15, EHF workshop
Lecce 1989

Targetry, Bunch Rotation, Cooling

G. Bisoffi, K. Bongardt, M. Conte, F. Griffin
C. Rossi-Alvarez, L. Tecchio

1) Targetry

a) users would like to get: $\approx 10^6$ Fragments / sec

Booster Intensity: $7 \cdot 10^9$ Ion / Pulse

Target production yield: $10^{-9} - 10^{-5}$ (thin target 1 cm)

accumulation and cooling time $T = 2\,sec$

$\rightarrow 7 \cdot 10^9$ Ion / pulse $\cdot$ 1 / pulse $\cdot 10^{-5} \cdot \frac{1}{2\,sec}$: $4 \cdot 10^5$ Ion

don't loose to much intensity in between!

b) Estimate of ε_T, $\frac{\Delta p}{p}$

spot size at target position: $\pm 1\,mm \mathrel{\hat=} \beta_T = 25\,cm$

$M_F = \lambda \cdot M_P$ $\qquad \lambda = 0{,}9$, $0{,}5$

$\lambda = 90\%$: $\frac{\Delta p}{p} = \pm 0{,}45\%$ (2σ-value)

$\varepsilon_T = 5\pi$ mm mrad (4σ-value)

$\lambda = 50\%$: $\frac{\Delta p}{p} = \pm 1{,}3\%$ (2σ-value)

$\varepsilon_T = 15\pi$ mm rad (4σ-value)

(ε_T, $\frac{\Delta p}{p}$): independent of projectile mass M_0!

2) Bunch Rotation

- conservative approach: $\frac{\Delta p}{p} = \pm 0{,}3\%$ before bunch rotation

which means: $\lambda =$ 0,9 : 66% capture effiency
0,5 : 30% " "

big problem: how fast can the cavity be empted?

$\frac{\Delta p}{p} = \pm 0{,}3\%$ → $V \sim 500$ keV at $f = 45$ MHz

in the Holding Ring: $\gamma_T \sim 4$: $\eta = 0{,}18$

$\frac{T}{4}$ quarter time ~20 μsec

it should be possible: $T_{Decay} \sim 30$ μsec

after bunch rotation: $\| \frac{\Delta p}{p} = \pm 0{,}1\% \|$

be aware: for a long transfer line (≳70m): bunch is tilted

- rf-stacking

with a second cavity, turned on during the bunch rotation, $V \sim 25$ kV:

bunch is captured and longitudinally stacked:

T ~ m sec (a few)

3) Cooling System

- basic parameters: $\varepsilon_T = $ 5 π mm mrad (λ = 0,9) / 15 π mm mrad (λ = 0,5)

  D = 0

  at position of e^--cooler: $\beta_H \sim 15$m, $\beta_V \sim 5$m

  ϕ_{e^-} = 13 mm

  r_H = 8,7 mm (λ = 0,9) (2σ) / 15 mm (λ = 0,5 (2σ-value)

  r_V = 5 mm (λ = 0,9) / 9 mm (λ = 0,5)

  which means: good overlap for $\frac{2}{3}$ - inbeam (λ = 0,5 / 100% " (λ = 0,9

  (transverse, longitudinal) cooling time $\tau \sim \Theta^3 \cdot \frac{A}{Z^2}$

  with: $\Theta^2 = \Theta^2_{i,H} + \Theta^2_{i,V} + \Theta^2_{i,L} + \Theta^2_{e,(H,V,L)}$

  for $\frac{\Delta p}{p} = \pm 0{,}1\%$, ε_T = 5π (λ = 0,9) / 15π (λ = 0,5), A = 10, Z = 5

  $\tau_{lon,H,V} \sim$ 100 m sec (λ = 0,9) / 470 m sec (λ = 0,5)

  but 12 C: $\tau \sim$ 1 sec (λ = 0,9)

- e^--cooling system

  U ~ 530 kV, I = 10 A, j = 7,5 A/cm²

  ϕ = 13 mm, L_{sol} = 8 m, $B_0 \sim$ 4 kG

  factor 2 more power than the Novosibirsk!

- after stacking + cooling: <u>decelerating system</u>

wanted here: $\left(\frac{\Delta p}{p}\right)_f = \pm 2.5 \cdot 10^{-5}$

in order to keep <u>$V \sim 70$ kV</u> in the cavity!

how to get there?

<u>$\lambda = 0.5$ case</u>: $\varepsilon_T = 15\pi \longrightarrow$ <u>$\varepsilon_T = 7.5\pi$</u>:
contains <u>$\frac{2}{3}$</u> of the beam!

which means: $\tau \sim$ 100 m sec Au; 1 sec 12 C !

<u>independent</u> of λ : $M_F = \lambda \cdot M_P$

end of the stack:

$\frac{\Delta p}{p} = \pm 10^{-3}$ Au

$\pm 5 \cdot 10^{-3}$ 12 C : <u>$\tau \sim 10$ sec!</u>

now: <u>longitudinal</u> stochastic system:

task: $\boxed{\frac{\Delta p}{p} = \pm 5 \cdot 10^{-3} \xrightarrow[\leq 1 \text{ sec}]{} \pm 1 \cdot 10^{-3}}$

following <u>cycle</u>: ↑

stoch. cool. e^--cool: $\pm 2.5 \cdot 10^{-3}$

[illegible]

- stochastic longitudinal system

with a stochastic system:

$\frac{\Delta p}{p} \doteq \pm 5 \cdot 10^{-3} \xrightarrow[\leq 1\,sec]{} \pm 1 \cdot 10^{-3}$

system should work for low (A, Z)-vals

- transverse cooling

at E = 1 GeV/N: $\varepsilon_T = 5\pi \cdot 10^{-6}$

deacceleration down to E = 12 MeV/N:

$\varepsilon_T = 50\pi \cdot 10^{-6}$ m

but: acceptance of PHR ~ 140 π!

in addition: users don't want $E \geq 50\pi \cdot 10^{-6}$ m

Remedy: e^--cooling at E = 1 GeV/N: does also transverse cooling

may be in addition foreseen: 'small' e^--cooling at E = 10 MeV/N ≙ U ~ 5 kV

- intensity effects

Booster: $7 \cdot 10^{9}$ Ion/pulse, Target Yield 10

in reality: both numbers depends A, Z

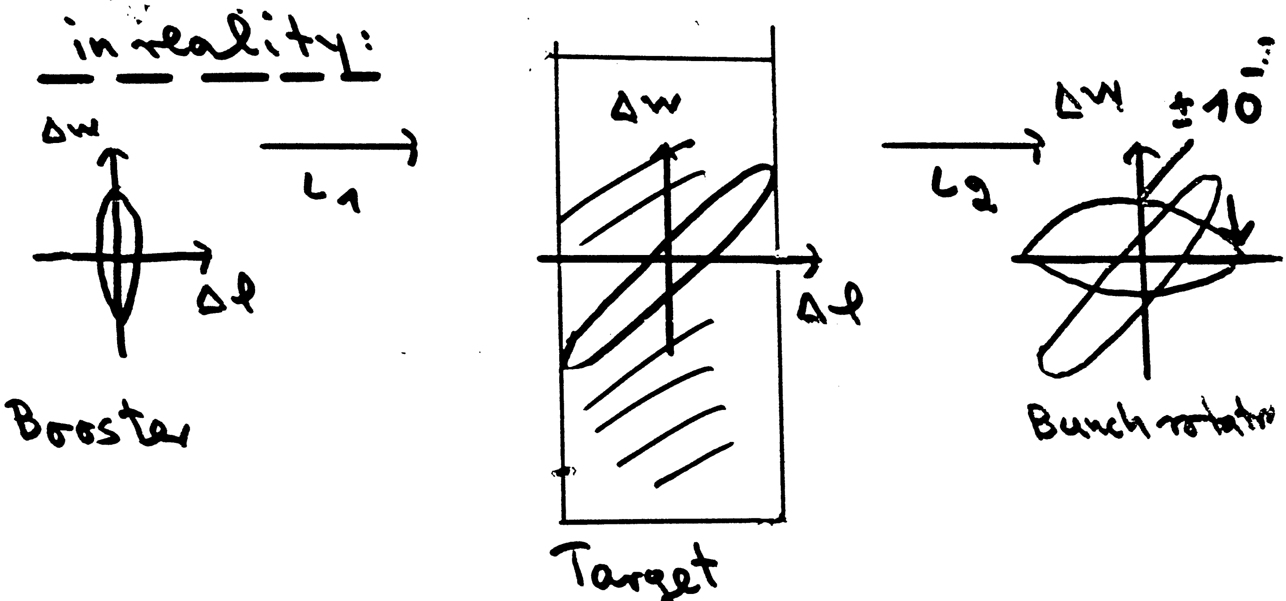
e^--cooling: look at $(\frac{\Delta p}{p})_c$: stoch. coo: τ = τ(N

- transfer line PB → PHR, degrader

1) long transfer line

up to now: upright ellipse at bunch rotation cavity

in reality:



for $L_1, L_2 \geq 30\,m$: look at the effect!

in addition: if green area is large:

$\left(\frac{\Delta p}{p}\right) \neq \pm 10^{-3}$ after rotation!

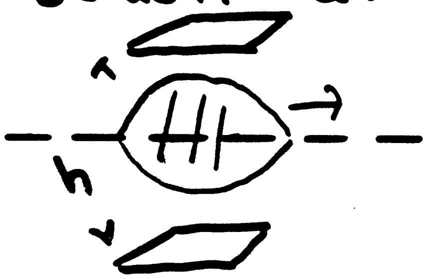
2) Degrader

for e^- - cooling:

$\tau \sim \varepsilon_T^2 + \left(\frac{\Delta p}{p}\right)^2$: only for good overlap!

but: $\phi_{e^-} = 13$ mm : limited to current density!

for stochastic cooling:



pickup sensitive is dependent on h!

Conclusion

for cooled fragments with 10^6 ion/sec

- at the production target:
  spot radius ~ 1mm

- bunch rotation cavity
  seems to be possible for $\frac{\Delta p}{p} = \pm 0,3\%$

- cooling of the fragments
  $\frac{\Delta p}{p} = \pm 2,5 \cdot 10^{-5}$: needs a careful designed e^- - system

- longitudinal stochastic system
  $$\frac{\Delta p}{p} = \pm 5 \cdot 10^{-3} \xrightarrow[\leq 1\,sec]{} \pm 1 \cdot 10^{-3}$$
  system should work for low (A, Z)-values and different particle numbers

- after deceleration to E = 12 MeV/N:
  'small' e^- - system with U ~ 5 keV reduces transverse dimensions

- length of transfer line, degrader cheque carefully with the cooling system if 10^6 Ion/sec!