Low Energy Cooling, Report from Montauk '99

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Historical Perspective:
Not part of the neutrino source!.
==> Muon Collider only.

Low priority topic in our collaboration:
* It's Muon Collider !
* It's far fetched !
(high risk, high gain business..)

Progress at Montauk:
* Frictional Cooling, as demonstrated by the PSI group is OUT!
* "Hot Tunsgten" is the next best shot..
* negative muon beam is still "really hard".

Frictional Cooling: Status
P. Lebrun, Fermilab

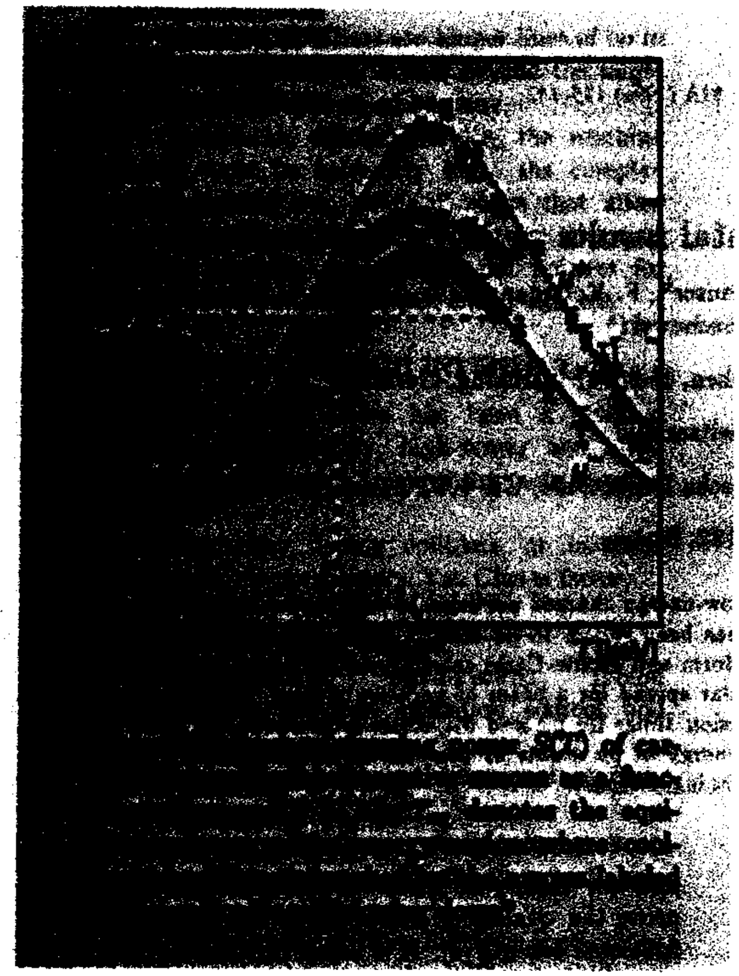
- Motivation
- Understanding what has been done: report on the PSI measurement.
- Applicability for intense muon bunches:
  - How do we get the low energy beam without loosing too much intensity
  - How do we handle Space Charge while re-accelerating
- Is Space Charge gona to kill all "zero energy" option ?

"Zero energy" = T<< M (highly non-relativistic muons)

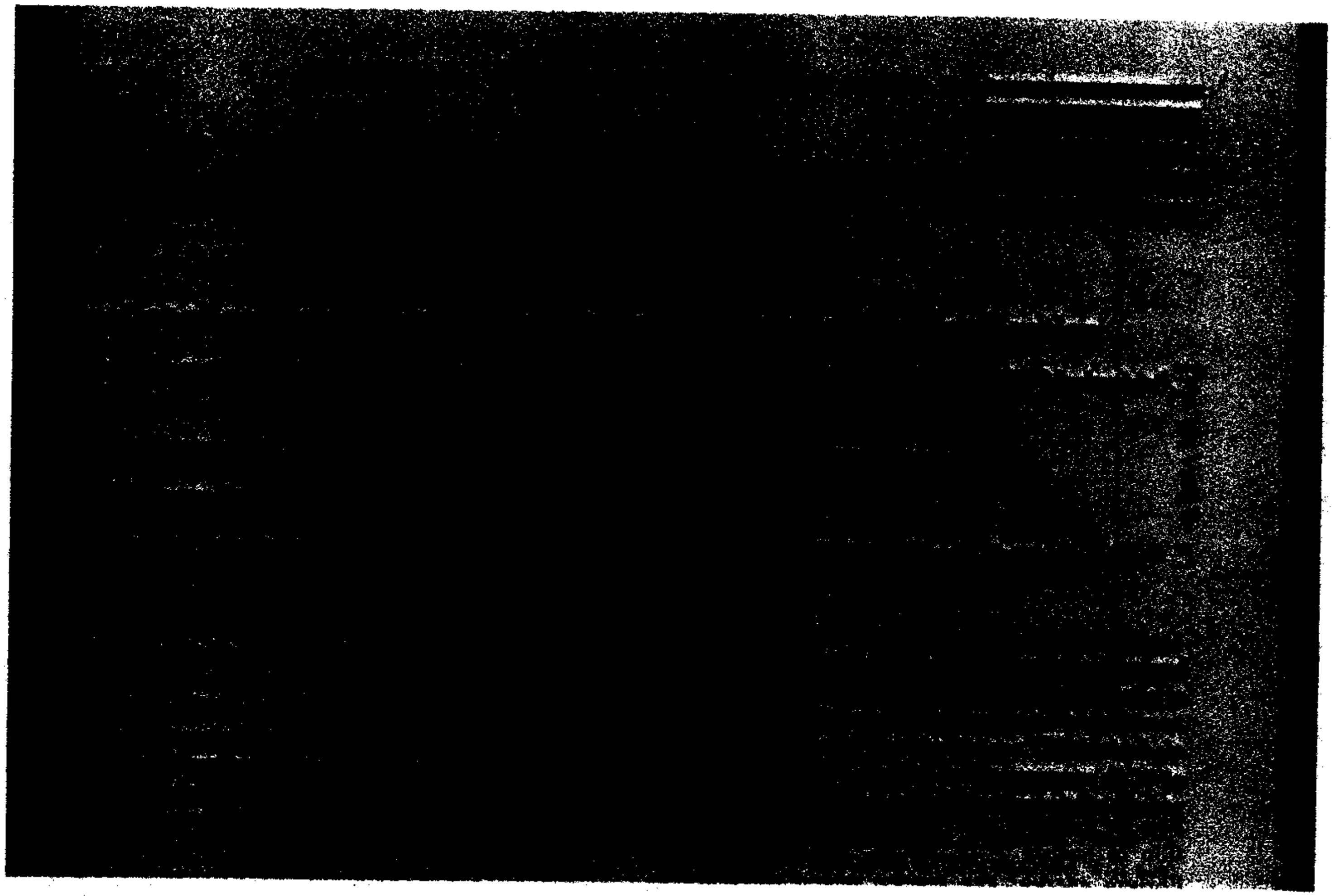
- Frictional Cooling, where P ~ 2.1 MeV/c (10 KeV kinetic energy), and one life time corresponds to 12.5 m. => L < 1 m.
- Muonium diffusing through a Tungsten foil, where we need to "act" in less than a few hundred ns.
- Muon induced Deuterium nuclear fusion..
- ....

Frictional Cooling.

- The shape of the de/dx curve has the desirable curvature => potential for longitudinal cooling.
- Transverse cooling also possible, if re-acceleration applied (~10 KeV/m)



The PSI experiment ('96)



πE5

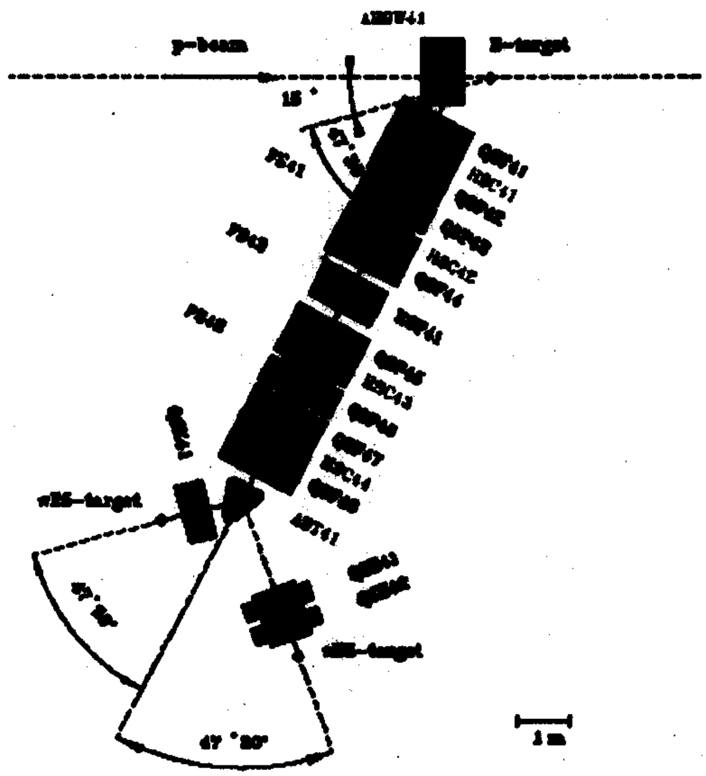


Fig 1 : Magnetic elements in piE5 beam line

+ 8.5 m. long sol. for decay channel.

+ Wien filter.

* $\varepsilon_\perp \sim 15$ mm × 1. rad. ~ .015 = 75 µ. mm.mrad.

before momentum selection!

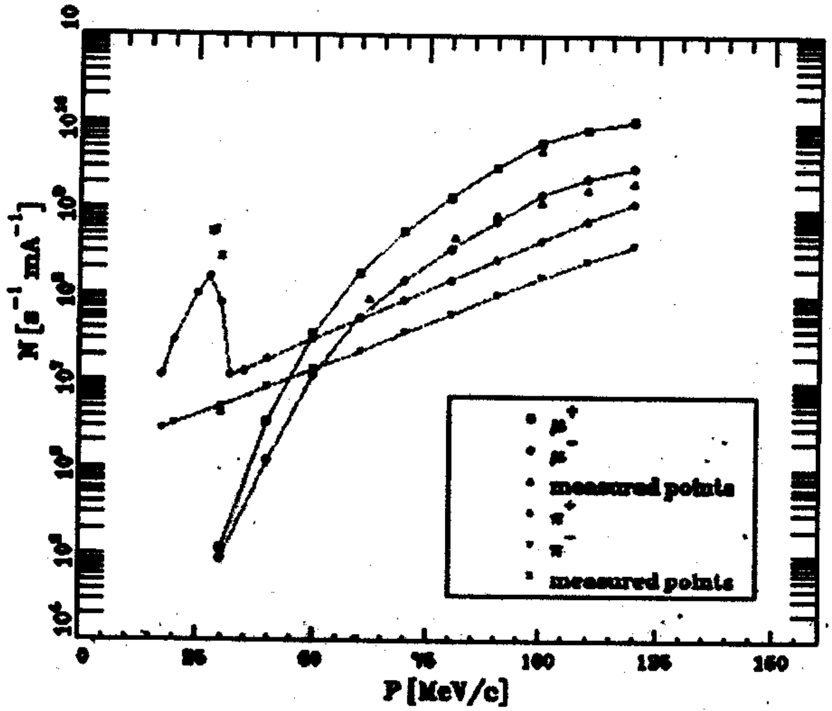


Fig 3 : Pion and muon flux in piE5

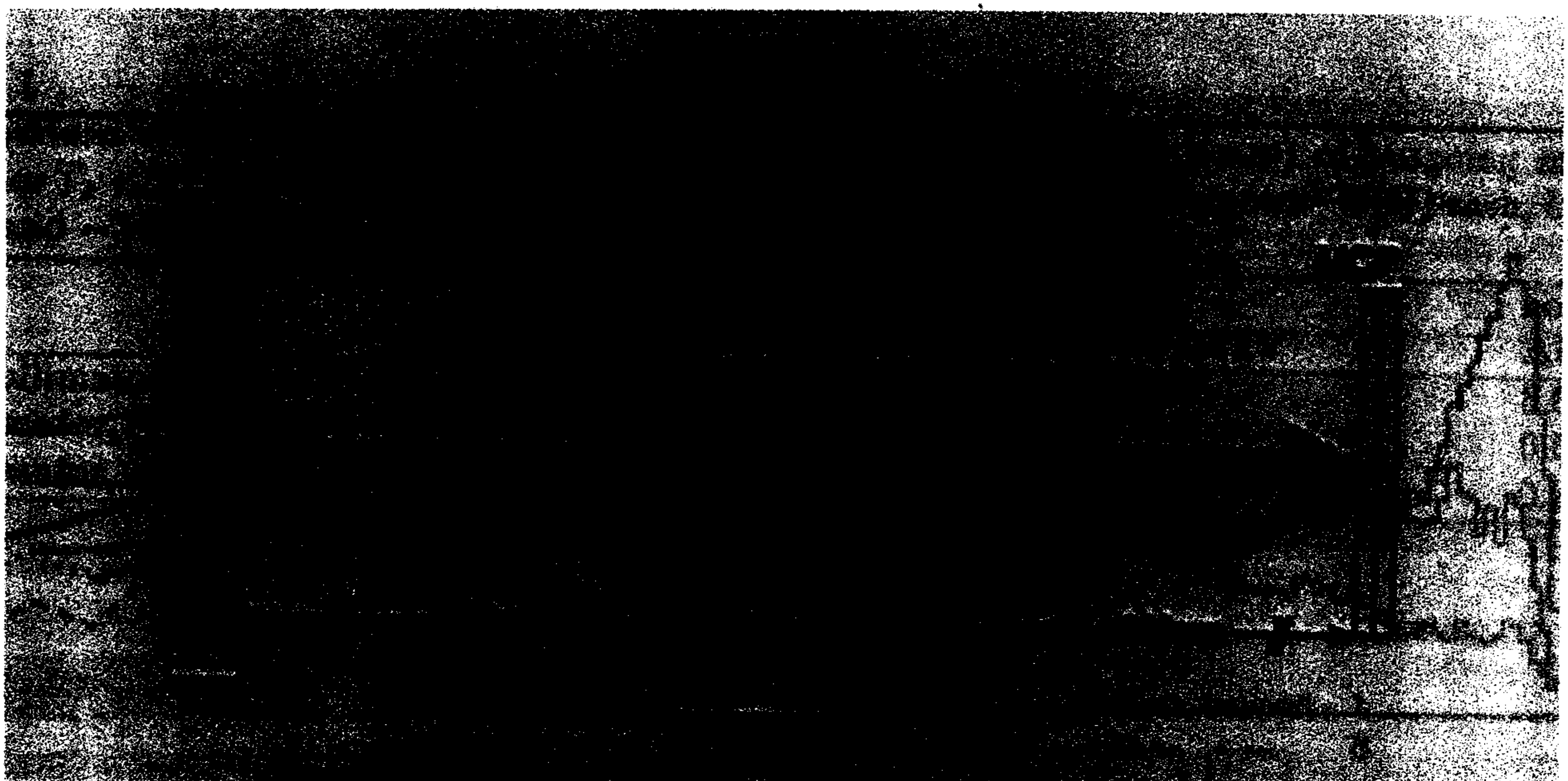
$1\ mA = 6.25\ 10^{15}$ proton.

$\mu/p\big|_{10\ MeV} = 5.10^{+6}/6.25.10^{15} \sim 10^{-9}$

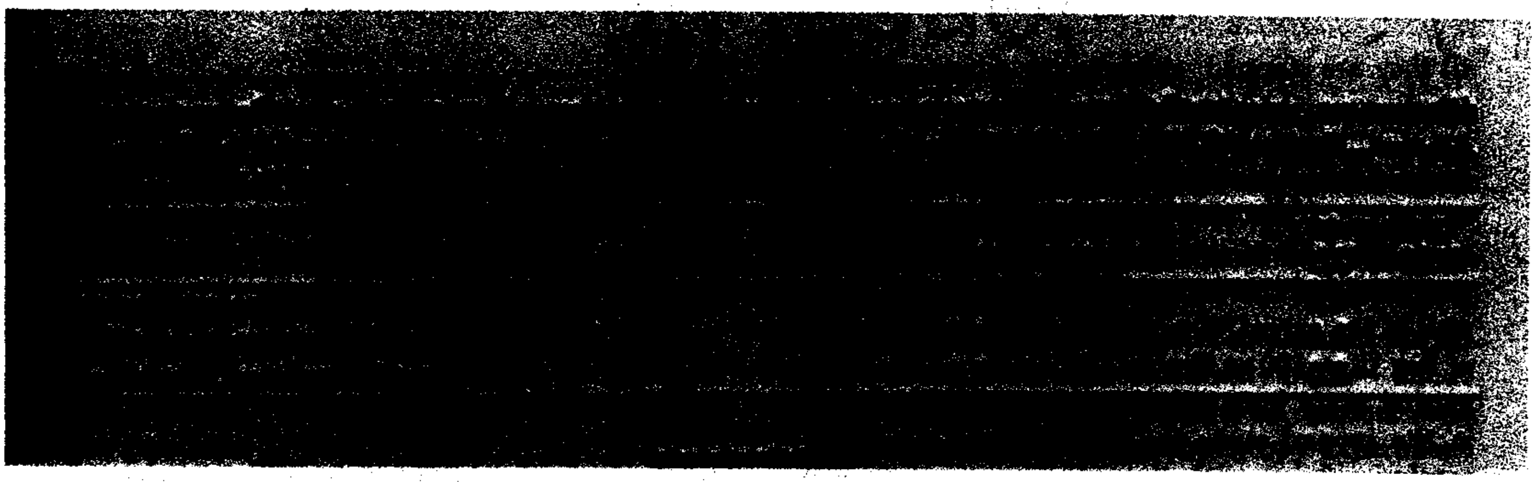
(No cooling!)

Poor capture.

The Apparatus



Results



- "Guessed" Emittance:
  - PiE5: 15 mm X 450 mRad X 0.095 = 640 \pi mm mRad.
  - Cooling entrance: 15 mm X 450 mRad X 0.014 = 95 \pi mm mRad ==> 75 (Private comm.)
  - From above, using 1 mm. colimator, 2D cooling ~ a few.. ==> 50 mm mRad "achievable"

However....Space Charge will be an issue!

- This works with "one muon at a time in the bottle" !
- a bunch of a few MeV/c momentun, 2 10^12 muons, 2 cm in radius, 20 cm. long will generate 3,500 kV/m electric, about 100 time higher than the natural fields needed to control frictional cooling. And going in "all directions".. (J. Gallardo, Mucool note, August 3 1999)

Issues: getting to frictional cooling.

- How do we get to such low momentum without reheating (or loosing intensity)
  - De/dx method to decelarate is no good, due to straggling.. (muons will stop, or go too far).
  - r.f. : beam dynamic dominated by Space Charge. Not if low beam current! (Many bunches!!)
  - A collection of Wien filters => which configuration? + then Absorber (~5D emitt. exch. ?)
  - How do control such a beam : instrumentation tricky..

From Frictional Cooling to Plasma.

- ~10 ^12 muons + secondary electrons + ~ 10 -> 100 micro-gram of materials => Plasma (quite likely!).
- So be it!..
- However...
  - Resonant ionization of muonium will be less efficient (doppler braodening..)
  - Very high power laser
- ---.> Make it hot enough so that muonium dissociate in the plasma..

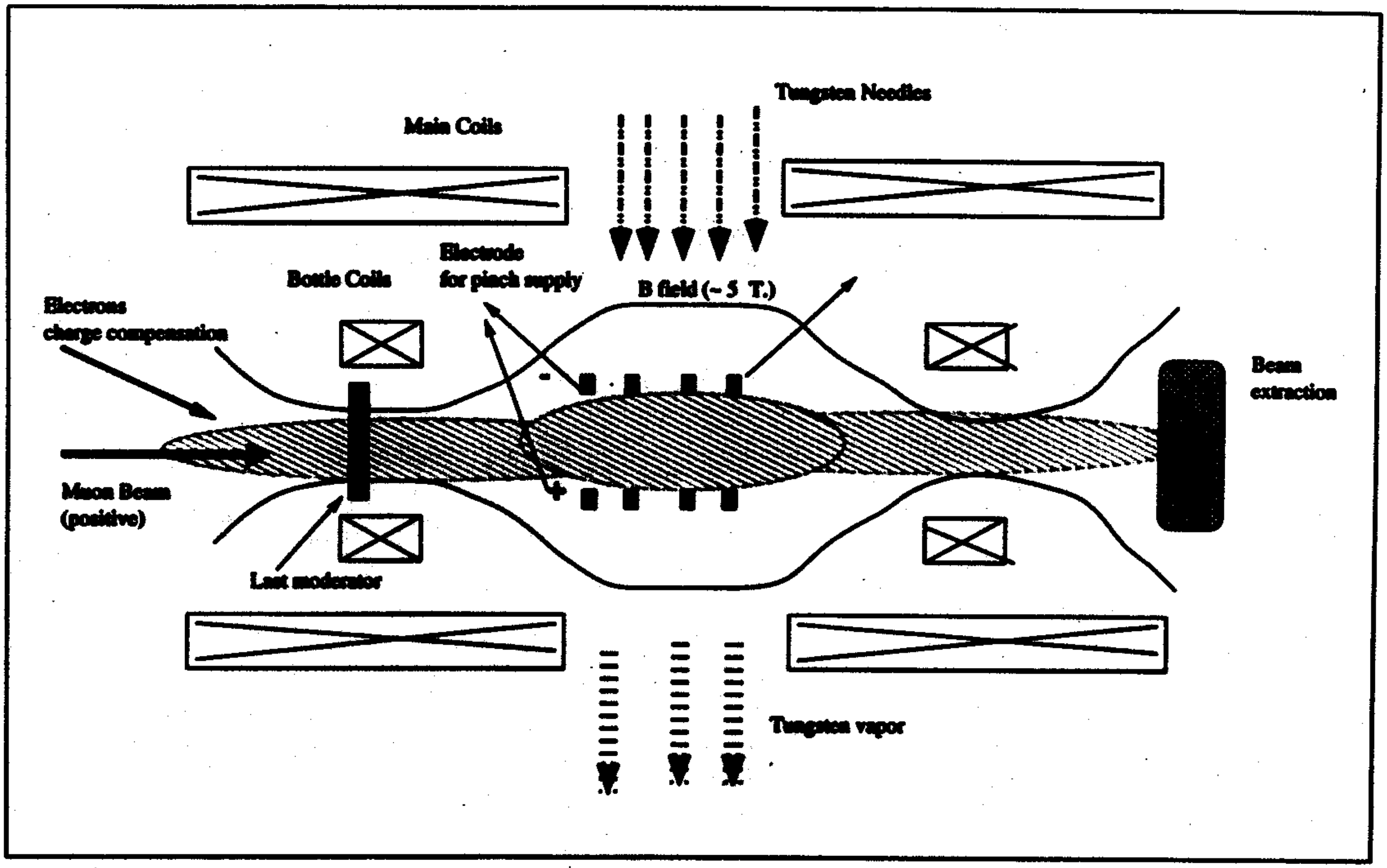
Then..

- This muon cooling setup will look more like an exotic ion source than a device found in existing slow muon beams...
- Tungsten heating to hundreds of eV in 100 ns: dense Z-Pinch.
- A sketch (no more than that!)..

The Problem:

- Ionized mu+ out of the Plasma.
  - Can not do this in a single bunch !
- However,
  - The transverce emittance of such a beam would be << 500 mm. mRad..
- Mu- : Much harder!..
  - Defeat muon capture..
  - Take advantage of muon capture.
    - Muon induced deuterium fusion...

Hot Tungsten Cooler.



Plan for futur work

- Necessary condition: Reaching relatively low transverse emittance and low P, Delta P/P without loosing intensity.
- Such beam can be completly debunched..
- Channel will look similar to the one we are currently designing for emittance exchange, except no r.f. ! ==> "5D" cooling.
- If that work, the Neutrino Front has a (small) chance to be relevant to the Muon Collider: The exotice ion source "collapses" the 250 ns. long bunch train, and reduce the transverse emittance.