Research and Development on

Frictional Muon Cooling

MPI Project Review 2006

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Why Muon Collider?

Electron collider	Hadron collider
clean environment – only e^+e^-	only two partons interact – the rest → QCD junk
strong synchrotron radiation ⇨ large energy losses ⇨ large radii, linear collider (LEP ≈ 200 GeV)	negligible synchrotron radiation ⇨ higher energy for the same radius (LHC ≈ 14 TeV)
energy of e^+e^- interaction known exactly	exact energy of qq interaction unknown – range of qq energies for a given pp energy
suitable for precision measurements	suitable for discoveries

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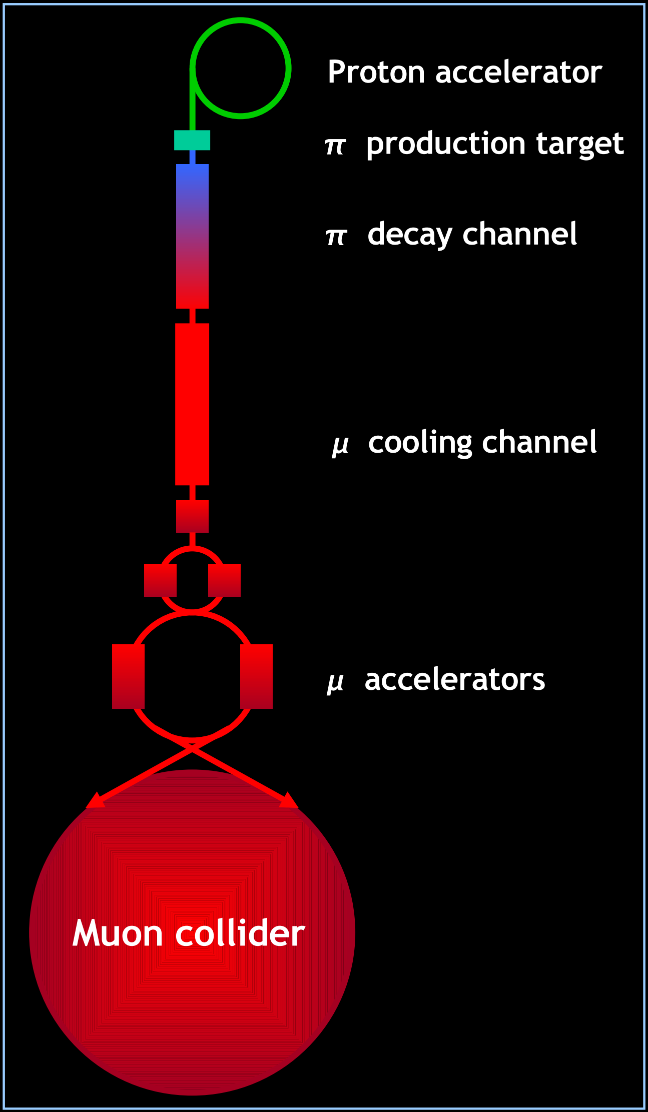
Muon collider

Muon Collider



Problems

Muons decay with $\tau_\mu = 2.2\ \mu s$

→ need a multi MW source
2-16 GeV (10^{22} p/year)
⇨ **large starting cost**

→ large experimental background
lots of high energy $e^\pm$ from $\mu^\pm$ decay

→ limited time for cooling, bunching, and accelerating
⇨ **need new techniques**

Muon cooling

→ emittance reduction of the μ beam by 10^6 required for a collider

Frictional Muon Cooling

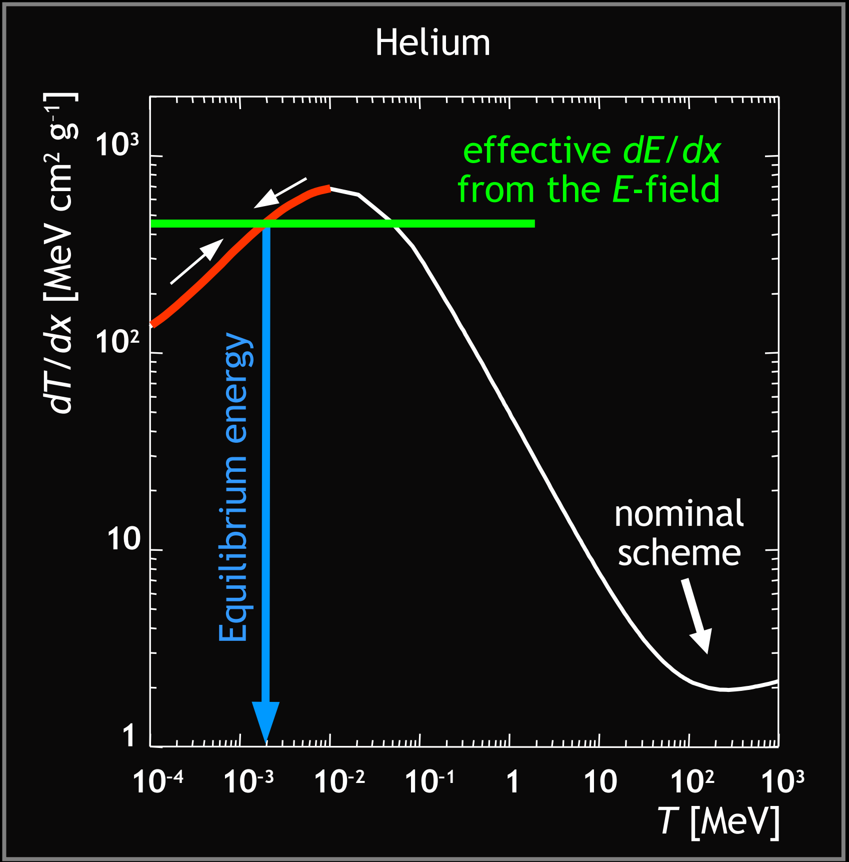
(similar idea first studied by Kottmann et al. at PSI)

– let muons pass through a slowing-down medium

– bring muons to kinetic energy *T* where *dT/dx* increases with energy

– apply const. accelerating ***E*** field resulting in **equilibrium energy**

– large ***dT/dx*** at low ***T***
⇨ low average density of stopping medium ⇨ **GAS**



Frictional Muon Cooling

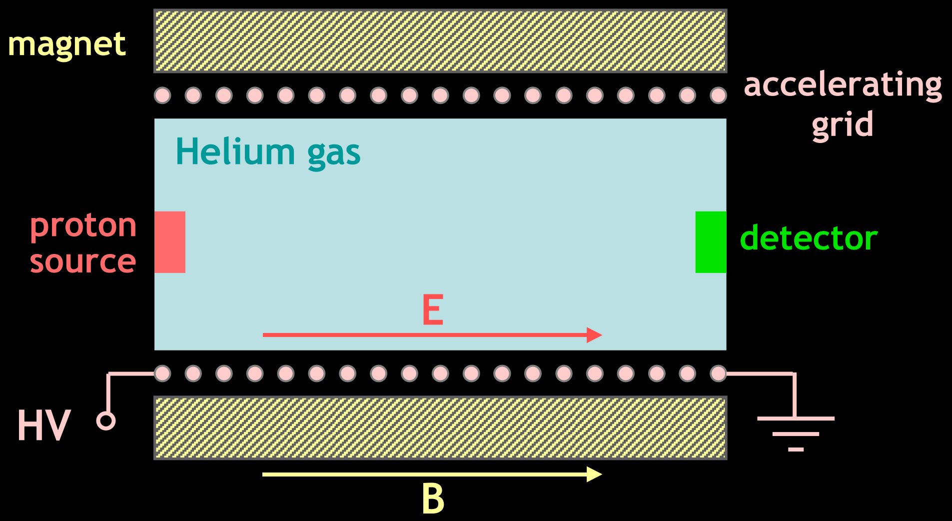
– simulation of the whole muon collider front-end based on frictional muon cooling → **cooling factor of 10^7 simulated** (NIMA 546, 356, 2005)

– experimental demonstration of frictional cooling is still necessary:

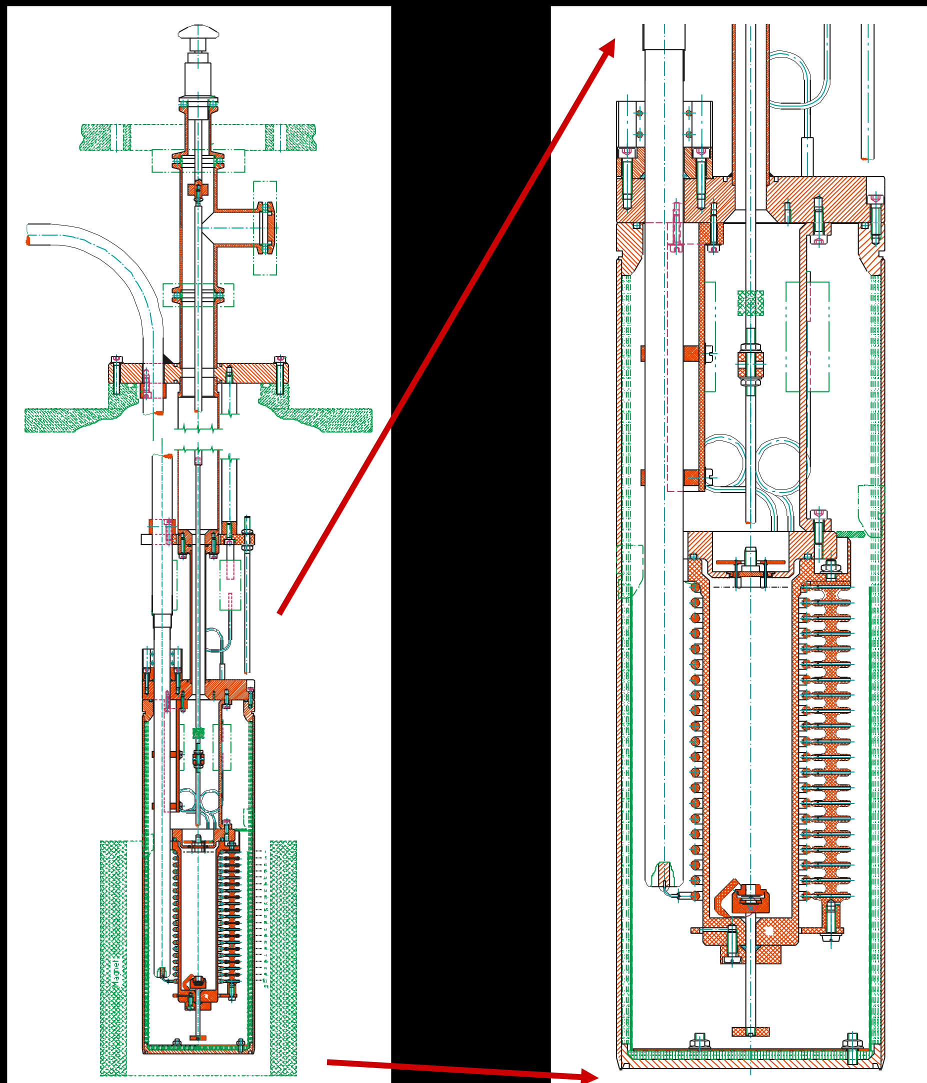
⇨ **Frictional Cooling Demonstration Experiment (FCD)**

– demonstration of frictional cooling principle on protons

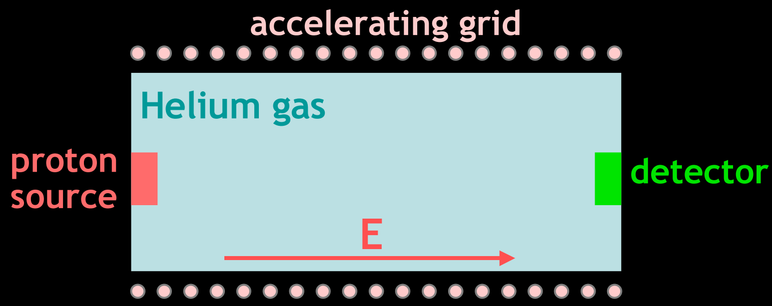
→ should work for any charged particle

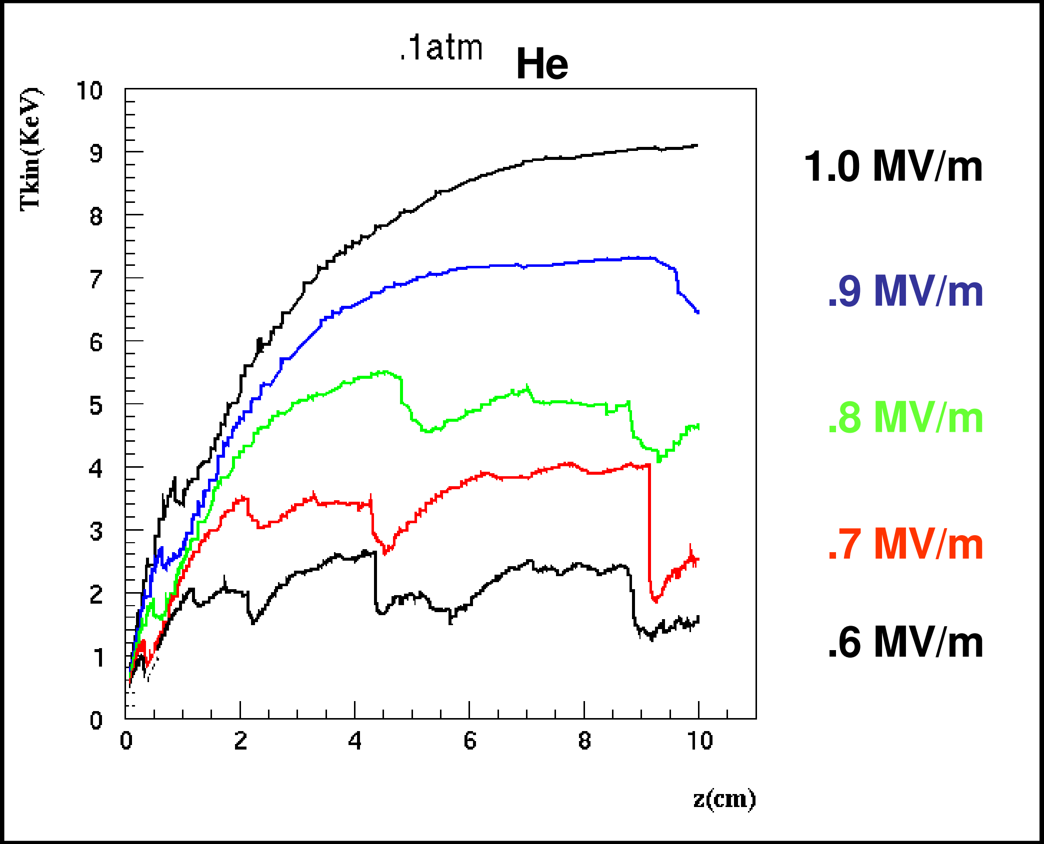


FCD – Construction



FCD – The Goal





We are able to vary
- pressure/density of the gas
- detector-source distance
- strength of the ***E*** field

Can our MC simulation predict equilibrium energies?

FCD - Status

Construction and HV grid

– ready and tested for some time now

Detector & Read-out electronic

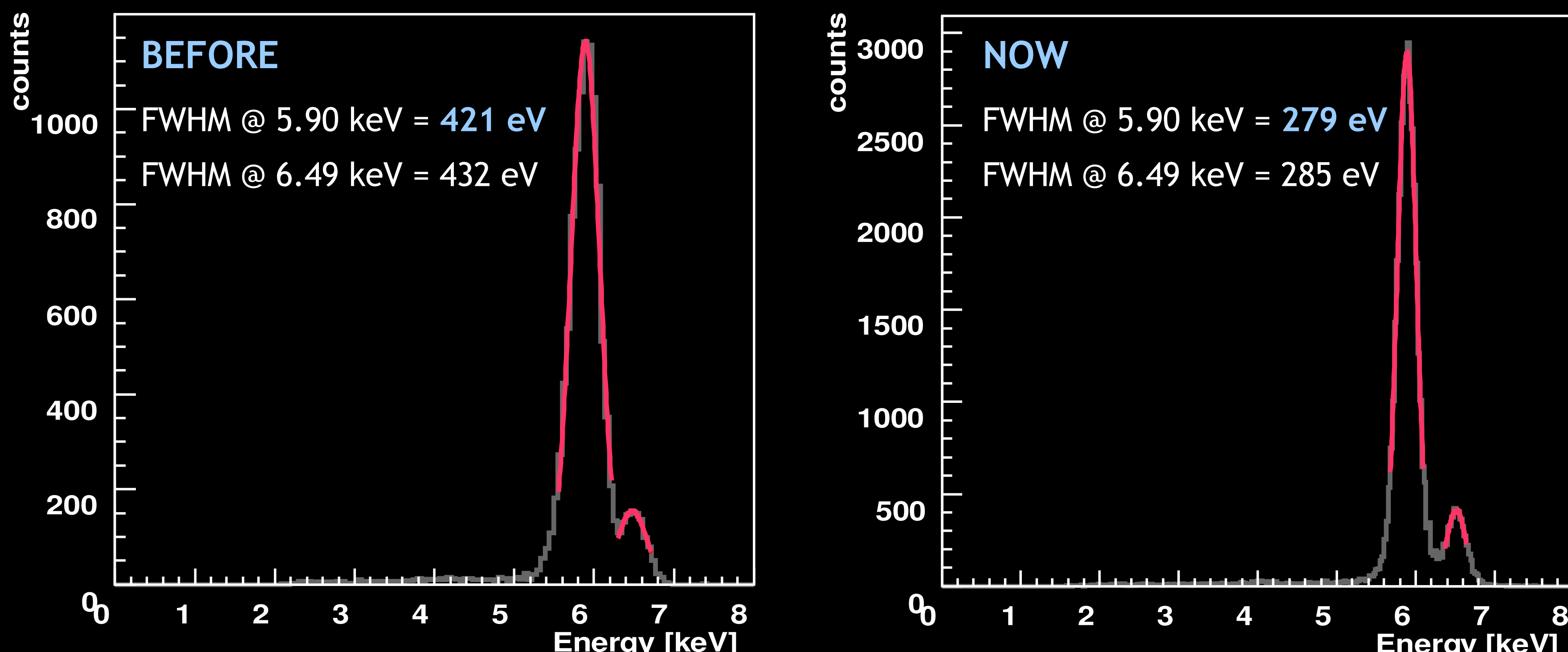
– Silicon Drift Detector (SDD) from HLL + in-house made read-out
– in spring 2005 it turned out we have to re-design our read-out from scratch → expected time required by the electronic dept. → 6 months

At present

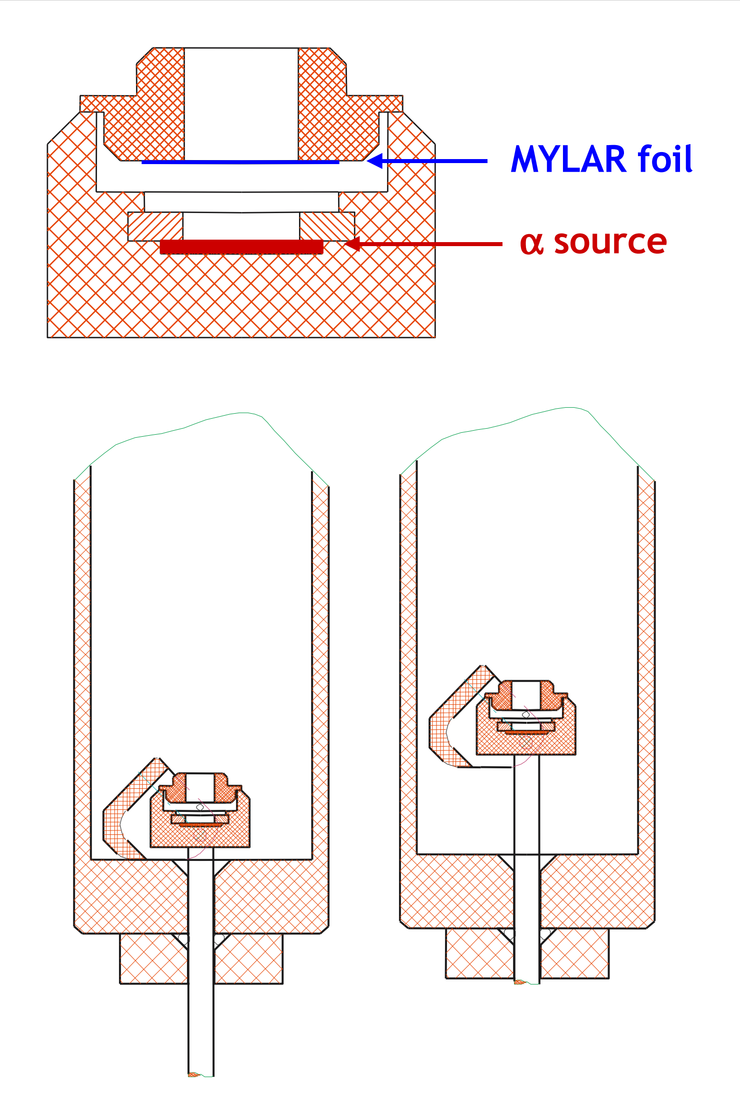
– new read-out designed and working
– resolution improvement
– lot of improvements on filtering out the noise
– successful SDD operation with the HV grid ON at up to 20 kV

FCD – Detector resolution

– testing and calibration with the ^{55}Fe source
– clean spectrum with two X-ray lines at 5.9 keV and 6.49 keV
– improvements on grounding, shielding, read-out and DAQ
– further improvement possible, aim is ~ 200 eV



FCD – Proton source

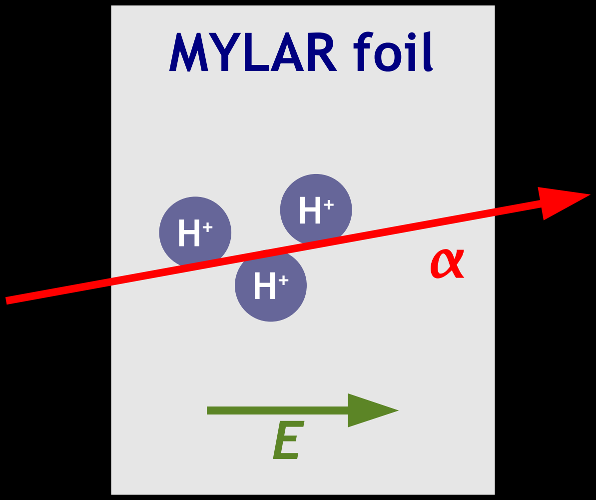


– strong α source → ^{241}Am (74 kBq)

– hydrogen rich plastic foil → MYLAR

– free protons by e^- stripping from H atoms

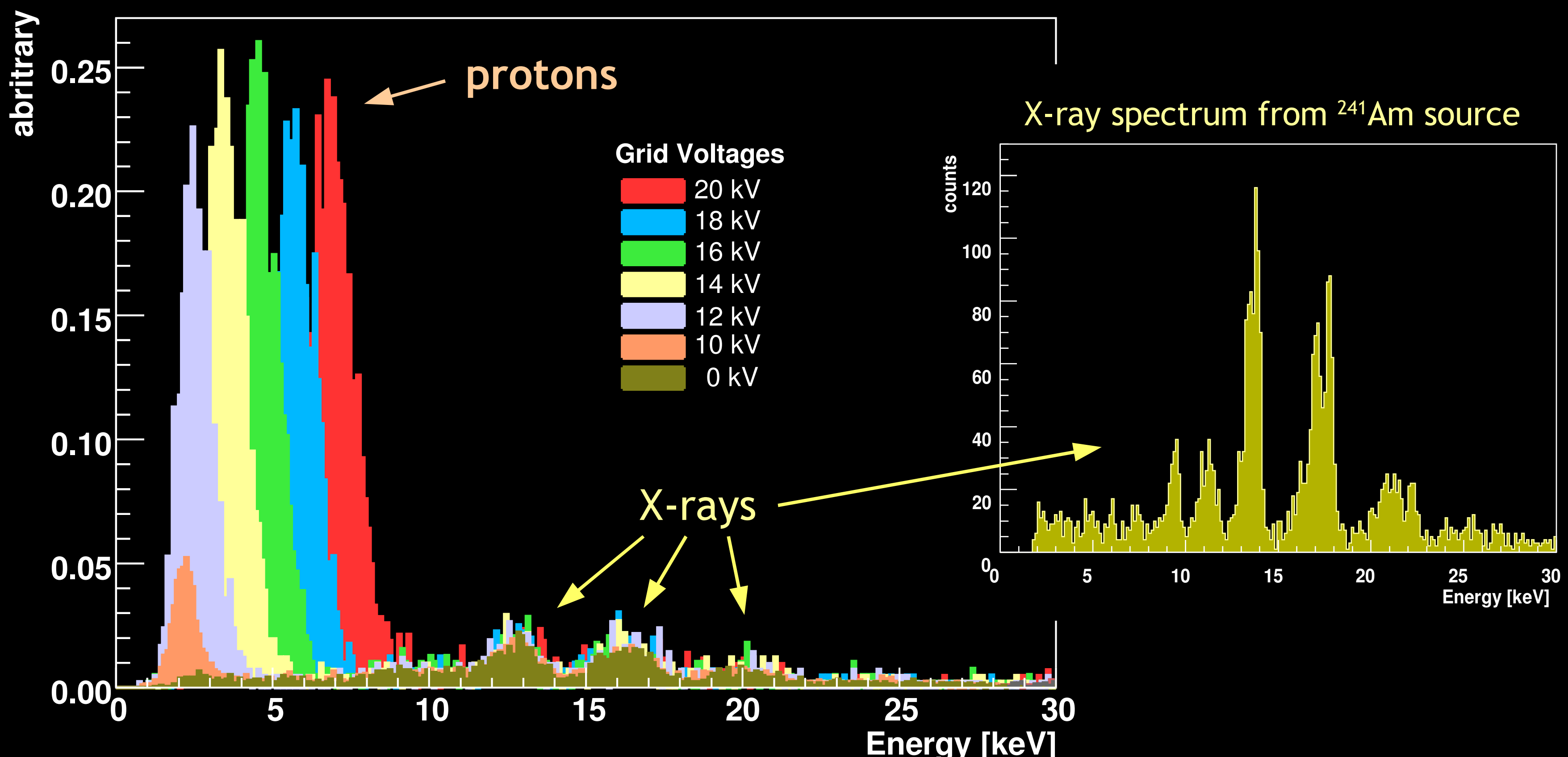
– due to electric field protons will drift and eventually escape from the foil



FCD – Proton spectra

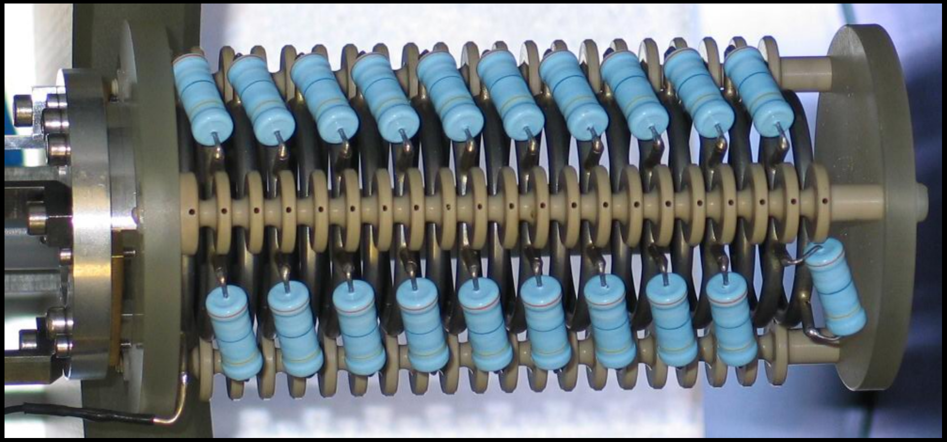
– energy spectra measured for different applied grid voltages with an α source covered with a 23µm MYLAR foil

– proton peak is moving with applied voltage



FCD – Other components

- superconducting magnet commissioned and ready
- accelerating grid tested up to 90 kV
- gas pressure control system installed and tested



Summary & Outlook

– we can produce and detect protons

– thorough understanding of the proton source
  Diploma thesis of D. Greenwald
  ↪ Characterization of the proton source for the FCD experiment

– work on further resolution improvement

– once we fully understand the proton source, we move to the magnet

– demonstrate the frictional cooling