



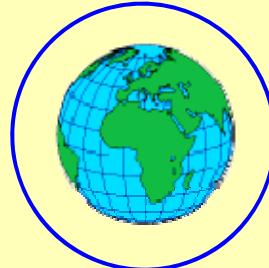
# Electrostatic Low-Energy Antiproton Recycling Ring

Michele Siggel-King

on behalf of the Recycling Ring Design Group  
(Quasar, Musashi & Ullrich groups)

# Motivation

Now



Low-Energy  
Antiproton Research



CERN Antiproton Decelerator

One possible future:



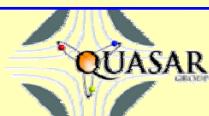
Facility for Antiproton and Ion Research



Facility for Low energy  
Antiproton and Ion Research



Ultra low energy  
Storage Ring



TCP 2010 Conference 12 April 2010

"Electrostatic Low-Energy Antiproton Recycling Ring" – Michele.Siggel-King@quasar-group.org

# Motivation

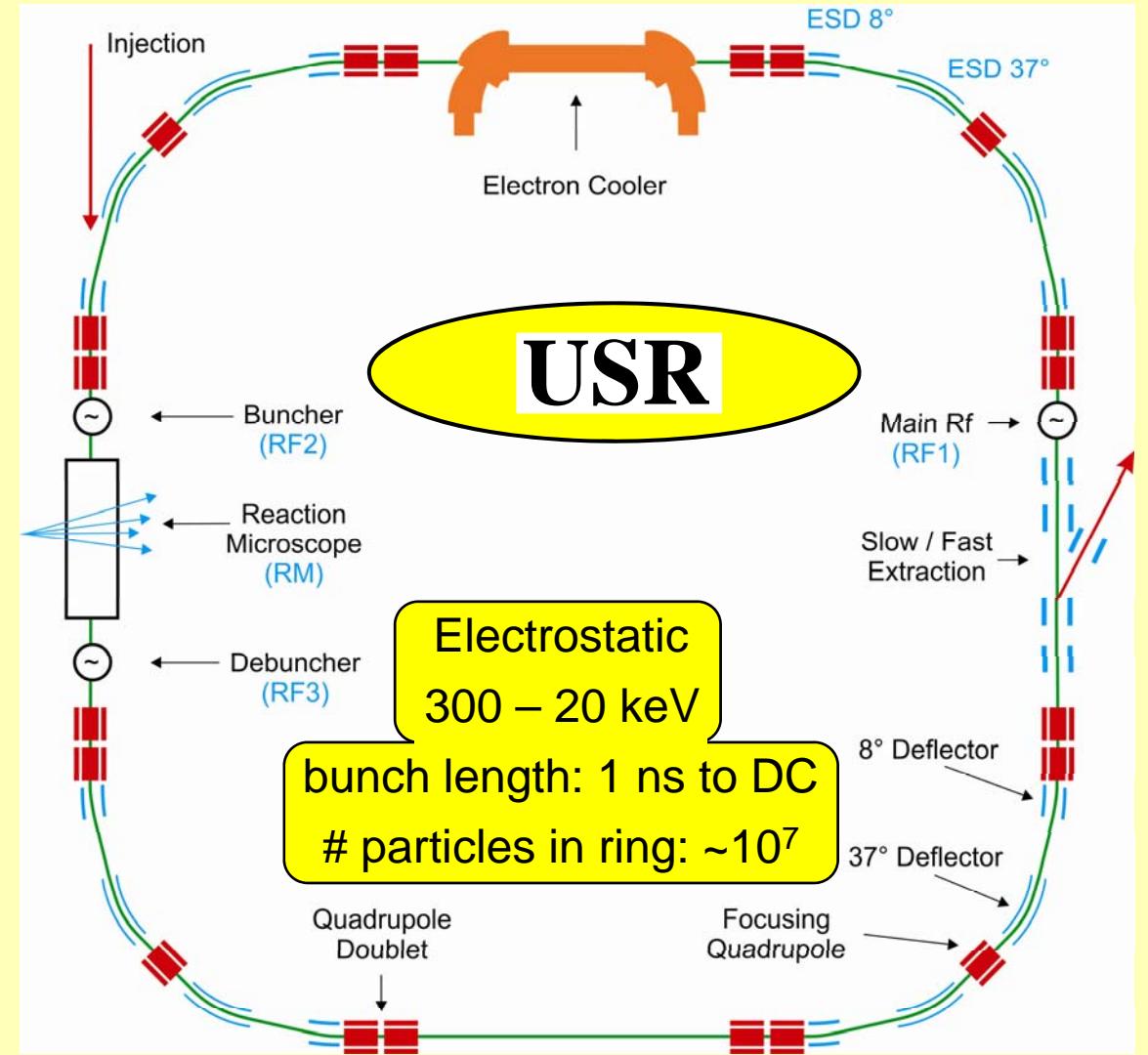


is leading developments towards USR

"ring of the future" to enable atomic physics experiments

Welsch et al. Nucl. Instr. and Meth. A  
546 (2005) 405

Papash & Welsch, NIM A,  
(2010) accepted



# Motivation

Now



Low Energy  
Antiproton Research



could be  
operational  
~2012

## Electrostatic Low-Energy Antiproton Recycling Ring

- Prototype for USR
- Enable atomic physics crossed-beam studies



antiprotons available from

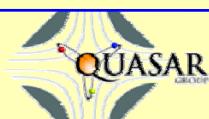
delayed



delayed



2019, 2020?



TCP 2010 Conference

12 April 2010

"Electrostatic Low-Energy Antiproton Recycling Ring" – Michele.Siggel-King@quasar-group.org

# Installation Configuration

ASACUSA  
Collaboration  
<http://cern.ch/ASACUSA>



CERN  
Antiproton  
Decelerator

Musashi



Trap and  
beamline

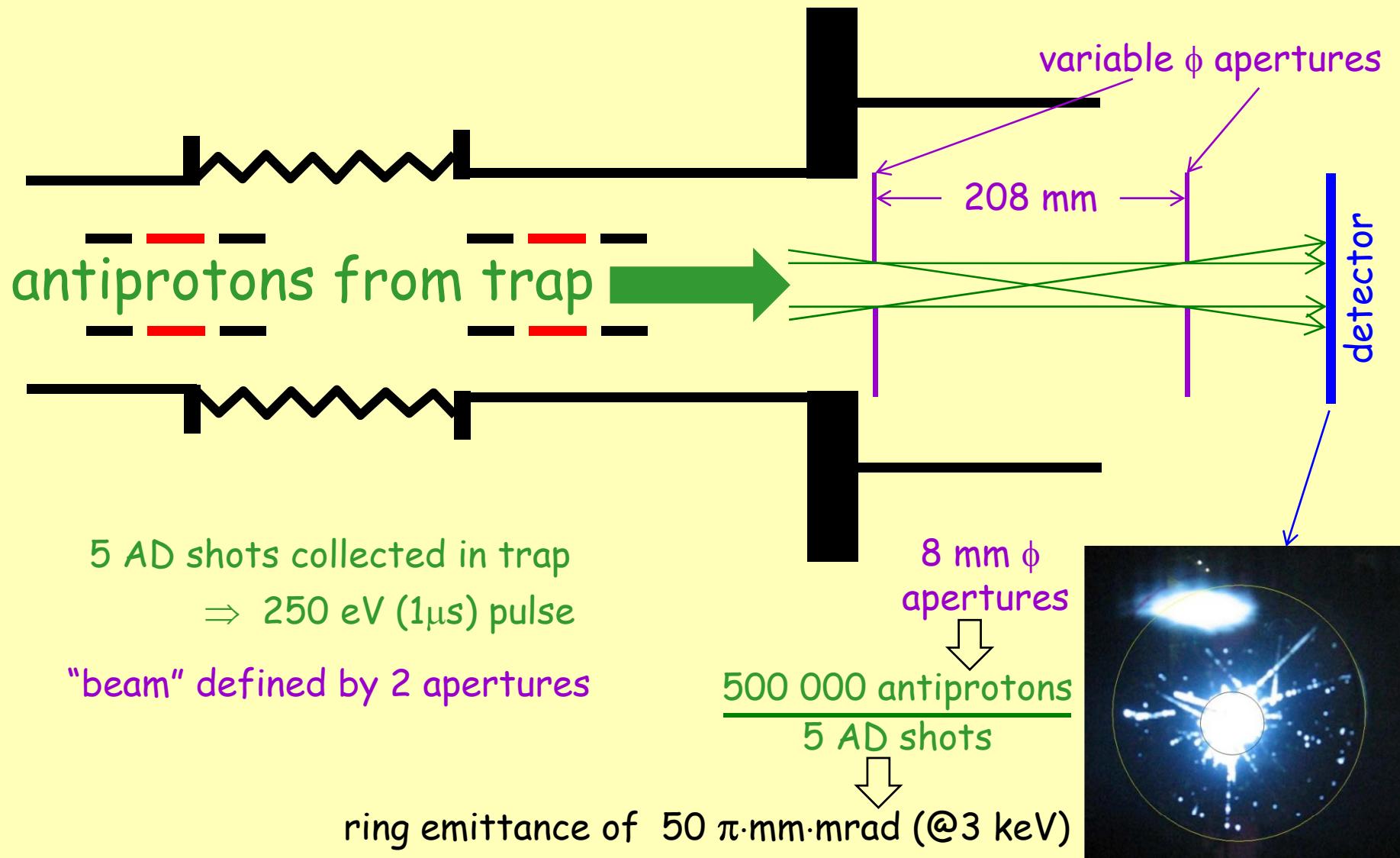
CERN-AD: S. Baird *et al*, PAC 97 Conf. Proc. 979  
Musashi beamline: Torii *et al*, AIP Conf. Proc. 273 (2005) 293

TCP 2010 Conference  
12 April 2010

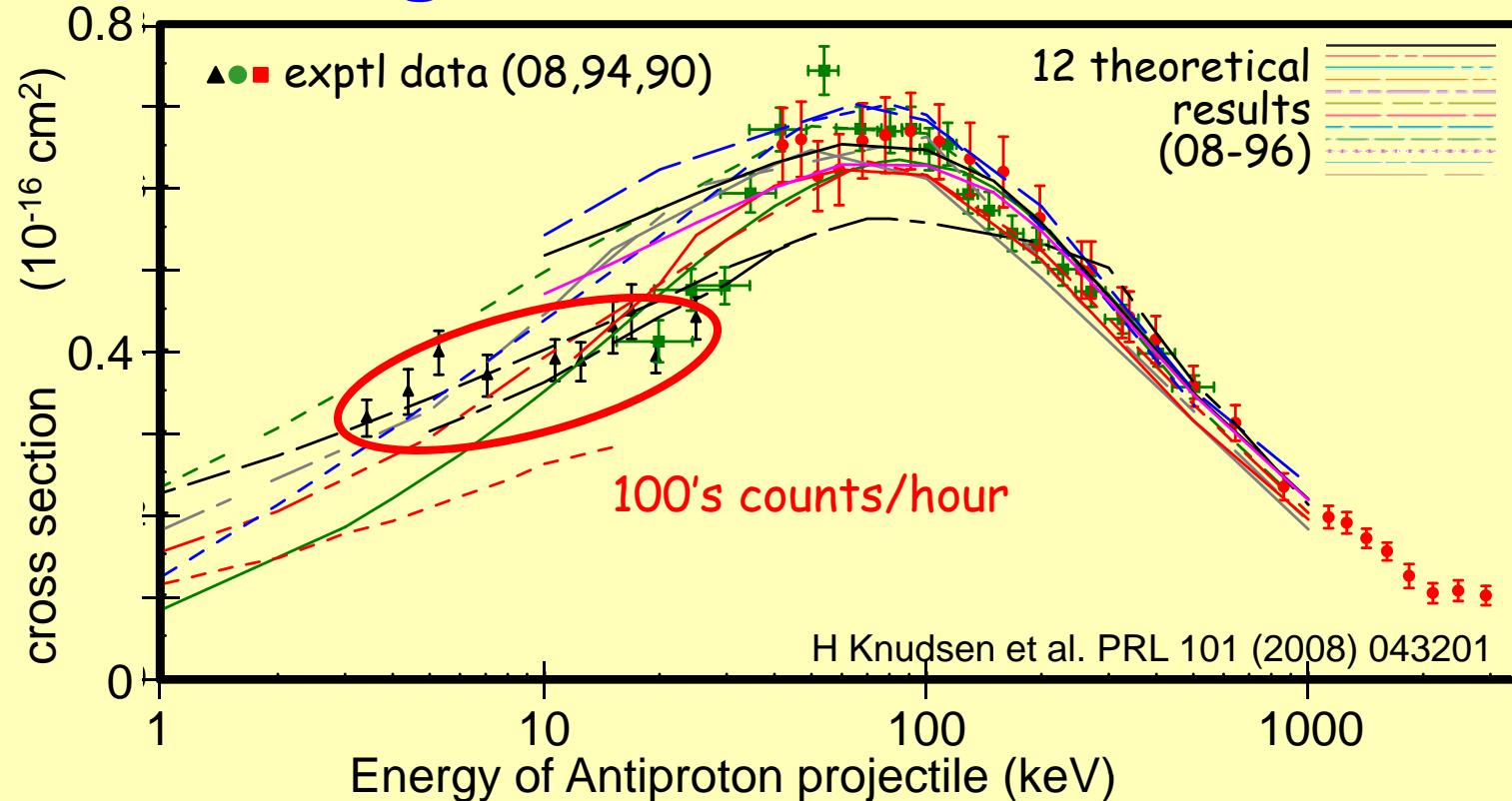
"Electrostatic Low-Energy Antiproton Recycling Ring" – Michele.Siggel-King@quasar-group.org



# Antiprotons from Musashi Beamline



# Helium single ionisation cross section

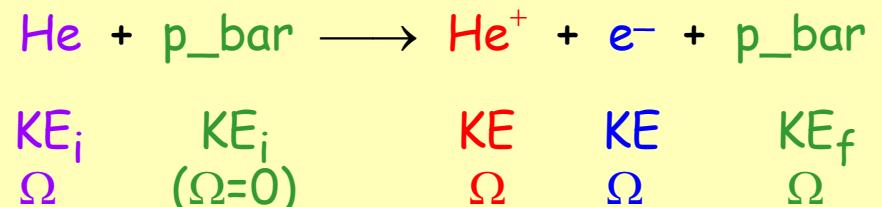
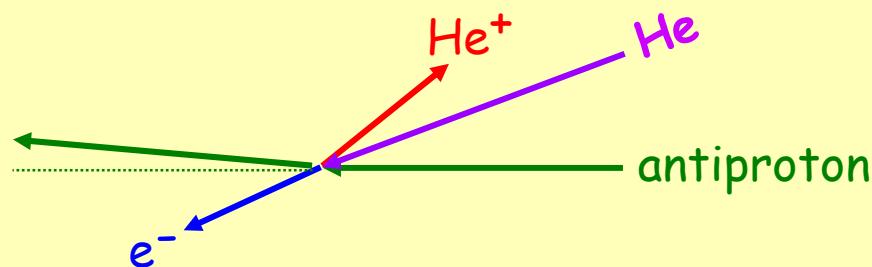


fundamental atomic physics experiment



Aarhus  
Ionisation  
Apparatus

# Helium single ionisation cross section



USR

fully differential cross sections

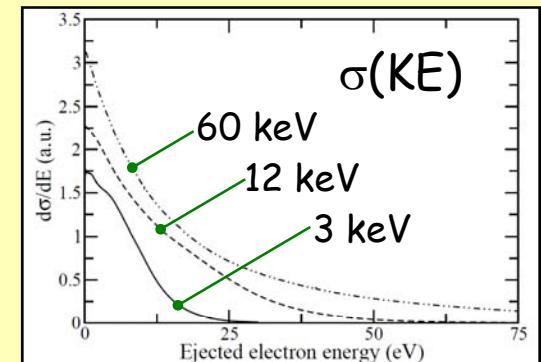
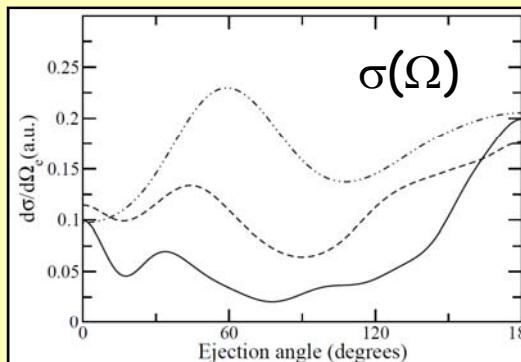
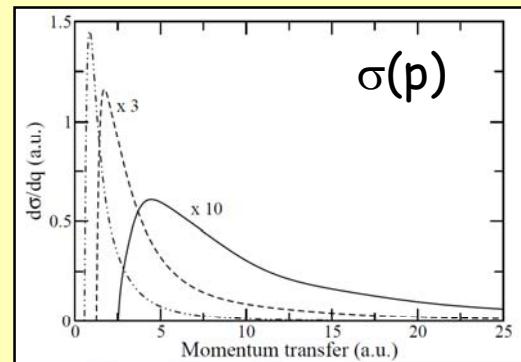
$\sigma(KE, \theta, \phi)$  for each particle

Recycling Ring

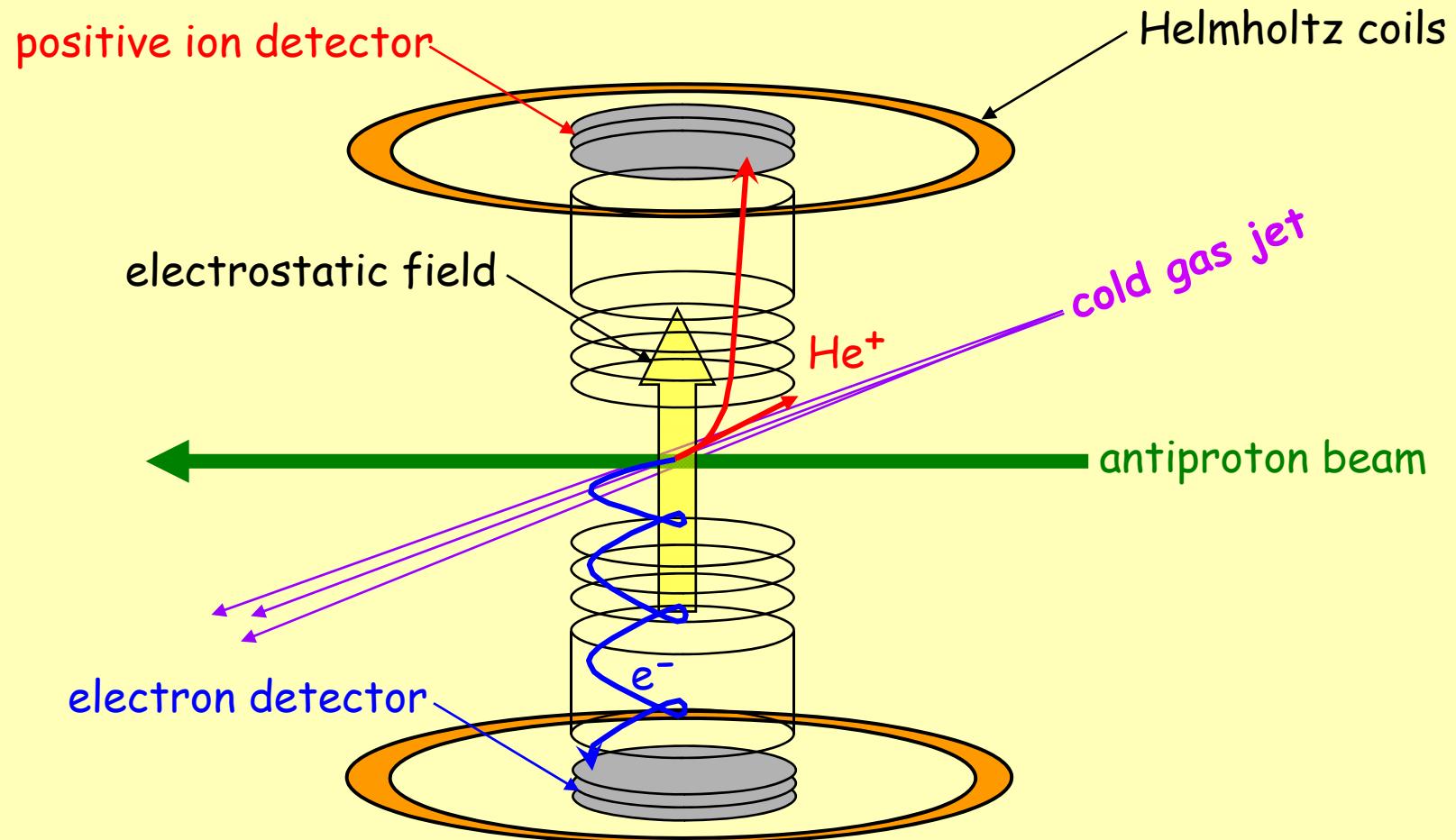
partial differential cross sections

e.g.  $\sigma(p)$  or  $\sigma(\Omega)$  or  $\sigma(KE)$

figures from  
M. McGovern  
et al.,  
accepted for  
publication



# Differential Cross Section Measurements



Reaction Microscope

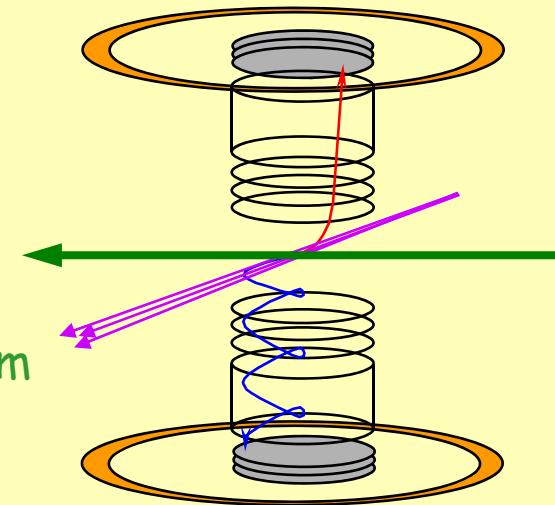
# Reaction Microscope Resolution

## (momentum: energy and angular distribution)

Resolution is a function of many parameters including

size of interaction region  
divergence of projectile beam

union of target gas jet & projectile antiproton beam



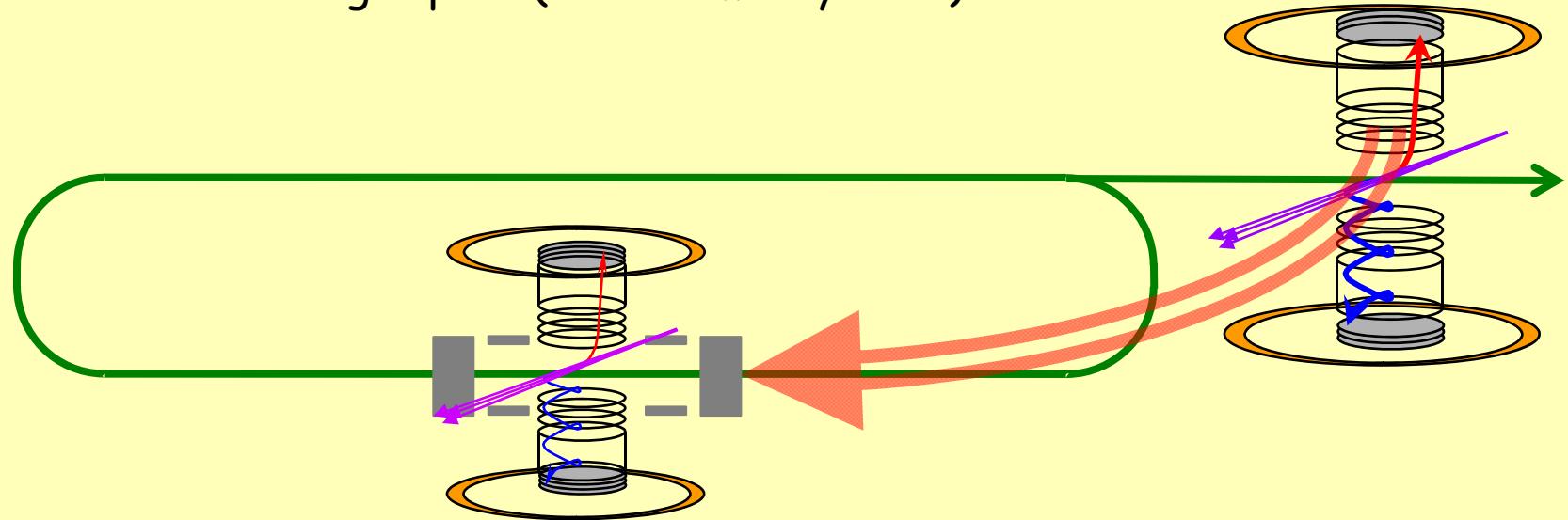
- beam cross sectional area at interaction point:  $\leq 3 \text{ mm diameter}$
- beam divergence at interaction point:  $\leq \pm 1^\circ (\pm 17 \text{ mrad})$

$\Rightarrow$  experimental upper limit on the beam emittance of  $\sim 26 \pi \cdot \text{mm} \cdot \text{mrad}$

# Experimental Set-up

most cross-beam experiments:

- single-pass (use beam only once)



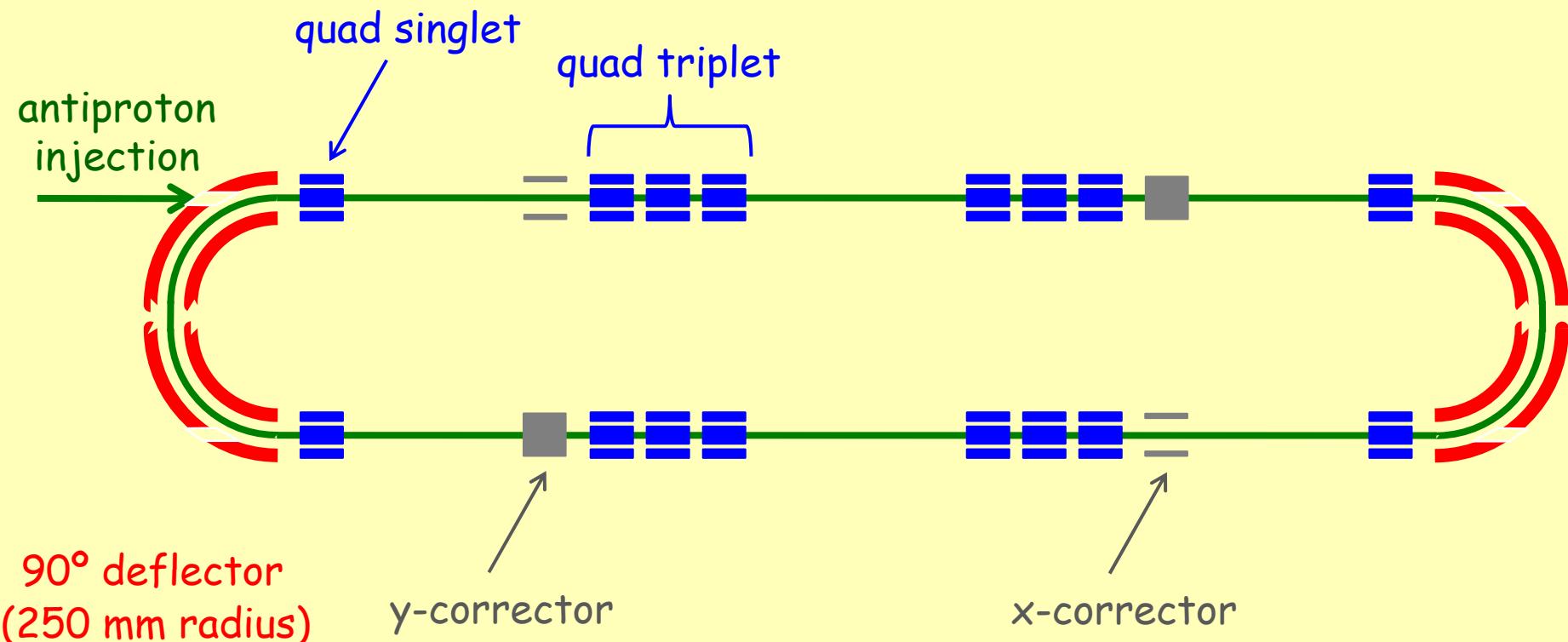
Why not incorporate the experiment into the ring?

- Use beam many times (improvement in luminosity)
- USR and this ring

# Electrostatic Antiproton Recycling Ring

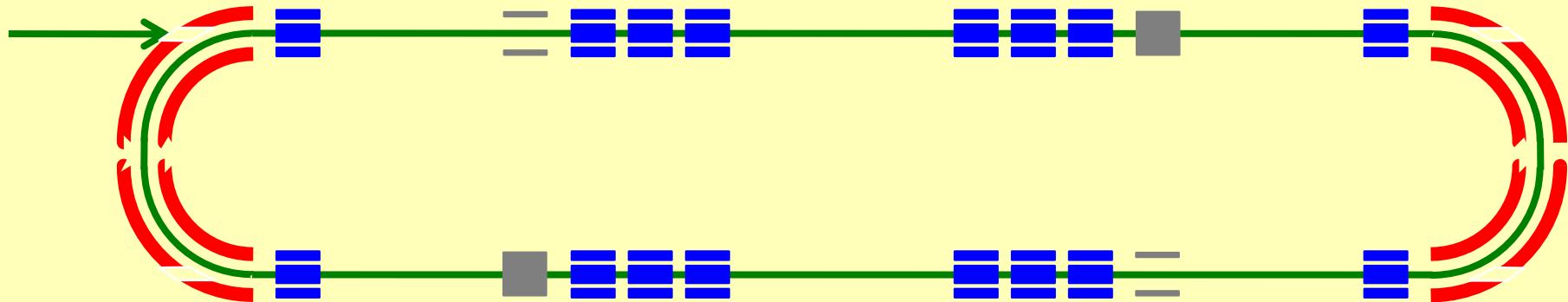
Fixed-Energy Ring

circumference = 7.2 m

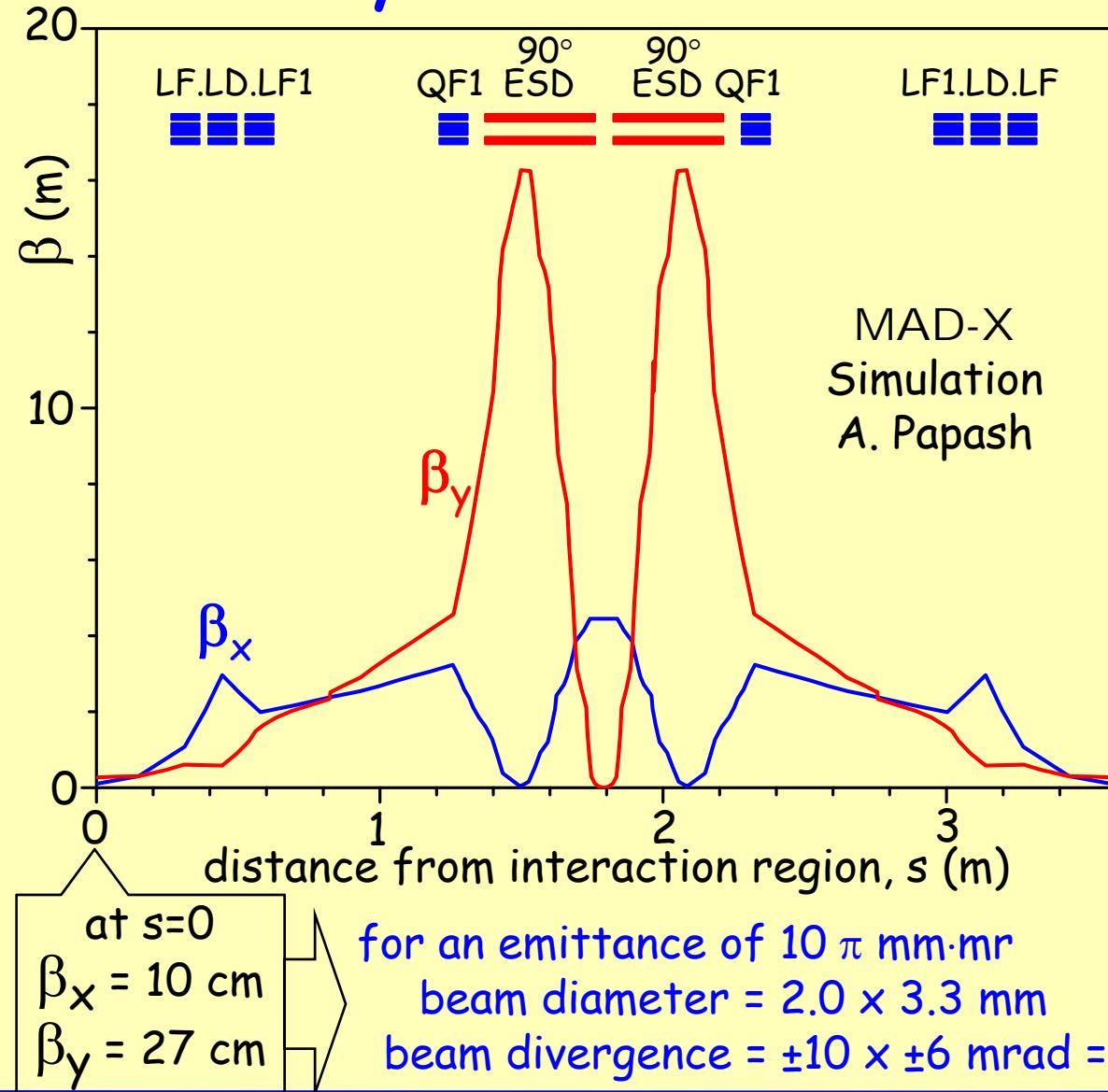


# Ring and Injection Parameters

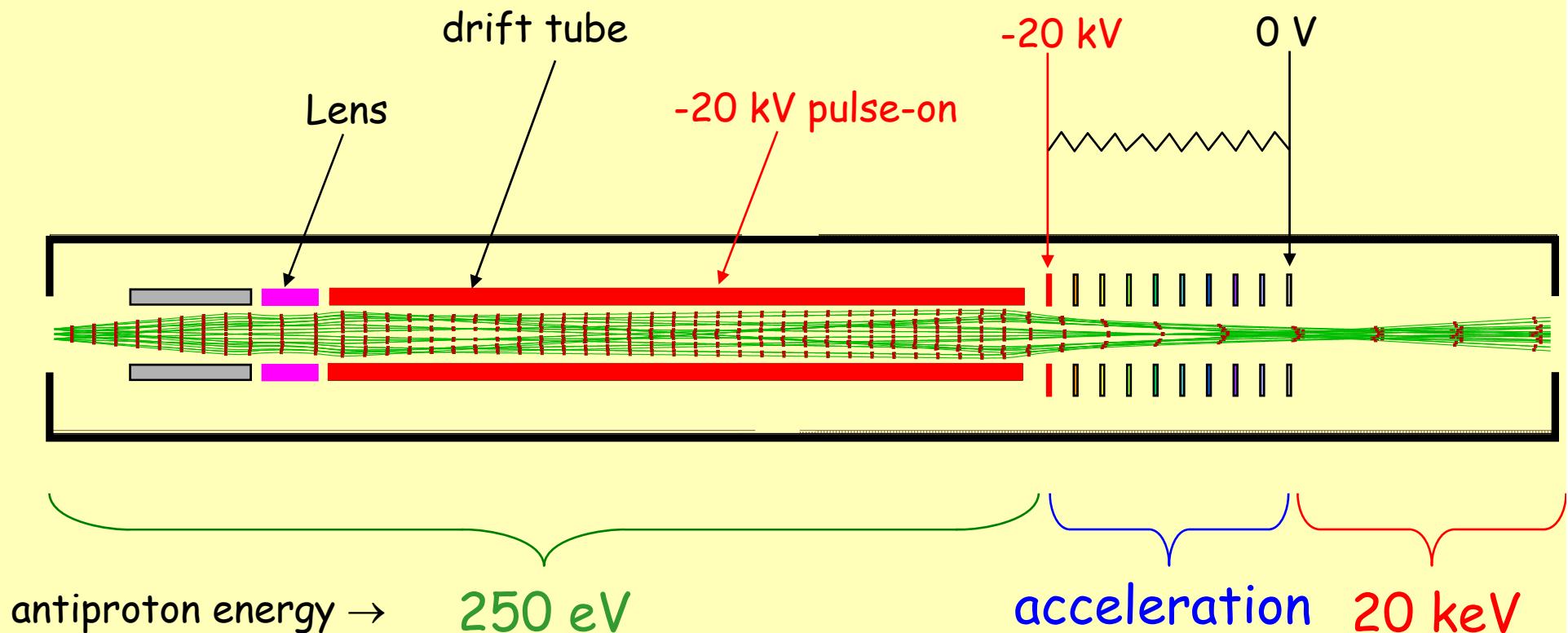
Maximum available intensity	$5 \times 10^5$ particles
Energy of injected particles	10 - 30 keV
Antiproton rotation frequency	193 - 335 kHz
Antiproton rotation period	5.2 - 3.0 $\mu$ s



# Preliminary Simulation Results



# Electrostatic Acceleration Section



H. Knudsen

# Estimated Experimental Count rates

energy of antiprotons (keV)	20
emittance of beam in ring ( $\pi \cdot \text{mm} \cdot \text{mrad}$ )	10
number of antiprotons/fill	$\sim 155\,000$
% of 300 000 beam	52%
average number of $P_{\bar{}} \text{ bar}$ in ring	58 000
target density ( $\text{cm}^{-3}$ )	$5.0 \times 10^{11}$
average target length (cm)	0.079
ionisation cross section ( $\text{cm}^{-3}$ )	$4.8 \times 10^{-17}$
detection efficiency	0.4
number of times bunch revolves around ring	6000
number of fills per hour	7
<b>number ionisation events detected per hour</b>	<b>1828</b>

(conservative value)

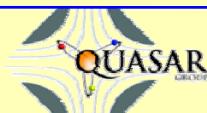
# Beam Diagnostics

a challenging part of the USR and Recycling Ring project  
beam diagnostics expertise in Quasar group

ultra-short bunches → DC beams

variable-energy beams      low-energy beams

ultra-low currents

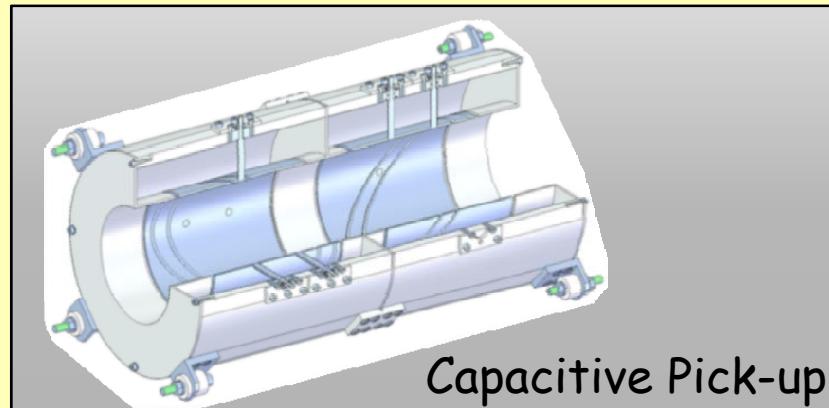




Janusz  
Harasimowicz

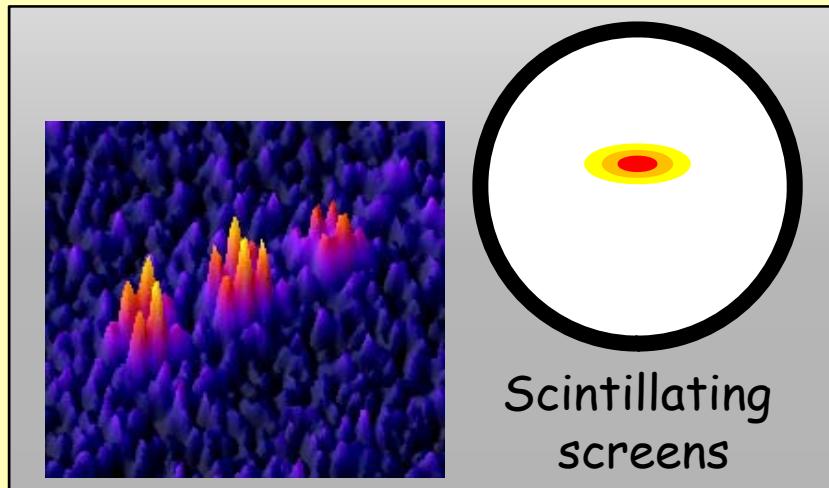
# Beam Diagnostics

## Beam Position Monitor



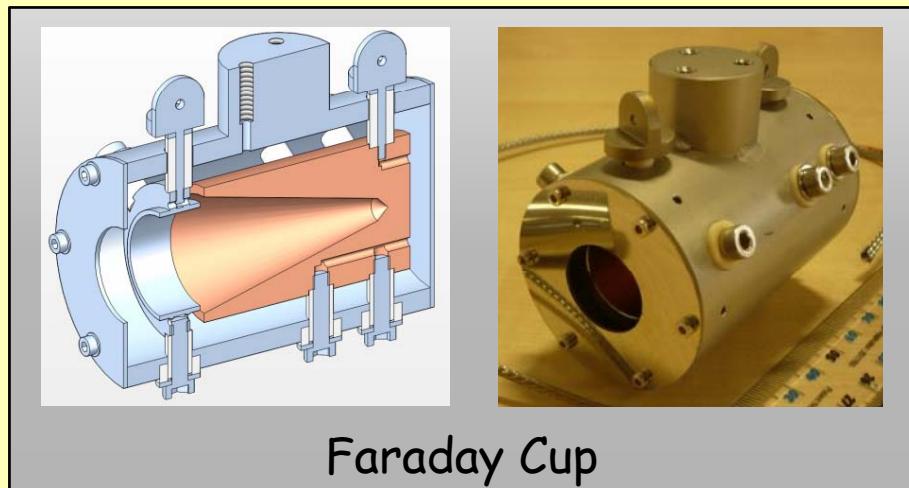
J. Harasimowicz  
et al. Hyperfine  
Interactions, 194  
(2009) 177.

## Beam Profile



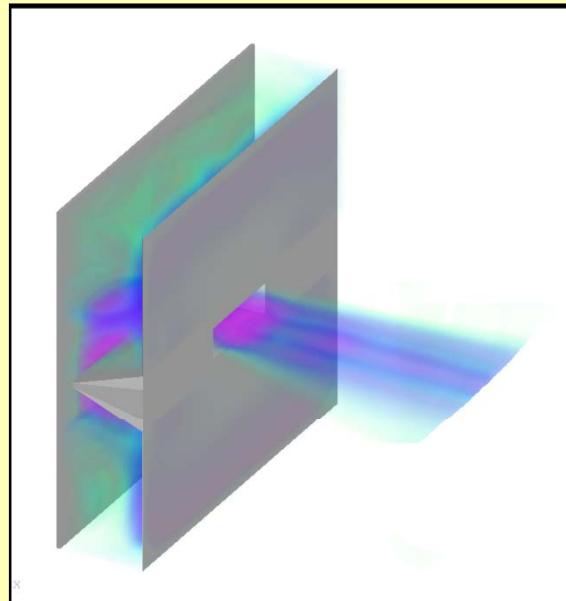
Scintillating  
screens

## Beam Current Monitor



Faraday Cup

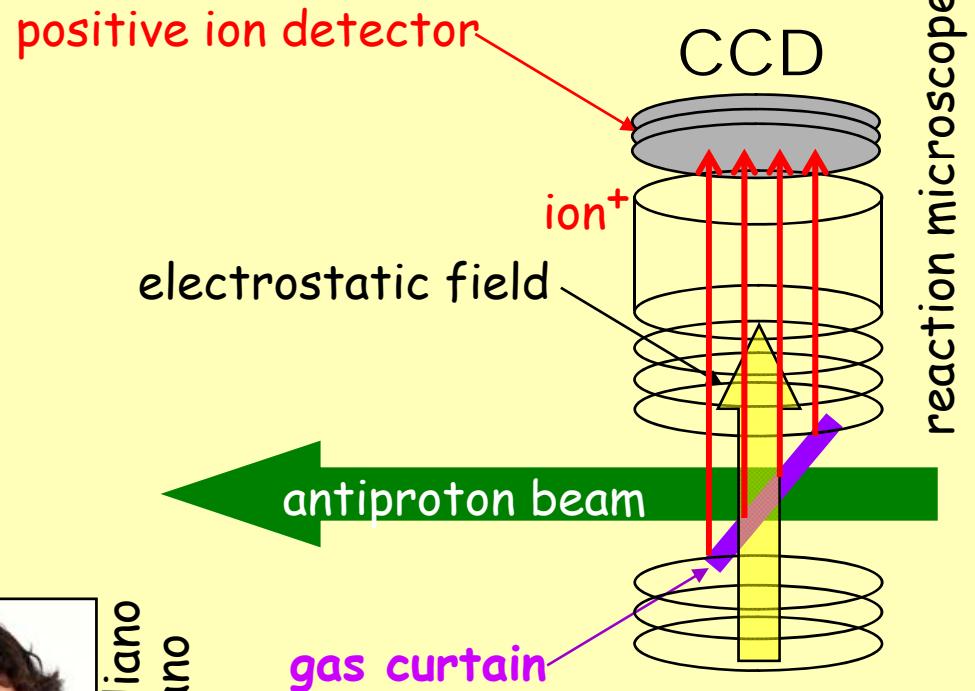
# Gas Curtain Beam Profile Monitor



supersonic expansion to  
a "gas curtain"



Massimiliano  
Putignano

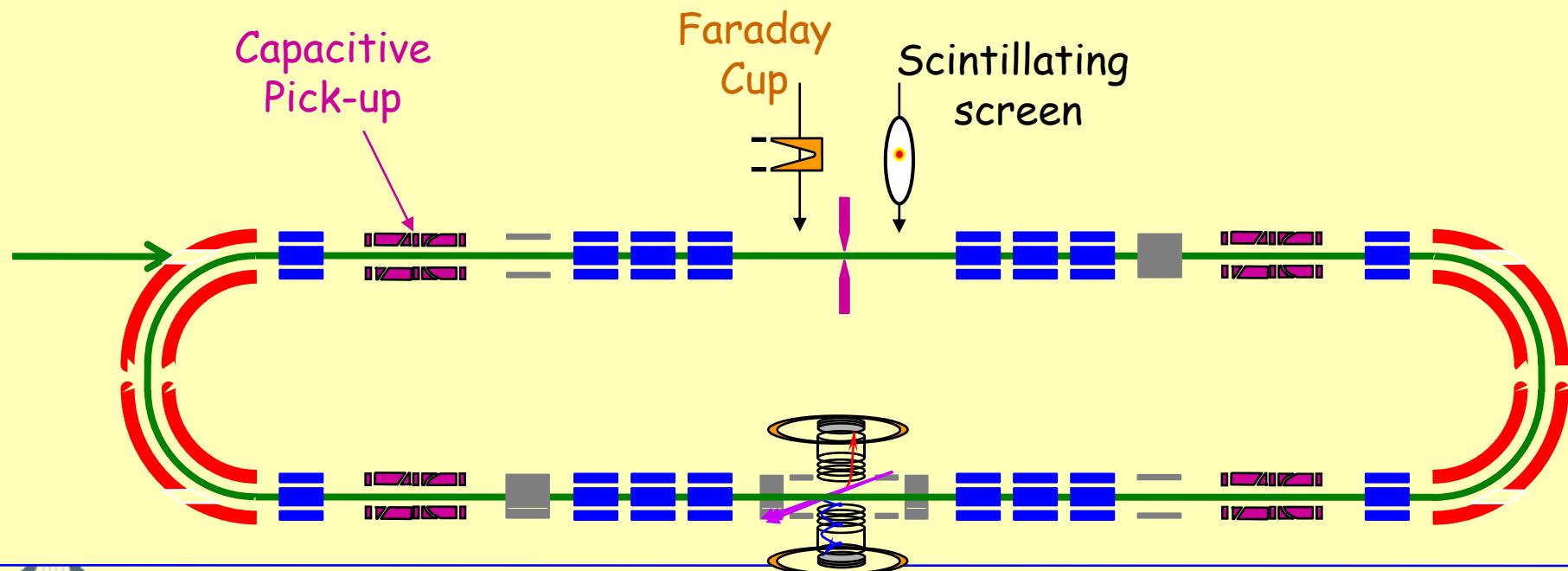


Hyperfine Interact (2009)  
194:189-193

# Summary and Outlook

## Electrostatic Low-Energy Antiproton Recycling Ring

*to bridge the gap between now and  
until a new low-energy antiproton facility is operational*



# Summary and Outlook

## Electrostatic Low-Energy Antiproton Recycling Ring

*to bridge the gap between now and  
until a new low-energy antiproton facility is operational*

- Prototype for USR  
testing and development
- Enable progress in atomic physics crossed-beam studies  
partial cross section measurements

Presently determining overall feasibility.

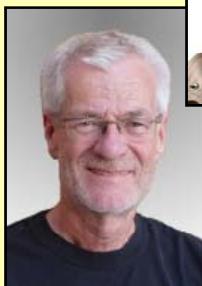


# Acknowledgments



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