



# ELECTRON COOLING OF $^{18}\text{Ne}^{10+}$ IN AN ACCUMULATOR RING BEFORE THE RCS

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THIS WORK WAS ALSO PRESENTED AT  
EPAC 2006 AS

# A LOW ENERGY ACCUMULATION STAGE FOR A BETA-BEAM FACILITY

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[ACCELCONF.WEB.CERN.CH/ACCELCONF](http://ACCELCONF.WEB.CERN.CH/ACCELCONF)

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# ELECTRON COOLING

FAST FOR COLD IONS, SLOWER WHEN  
ELECTRON AND ION VELOCITIES  
DIFFER

NOT DEPENDENT ON ION CURRENT

MUCH FASTER LONGITUDINALLY THAN  
TRANSVERSELY

$1/\text{COOLING TIME} \sim Q^2/A \times I_E / \Theta^3$ , WHERE  $\Theta$   
IS THE ANGLE

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BETWEEN IONS AND ELECTRONS



# ACCUMULATION

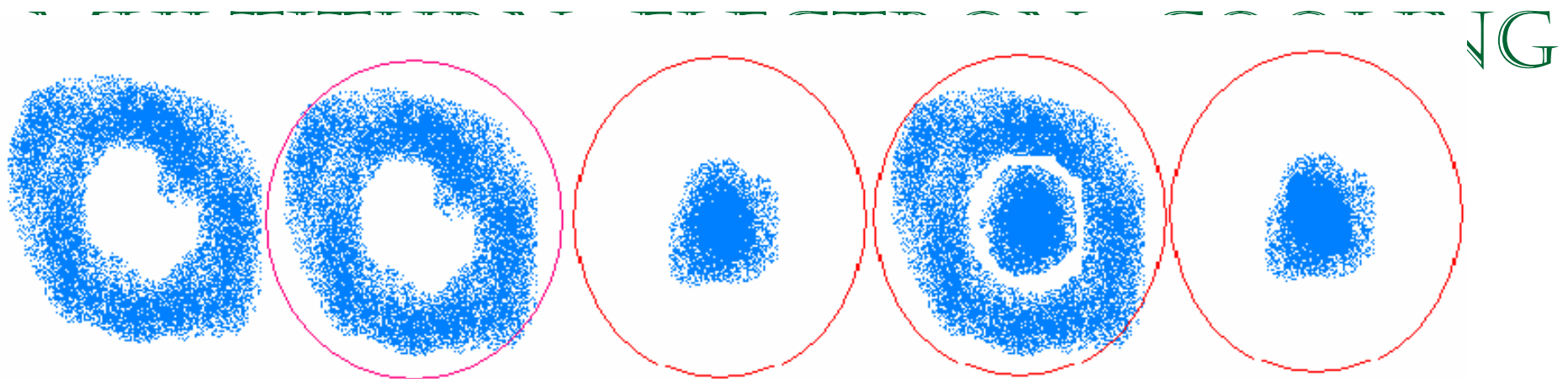
IN THE PREVIOUS MEETING WE HAVE DISCUSSED USING A RING TO ACCUMULATE IONS WITH ELECTRON COOLING AT 100 MEV/U. CALCULATIONS OF ELECTRON COOLING ARE ESSENTIAL FOR ESTIMATES OF ACCUMULATION WITH 0.1 S BETWEEN EACH INJECTION. HERE WE PRESENT MORE ACCURATE CALCULATIONS THAN EARLIER AND ALSO A FIRST VERSION OF THE ACCUMULATOR RING



# PRINCIPLE OF ACCUMULATION WITH COOLING

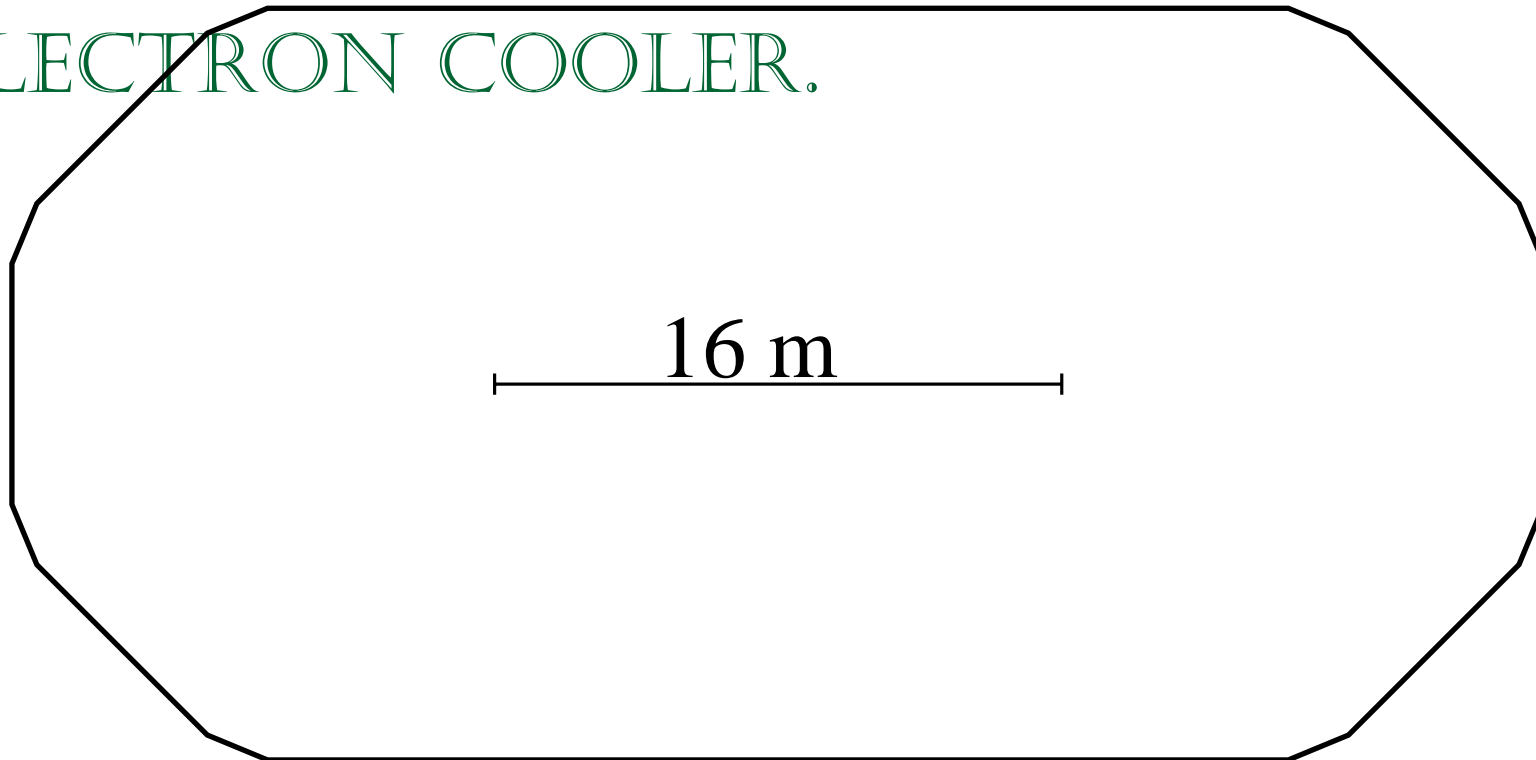
## HORIZONTAL PHASE SPACE

### HORIZONTAL NEW



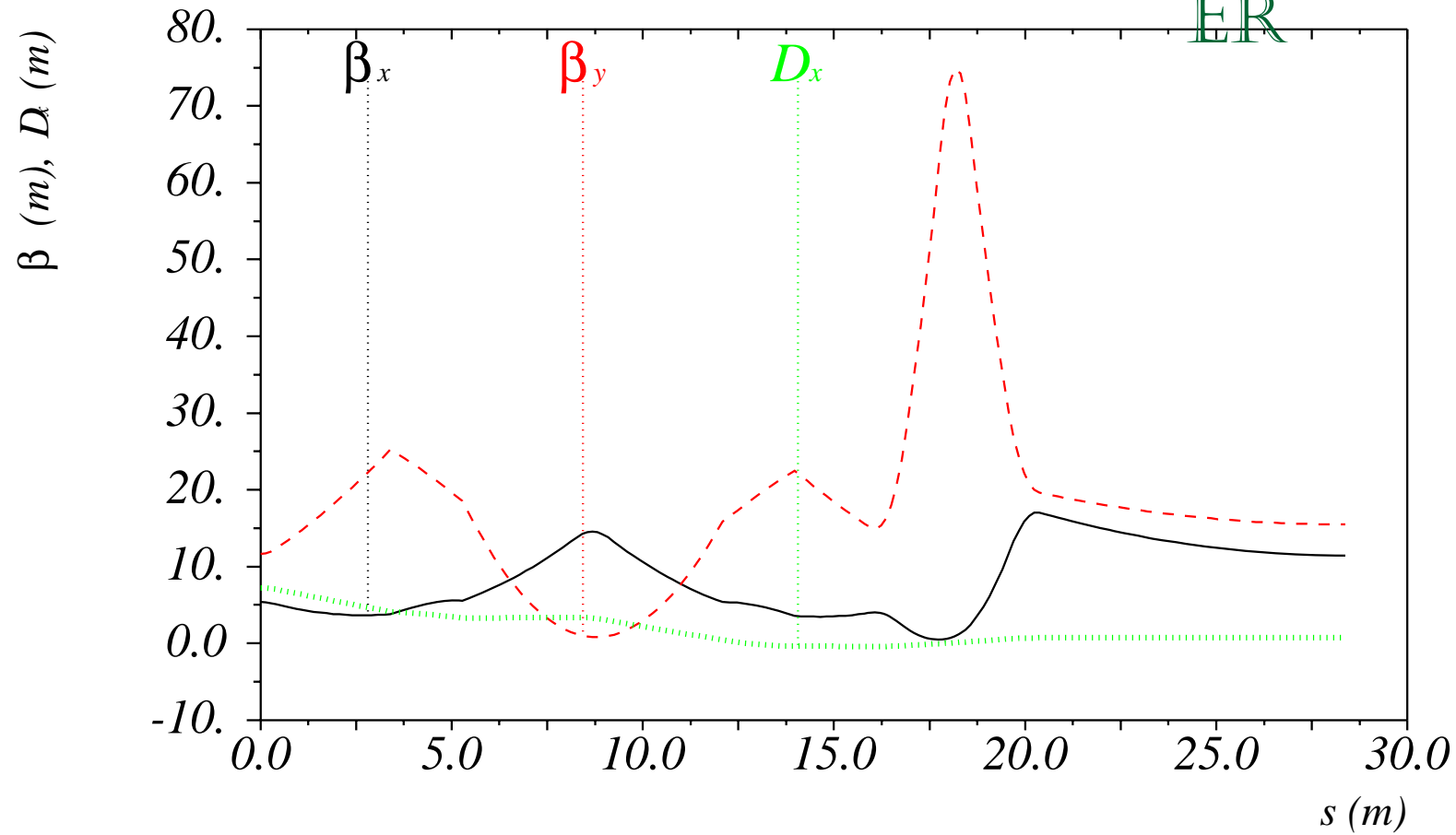
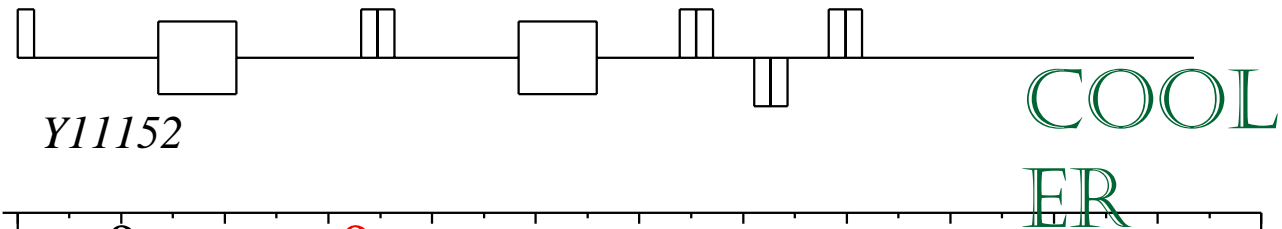


A BIRDS-EYE VIEW OF AN 114 M CIRCUMFERENCE ACCUMULATOR RING WITH TWO 16 M FREE STRAIGHT SECTIONS AND ROOM FOR A 14 M LONG ELECTRON COOLER.





# LATTICE FUNCTIONS OF $\frac{1}{4}$ OF THE ACCUMULATOR RING.





${}^6\text{He}^{2+}$  VS  ${}^{18}\text{Ne}^{10+}$

1/COOLING TIME  $\sim Q^2/A$  (THEORY)

OR

1/COOLING TIME  $\sim Q^{1.7}/A$  (CRYRING MEASUREMENTS)

COOLING OF  ${}^{18}\text{Ne}^{10+}$  IS 5 – 8 TIMES FASTER THAN COOLING OF  ${}^6\text{He}^{2+}$ , WHICH IS GOOD SINCE COOLING OF HELIUM IS PROBABLY NOT NEEDED. THE FOLLOWING CALCULATIONS ARE FOR NEON

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# ACTIVATION

IN THIS PRELIMINARY DESIGN  
ACTIVATION OF THE MAGNETS IS  
NOT STUDIED, BUT ONE HAS THE  
ADVANTAGE THAT ONLY NEON  
WILL BE STORED IN THE RING SO THE  
POSITIONING OF SCRAPERS WILL BE  
EASIER THAN IN OTHER RINGS IN  
THE COMPLEX.

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# SIMULATIONS OF TRANSVERSE COOLING

INPUT: HOLLOW ION BEAMS SO ALL IONS HAVE THE SAME TRANSVERSE EMITTANCE

SIMPLE TRACKING WITH 3 D COOLING FORCE AND ELECTRON BEAM SPACE CHARGE

INTRABEAM SCATTERING ISN'T INCLUDED, SO THE RESULTS FOR THE COLDEST IONS ARE WRONG

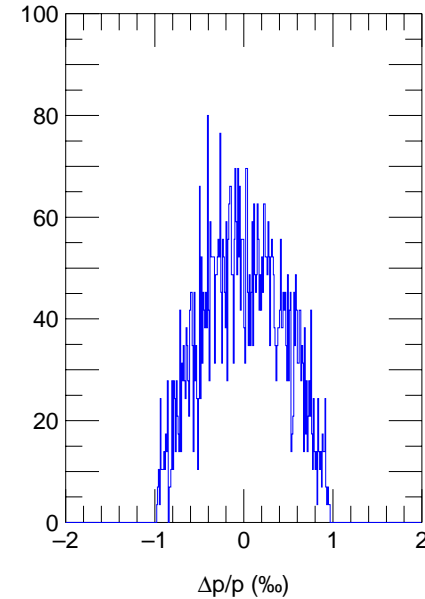
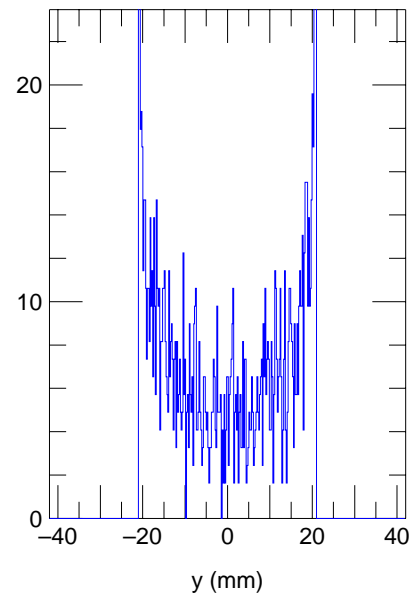
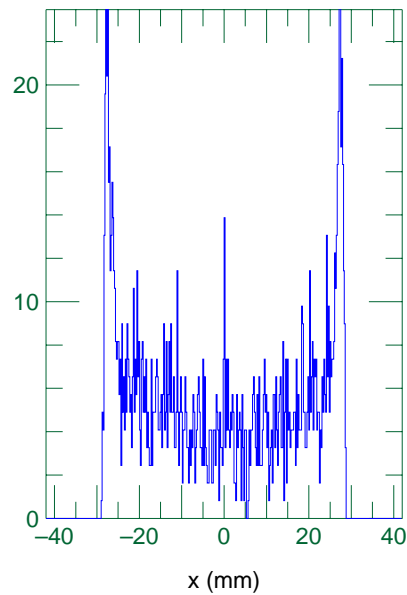
T=0.00 S



ALL IONS START WITH  $\epsilon_x = 65 \pi$  mm mrad and  
 $\epsilon_z = 30 \pi$  MM MRAD

INTEN

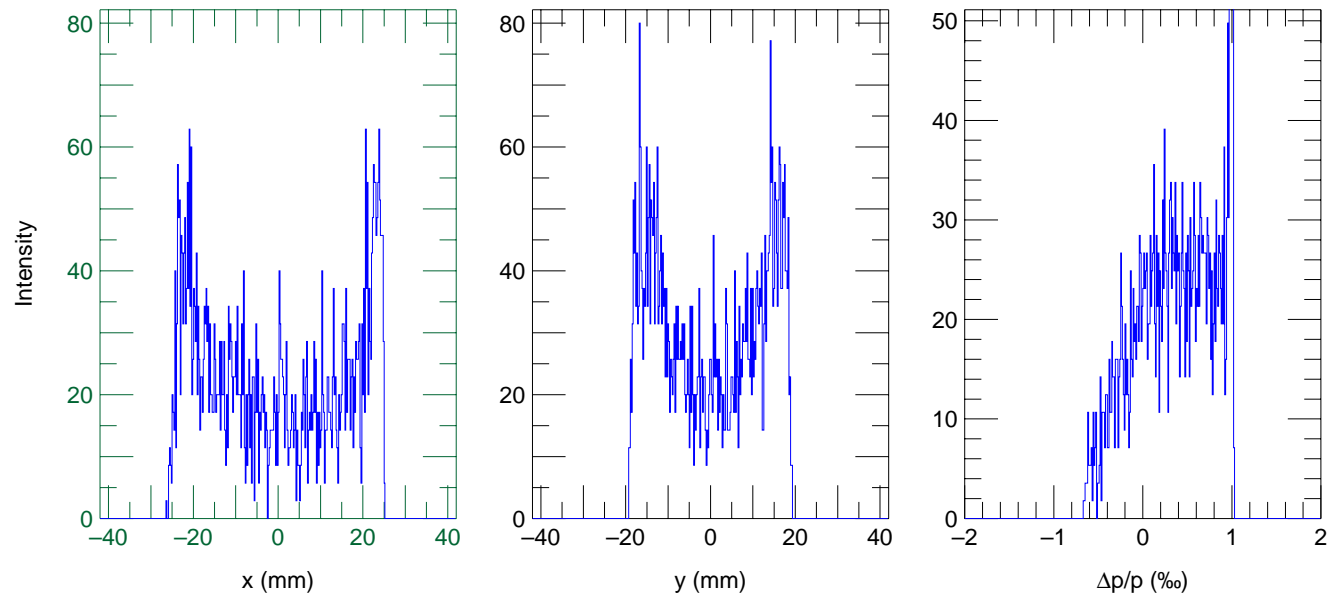
SITY  
Intensity



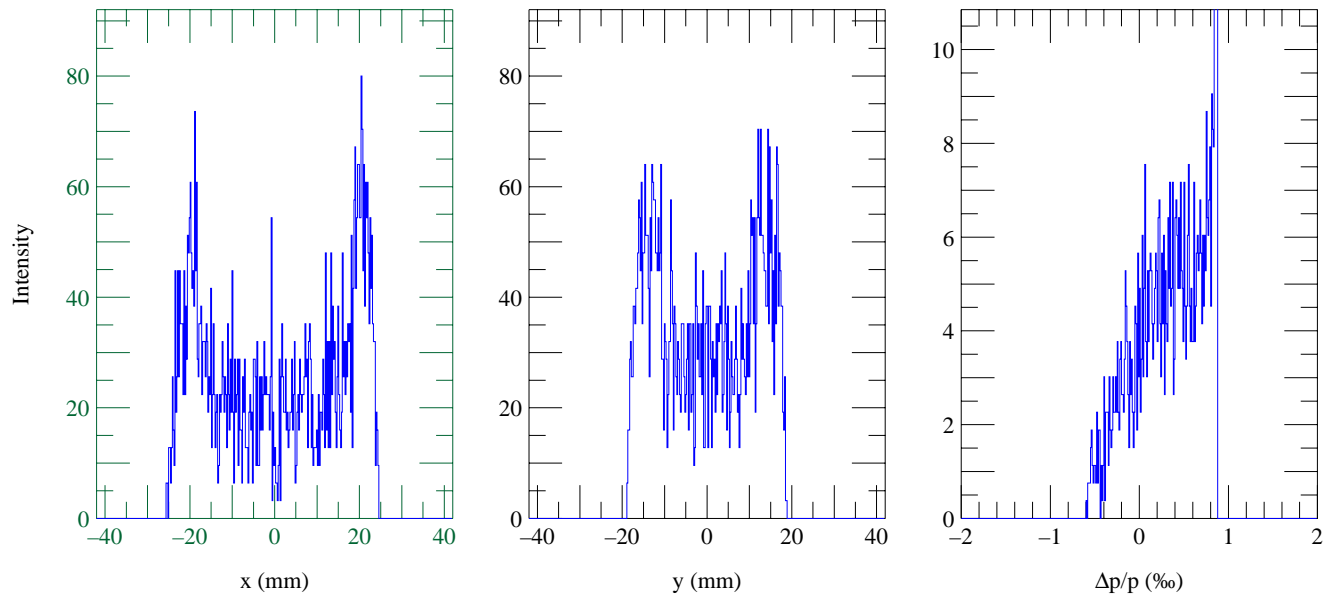
HORIZONTAL  
LONGITUDINAL

VERTICAL

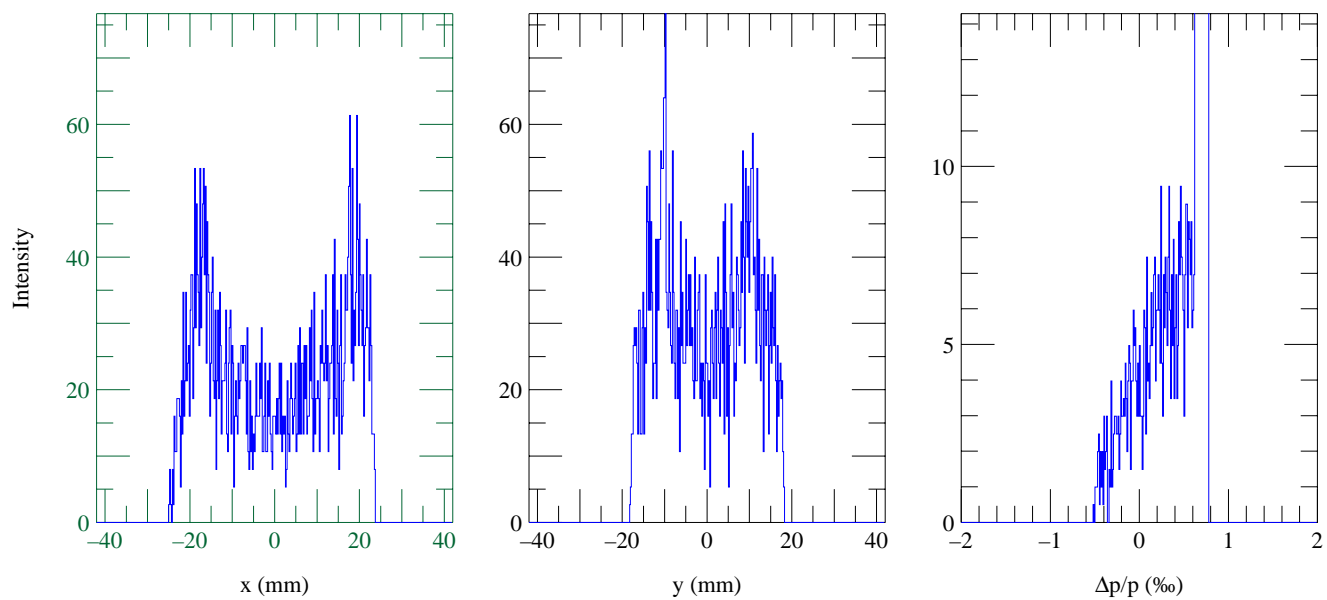
$T=0.05$  S



$T=0.06$  S



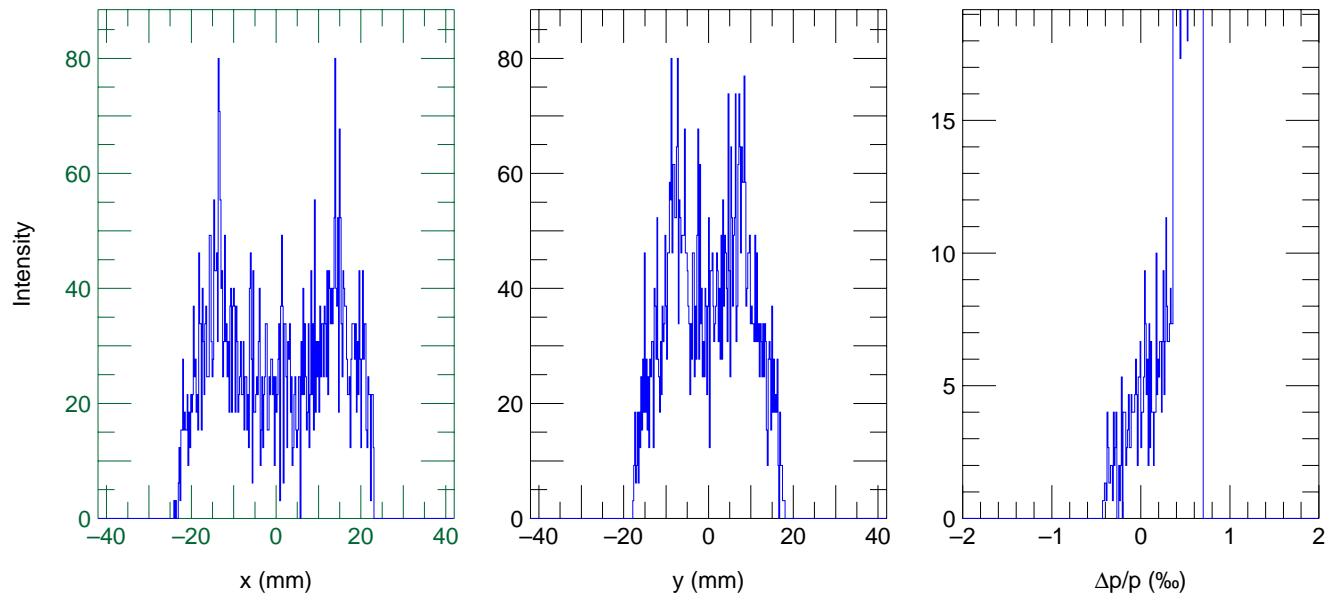
$T=0.07$  S



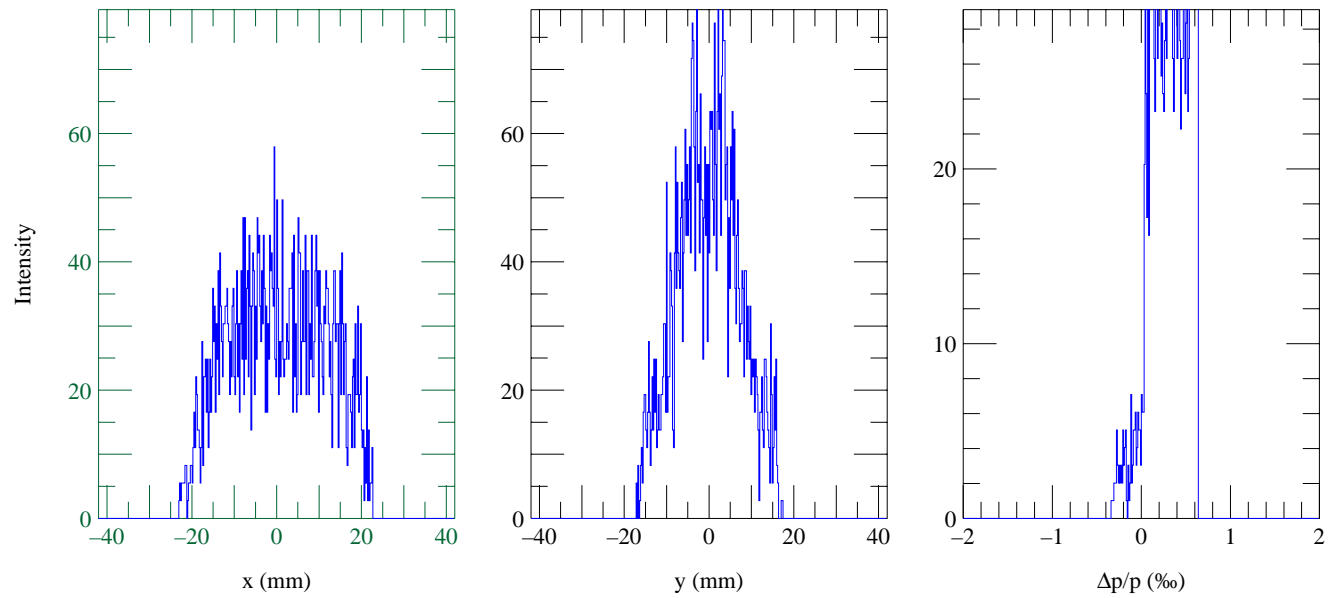
$T=0.08$  S



# LONGITUDINAL COOLING FASTER



$T=0.09$  S



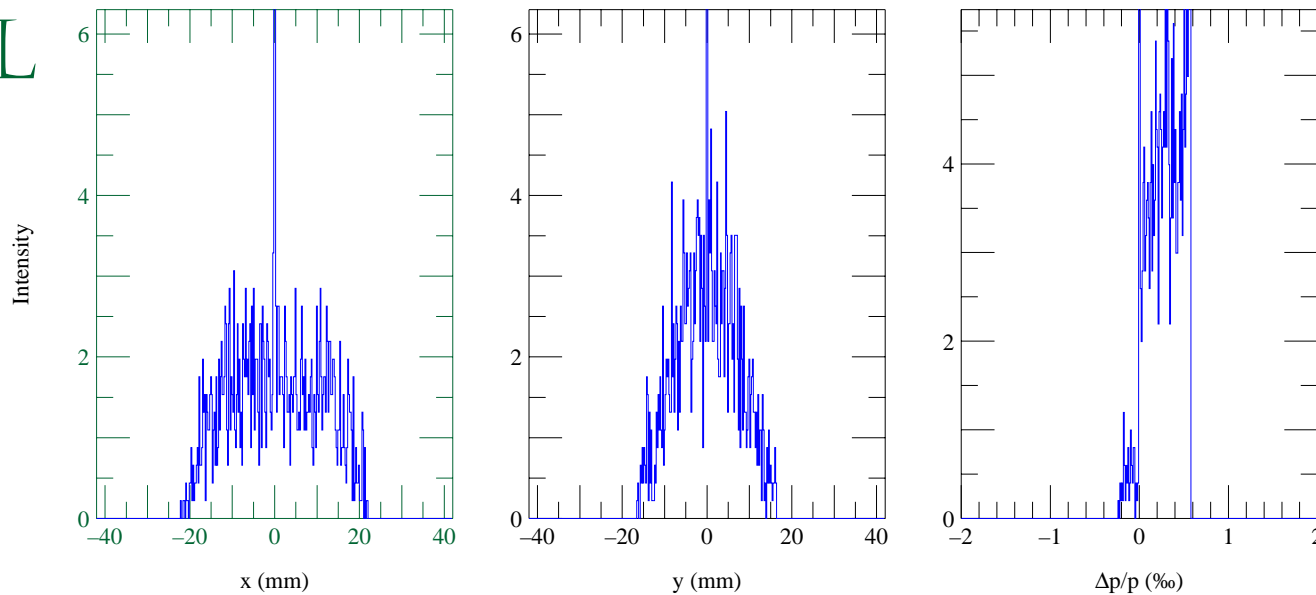


T=0.10 S

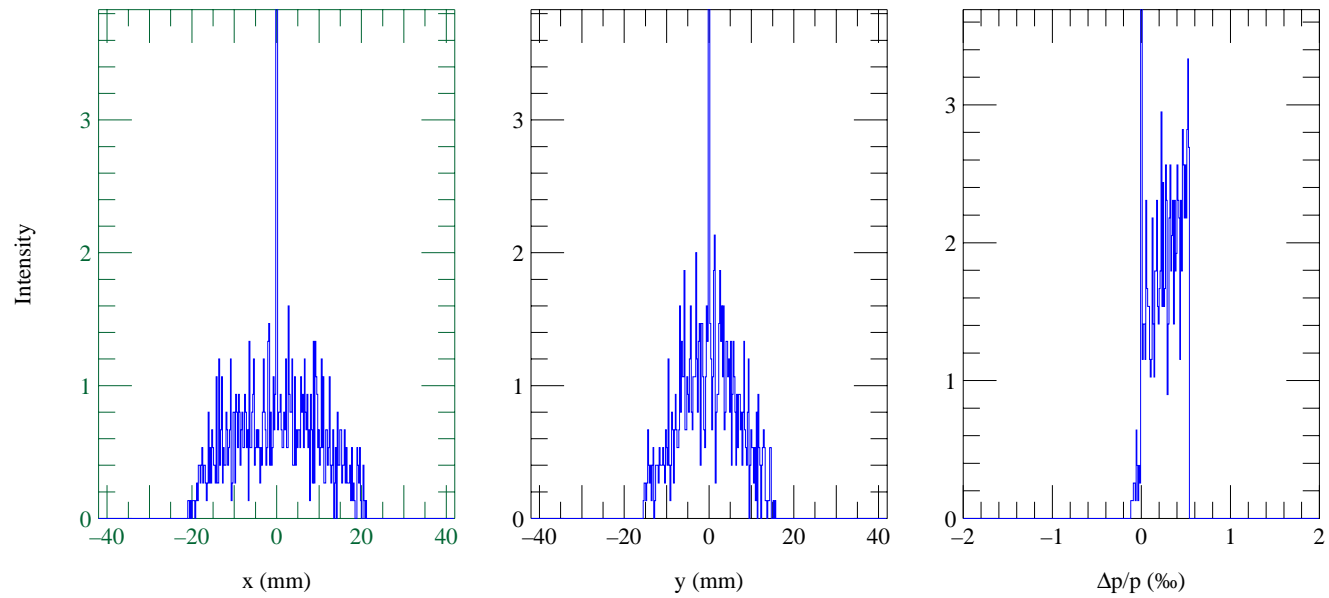


INTRABEAM SCATTERING IS NOT INCLUDED IN THE CALCULATIONS, SO THE BEAM CAN BECOME INFINITELY

SMALL



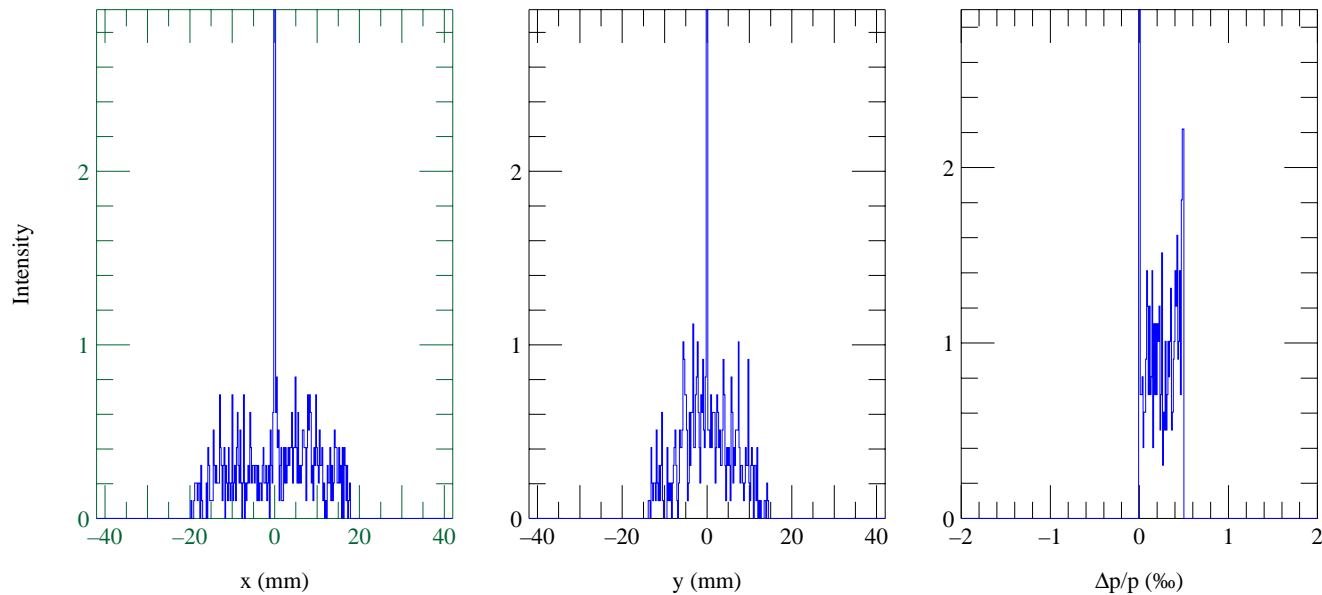
$T=0.11$  S



$T=0.12$  S



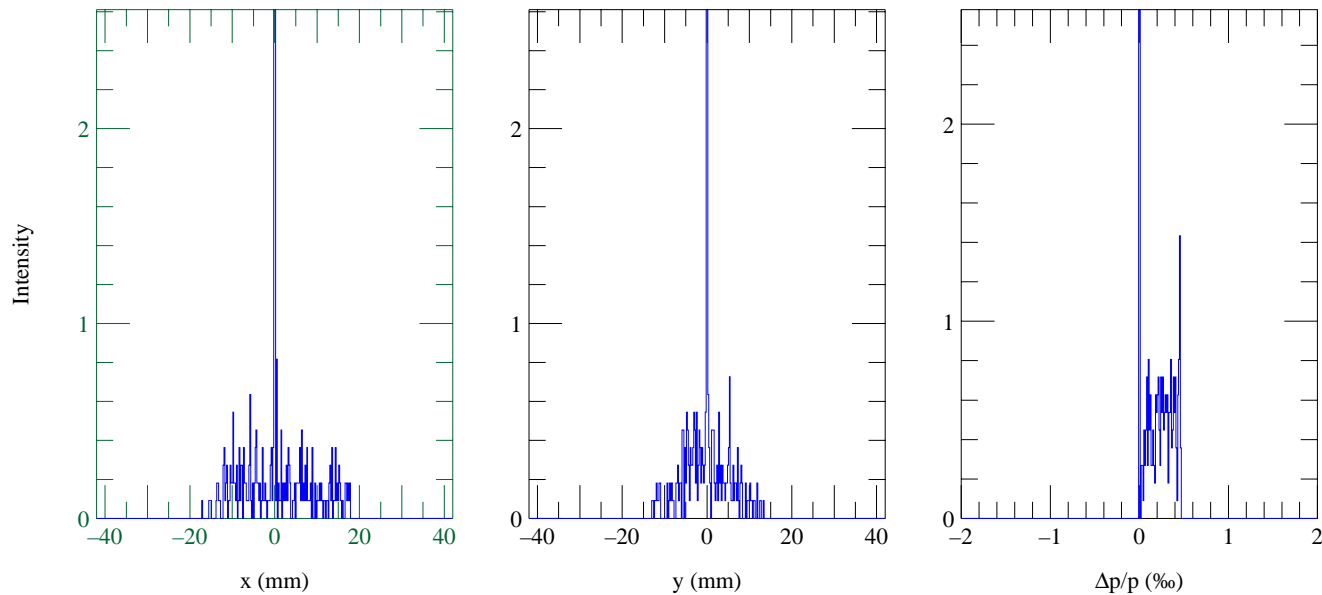
WHEN THE BEAM IS COLD THE COOLING RATE INCREASES



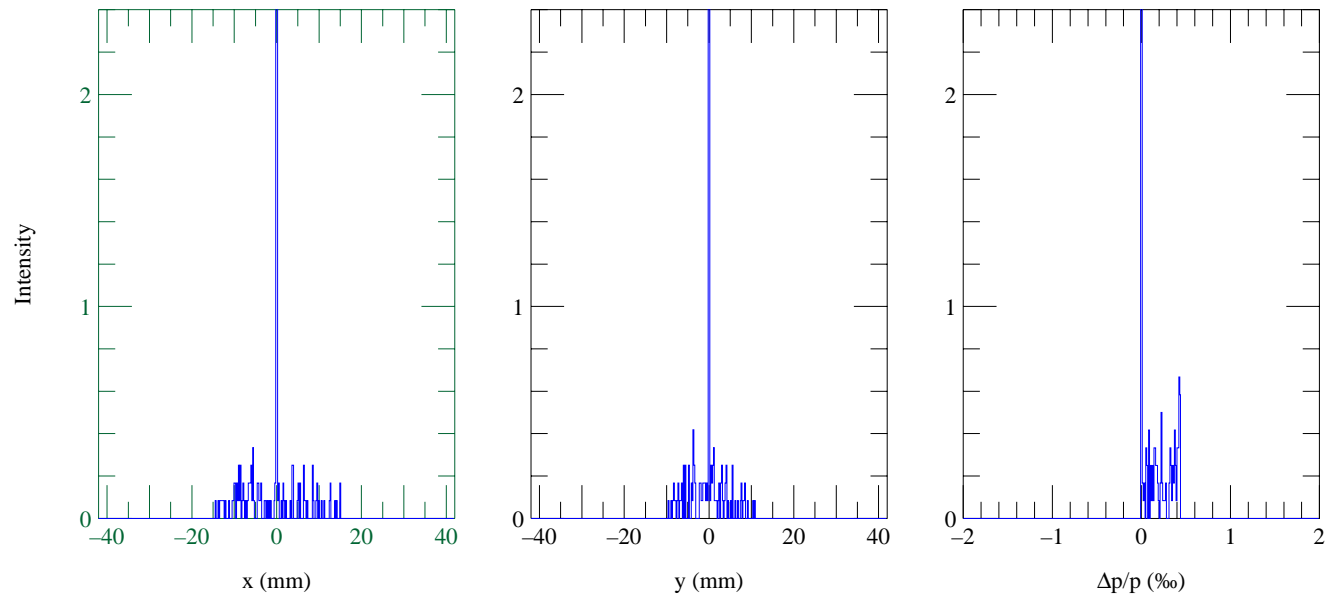
$T=0.13$  S



WITH A DISTRIBUTION OF EMITTANCES  
MOST OF THE BEAM WILL BE COOLED  
FASTER THAN 0.1 S



$T=0.14$  S





# CONCLUSION

A COOLING RING WITH MULTITURN INJECTION BEFORE THE RCS CAN REDUCE THE HORIZONTAL EMITTANCE OF  $^{18}\text{NE}^{10+}$  WITH 0.1 S COOLING.

HOWEVER, IN THESE SIMULATIONS THE ELECTRON CURRENT HAS BEEN 2.5 A WHICH MIGHT BE DIFFICULT TO ACHIEVE,  $\sim 1$  A IS THE PRESENT MAXIMUM.

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# FUTURE WORK



TO BE ABLE TO DETERMINE WHETHER  
AN ACCUMULATOR RING IS  
BENEFICIAL ONE HAS TO STUDY  
ELECTRON COOLING WITH HIGH  
CURRENTS

BOTH TO SEE HOW LARGE CURRENT  
IT'S POSSIBLE TO GET FROM A  
TECHNICAL POINT OF VIEW

AND TO VERIFY THAT THESE  
~~STRAIGHT-FORWARD SIMULATIONS~~  
STILL ARE VALID. SINCE THE

A 300 KV, 3 A COOLER WITH A 4 M  
INTERACTION REGION FROM NOVOSIBIRSK  
FOR THE LIDET - CSD PROJECT AT IND  
LA







HOWEVER, SO FAR SEVERAL ELECTRON COOLERS (INCLUDING THE ONE AT OUR LAB) HAS BEEN DESIGNED FOR A 3 A ELECTRON CURRENT, BUT TO MY KNOWLEDGE MORE THAN 1 A HAS NEVER BEEN BENEFICIAL FOR THE ION BEAM. HOPEFULLY THIS WILL SOON CHANGE.

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**Space charge tune shift**  
**1.12E+13 He, 1.90E+11 Ne**  
**normalized emittances set to PS limit**

