ beam

Working principle – drift velocity

Motion of a positively charged particle in crossed $\vec{E}$ and $\vec{B}$ fields

- in vacuum



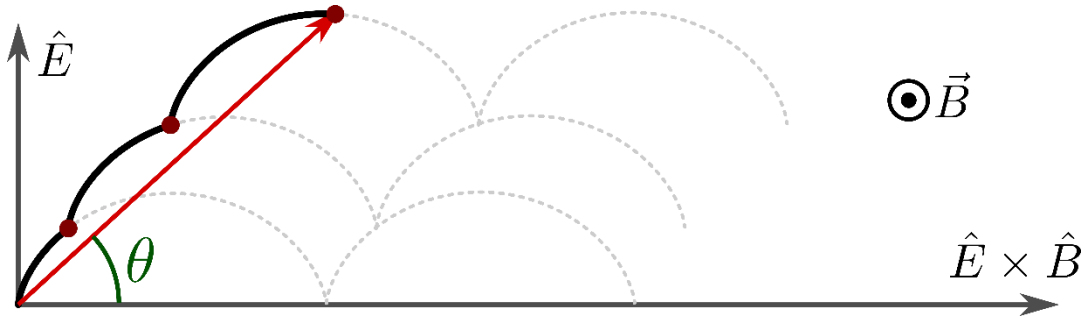
➡ drift in $\hat{E}\times\hat{B}$ direction

Working principle – drift velocity

Motion of a positively charged particle in crossed $\vec{E}$ and $\vec{B}$ fields

- in gas: collisions with gas atoms (frequency f_{col})

high f_{col}:

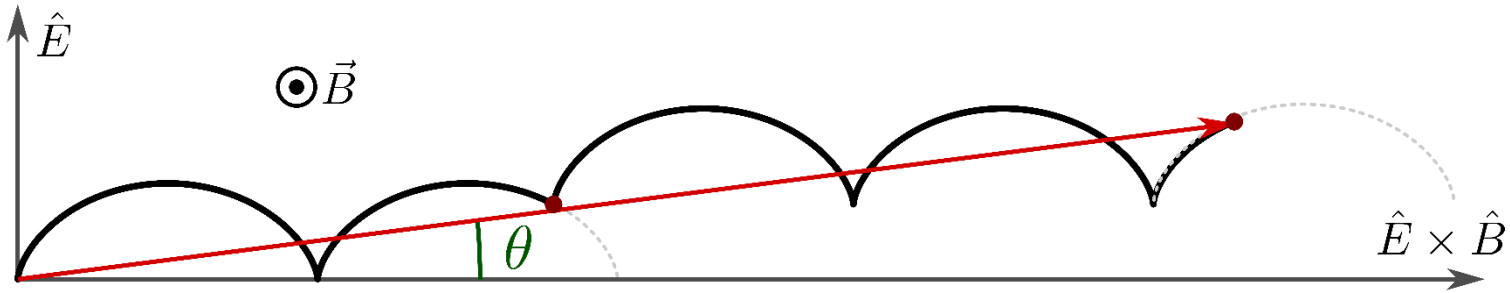


angle between drift velocity and $\hat{E}\times\hat{B}$ direction

$$\tan\theta = \frac{f_{col}}{\omega_C}$$

cyclotron frequency

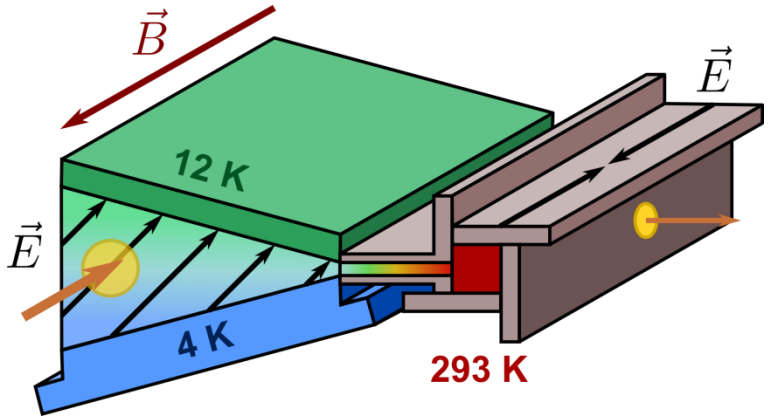
low f_{col}:

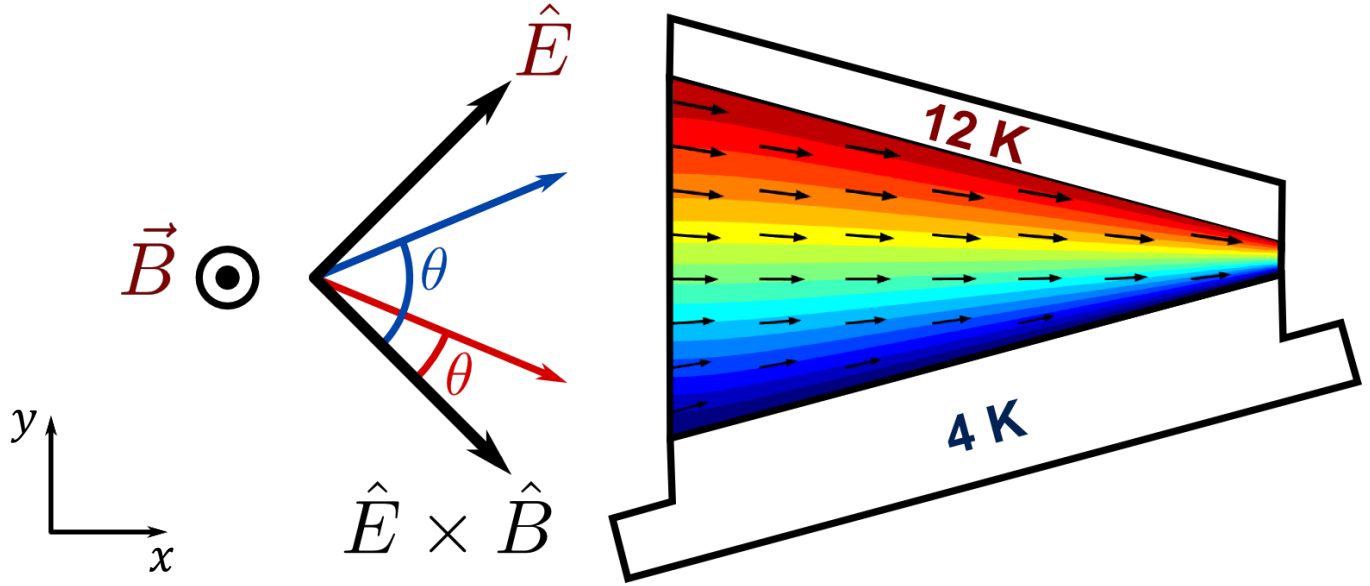


Working principle – transverse compression

- **position-dependent drift velocity → compression**

beamline:

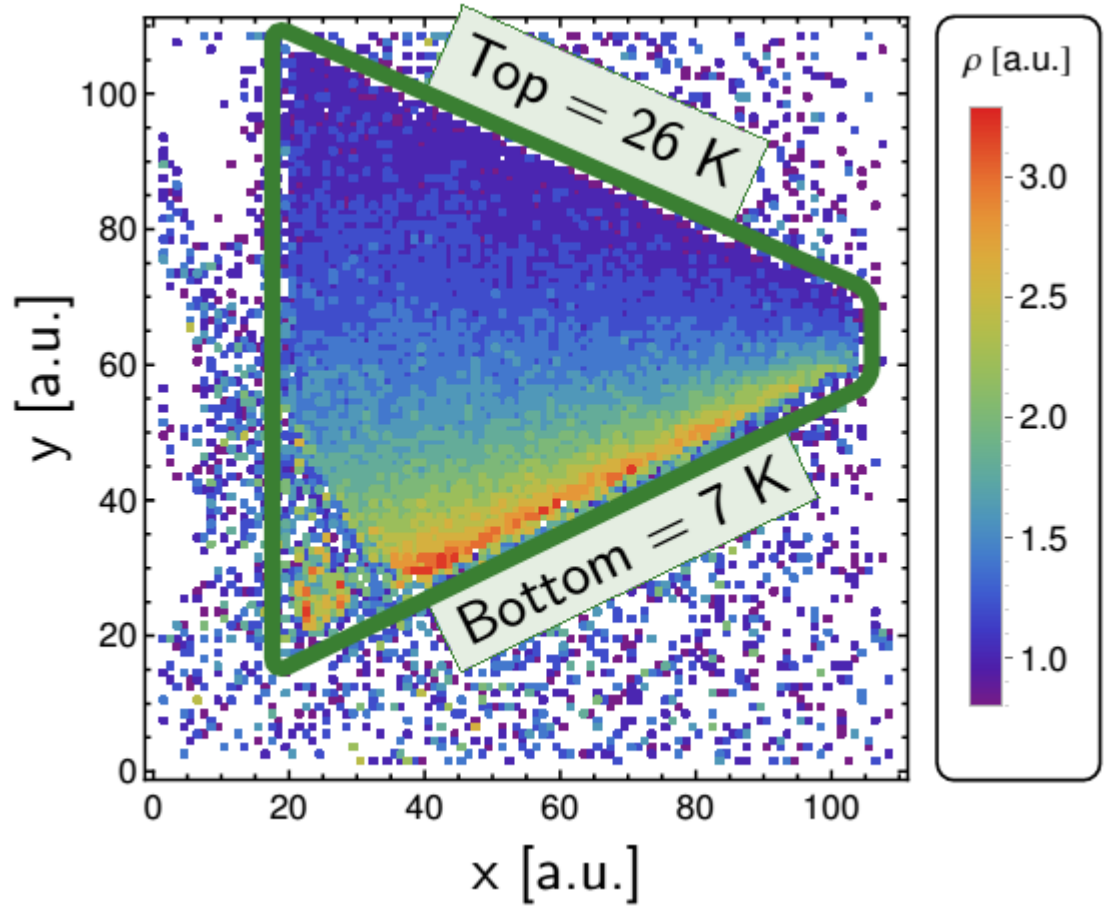




$$\tan\theta(x,y) = \frac{f_{col}(x,y)}{\omega_C}$$

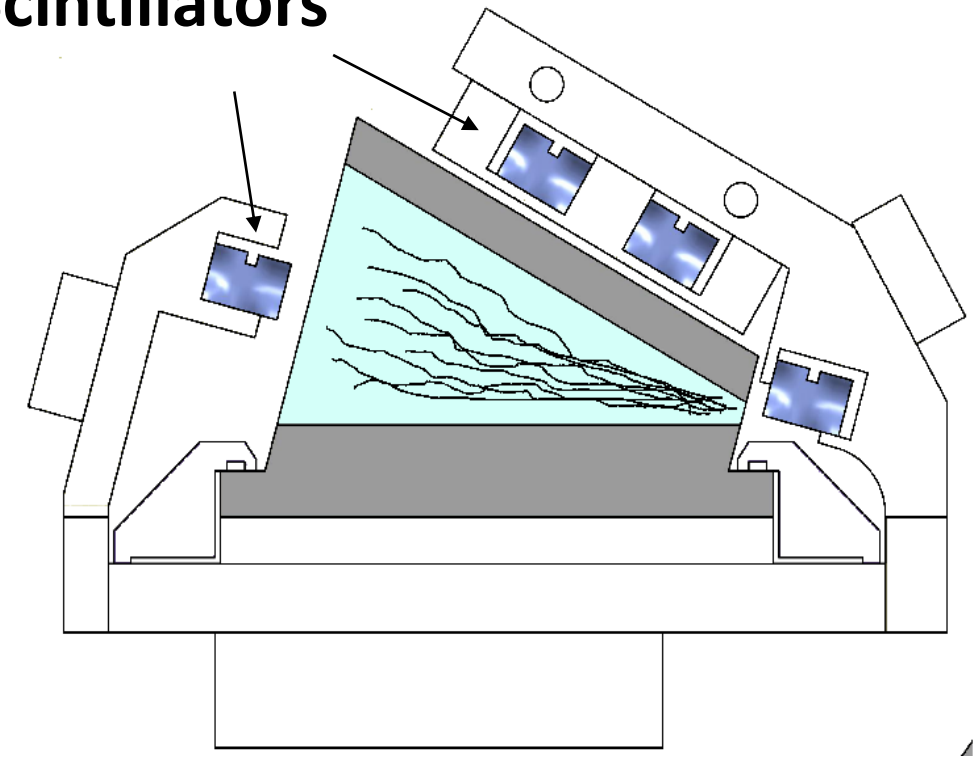
Working principle – transverse compression

- **temperature gradient – demonstrated via neutron radiography in 2013 at PSI**



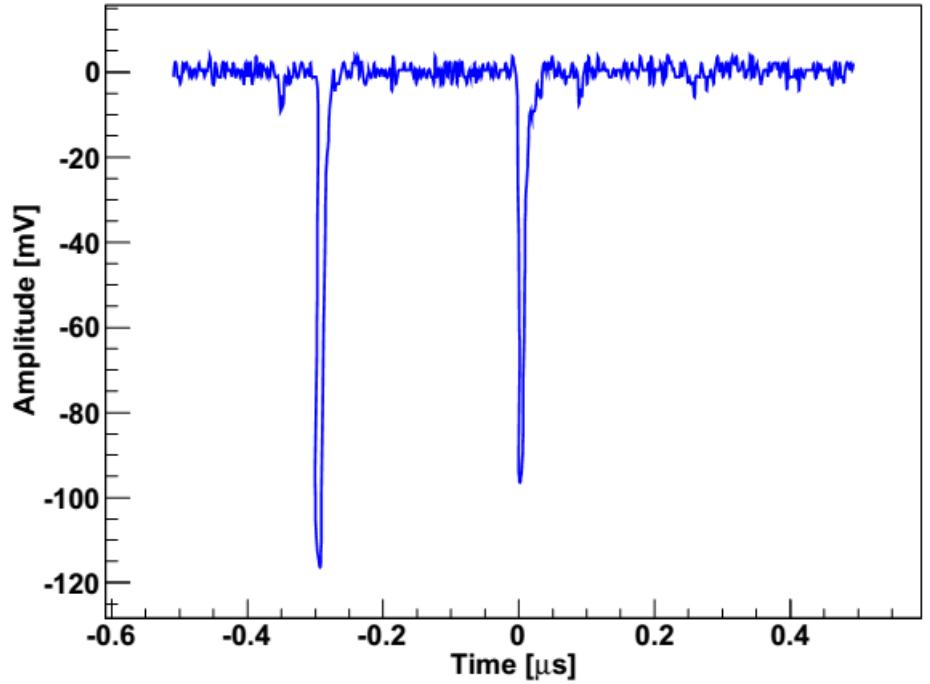
Engineering run setup (Dec 2014)

Scintillators



Scintillator + WSF signal:

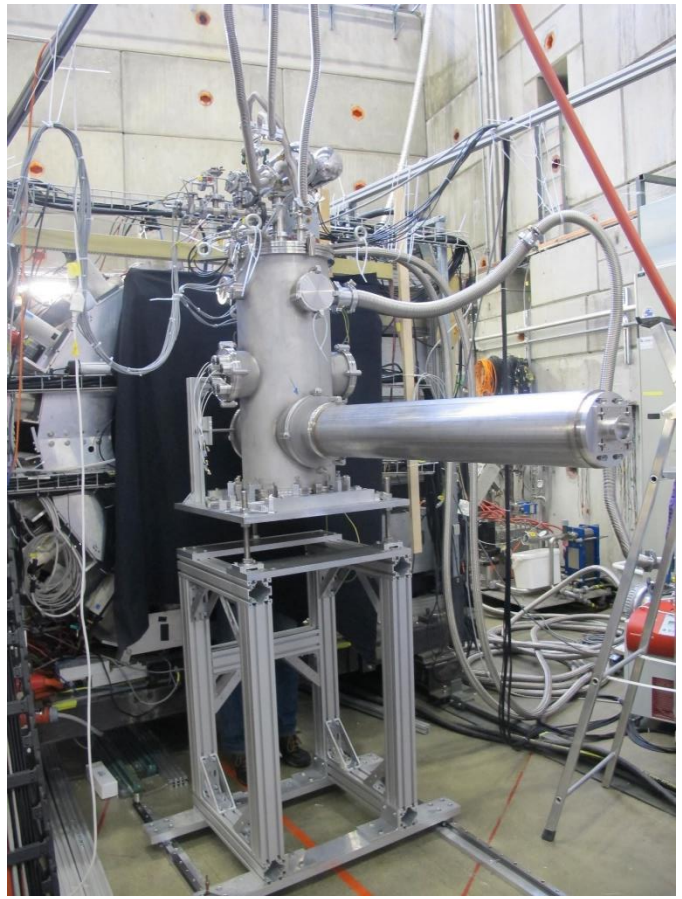
Detected e^+ from μ^+ decay



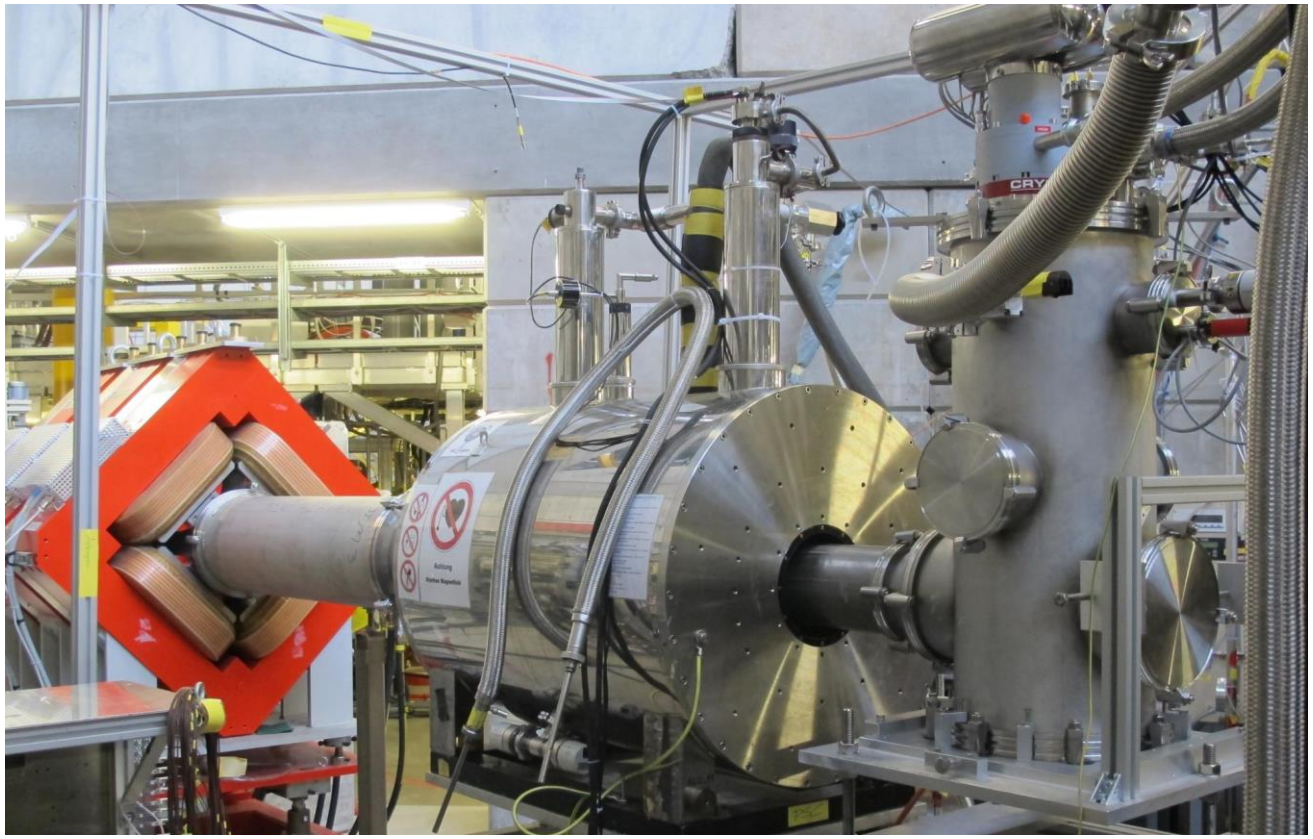
If μ^+ beam is compressed :

more counts in the detectors on the right side

Engineering run setup (Dec 2014)

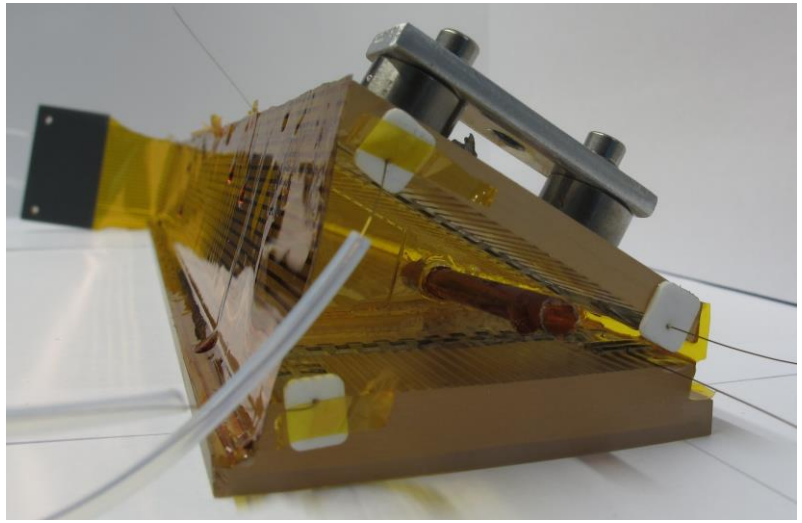


Cryostat with the cold finger



Full setup at πE1 PSI

Engineering run setup (Dec 2014)



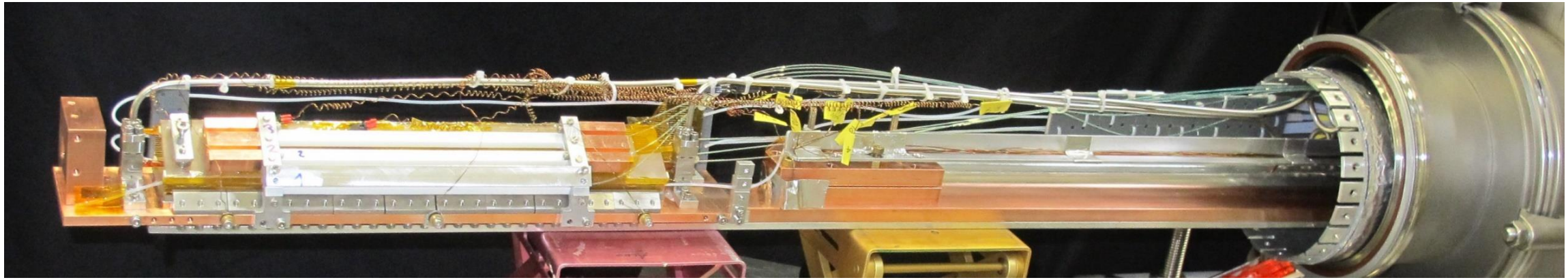
Target

Challenges

- strong electric field (1.8 kV/cm)
- He gas
- temperature gradient

  (from 4 to 12 K)

Target mounted on the cold finger



Transverse compression stage - challenges

Problems

(in engineering run 2014):

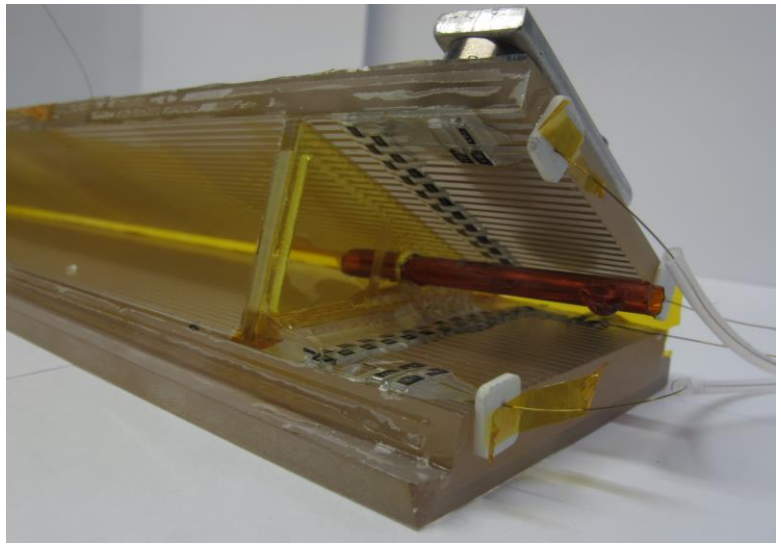
- HV connections
- breaking of the voltage divider on sapphire
- electrical breakdown in He
- leak tightness

Transverse compression stage - challenges

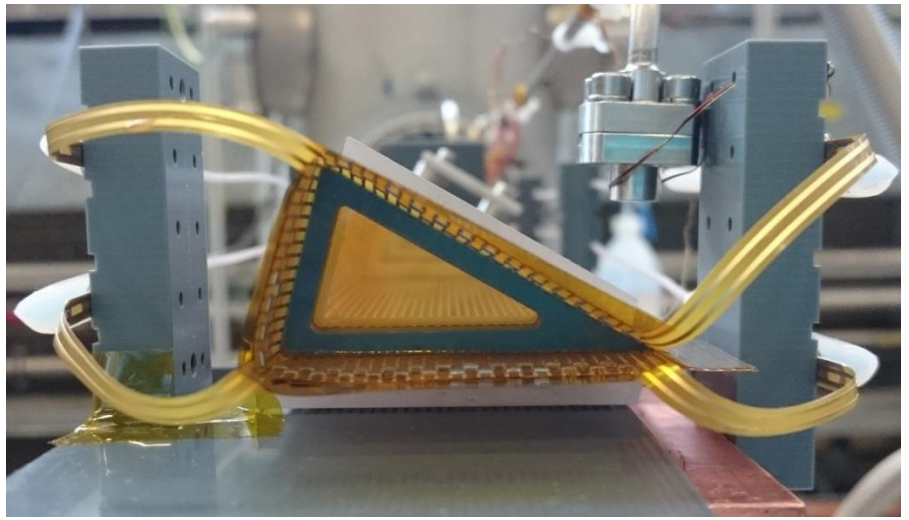
Problems

(in engineering run 2014):

- HV connections ✅
- breaking of the voltage divider on sapphire ✅
- electrical breakdown in He
- leak tightness ✅



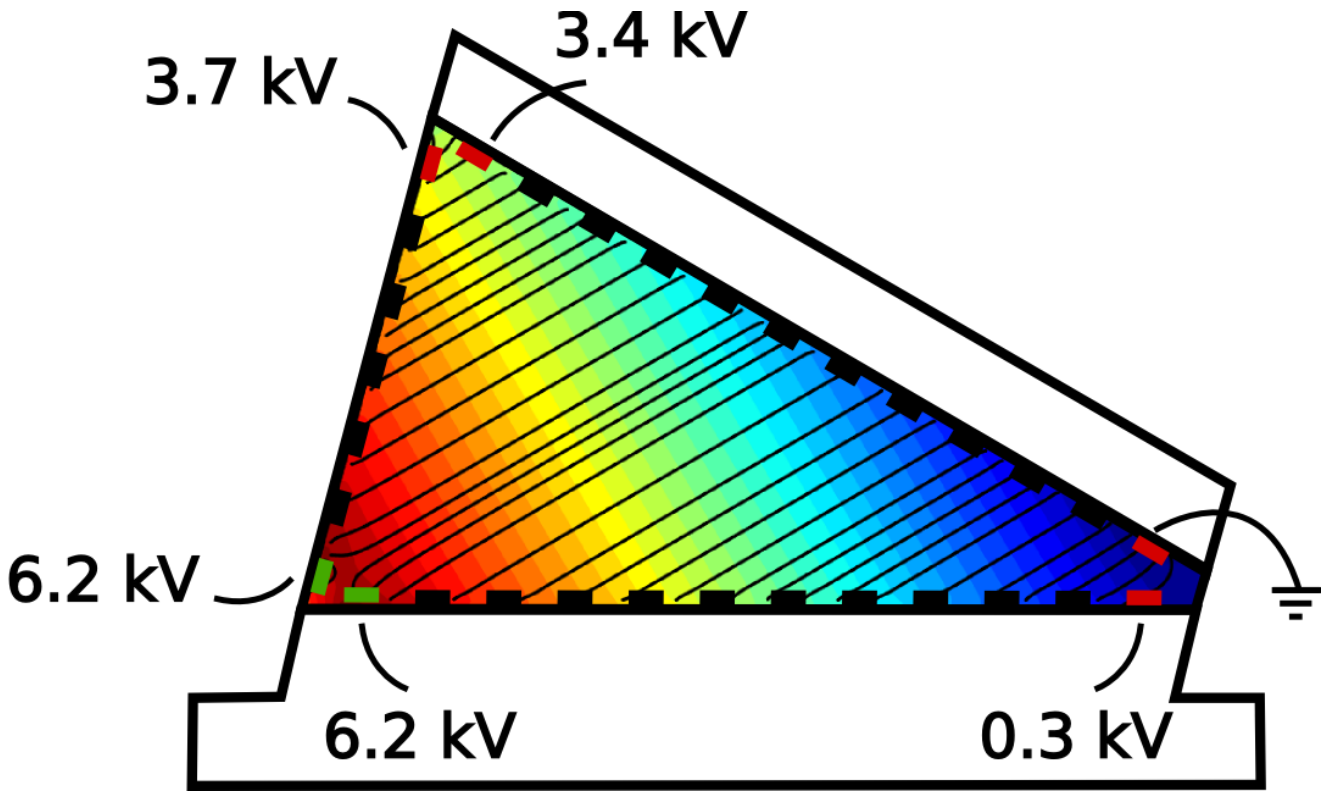
Engineering run



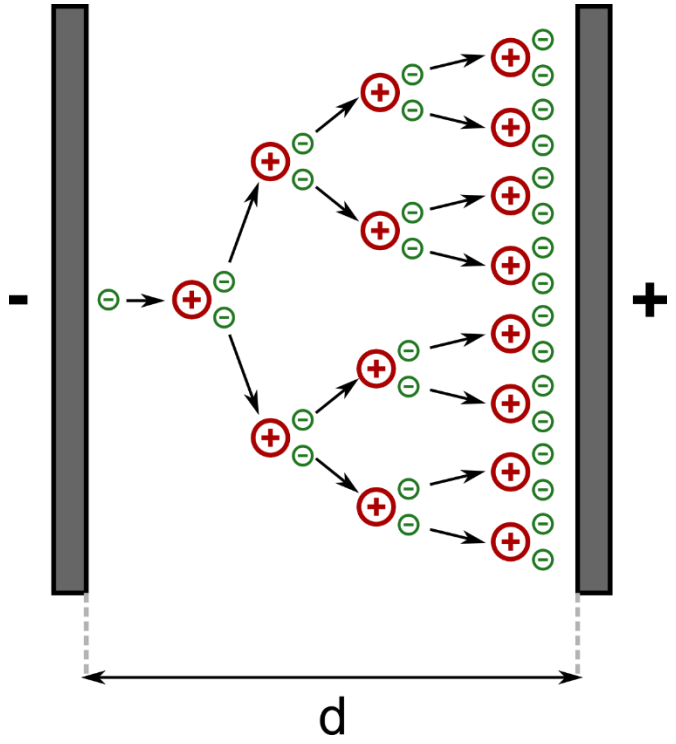
Now

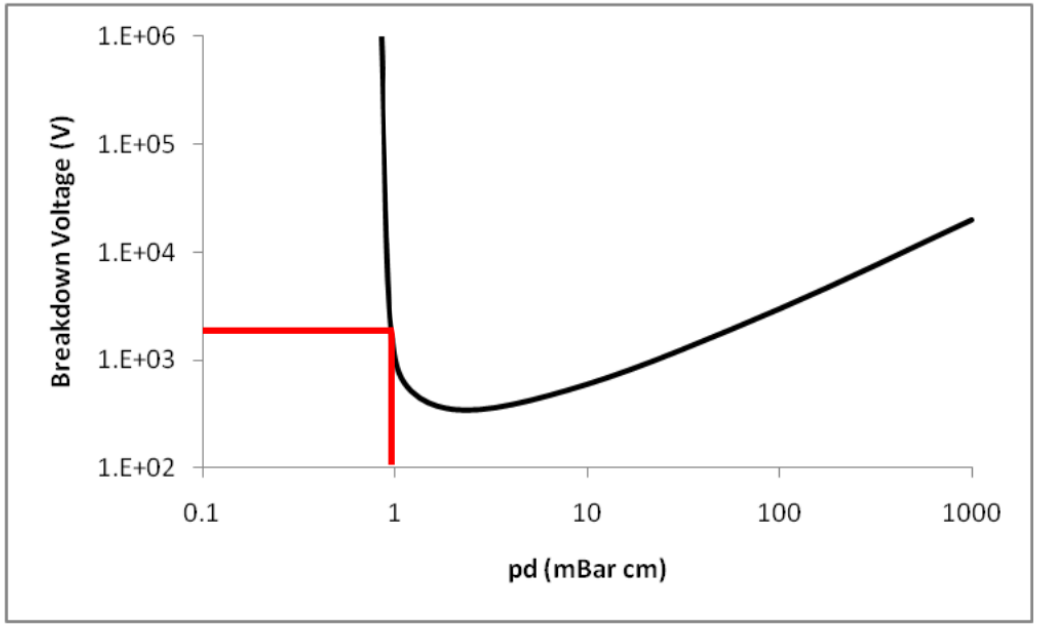
Electrical breakdown

We need high electric field (1.8 kV/cm) in He gas:



Electrical breakdown

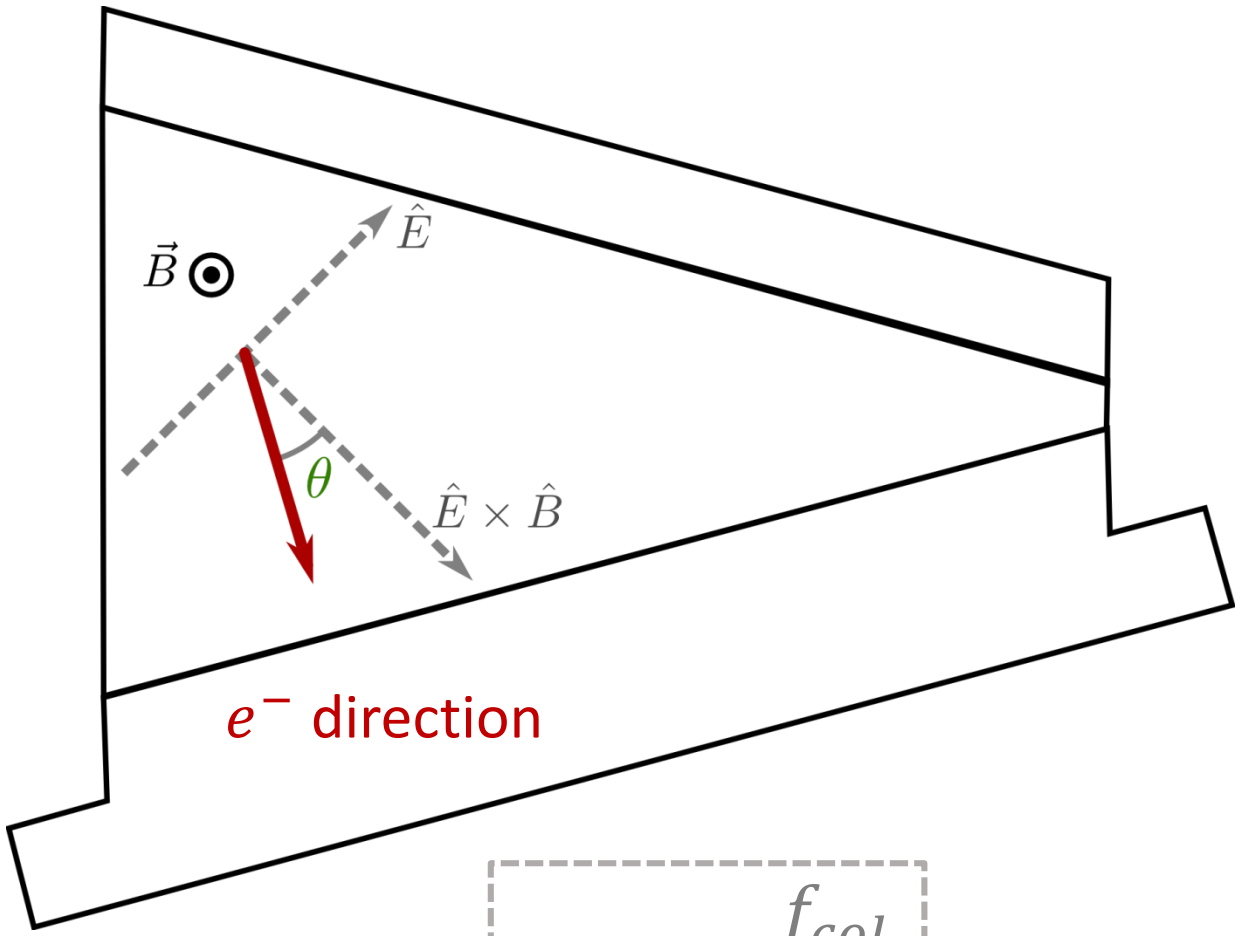


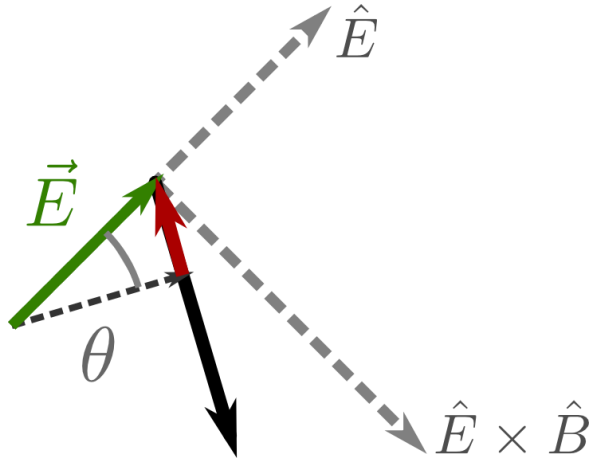


- **primary ionisation**: e^- ionise the gas
- **secondary ionisation**: gas ions hitting cathode → more e^- emitted

Paschen curve: breakdown voltage depends on the product of density and gap distance

Electrical breakdown in magnetic field





decreased electric field
in direction of motion:

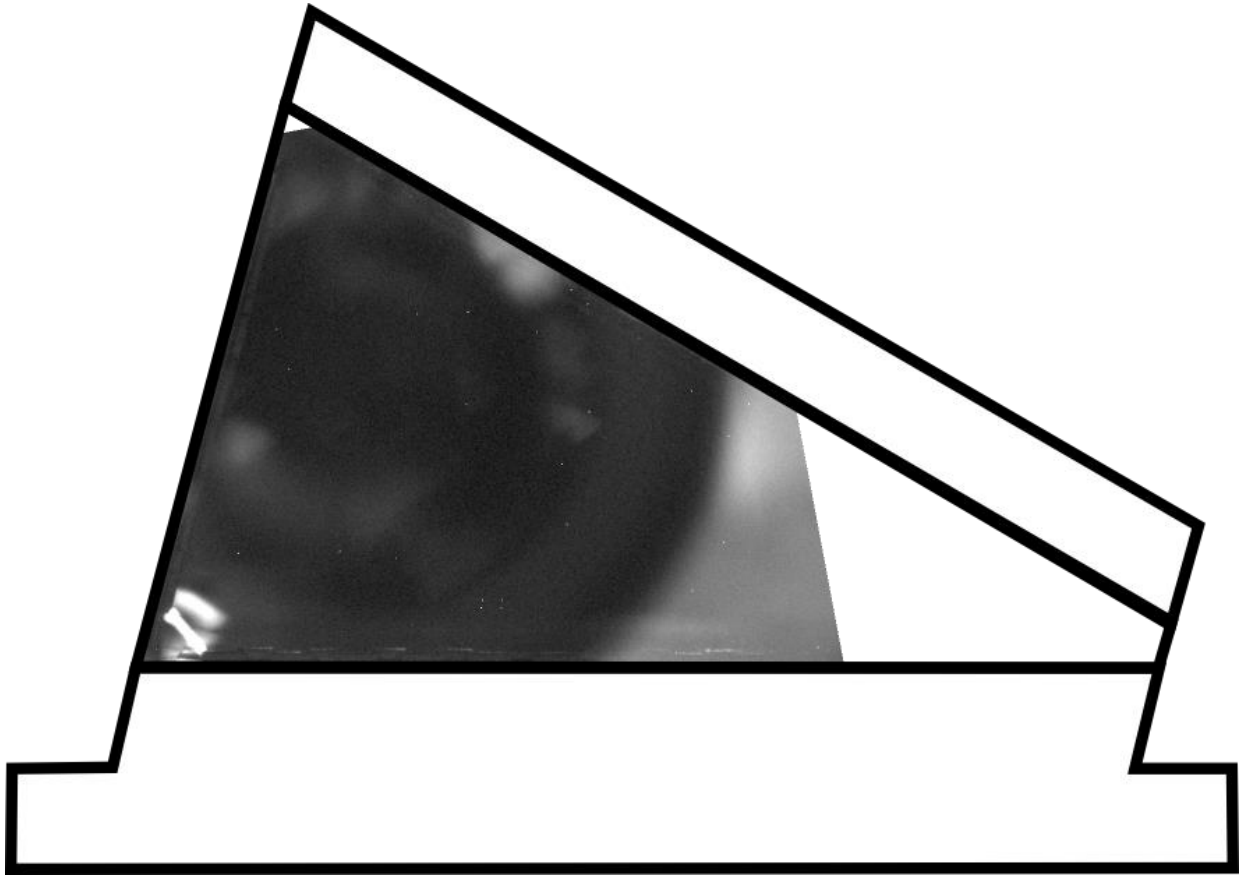
$E \rightarrow E \sin\theta$

$$\tan\theta = \frac{f_{col}}{\omega_C}$$

→ **equivalent to increased gas density**

Electrical breakdown

Discharge at room temperature, without magnetic field:



Conclusion

Transverse compression target development ongoing:

- ✅ temperature gradient demonstrated
- ✅ cryogenic temperatures reached
- ✅ HV connections and divider working at cold
- ✅ leak tightness
- ❓ electric field in He gas

→ See next talk for longitudinal compression