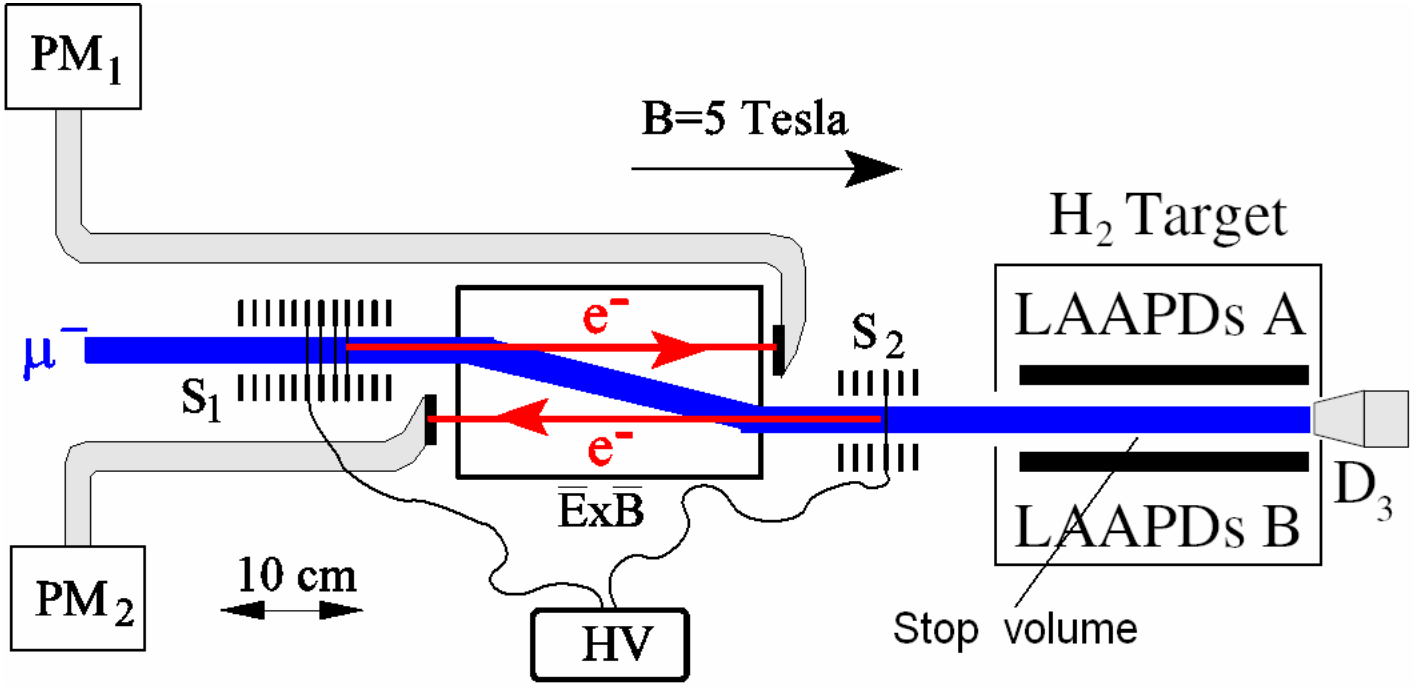
Slow μ^- BEAMS:
COOLING AND NEW SOURCE

1. Extension of the existing low energy μ^- beam into an ultra-low energy μ^- beam for stopping of μ^- on first solid surface layers.

2. A new concept for a low energy μ^- source

D. Taqqu

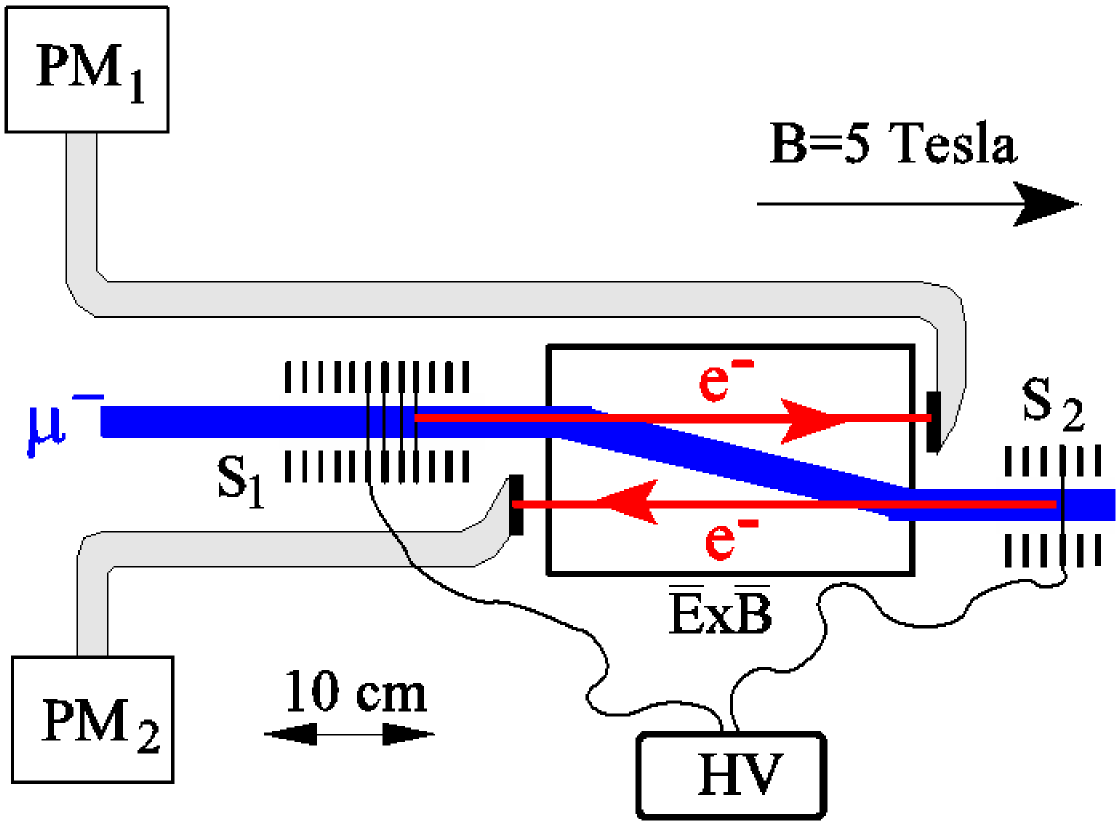


Detection efficiency of muon entrance detectors: S1-PM1 : 85%

S2-PM2 : 50% → 80%

Low energy (few keV) muon intensity : 400/s → 600/s

Beam size : 0.6 cm x 1.4 cm



Detection efficiency of muon entrance detectors: S1-PM1 : 85%

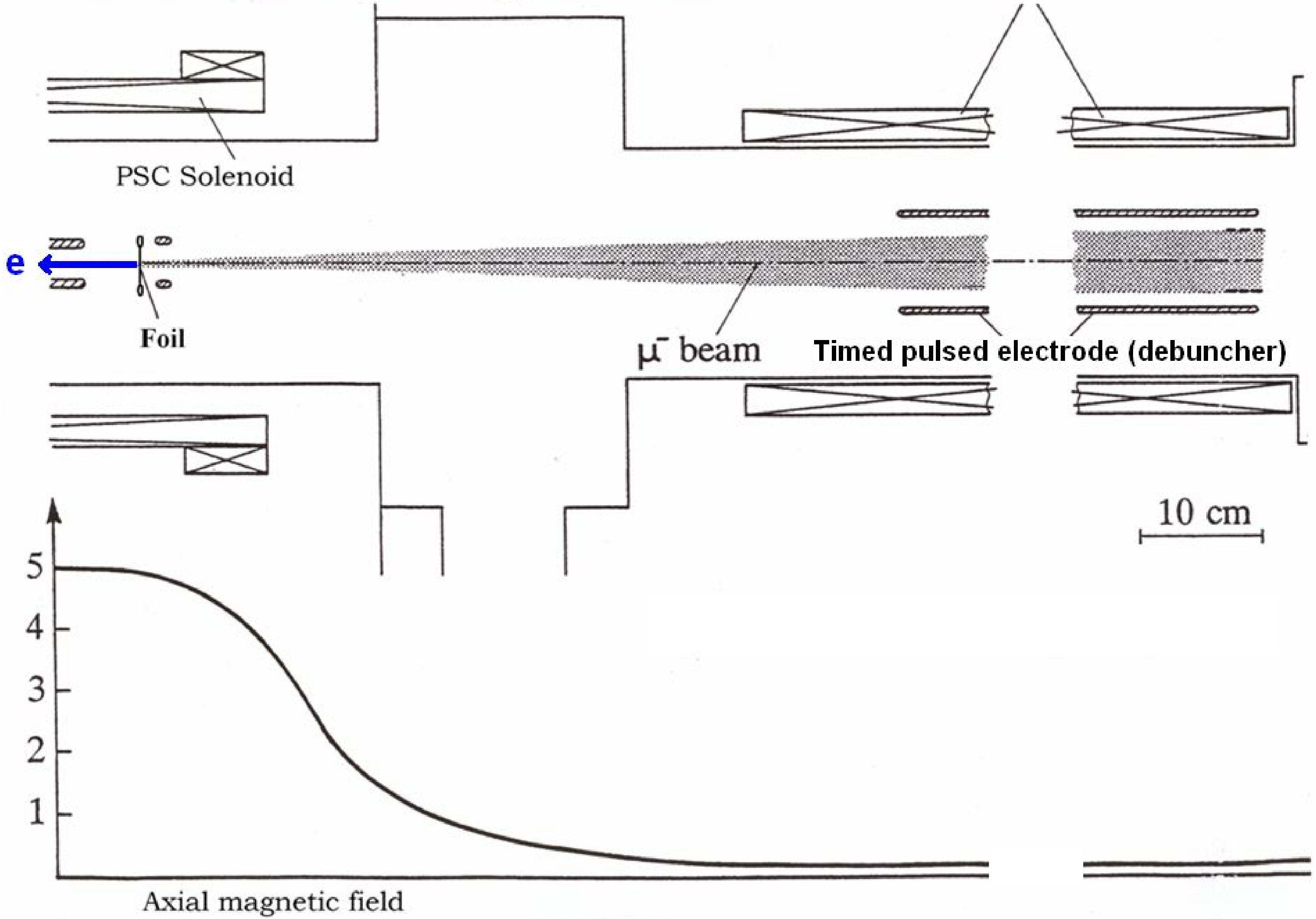
S2-PM2 : 80%

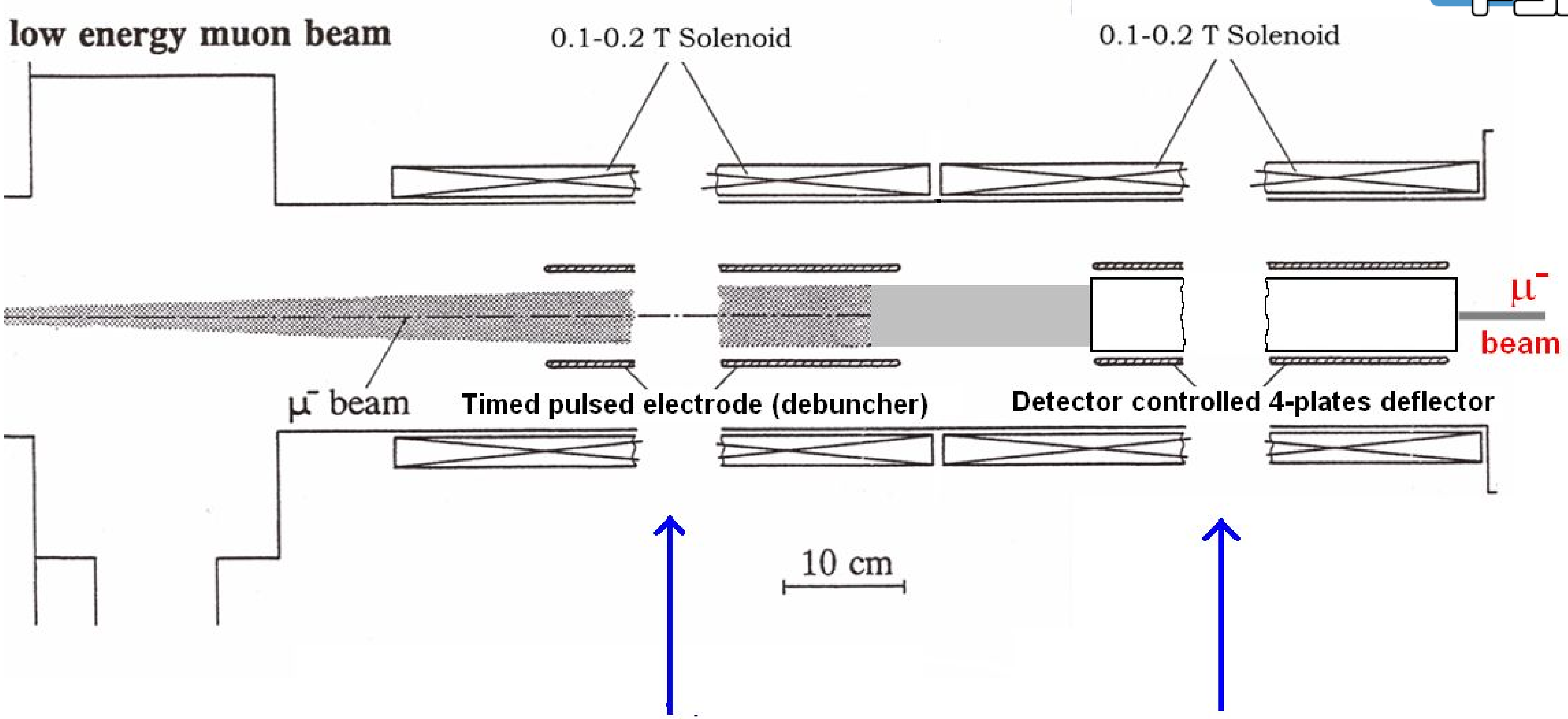
Low energy (few keV) muon intensity : 600/s

Beam size : 0.6 cm x 1.4 cm

Timing precision : 2 ns

Extraction into a low energy muon beam





Longitudinal PSC

→ ΔE = 50 eV, Δt = 100 ns

Transverse PSC

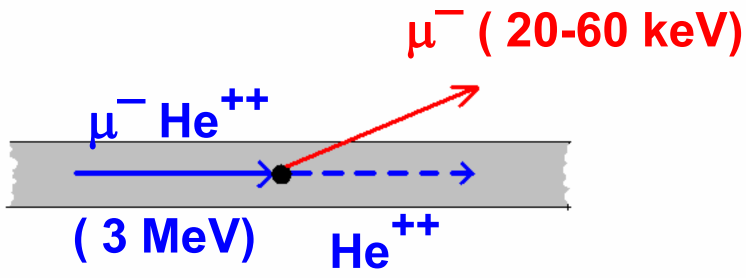
→ Δx = Δy = 0.5 cm

Ultra-low energy μ^- beam for study of surfaces of materials with monolayer resolution.

Intensity: 500/sec

Energy: variable with 50 eV resolution in 100 ns

AN INTENSE LOW ENERGY μ^- SOURCE BASED ON A μ^-He^{++} BEAM



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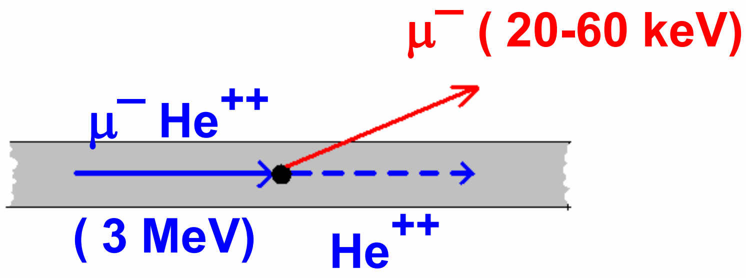
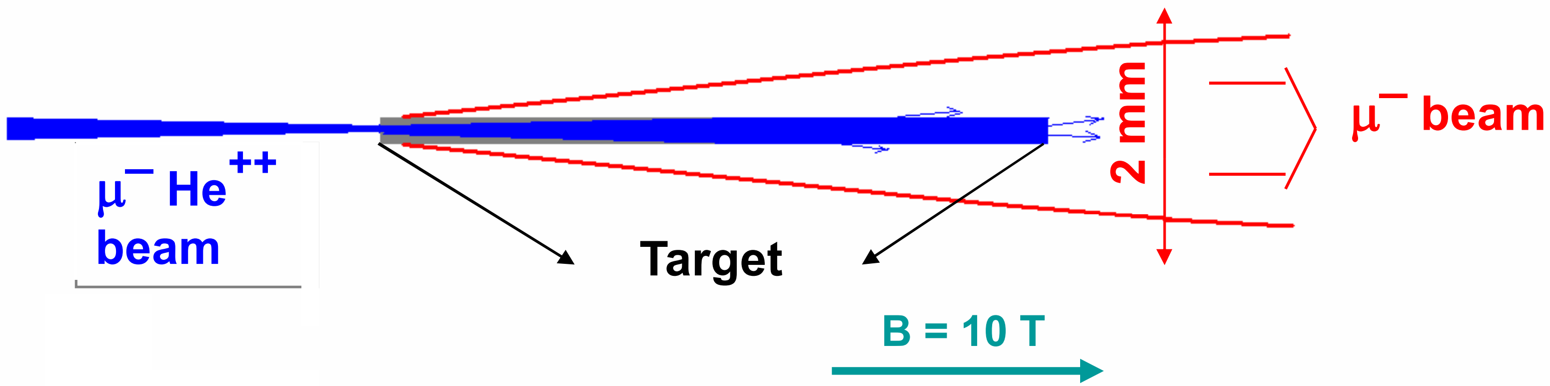
AN INTENSE LOW ENERGY μ^- SOURCE BASED ON A μ^-He^{++} BEAM





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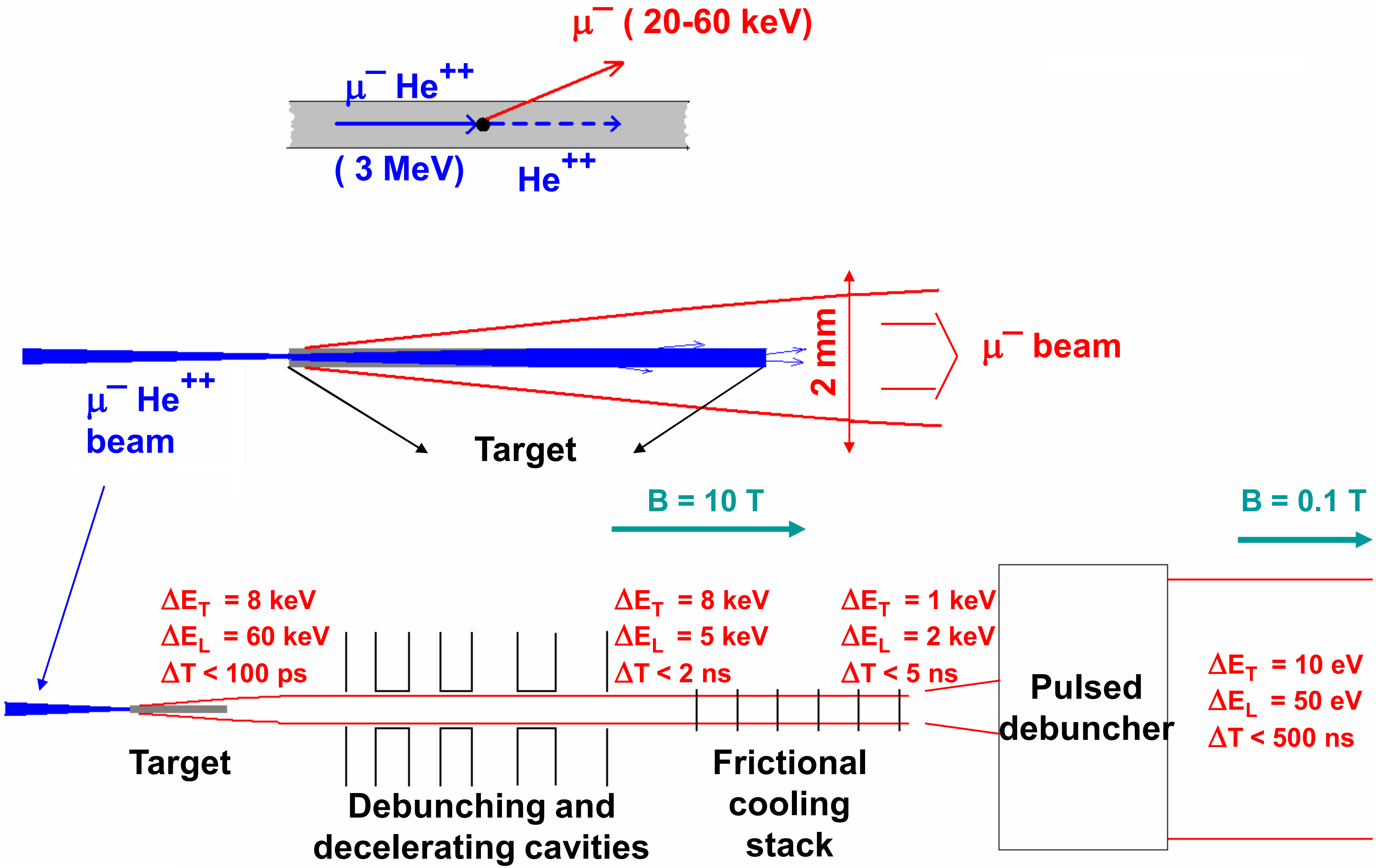
AN INTENSE LOW ENERGY μ^- SOURCE BASED ON A μ^-He^{++} BEAM



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SCALING OF EXISTING MEASUREMENTS

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M B Shah and H B Gilbody   J. Phys. B15 (1982) 413

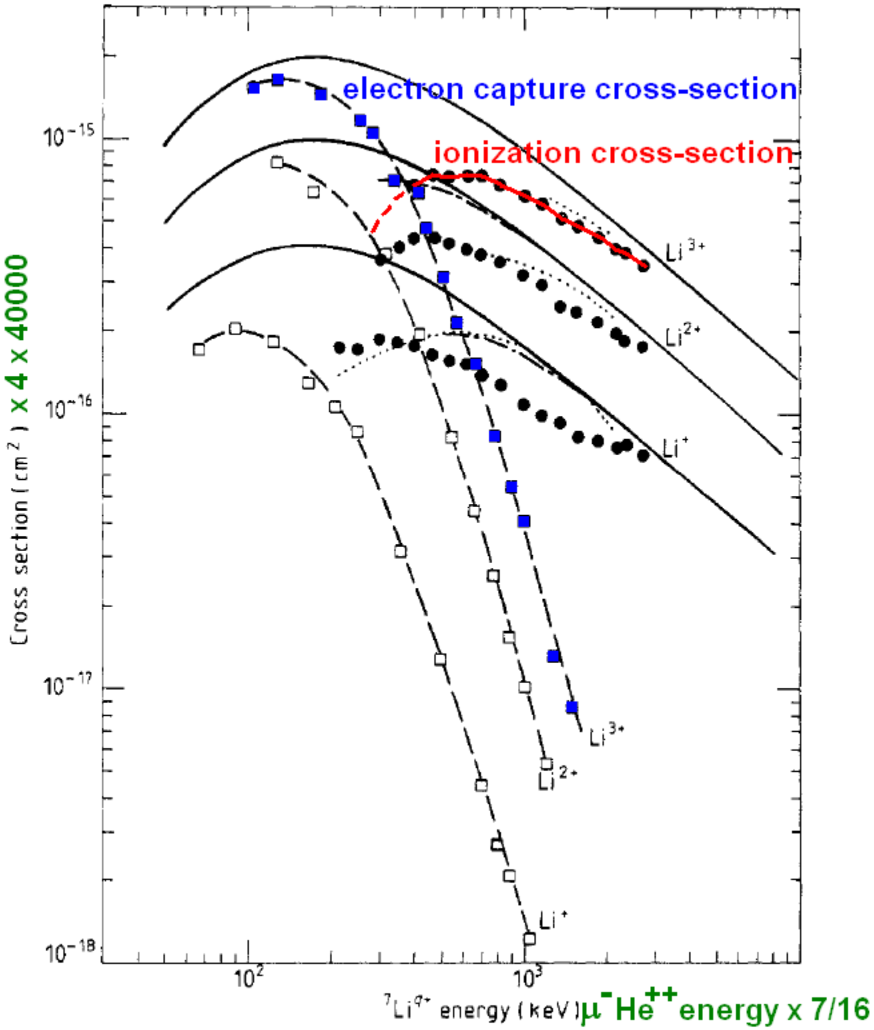

Figure 1. The cross sections $\sigma_i(Li^{q+})$ and $\sigma_c(Li^{q+})$ for ionisation and electron capture, respectively, in collisions of Li^{3+}, Li^{2+} and Li^{+} ions with H atoms. ●, $\sigma_i(Li^{q+})$, present data; ——, $\sigma_i(Li^{q+})$, Born approximation, McGuire (1981); —·—, $\sigma_i(Li^{q+})$, generalised Bethe approximation, Gillespie (1979); · · · · ·, $\frac{1}{2}$ (experimental cross sections for electron removal from H_2), Pivovar *et al* (1971); □, $\sigma_c(Li^{q+})$, Shah *et al* (1978).

I. D. Kaganovitch et al., New J. of Pysics 8(2006)278

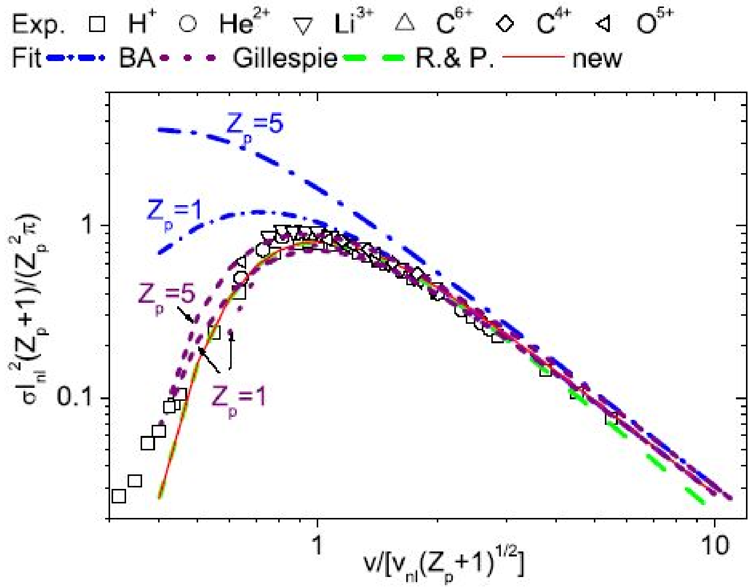

Figure 4. Ionization cross-sections of hydrogen by fully stripped ions

Projectile: Fully stripped ion with charge Zp
Target: Hydrogenic ion with charge Zt
Experiments: Zt=1
Scaling law:

$$\sigma^{\rm ion}(v, I_{nl}, Z_p) = \pi a_0^2 \frac{Z_p^2}{(Z_p/Z_T+1)} N_{nl} \frac{E_0^2}{\underbrace{I_{nl}^2}_{\sim Z_T^4}} G^{\rm new}\left(\frac{v}{\underbrace{v_{nl}}_{\sim Z_T}\sqrt{Z_p/Z_T+1}}\right)$$

$\sigma(Z_P=6, Z_T=2, v) = (1/4)\,\sigma(Z_P=3, Z_T=1, v/2)$

C^{6+} + He^{+}

C^{6+} + $\mu^{-}He^{++}$

$$\text{Energy :} \qquad E(x) = E_{initial} - \int_0^x \frac{dE}{dx} dx$$

$$\text{Population :} \qquad P(x) = \exp\left(- \int_0^x N\Big(\sigma_{ionization}\big(E(x)\big) + \sigma_{capture}\big(E(x)\big)\Big) dx \right)$$

$$\text{Ionization :} \qquad P_{ionization} = \int_0^x N \sigma_{ionization}\big(E(x)\big) P(x) dx$$

$$\text{Energy}: \qquad E(x) = E_{initial} - \int_0^x \frac{dE}{dx}dx$$

$$\text{Population}: \qquad P(x) = \exp\left(-\int_0^x N\Big(\sigma_{ionization}(E(x)) + \sigma_{capture}(E(x))\Big)dx\right)$$

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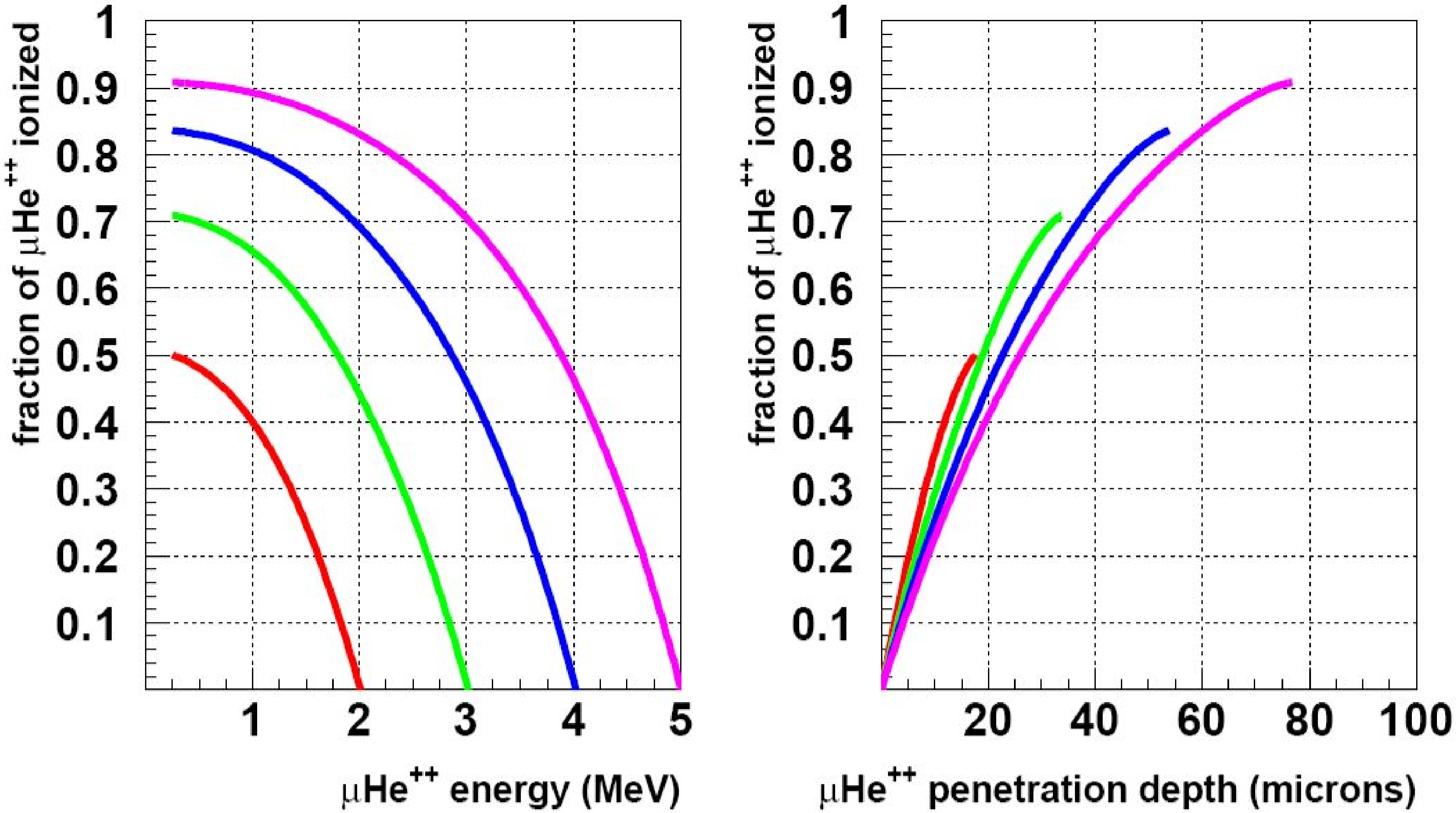


G G Nancolas, R M Bowley and P V E Clintock, J. Phys. C19(1986)L37

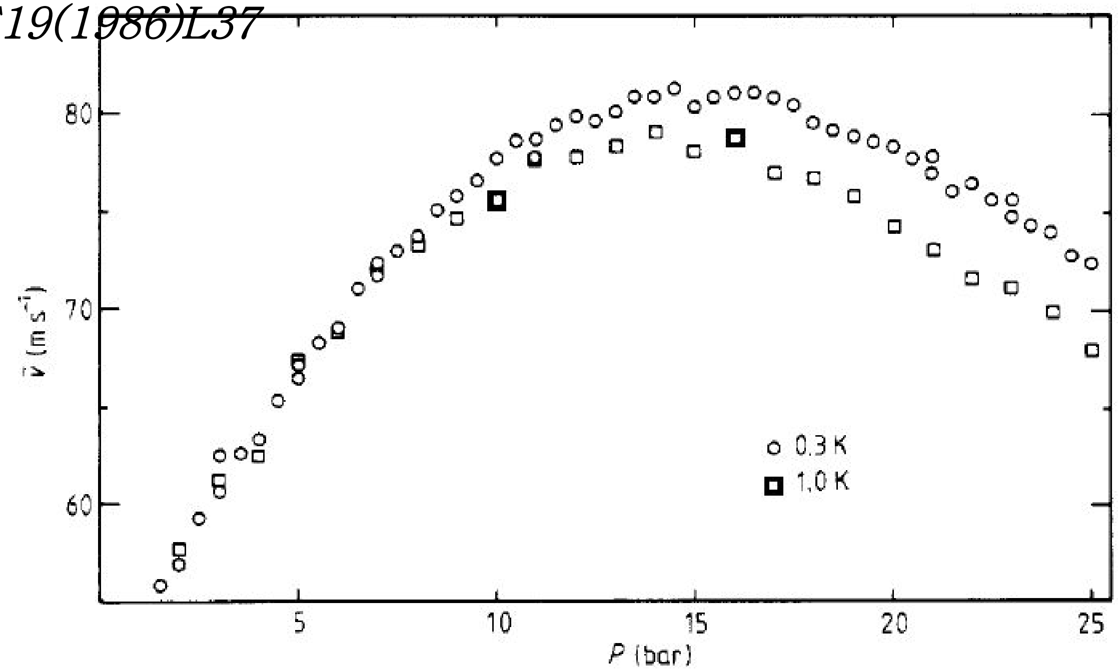
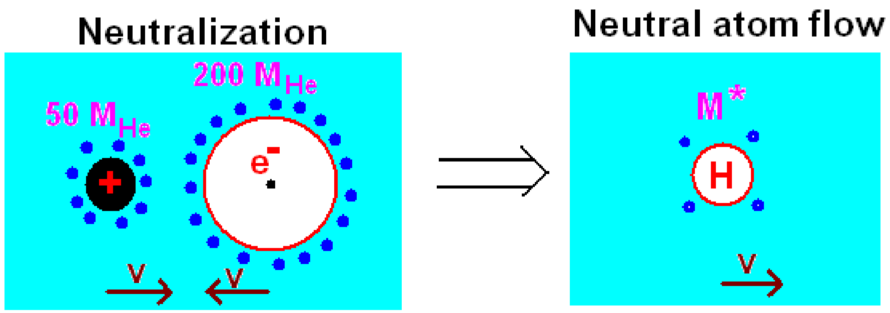


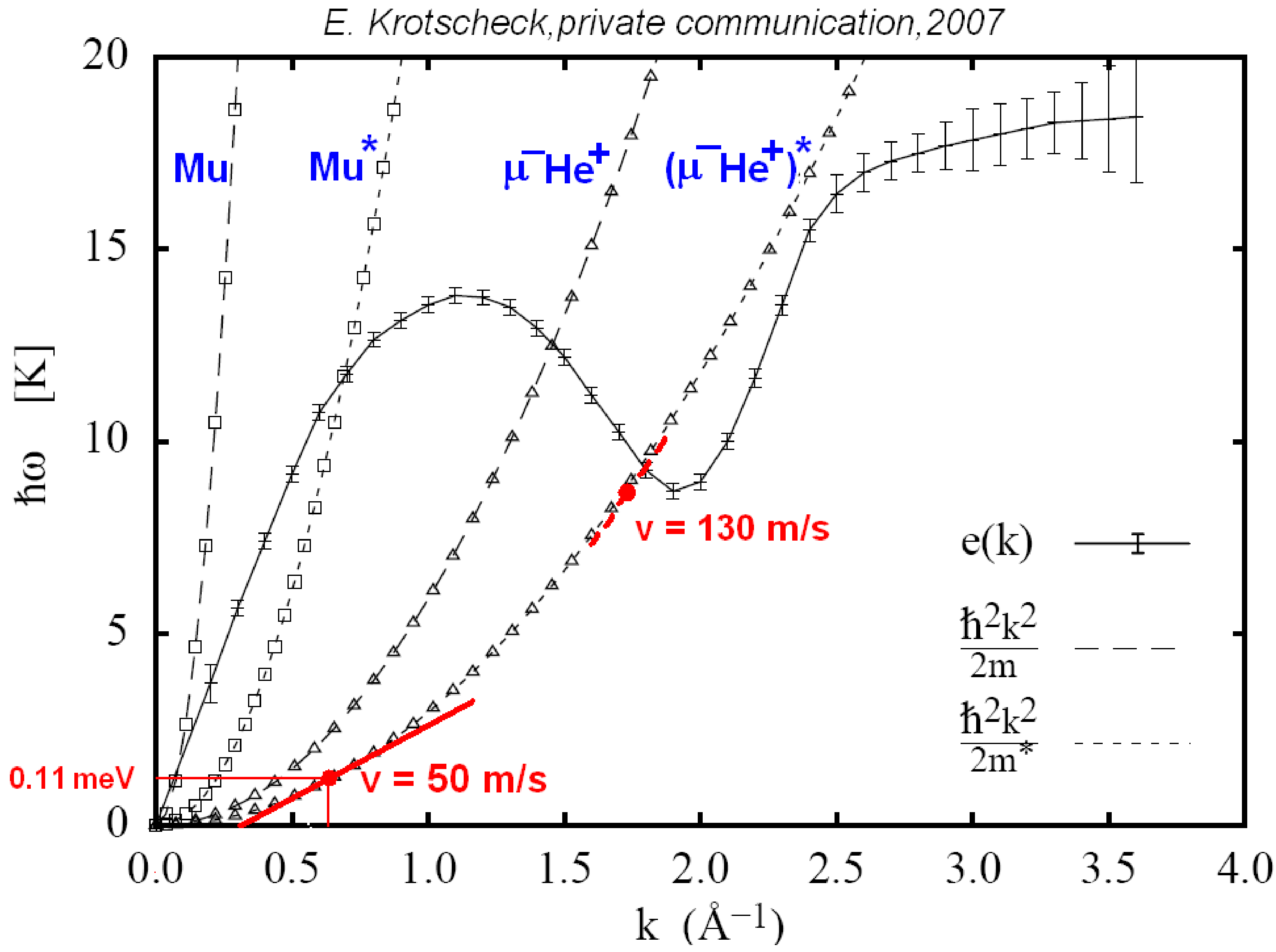
Figure 1. The drift velocity $\bar{v}$ of negative ions moving through He II under the influence of an electric field of 2.7 MV m^{-1}, plotted as a function of pressure P for two different temperatures.

→Velocity of electron bubbles at high field : v = 50 m/s

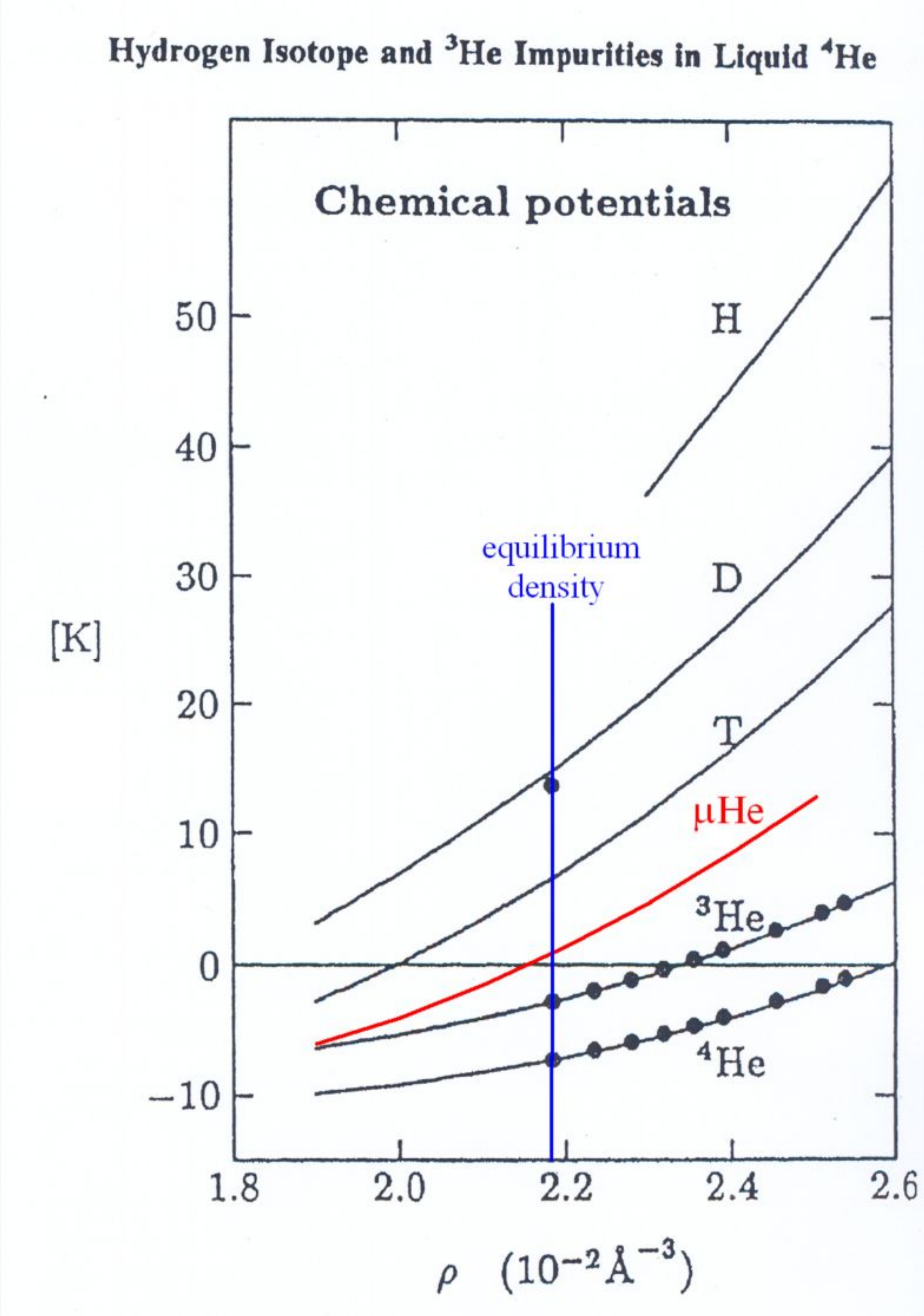
→Velocity of positive ion snowballs at high field: v = 50 m/s



Momentum conservation → Velocity of neutral atom: v = 50 m/s



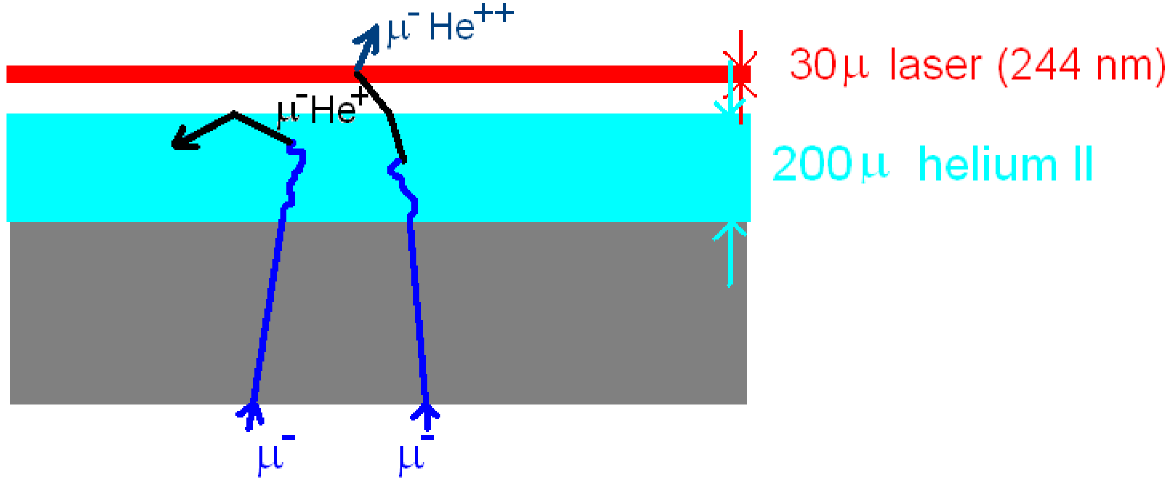
Superfluid helium excitation spectrum and muonic atom motion



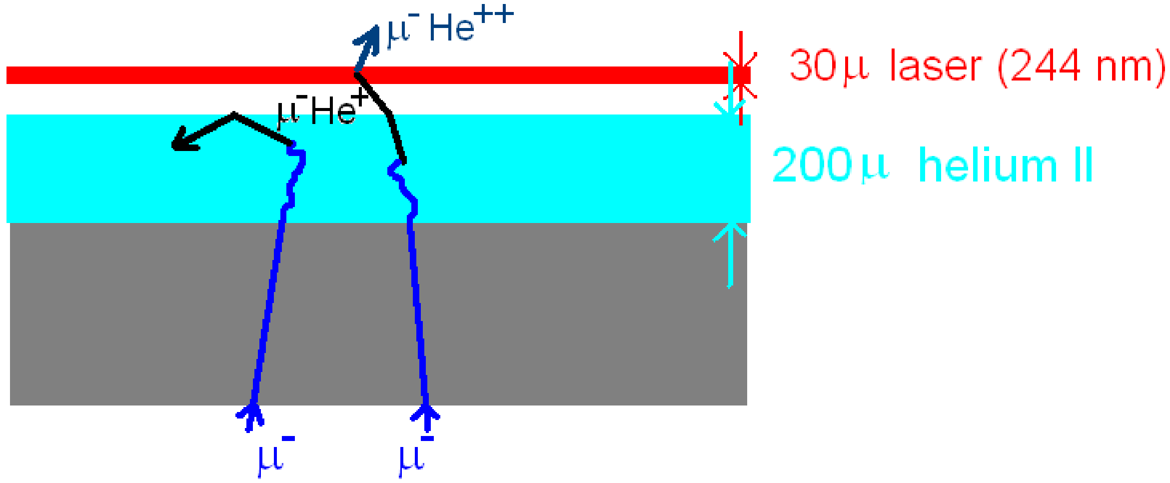
→any μHe (neutral) atom approaching the helium surface is kicked into vacuum with an excess kinetic energy of 0.9 K

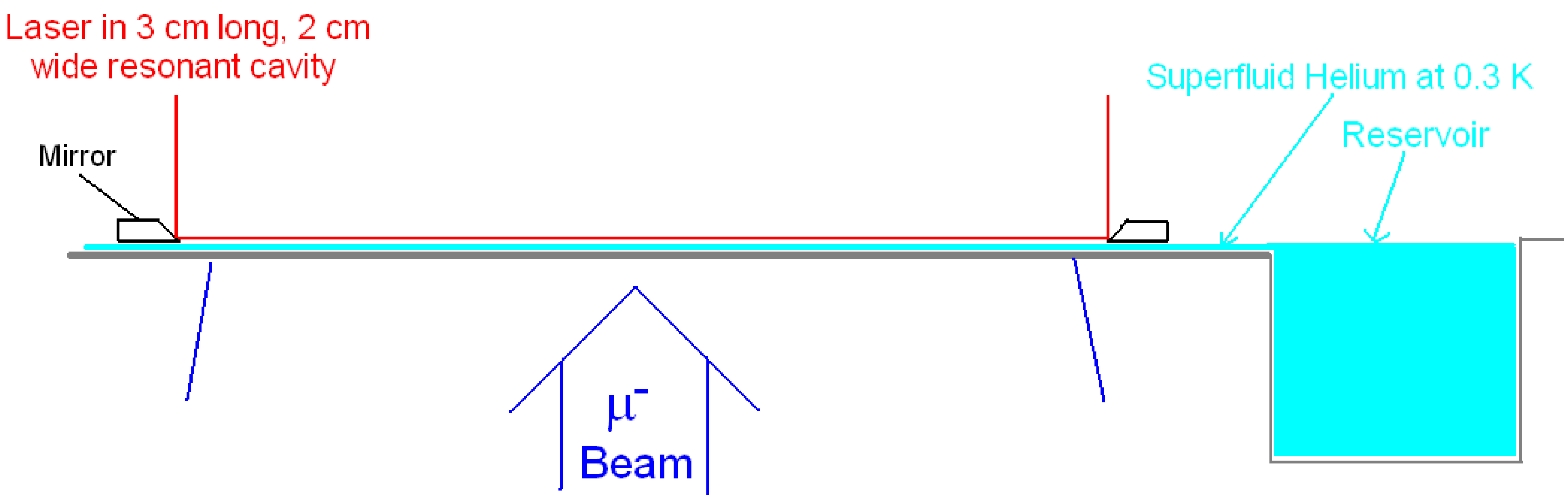
For μHe atoms having a velocity of 50 cm/s or an energy of 1.3 K the total energy after emission will be 2.2 K

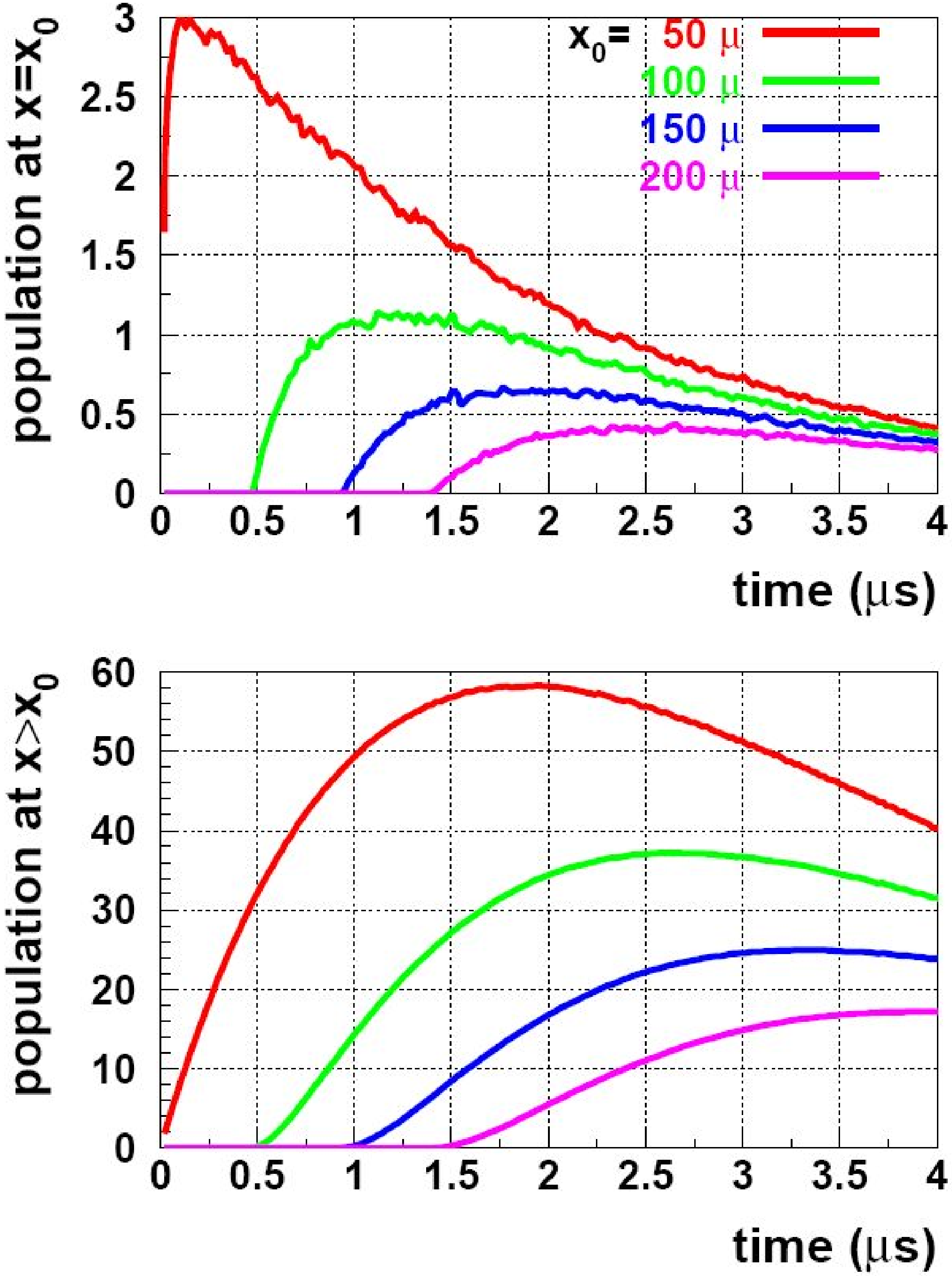
LASER IONIZATION OF μHe ATOMS



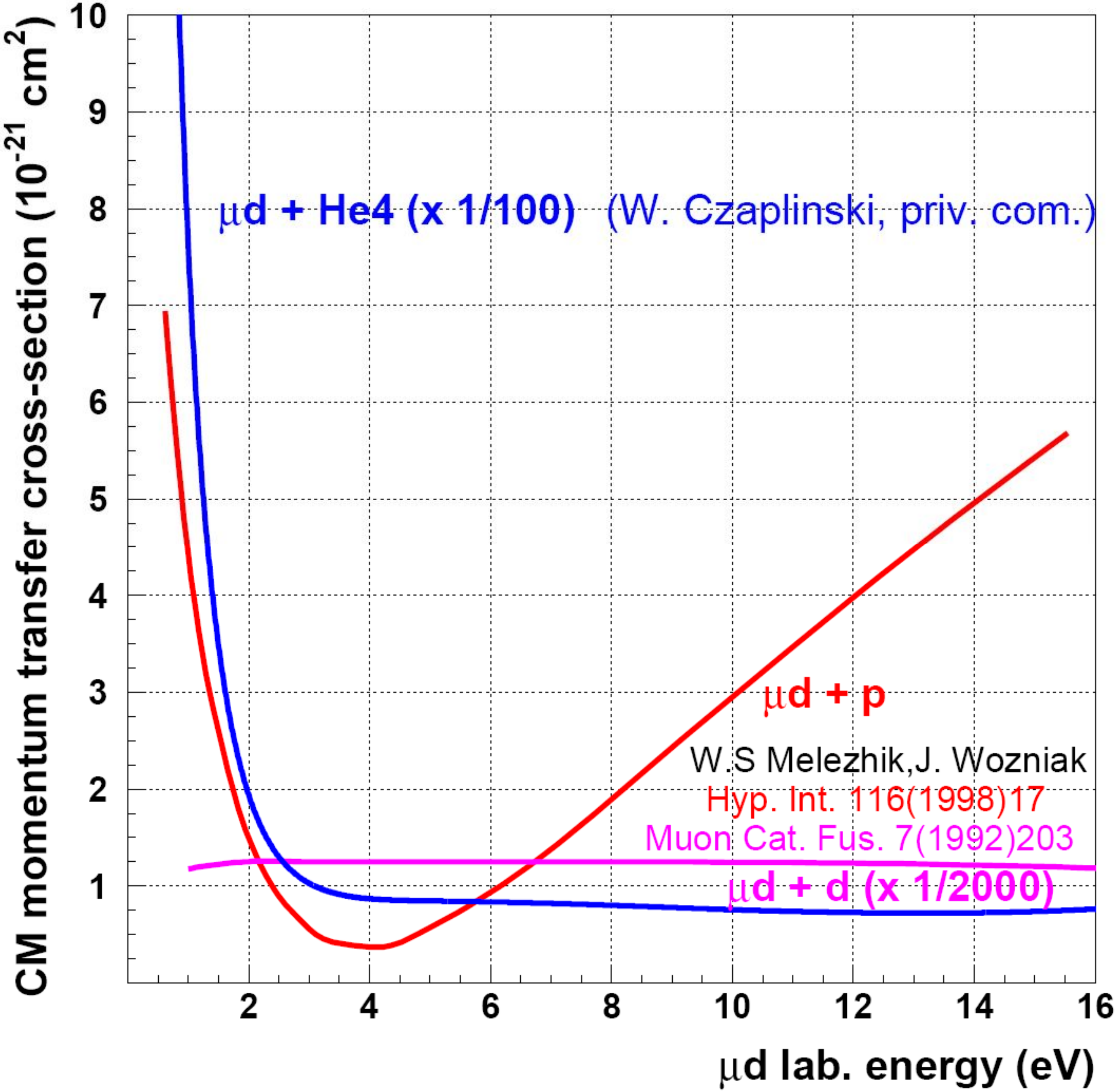
LASER IONIZATION OF μHe ATOMS







population at x=x0
x0= 50 μ
100 μ
150 μ
200 μ
0
0.5
1
1.5
2
2.5
3
3.5
4
time (μs)
population at x>x0
0
10
20
30
40
50
60
time (μs)



CM momentum transfer cross-section (10^-21 cm^2)
μd lab. energy (eV)
μd + He4 (x 1/100) (W. Czaplinski, priv. com.)
μd + p
W.S Melezhik,J. Wozniak
Hyp. Int. 116(1998)17
Muon Cat. Fus. 7(1992)203
μd + d (x 1/2000)
10
9
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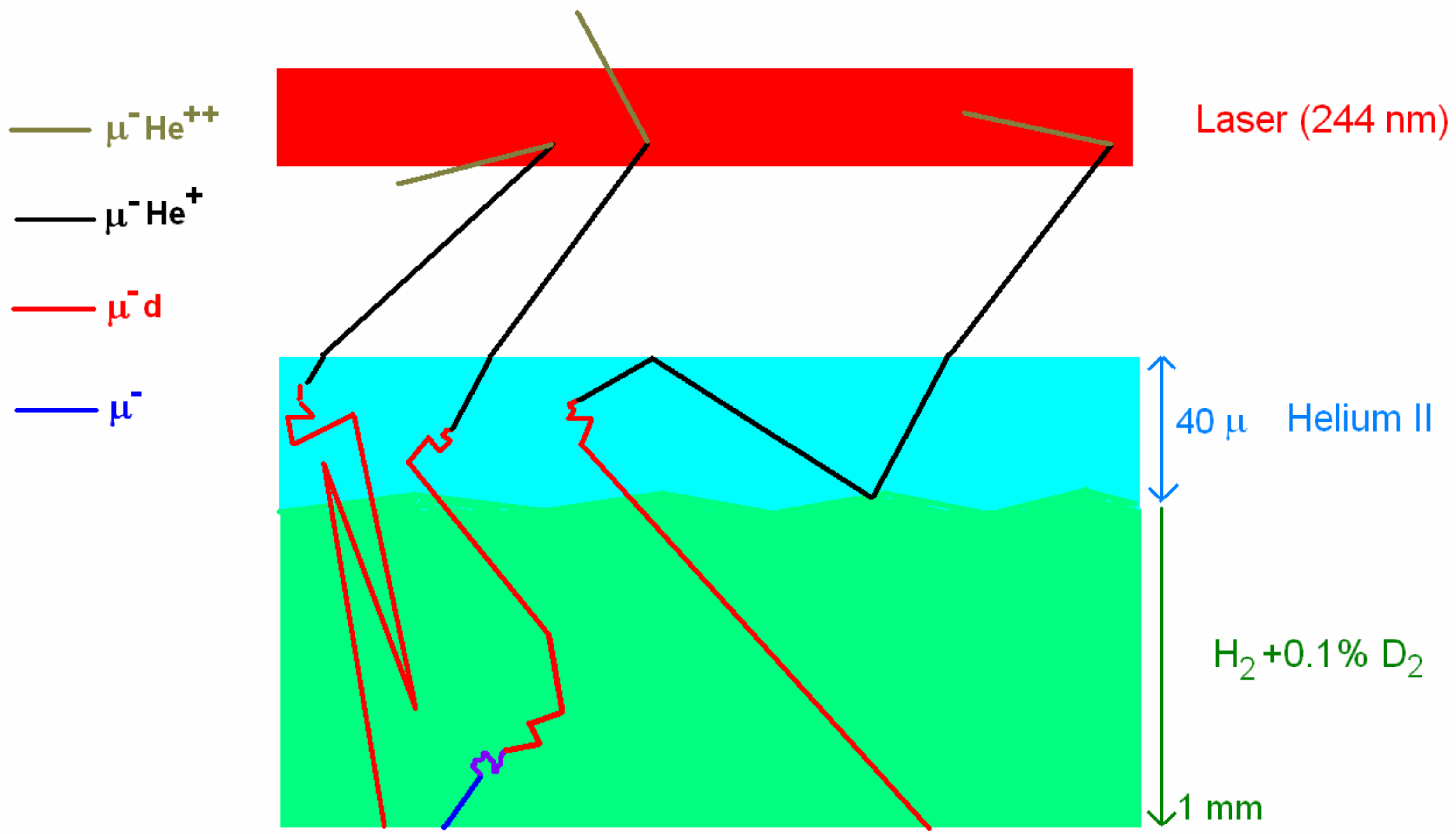
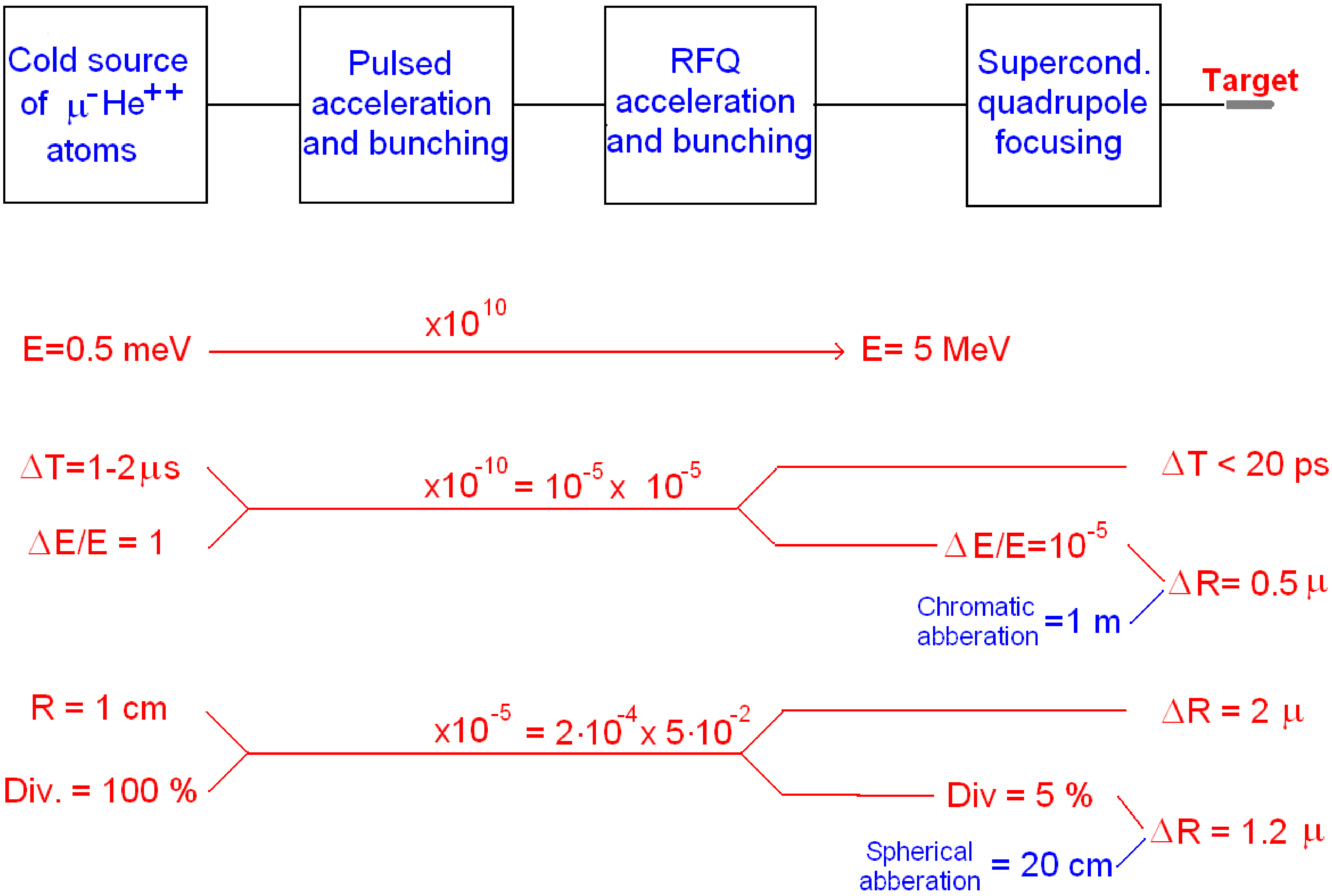
CONVERSION PROCESSES



ACCELERATION AND BEAM PROPERTIES



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CONCLUSIONS

1. A μ^- beam of 10 – 100 eV is feasible.
2. Achievable by adding a final stage to existing PSI beam. Intensity: 300 - 500 /s.
3. A new concept for intense low energy μ^- source in pulsed mode is proposed.
4. The basic property, the emission of $\mu^- He^{++}$ from Helium II into vacuum can be experimentally tested.