01/29/2013

On Possibility of Demonstration of Ionization Cooling at IOTA Ring.

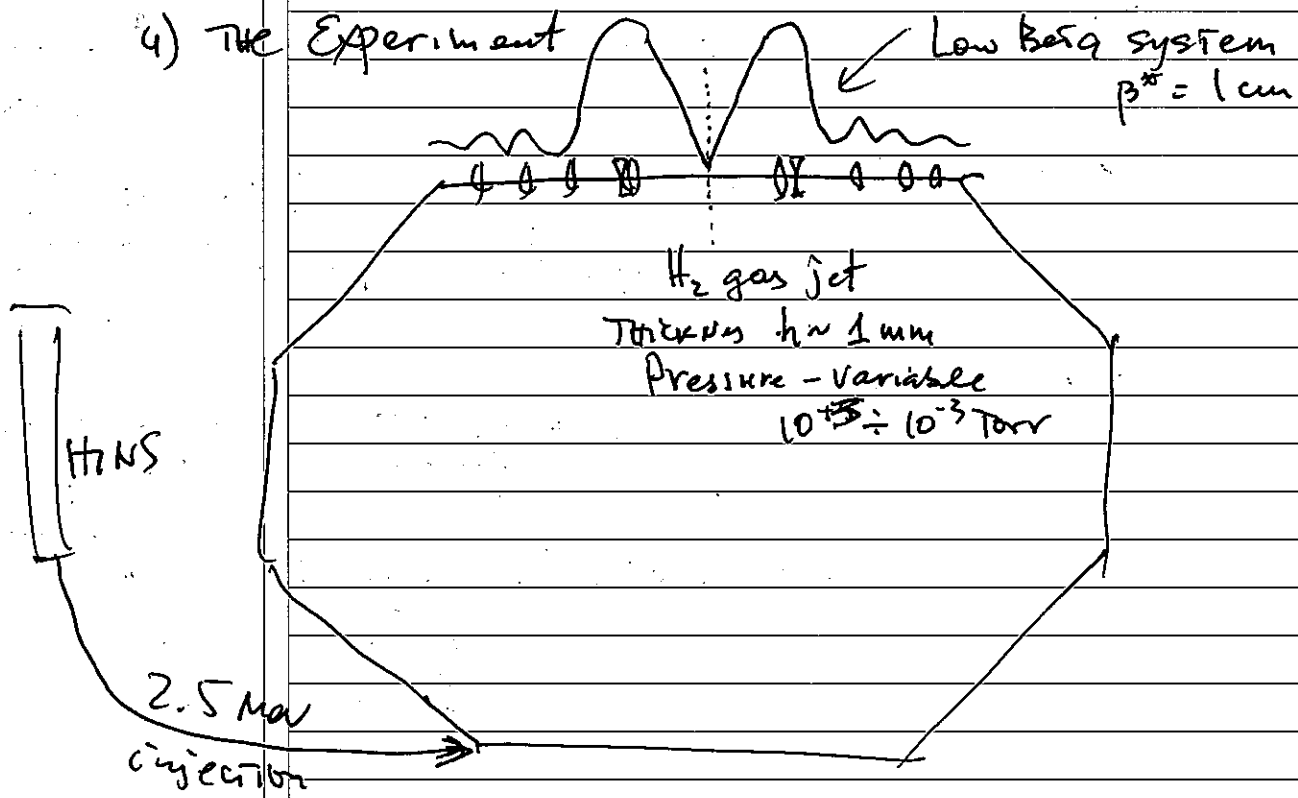
1) IOTA will have injection of 2.5 MeV protons

$pc = 70$ MeV/c

2) circumf. ~38 m $\beta_{proton} \approx 0.07 \rightarrow T_{rev} \approx 1.4\ \mu s$

3) in principle, we can arrange optics with $\beta^* = 1$ cm

4) The Experiment



5) Cooling decrement is about $\frac{1}{l_{cool}} = \frac{dE/dx}{E_{kin}} \cdot 2$ (or 1)

6) dE/dx for 2.5 MeV protons in H_2 appox 600 MeV/g/cm^2

ρ_{H_2} (@ 1 atm) ≈ 0.07 g/cm^3 (liquid) 0.084 g/l $= 8.4 \cdot 10^{-5}$ g/cm^3 (gas @ 1 atm)

$\Rightarrow l_{cool} = \frac{2.5}{600} \approx 4 \cdot 10^{-3}$ g/cm^2 $\times P[\text{atm}] = 0.6$ mm (liq.) $\times P[\text{atm}]$

gas $\rightarrow 500$ mm $\cdot P[\text{atm}]$

7) Scattering $\frac{\Delta\theta^2}{\Delta l} = \left(\frac{13.6\ \text{MeV}}{\beta p c}\right)^2 \frac{1}{X_0}$

≈ 70 MeV/c · c · 0.07 = 5 MeV

for H_2

$\rightarrow X_0 = 63\ g/cm^2$ @ 1 atm or 900 cm/p[atm]

8) emittance evolution: $\frac{d\varepsilon}{dt} = -\frac{\varepsilon}{l_{cool}} + \beta^* \frac{\Delta\theta^2}{\Delta l}$

$\varepsilon = \beta^* \frac{\Delta\theta^2}{\Delta l} \cdot l_{cool}$ or for NORM emittance

$$\varepsilon_n = \varepsilon \cdot (\beta\gamma) = 0.07 \cdot 10^4 [\mu m] \cdot \left(\frac{13.6}{70}\right)^2 \cdot \frac{E_{kin}}{\frac{dE}{dx} \cdot X_0}$$

$$= 7 \cdot 10^{-2} \cdot 10^4 \cdot \frac{200}{26} \cdot \frac{2.5}{600 \cdot 63} = 1 \cdot 10^{-1}\ \pi\ \text{mm·mrad}$$

@ 1 atm

9) So, if gas pressure is P (atm): $\frac{dE}{dx} \sim P$ $X_0 \sim \frac{1}{P}$

$\rightarrow \varepsilon_n = 0.4\ \pi$ mm mrad

10) Cooling Time

$$\tau_{cool} = \frac{E_{kin}}{\frac{dE}{dx} \cdot \rho \cdot h} \cdot T_{rev} = \frac{2.5\ \text{MeV}}{600 \cdot 8.4 \cdot 10^{-5} \cdot 0.1} \times 1.4\ \mu s =$$

$h = 1$ mm $= 0.1$ cm

$= 500$ turns $\cdot 1.4\ \mu s = 0.7$ ms !! @ 1 atm

0.5 s @ 1 Torr

500 s @ 1 mTorr

11) nuclear interactions – NON existant @ $E_k = 2.5$ MeV?

– So lifetime will be determined by large angle scattering

12) So DOTA experiments:

1) Demo ionization cooling of 2.5 MeV protons –

– requires $\beta^* = 1$ cm and gas jet @ DOTA + HINS

2) M.b. Test of PIC (parametric ionization cooling)

3) vary gases and see effect

4) chromatic effects $d\beta^*/dp/p$ and cooling

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