Research and Development on
Frictional Muon Cooling

MPI Project Review 2004

December 13-14 2004

Allen Caldwell	***Responsible Director***
Raphael Galea	*Guest scientist - Columbia University, New York*
Claudia Büttner	*Postdoc*
Daniel Kollar	*Postdoc*
Daniel Greenwald	*Technical Support*

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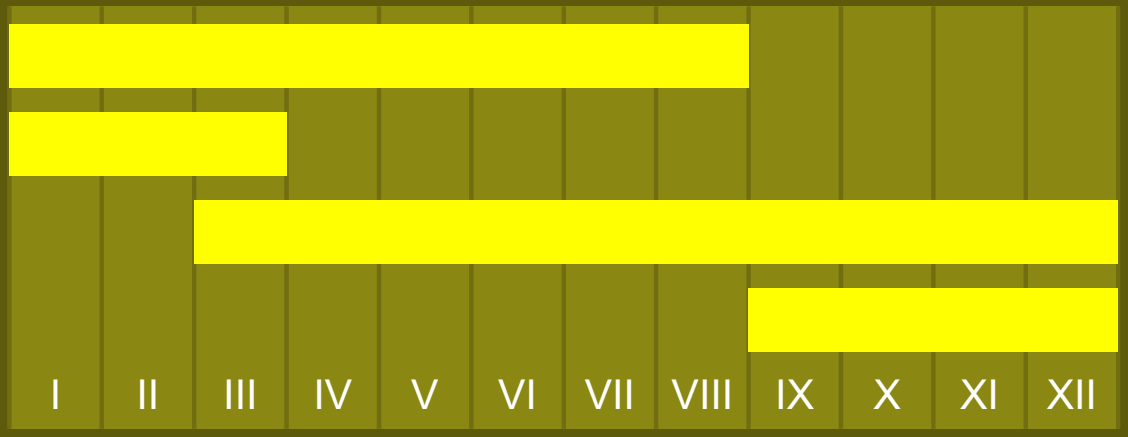
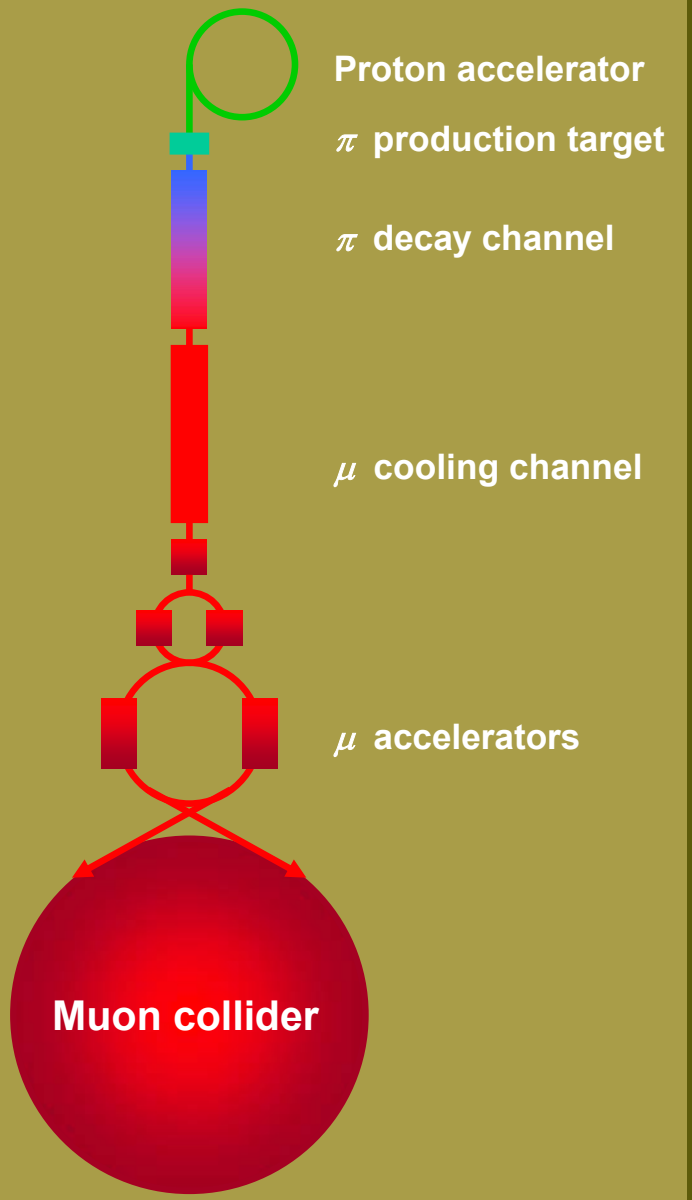


Outline

- muon collider
- frictional muon cooling
- FCD experiment at the MPI
- present status
- conclusions and outlook

Muon Collider



Advantages

→ $m_\mu \approx 200 m_e$ ⇒ ~~synchrotron radiation problem~~

→ μ – point-like particle (unlike hadrons)

Meaning

- smaller machines
- higher energies
- more precise measurements

⇒ **lower cost**

⇒ **more physics**

Physics

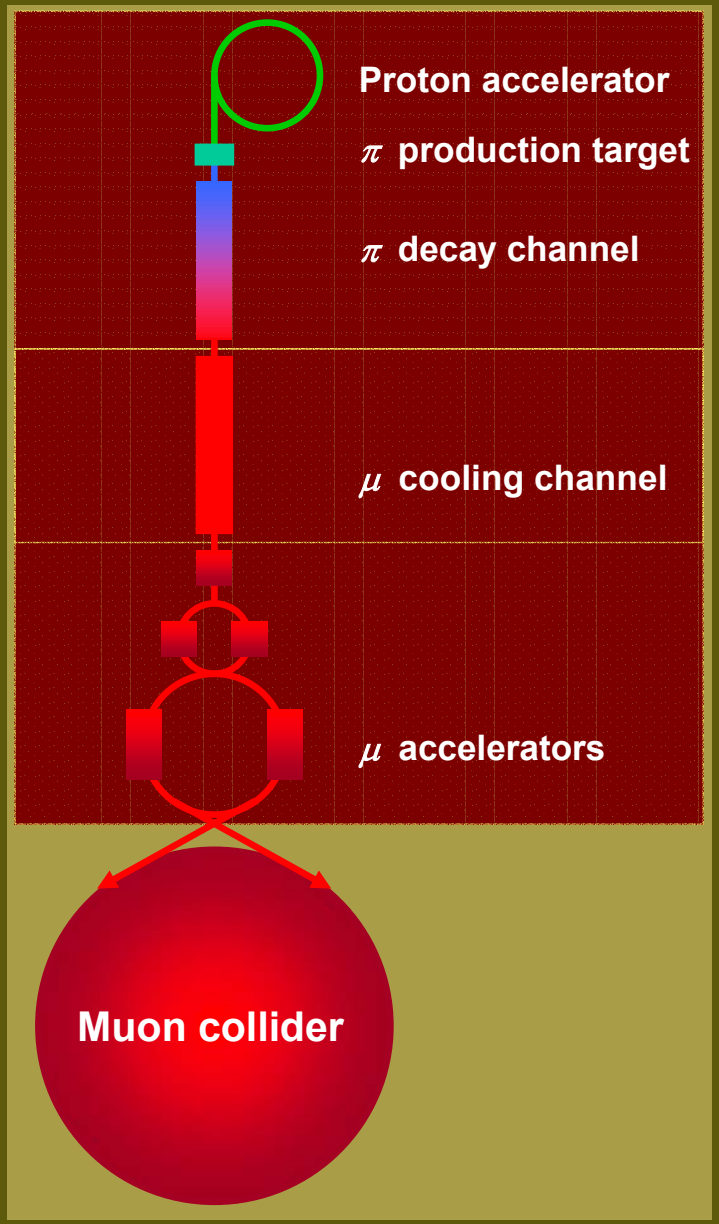
– higher energy frontier

→ new physics searches

– ν physics

– slow μ physics

Muon Collider



Problems

Muons decay with τ_μ=2.2 μs

→ 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**

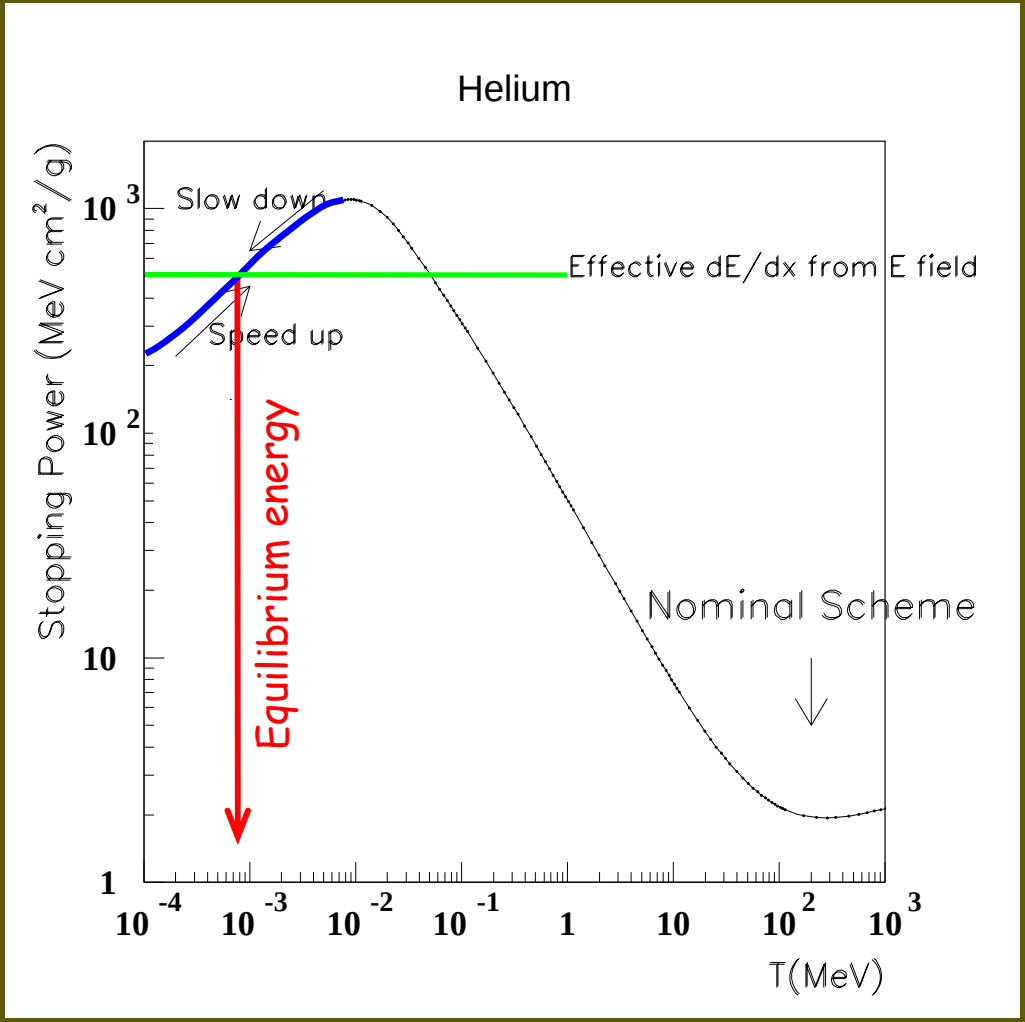
Muon cooling

→ 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***
  $\Rightarrow$ low average density of stopping medium $\Rightarrow$ **GAS**



Frictional Muon Cooling

– simulation of the whole muon collider front-end based on frictional muon cooling

→ **cooling factor of 10^7 simulated**

(arXiv: physics/0410017)

– experiment performed at Nevis Labs

- no frictional cooling was seen

  → windows absorbed all cooled particles

- simulation were still able to reproduce the results

(NIM**A** 524, 27, 2004)

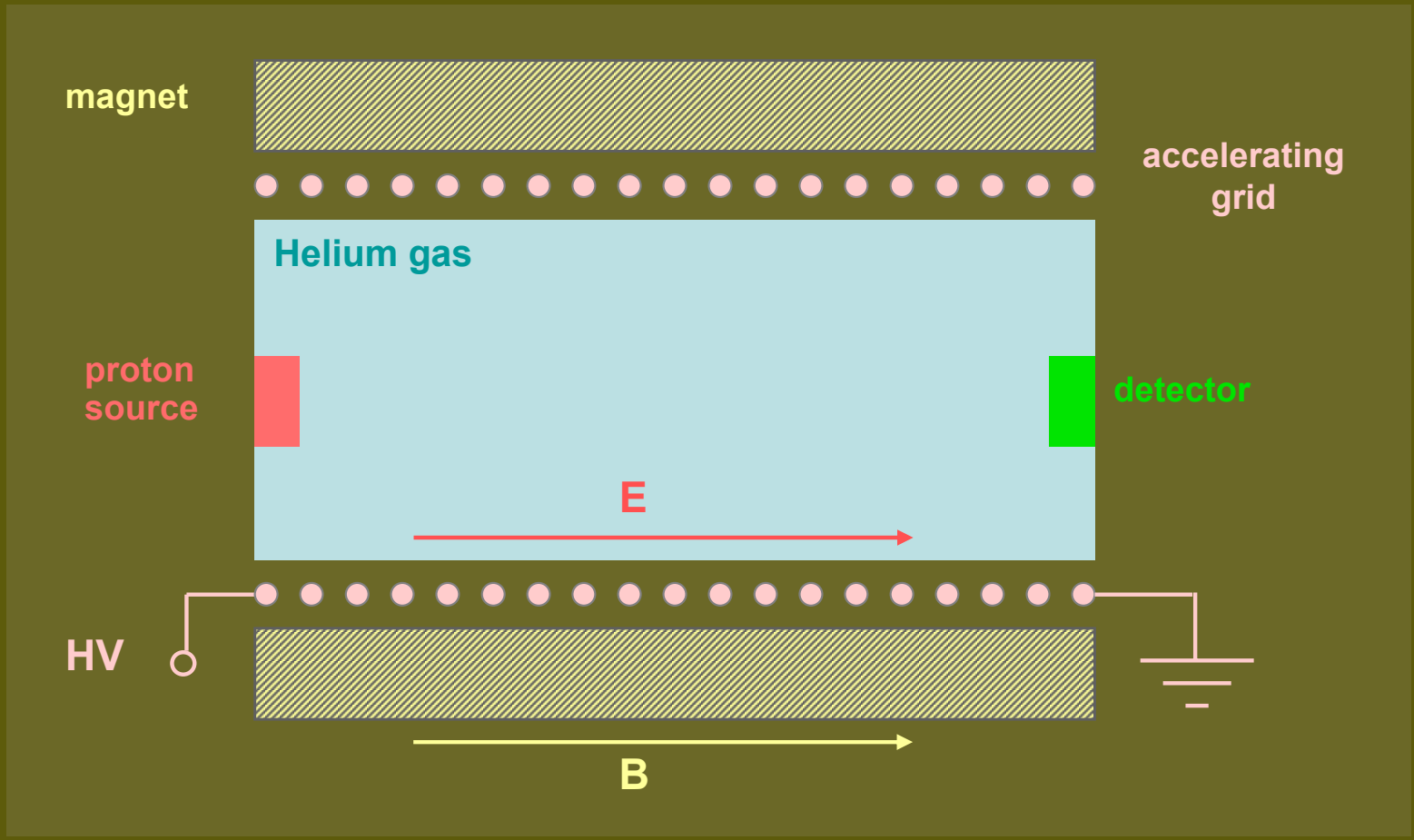
– experimental demonstration of frictional cooling is still necessary:

Frictional Cooling Demonstration Experiment

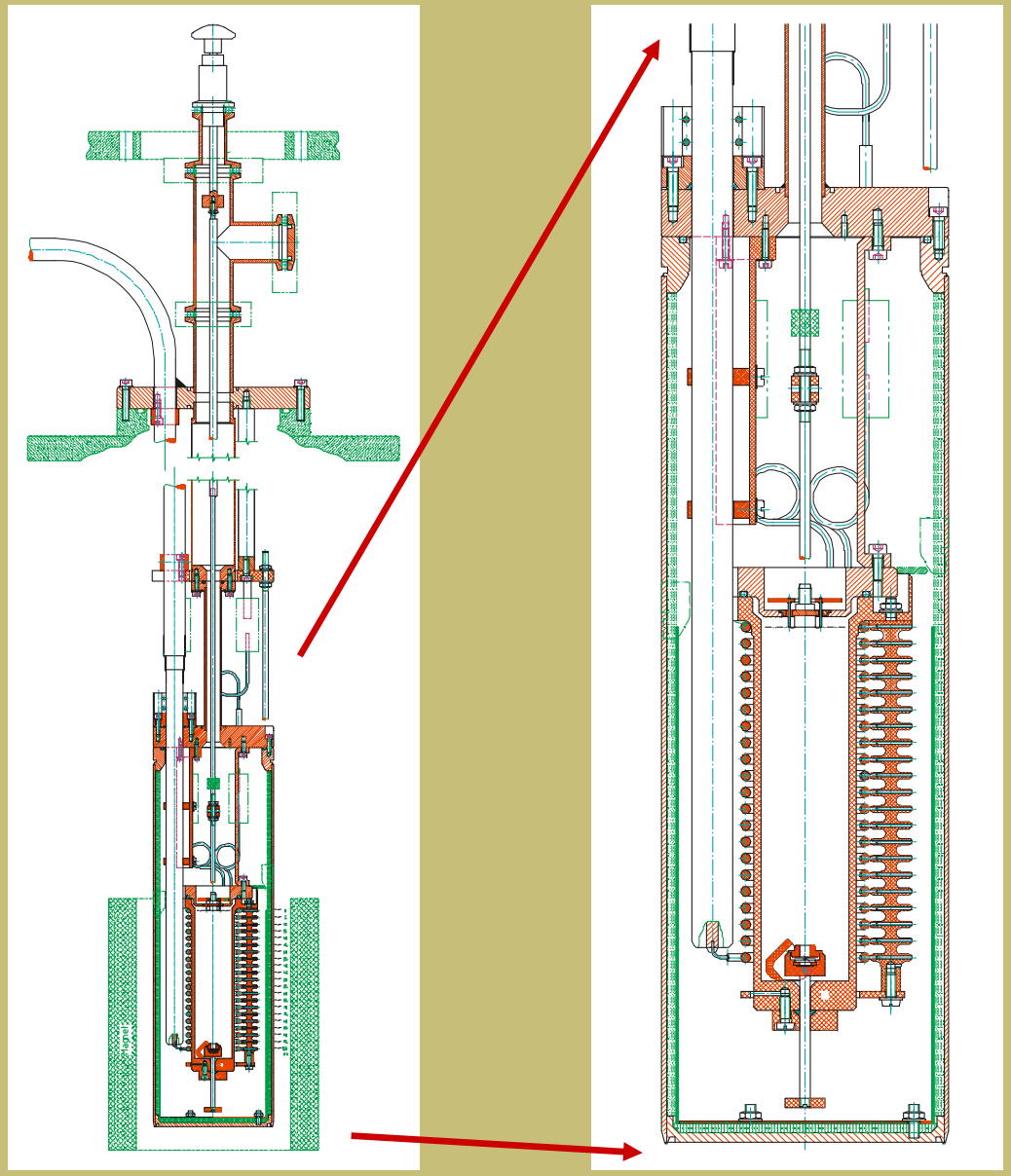
at MPI

Frictional Cooling Demonstration

– demonstration of frictional cooling principle on protons
→ should work for any charged particle



FCD - Technical drawings



FCD - Magnet

- **5 Tesla** superconducting magnet
- operation at temperature of liquid He

COMMISIONED

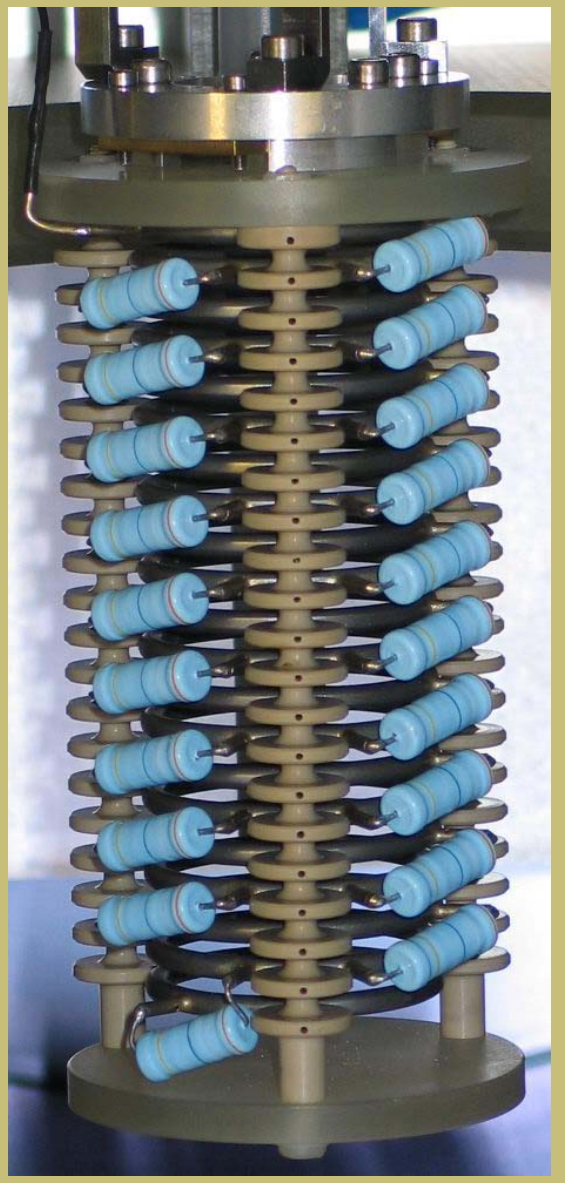
- performed magnetic field measurements

FCD – Accelerating grid

– constructed and tested

→ at pressure 10^{-3} mbar reached and maintained up to **90 kV**

E = **0.9 MV/m**



FCD – Accelerating grid

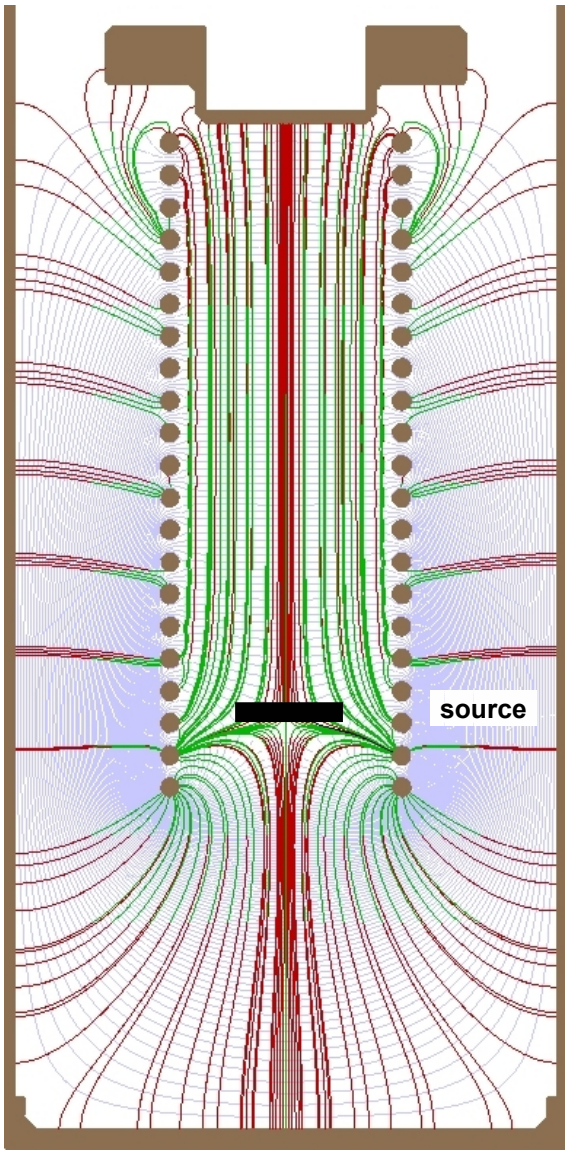
– constructed and tested

→ at pressure 10^{-3} mbar reached and maintained up to **90 kV**

E = **0.9 MV/m**

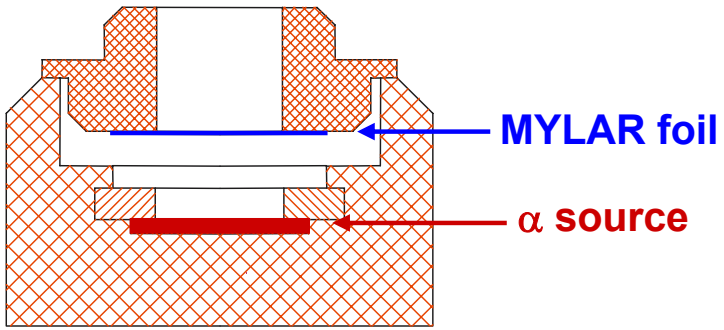
– simulations of the ***E*** field with SIMION

→ need to shift the source to be able to accelerate



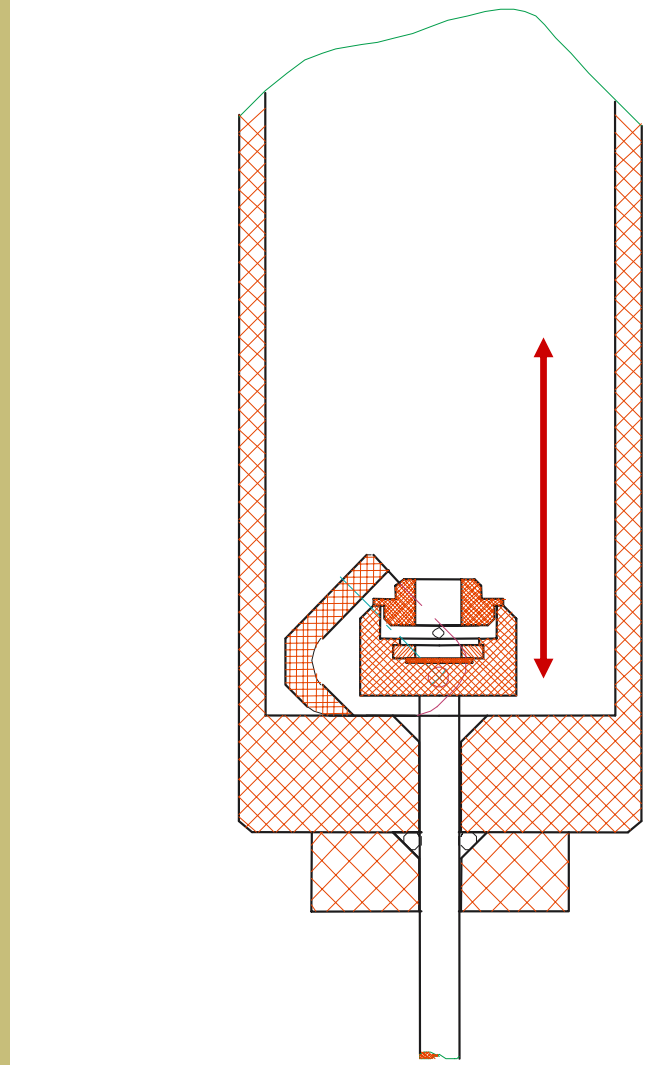
FCD – Proton source

- strong α source $\rightarrow$ ^{241}Am
  74 kBq
- Hydrogen rich foil
  $\rightarrow$ MYLAR
- free protons by e^-
  stripping from H atoms



FCD – Proton source

- strong α source $\rightarrow$ ^{241}Am
  74 kBq
- Hydrogen rich foil
  $\rightarrow$ MYLAR
- free protons by e^-
  stripping from H atoms
- possibility of moving the source



FCD - Detector

Silicon Drift Detectors

→ from HLL

→ very sensitive to precise voltage setup on individual parts of the detector

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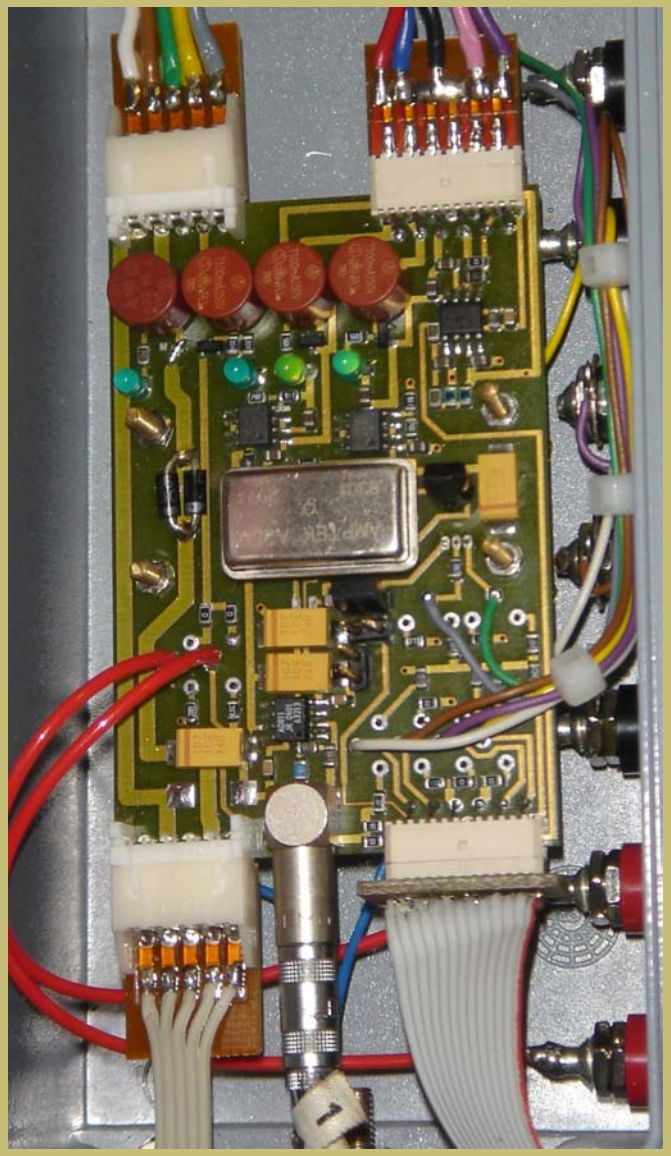
Read-out electronics

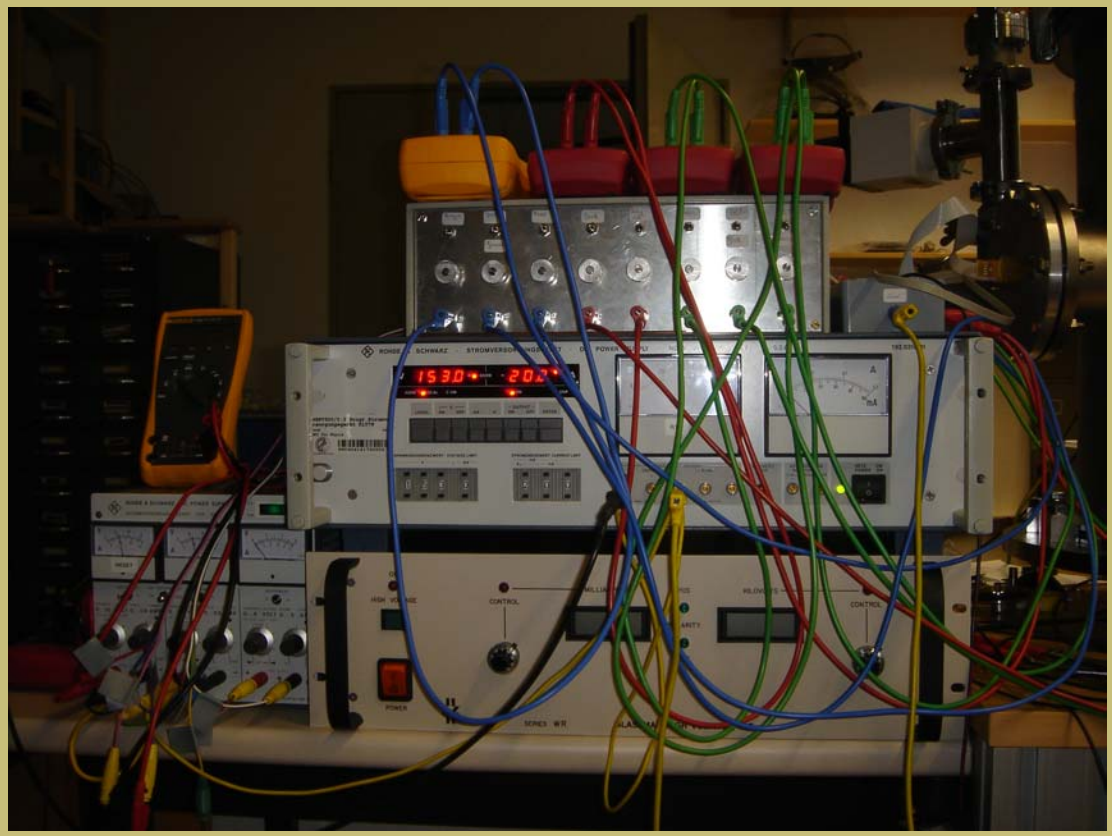
→ built by Electronics dept.

We were unable to run them together successfully for 4 months



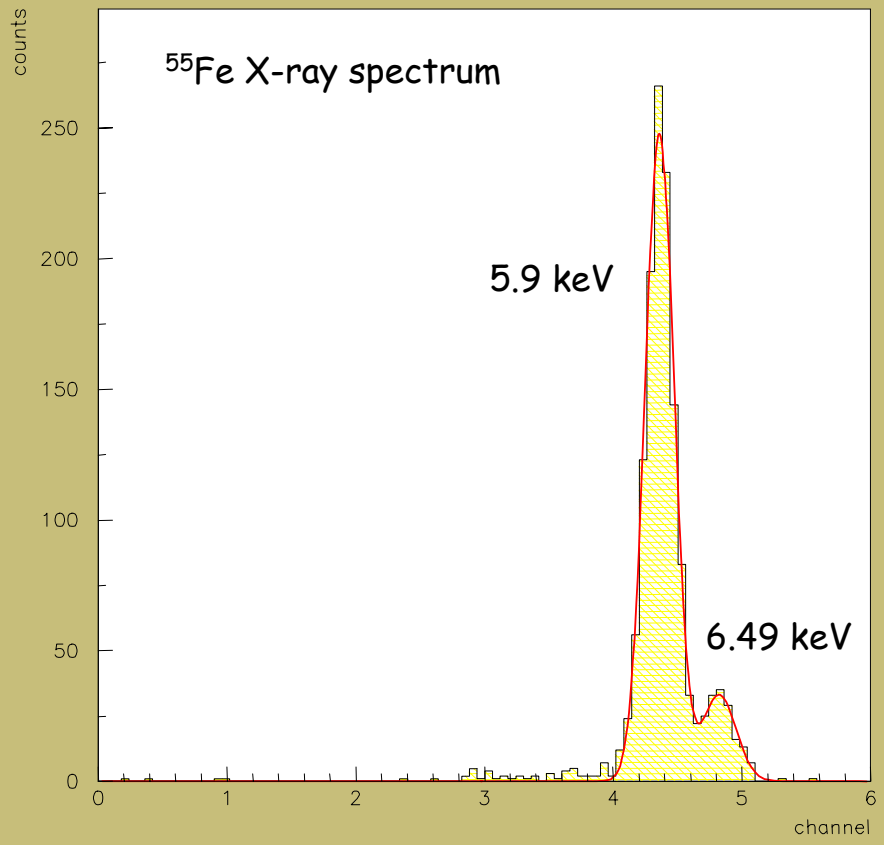
FCD - Detector

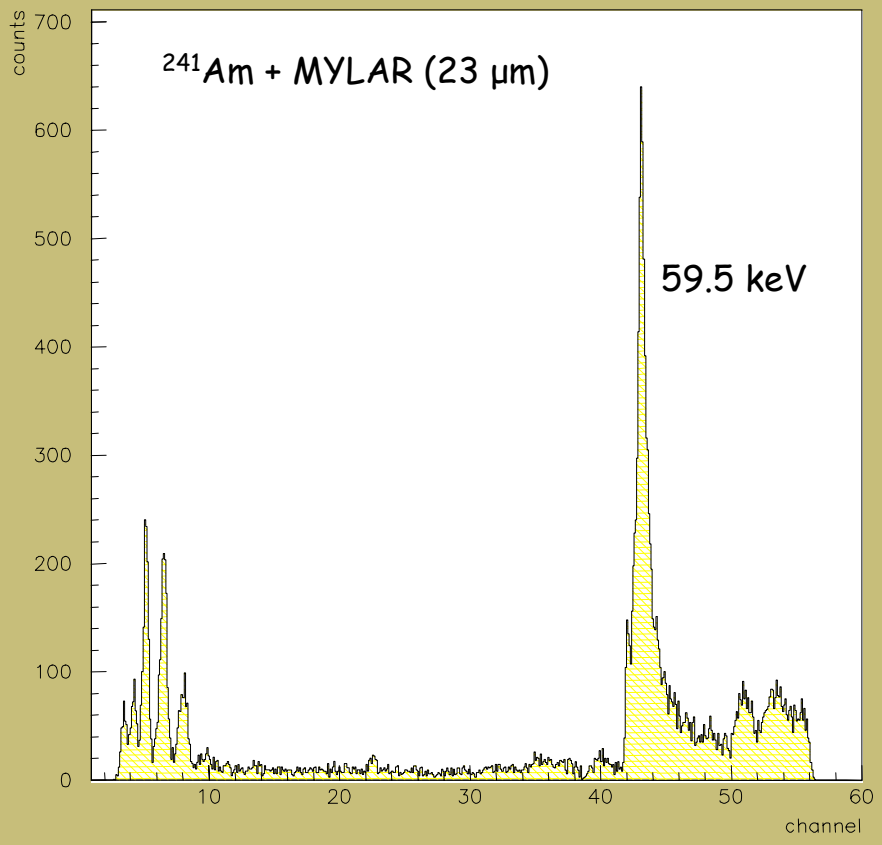
- new setup running now successfully for testing
- however, new read-out electronics has to be designed
  - → improved control
  - → operation at low temperatures



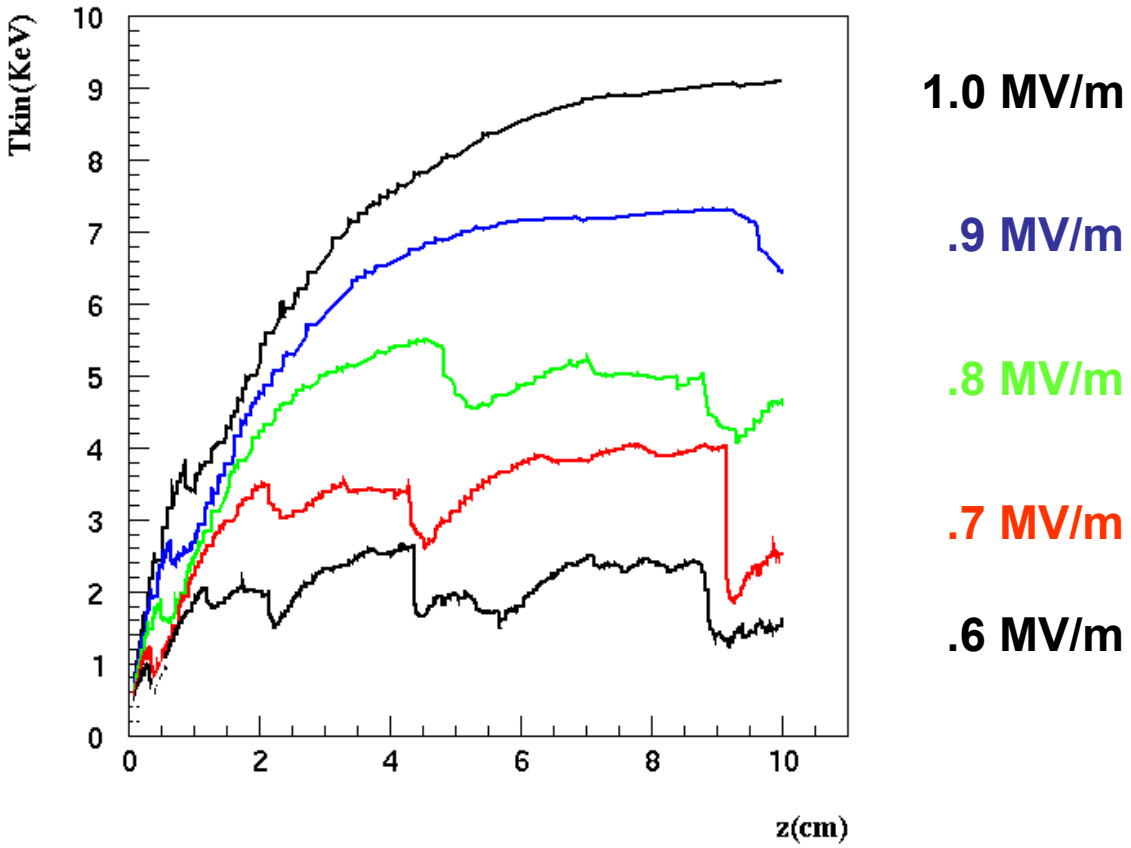
FCD – First spectra

Data taken last week → ^{55}Fe X-ray spectrum (FWHM = 340 eV @ 5.9 keV)
→ ^{241}Am + plastic foil (23 µm) – not yet analyzed





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?

Conclusions

- all structures ready

  Thanks to **K.-H. Ackermann** and **H. Schendzielorz** from construction department

- magnet and grid commissioned and tested

  Thanks to **CRESST** people for help with cryogenics

- detector + electronics running (finally)

  Many thanks to **T.-S. Tran** and **Ch. Braquet** from electronics department and **L. Andricek** from HLL

Outlook

- more tests of electronic read-out
  + new design suitable for low temperatures
- finish all testing and start taking data
- preparation of experiment to measure μ^- **capture cross-section**

  → crucial parameter in the frictional muon cooling scheme for negative muons – no data exist at the moment