Experimental Study of Dispersion Control Utilizing Both Magnetic and Electric Fields

COOL05
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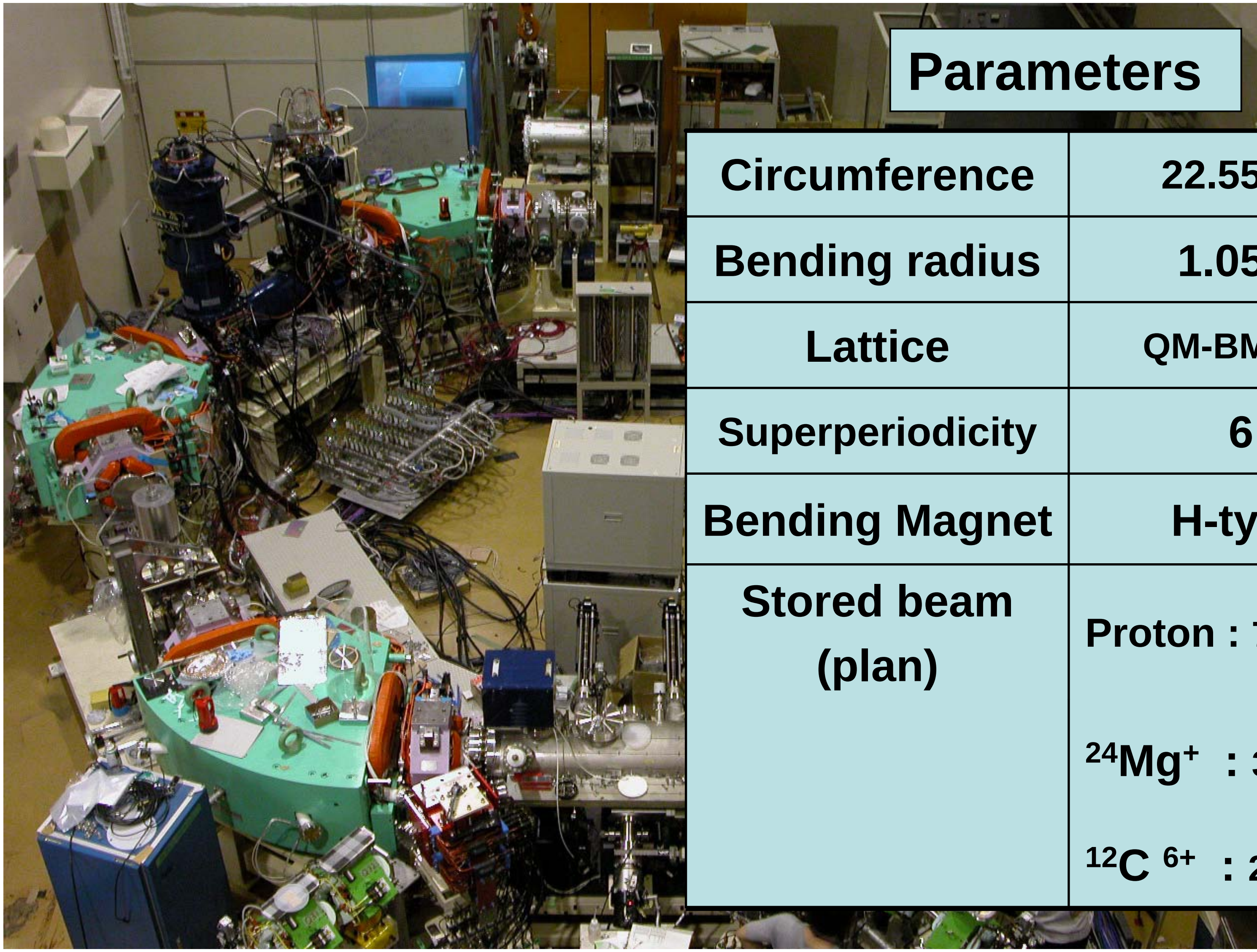
Ion Storage Ring 'S-LSR'

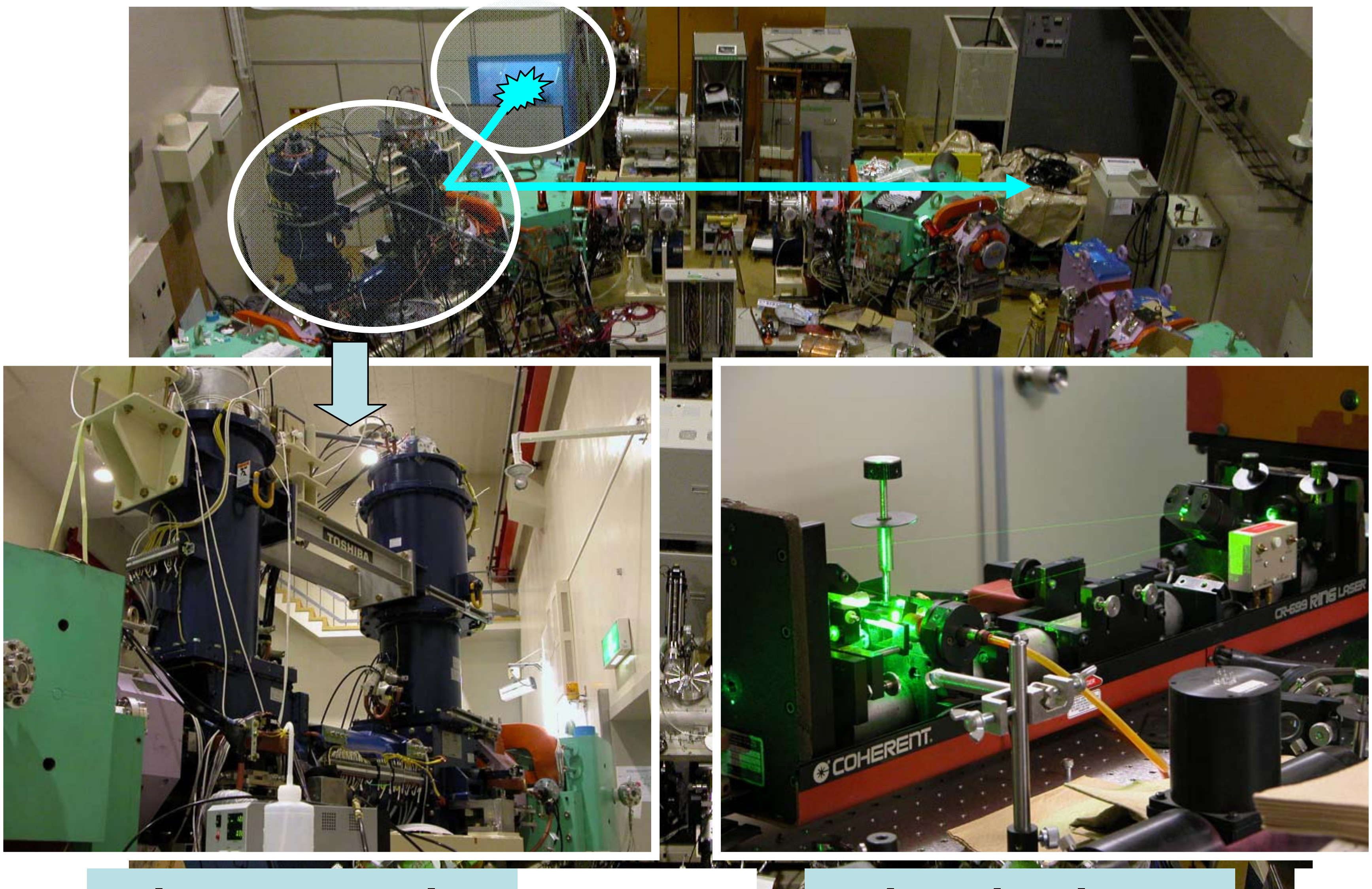


Parameters

Circumference	22.557m
Bending radius	1.05m
Lattice	QM-BM-QM
Superperiodicity	6
Bending Magnet	H-type
Stored beam (plan)	Proton : 7MeV $^{24}Mg^{+}$: 35keV $^{12}C^{6+}$: 24MeV

S-LSR (under construction)

Cooling Experiment

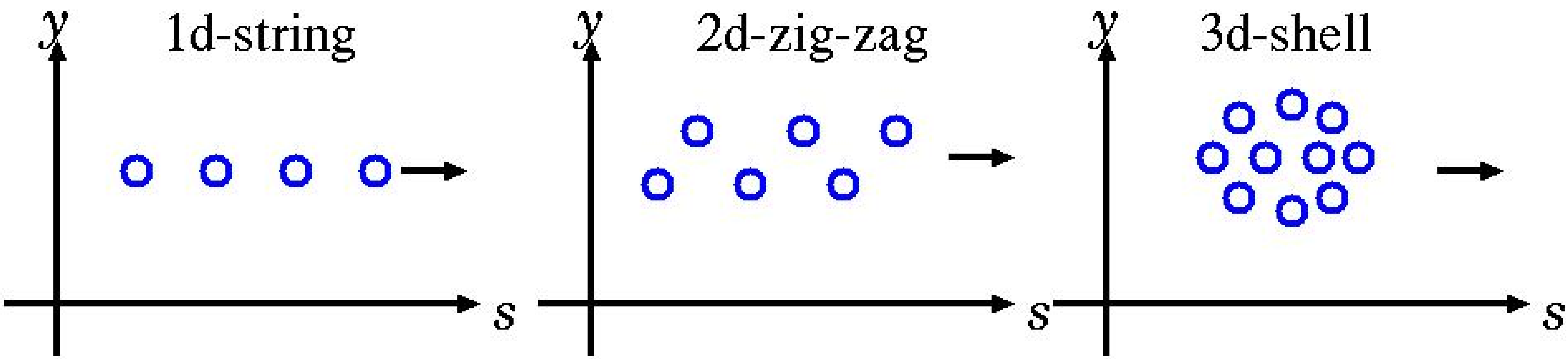


Electron cooler → Proton **Ring dye laser → Mg$^+$**

Aim of our LASER cooling

To realize <u>ordering or crystallized beam</u>

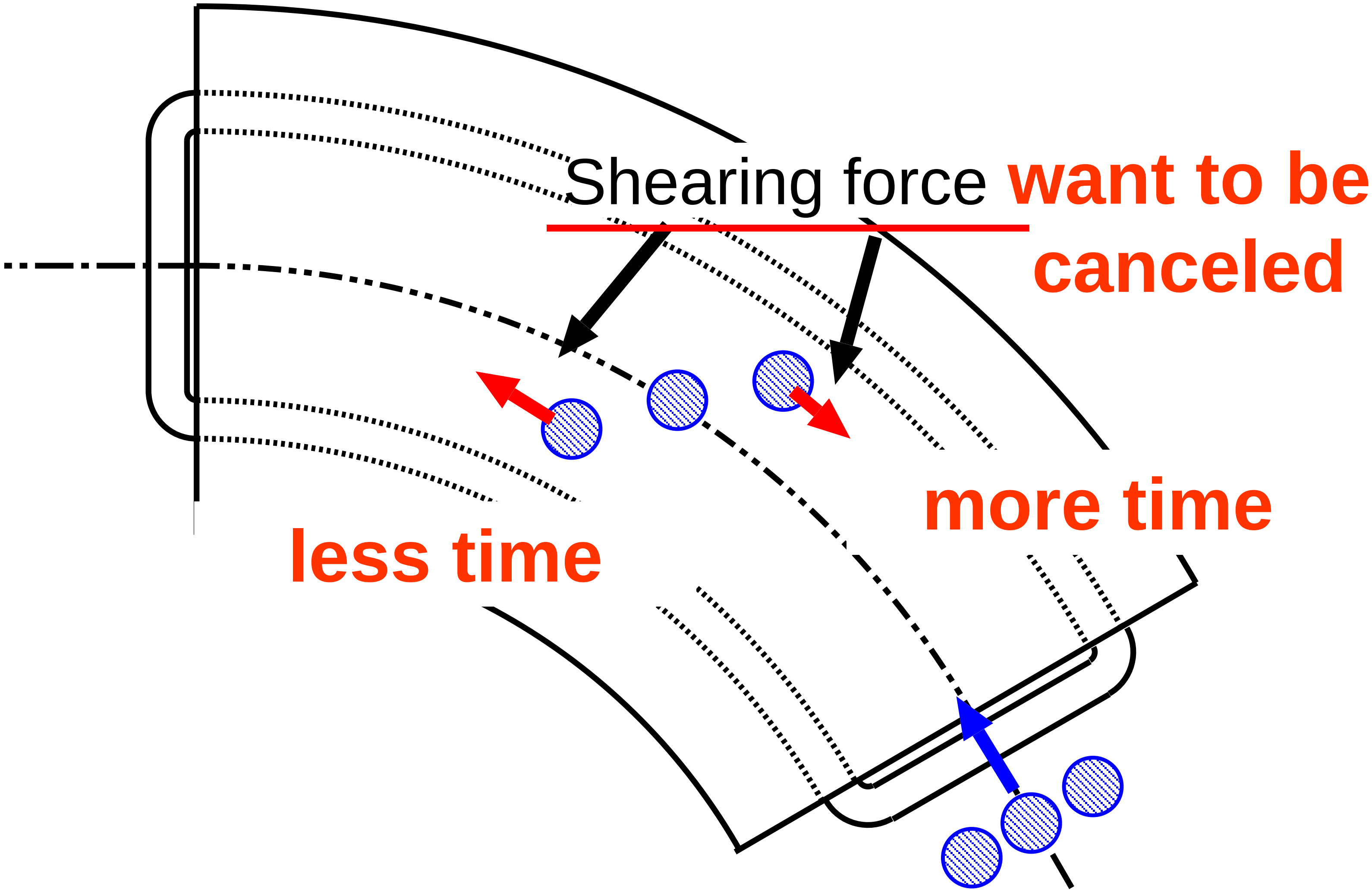
What is <u>ordering or crystallized beam ?</u>



Models of Ordering beams

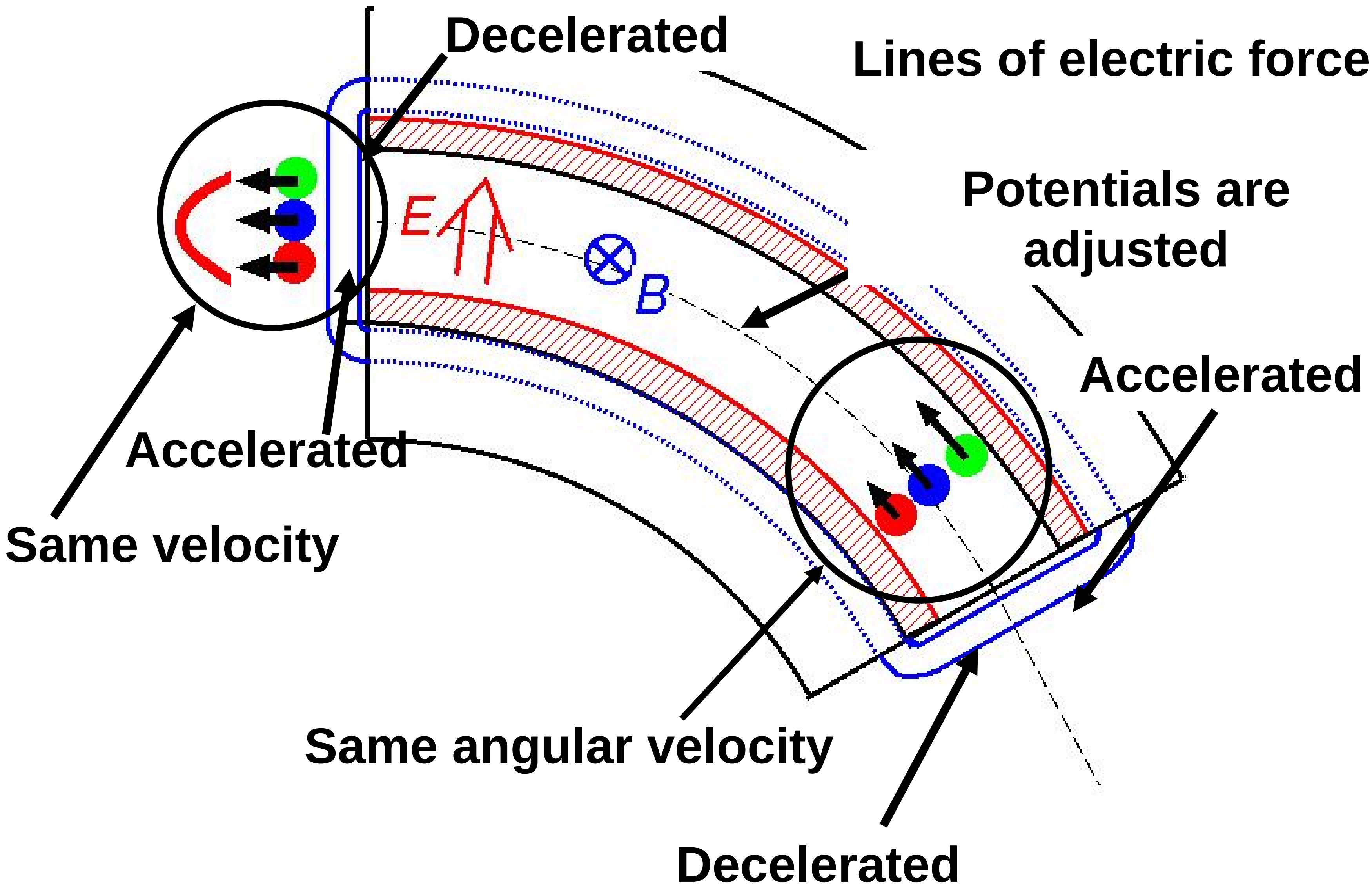
Each particle keeps about the same relative position

Issue in storing ordered beam

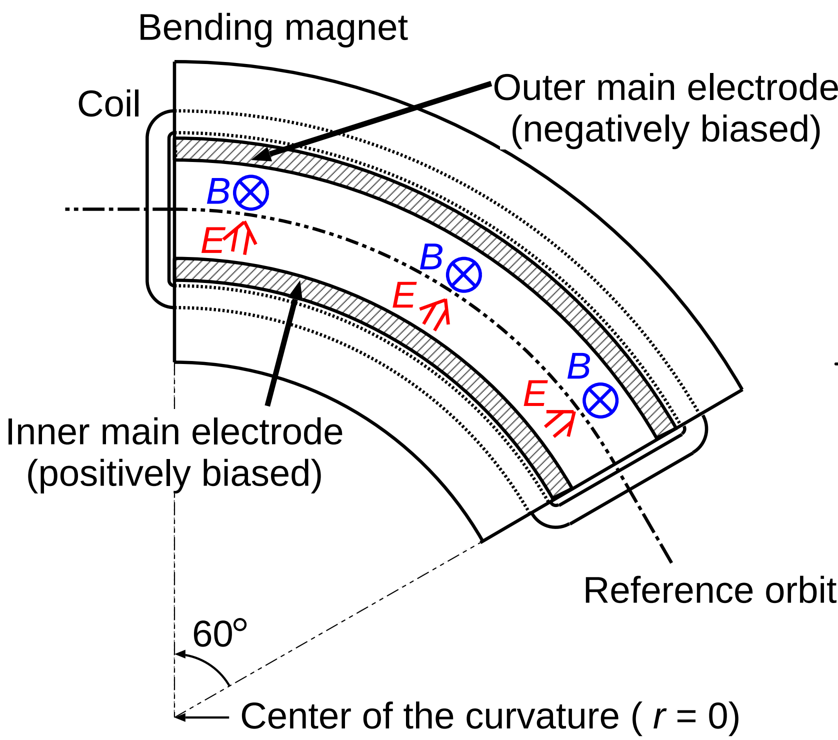


Ordering particles at a bending section

How to overcome 'Shearing force'



Example: Uniform electric field strength



- Equation of motion

$$m\frac{v^2}{r} = qvB - qE$$

- When $v \to v + \Delta v$,

$$\underbrace{\frac{m}{r}\left(1+\frac{\Delta r}{r}\right)^{-1}} = \underbrace{\frac{qB}{v}\left(1+\frac{\Delta v}{v}\right)^{-1}} - \underbrace{\frac{qE}{v^2}\left(1+\frac{\Delta v}{v}\right)^{-2}}$$

- Neglecting 2nd or higher order,

$$\frac{\Delta r}{r} = \frac{qr}{mv^2}\frac{\Delta v}{v}\left(vB - 2E\right)$$

Condition to cancel linear dispersion

$$vB - 2E = 0$$

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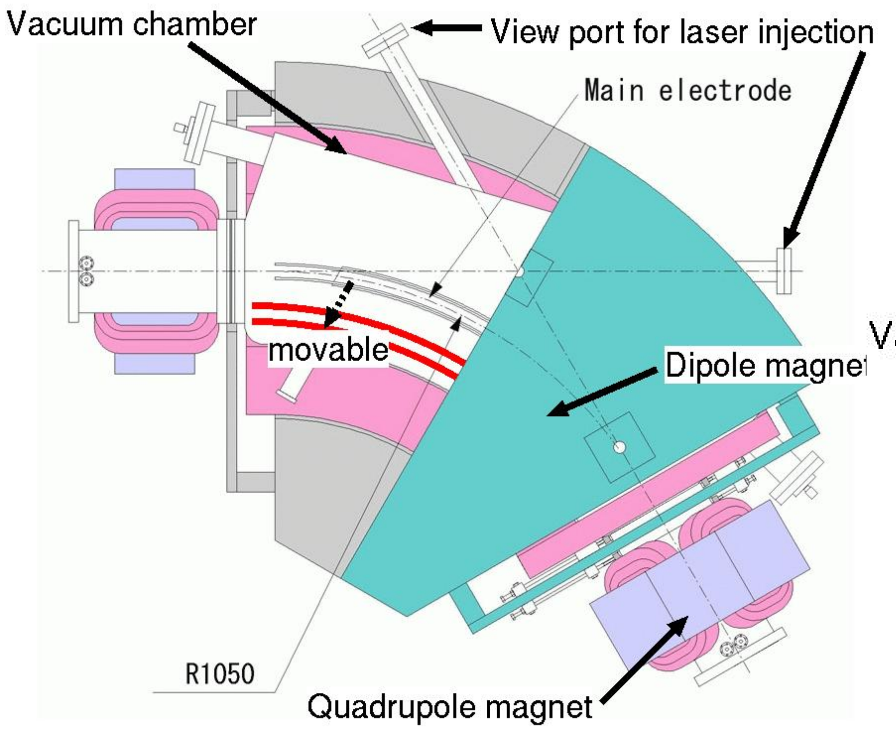
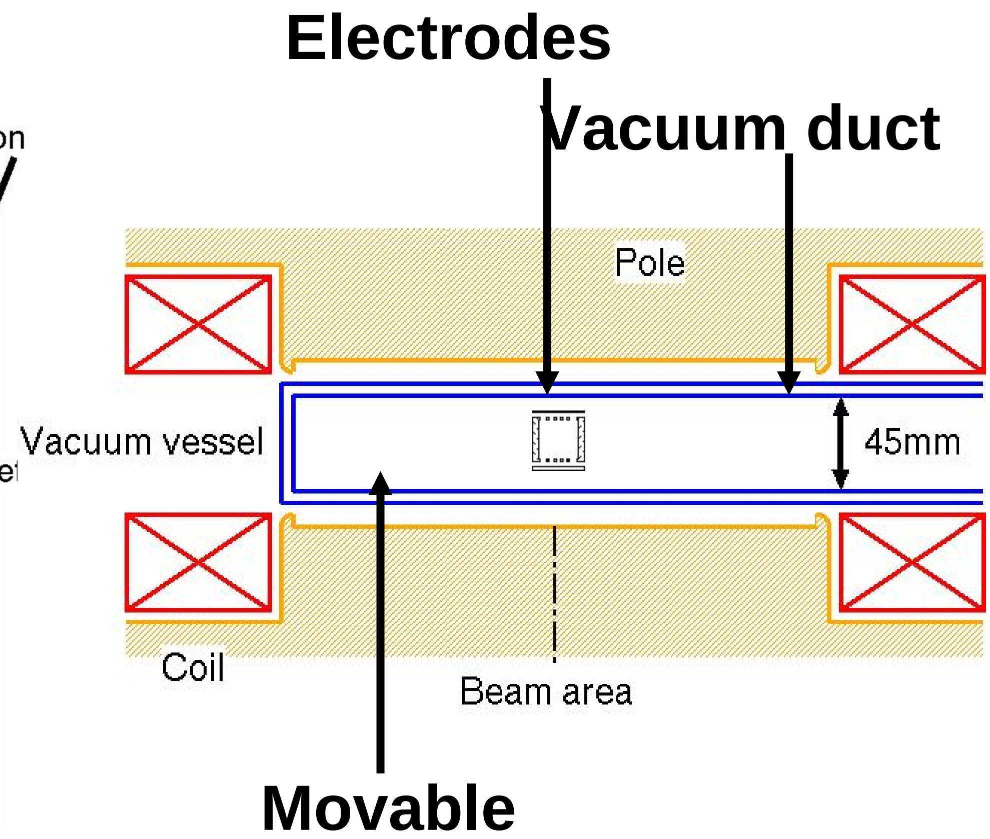
Conditions at electrodes set point



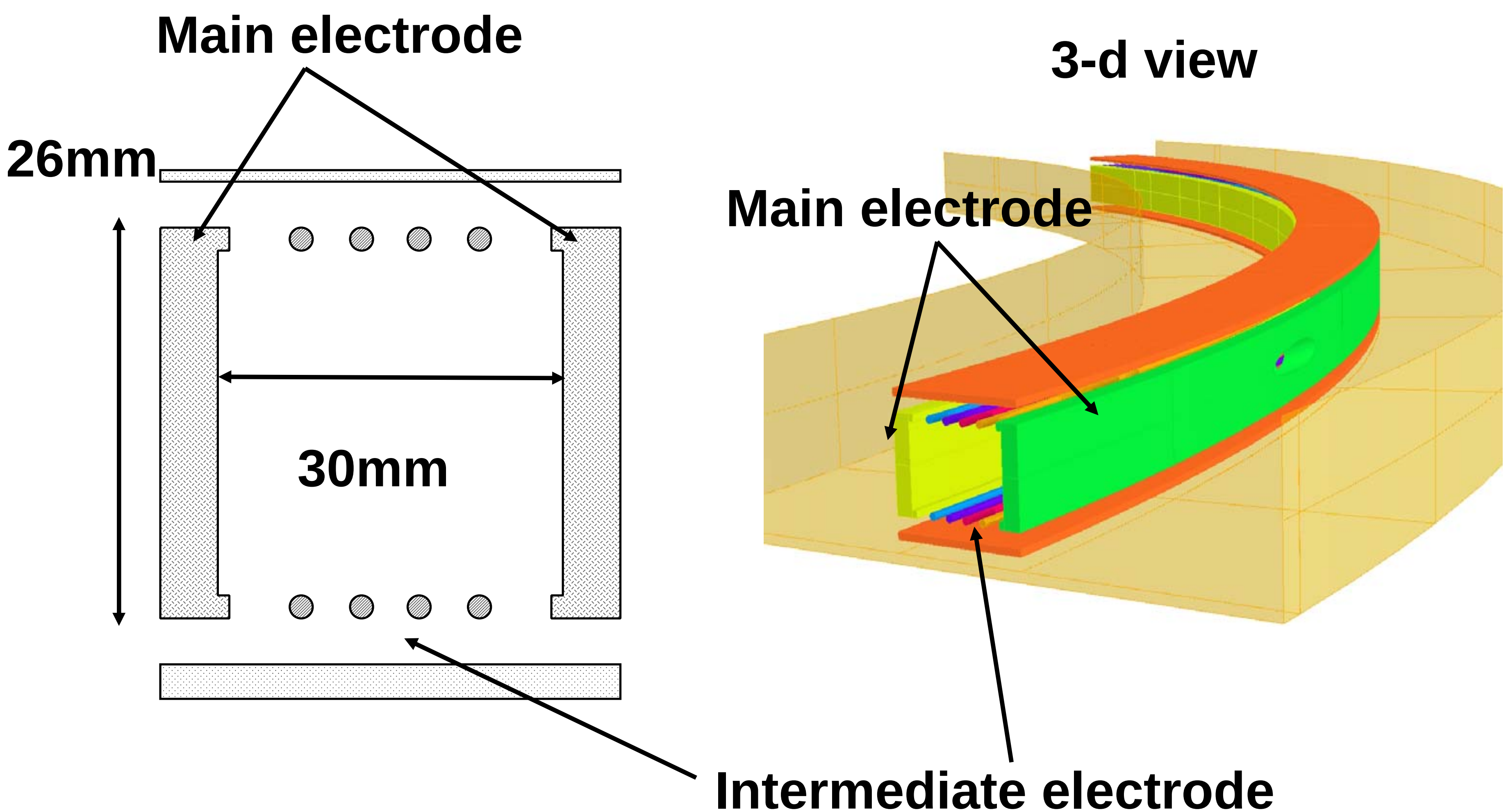
Bending magnet of S-LSR



Cross section of the magnet

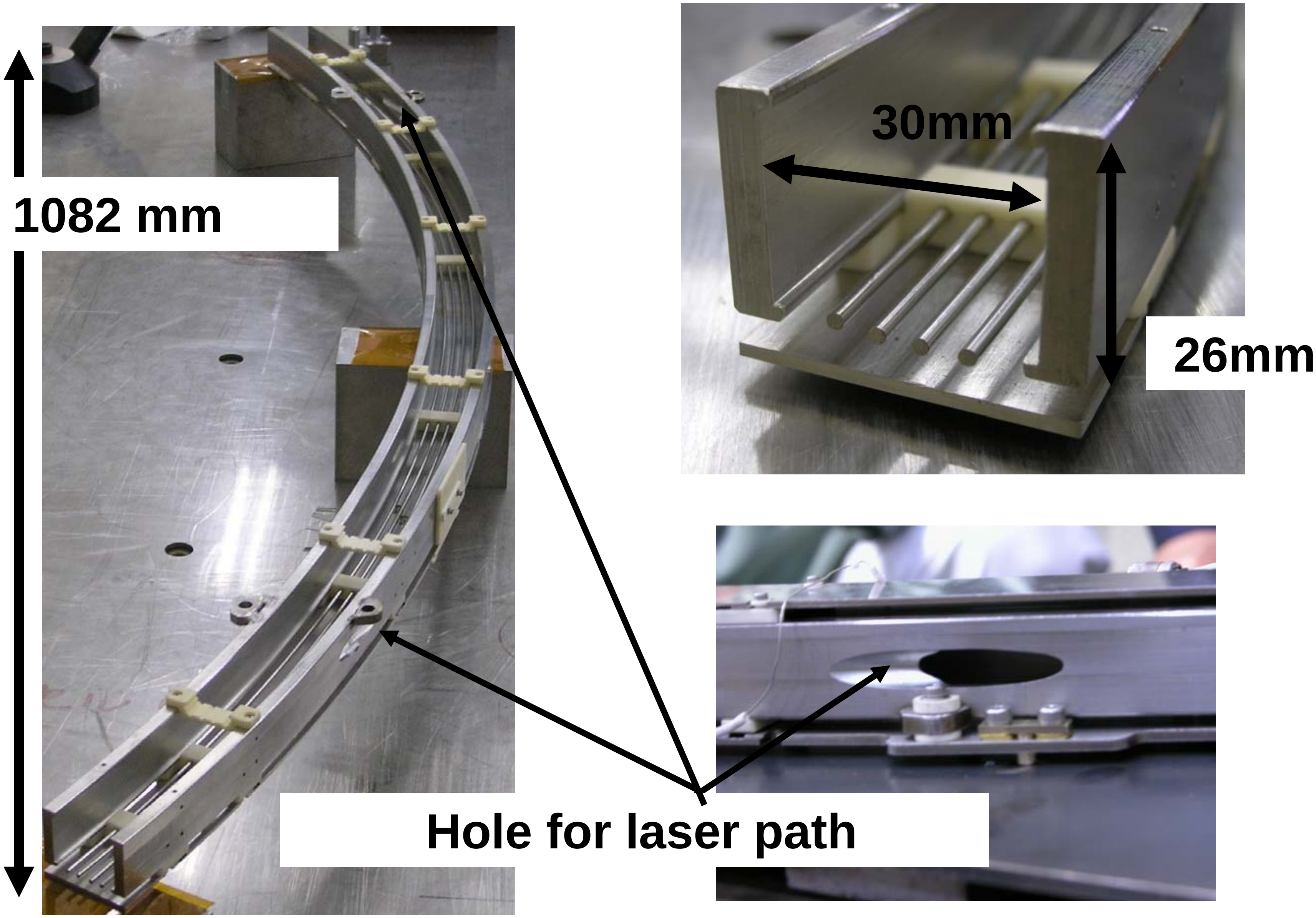
Structure of a set of electrodes

3-d view

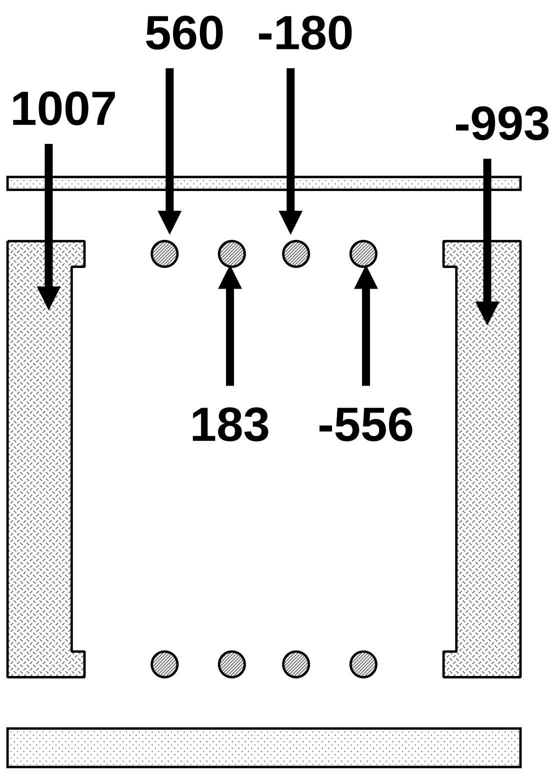


Cross sectional view

Picture of a set of electrodes



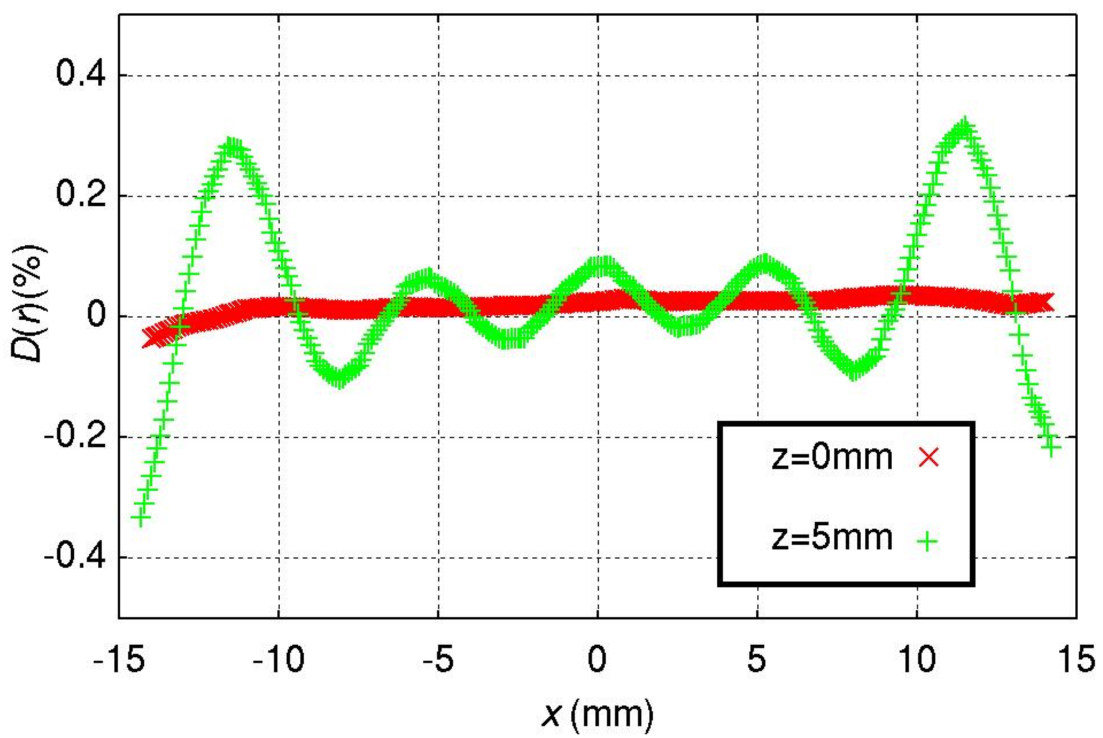
Electric field precision



Voltages given each electrode [V]

(optimized for 35keV $^{24}Mg^{+}$)

Errors from E=k/r near the reference orbit



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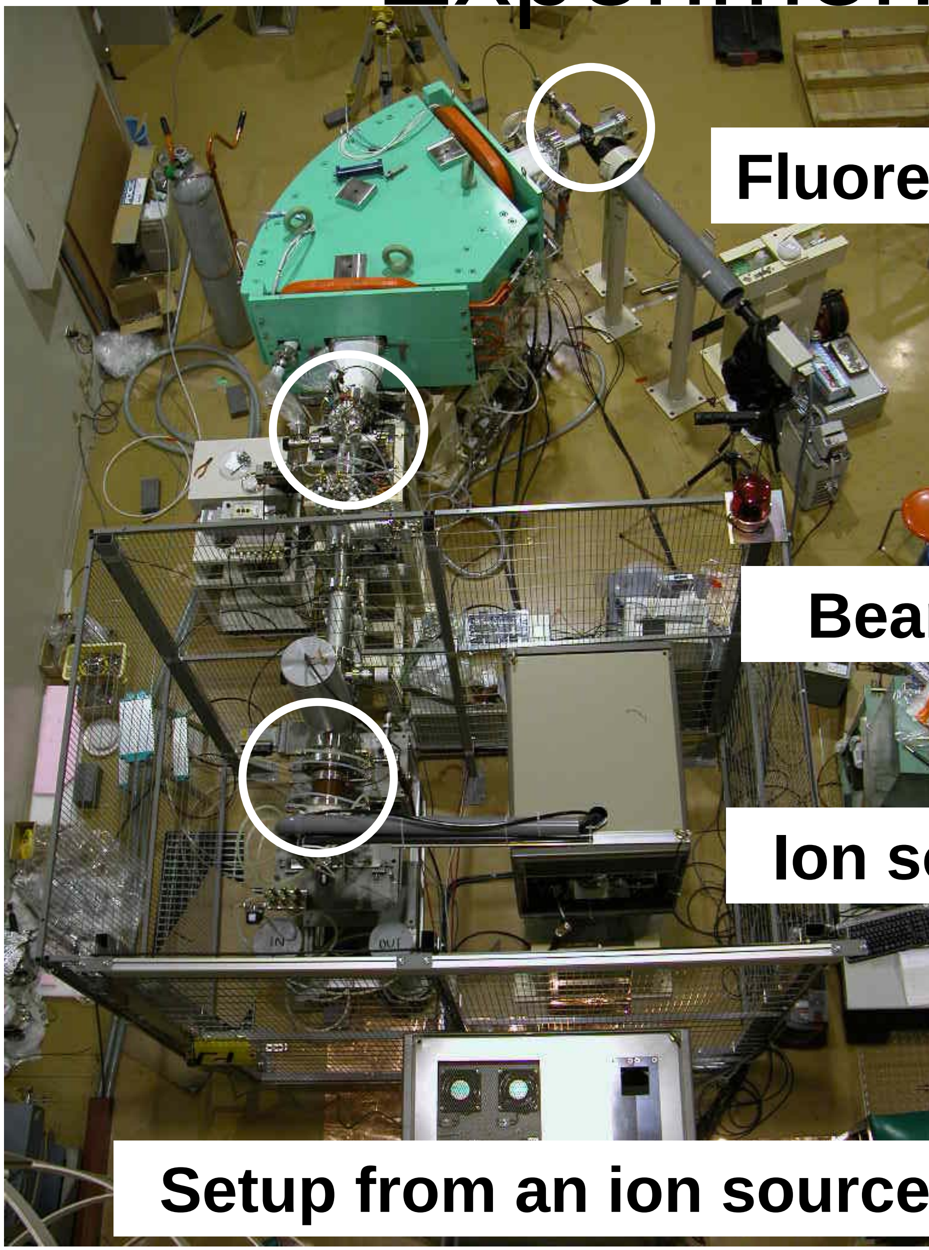
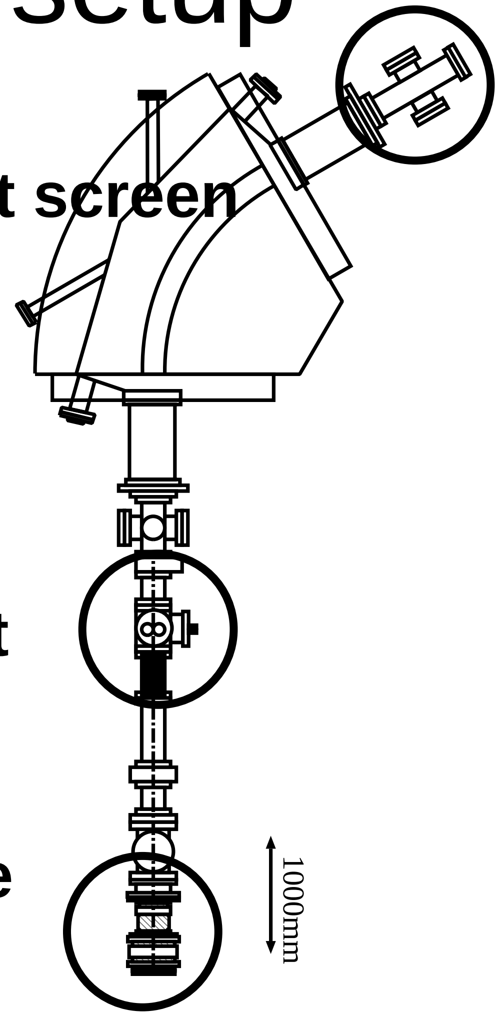
Experimental setup



Fluorescent screen

Beam slit

Ion source



Setup from an ion source to fluorescent screen

Experimental condition

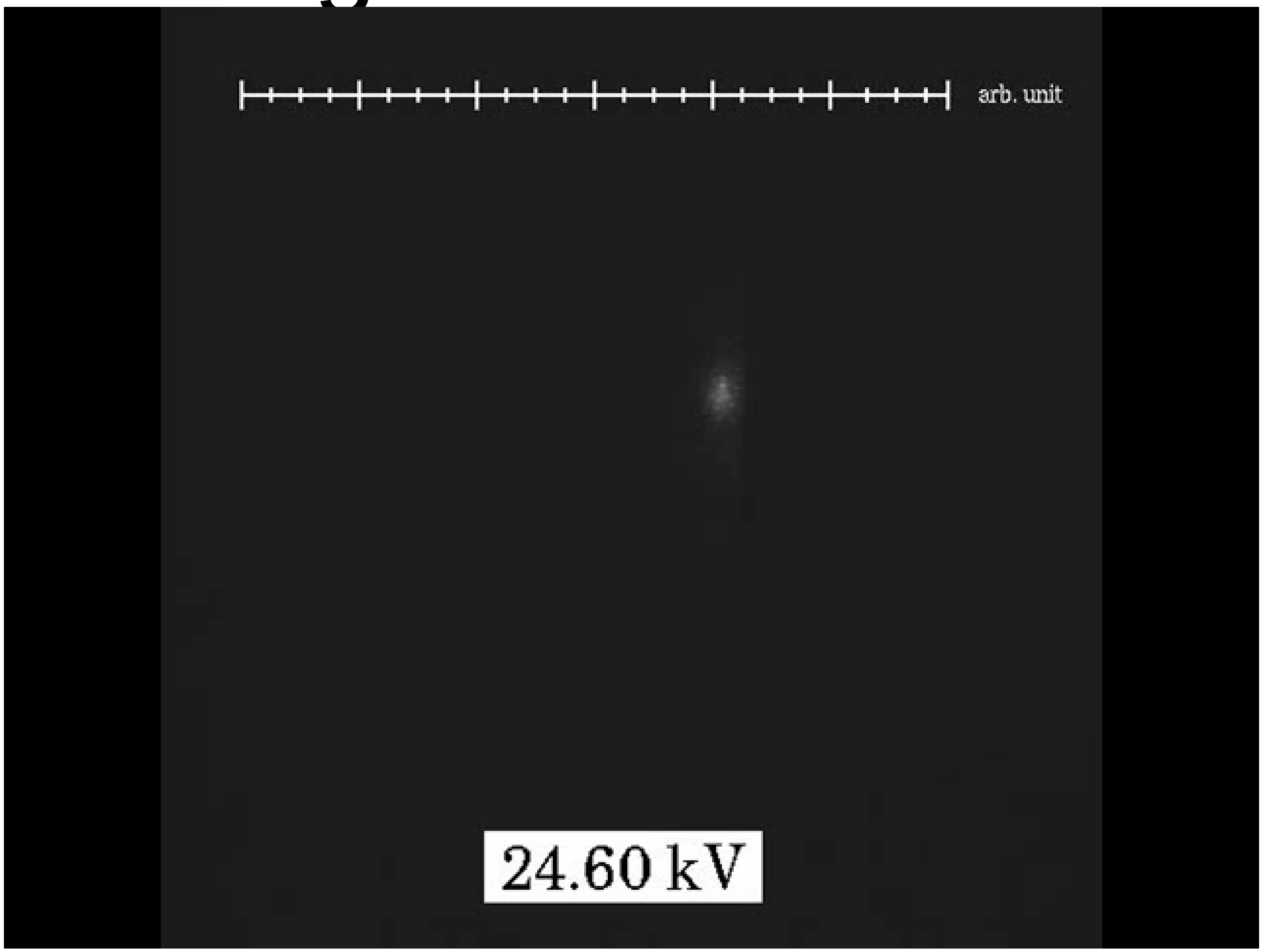
- Beam : N_2^+
- Energy : 25 keV
- Emittance : 5 π mm mrad
- Vacuum condition : ~10^{-5}Pa
- Magnetic and Electric field strength

B [T]	E[V/m]	
0.115	None	Only B
0.252	5.71×10^4	Ex.) $vB > 2E$
0.230	4.76×10^4	$vB = 2E$ ← **Dispersion free**
0.205	3.81×10^4	Ex.) $vB < 2E$

Images on screen 1

Outside

increase



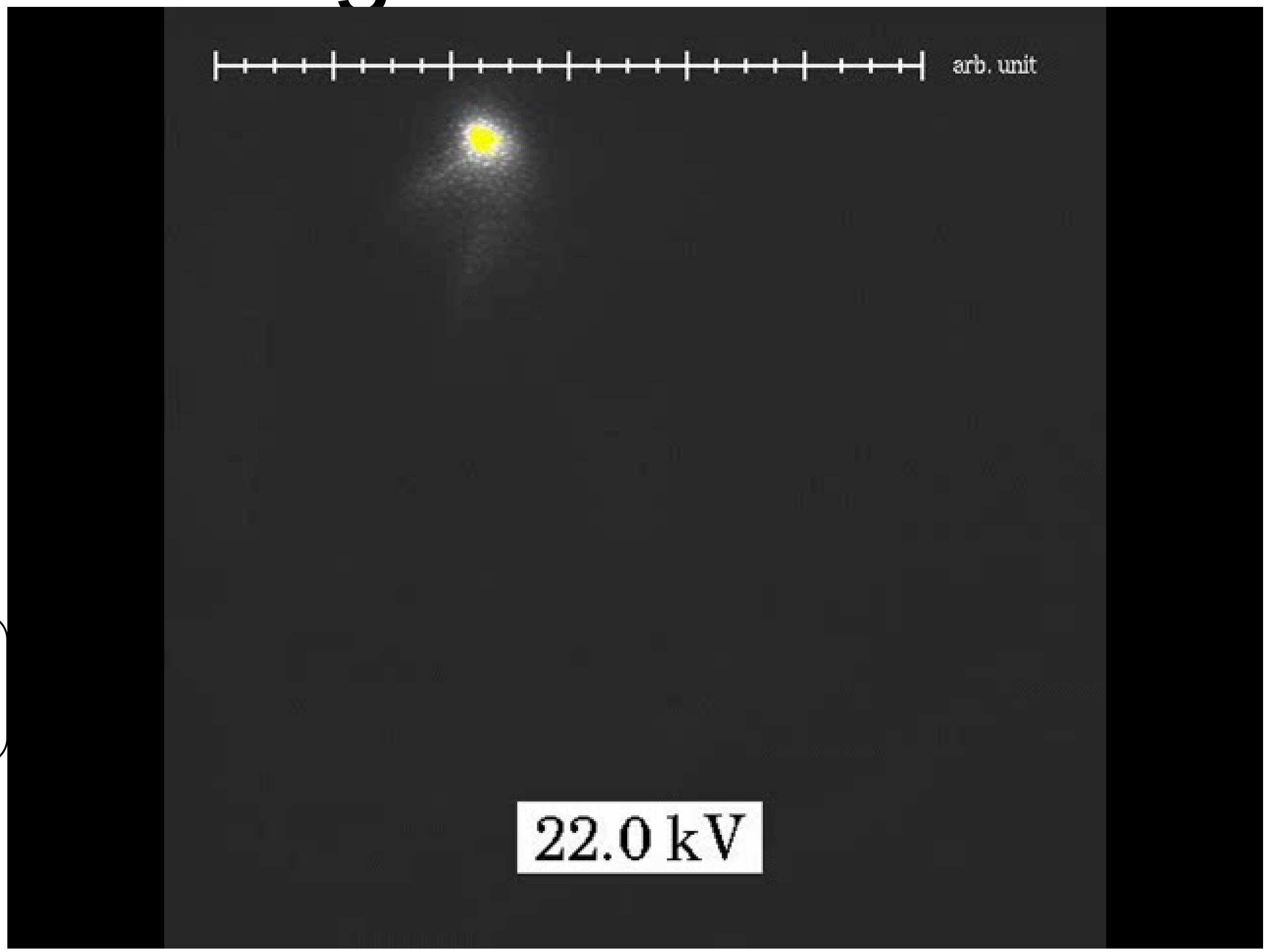
Inside

Δr
decrease

keV (beam kinetic energy)

Magnetic field only

Images on screen 2



Outside

increase

Inside

Δr
decrease

keV (beam kinetic energy)

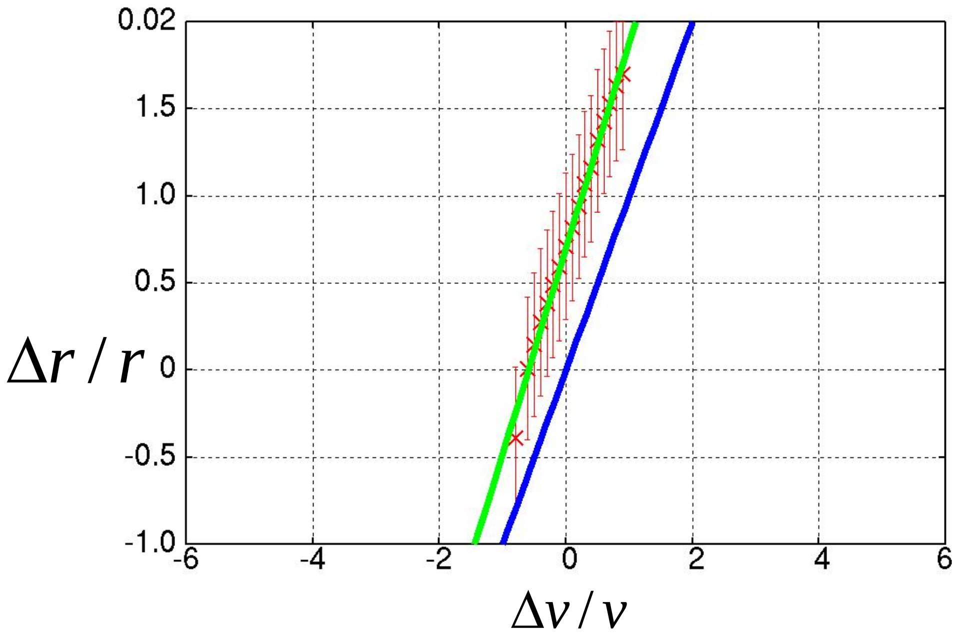
Magnetic and electric field (dispersion cancel condition)

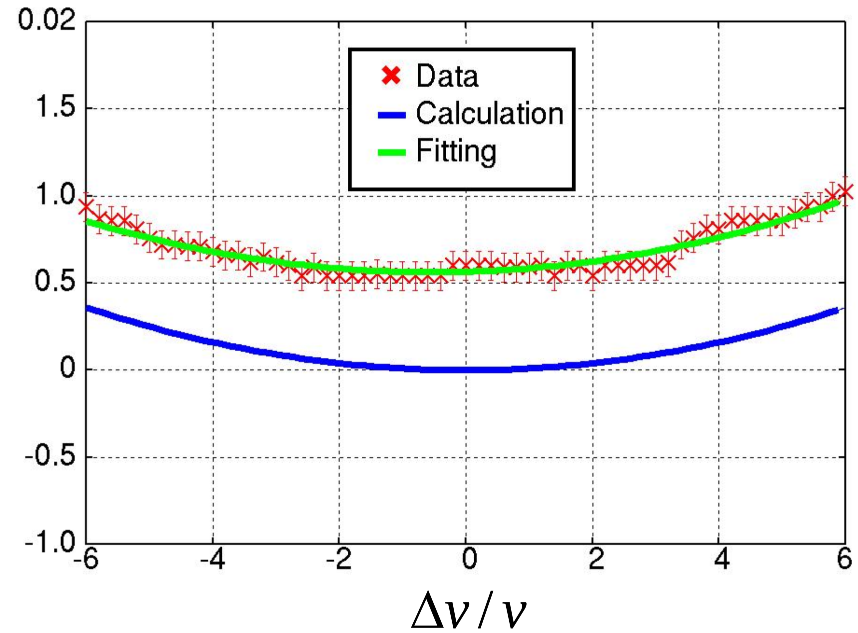
Results 1

Deviation of radial position (%)

Magnetic field only

Magnetic and electric field (dispersion cancel condition)





Momentum deviation (%) **Momentum deviation (%)**

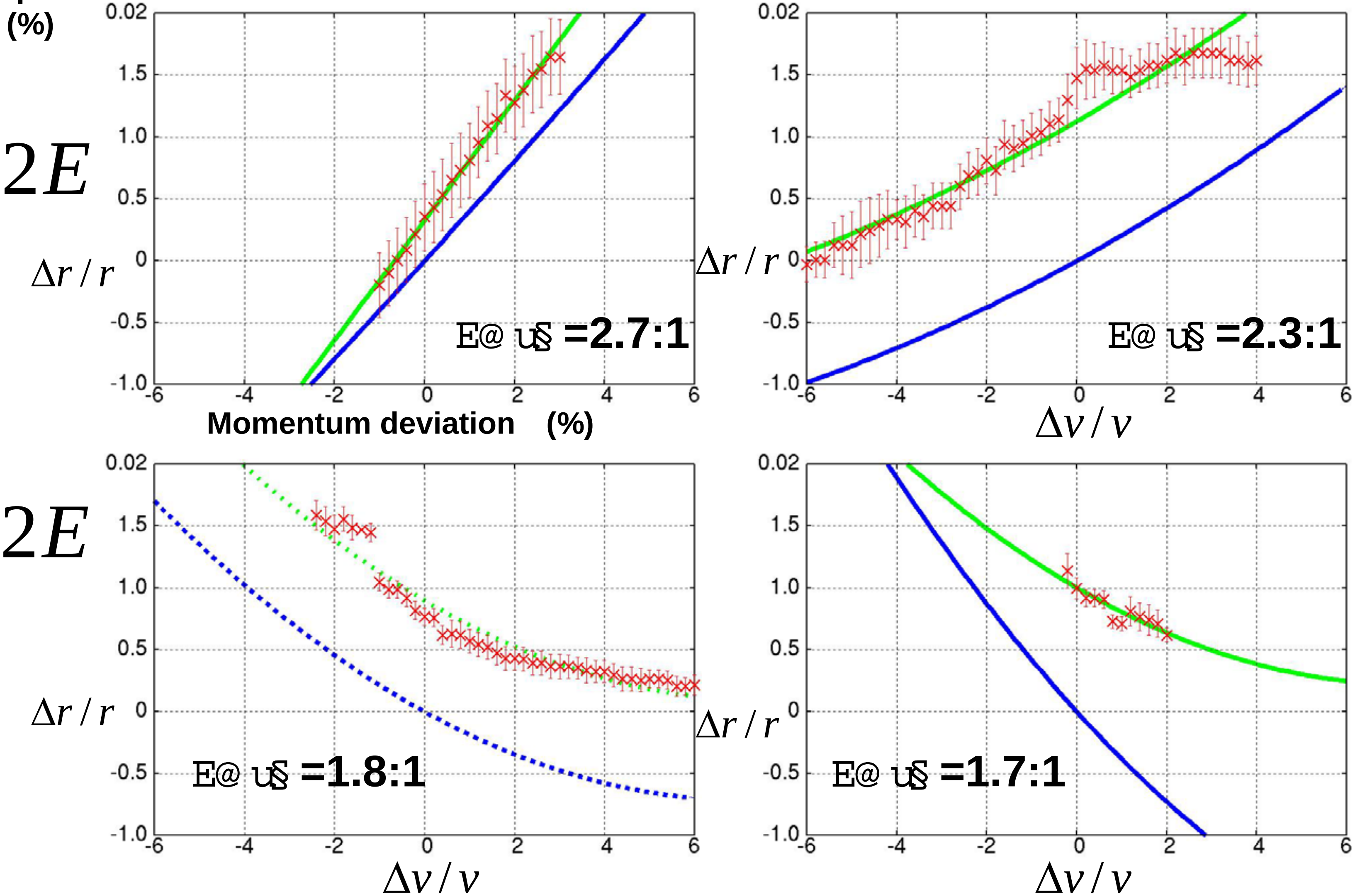
Linear dispersion is canceled

Results 2

Deviation of radial position (%)

$vB > 2E$

$vB < 2E$



Dispersions are controlled

Summery and Future Plans

Summery

1. Design a set of Electrodes
- Field error<0.1% (+-5mm from the reference orbit)
2. Test the effect of electric fields
- Canceled linear dispersion
- Controlled linear dispersion (from + to —)

Future

1. Apply dispersion control to storage ring
2. Apply these dispersion control to laser cooling