SIMULATION OF PROTOTYPE PROTON EDM STORAGE RING

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CONTENT

- EDM Measurement using Storage Ring
- Prototype EDM Storage Ring
- Simulation
- Conclusion

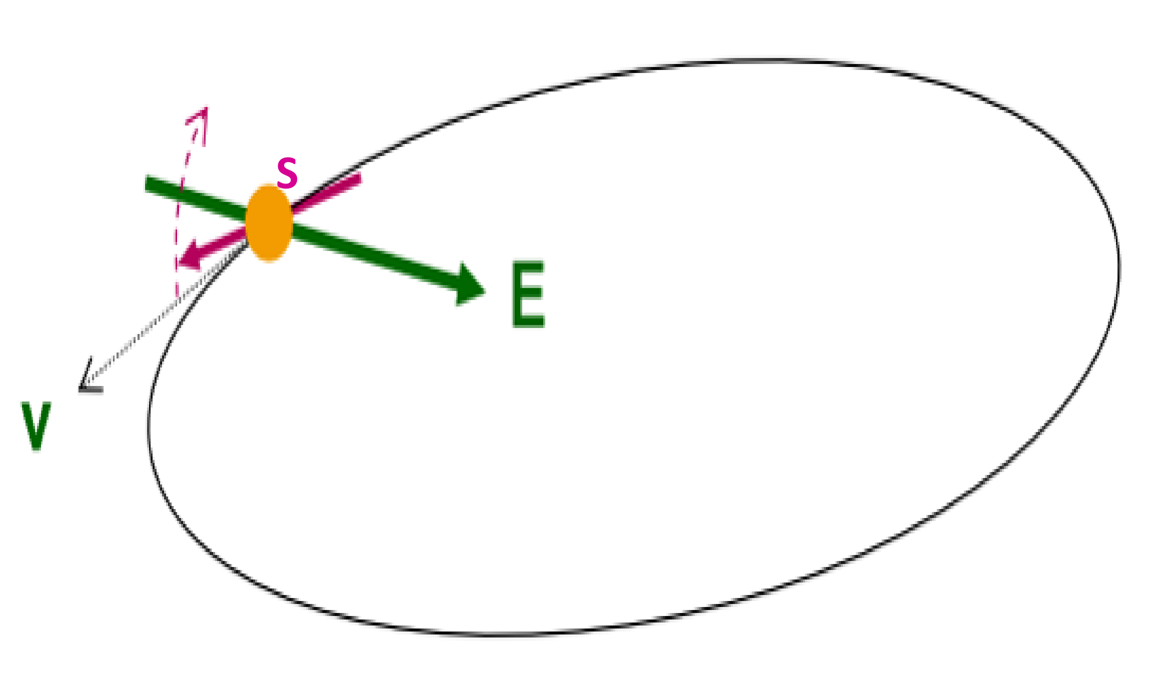
EDM MEASUREMENT USING STORAGE RING

Basic Principle

1) Inject longitudinally polarized beam in storage ring
2) Radial electric field interacting with EDM (**torque**).
3) Observe vertical polarization with time.

Spin motion: **Thomas BMT-Equation**

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S}$$



EDM≠ 0: spin rotation out of horizontal plane

$$\vec{\Omega} = \frac{q}{m}\left\{ \underbrace{G\vec{B} + \left(G - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta}\times\vec{E}}{c}}_{\text{MDM}} + \underbrace{\frac{\eta}{2}\left\{\frac{\vec{E}}{c} + \vec{\beta}\times\vec{B}\right\}}_{\text{EDM}} \right\}$$

$\eta \sim$ Electric dipole moment

Frozen Spin:

$$\left(G - \frac{1}{\gamma^2 - 1}\right) \equiv 0!$$

ϒ=magic moment $\rightarrow \vec{p} \,||\, \vec{S}$

If $\frac{1}{G} > -1$ pure electric ring

If $\frac{1}{G} < -1$ Combination of E-B

EDM MEASUREMENT USING STORAGE RING

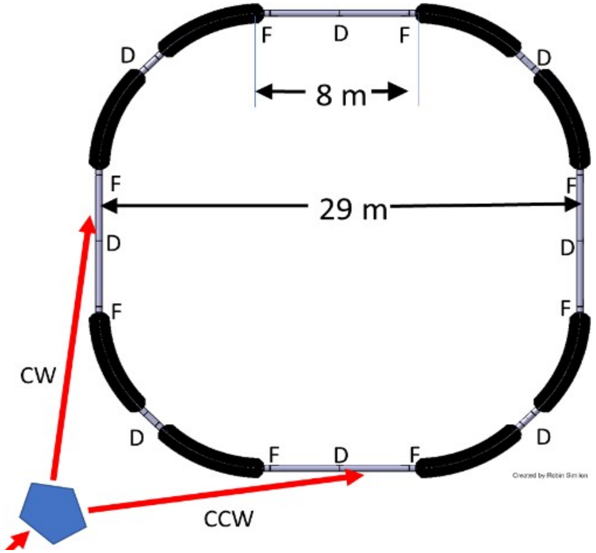
Stage 1

Precursor experiment at COSY (FZ Jülich)

- Magnetic storage ring
- Momentum 970 MeV/c

Stage 2

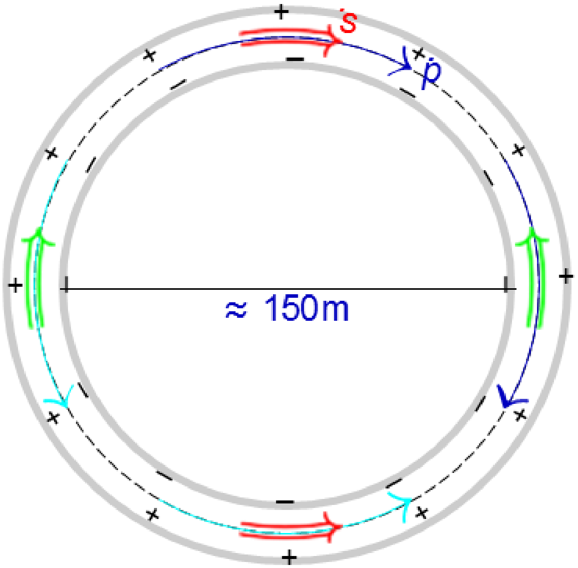
Prototype storage ring



- Electric magnetic storage ring
- Simultaneous CW and CCW beams
- Operates at 30 MeV and 45 MeV

Stage 3

Final storage ring



- Pure Electrostatic Storage Ring
- Magic momentum (701MeV/*c*)

Advancement towards final storage ring will
- Decrease the systematic errors
- Increase EDM measurement`s precision

PROTOTYPE EDM STORAGE RING:

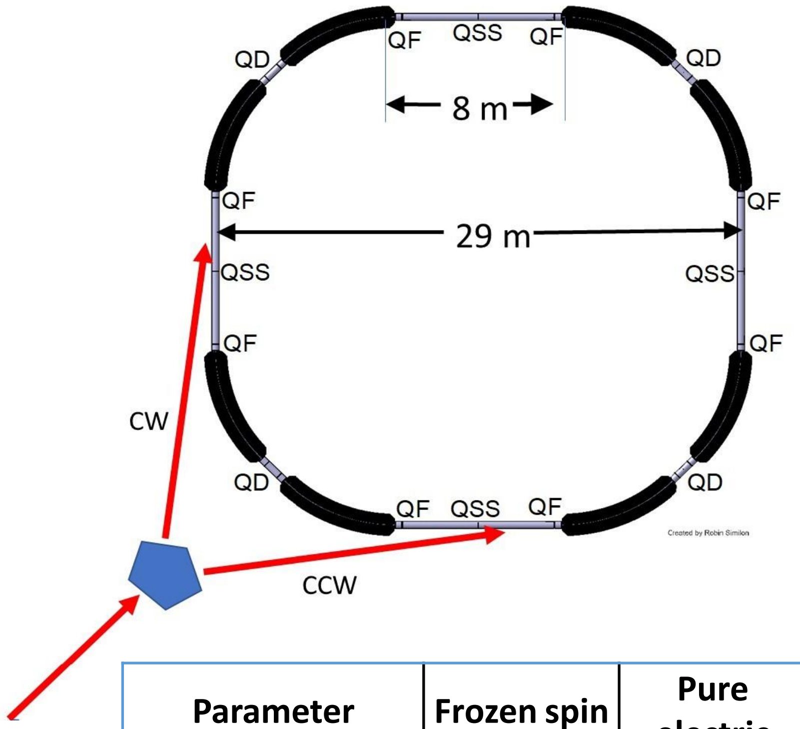
Goals:

- Frozen spin capability.
- Storage of high intensity of CW and CCW beams simultaneously.
- Beam injection with multiple polarization states.
- Develop and benchmark simulation tools
- Develop key technologies beam cooling, deflector, beam position monitors, magnetic shielding....
- Perform EDM measurement

RING DESIGN AND PARAMETERS

Basic layout

- Fourfold symmetric squared ring.
- Circumference = 100 m
- Each straight section is 8m long
- Three families of quadrupoles will be used
    - i. Focusing QF
    - ii. Defocusing QD
    - iii. Straight section QSS
- Ring will be operated in two modes
    - i. With all electric bendings (at T=30 MeV)
    - ii. With electric and magnetic bendings (at T=45 MeV)

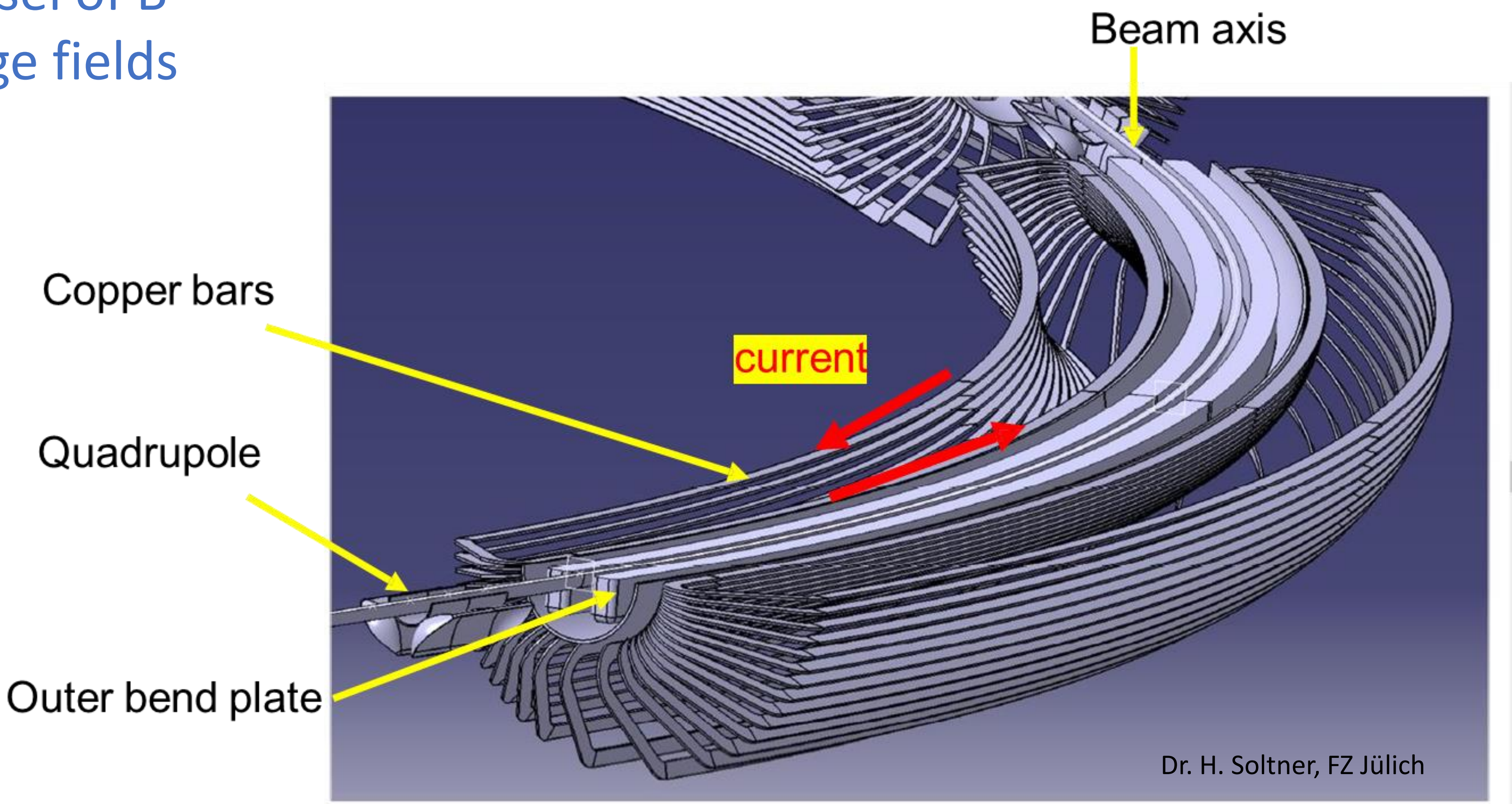


Parameter	Frozen spin	Pure electric	Unit
$E_{Kinetic}$	45	30	MeV
β	0.299	0.247	
Pc	294.057	239.158	MeV/c
Bρ	0.981	0.798	Tm
Eρ	87.941	59.071	MV
ϒ	1.048	1.032	
Emittance	1.0	1.0	mm mrad
Acceptance	10	10	mm mrad

ELECTRIC MAGNETIC BENDING

- Iron free shielding for reversel of $\vec{B}$
- Special design to avoid fringe fields

Electric		
No.of bends	8	
Length $_{\text{effective}}$	6.959	m
Horizontal $_{\text{gap b/w plates}}$	60	mm
Potential $_{\text{b/w Plates}}$	200	KV
Electric field	6.667	MV/m
$\theta_{\text{Bendig angle}}$	45	degree
Magnetic		
Magnetic field	0.04	T
Current density	5	Amm^{-2}
No. of windings	60	per element



SIMULATION

SIMULATION OF LATTICE OPTICS

- Software = MADX

- For quadrupole strength

  $k_{QF} = 0.05$,

  $k_{QD} = 0.3$,

  $k_{QSS0} = 0$

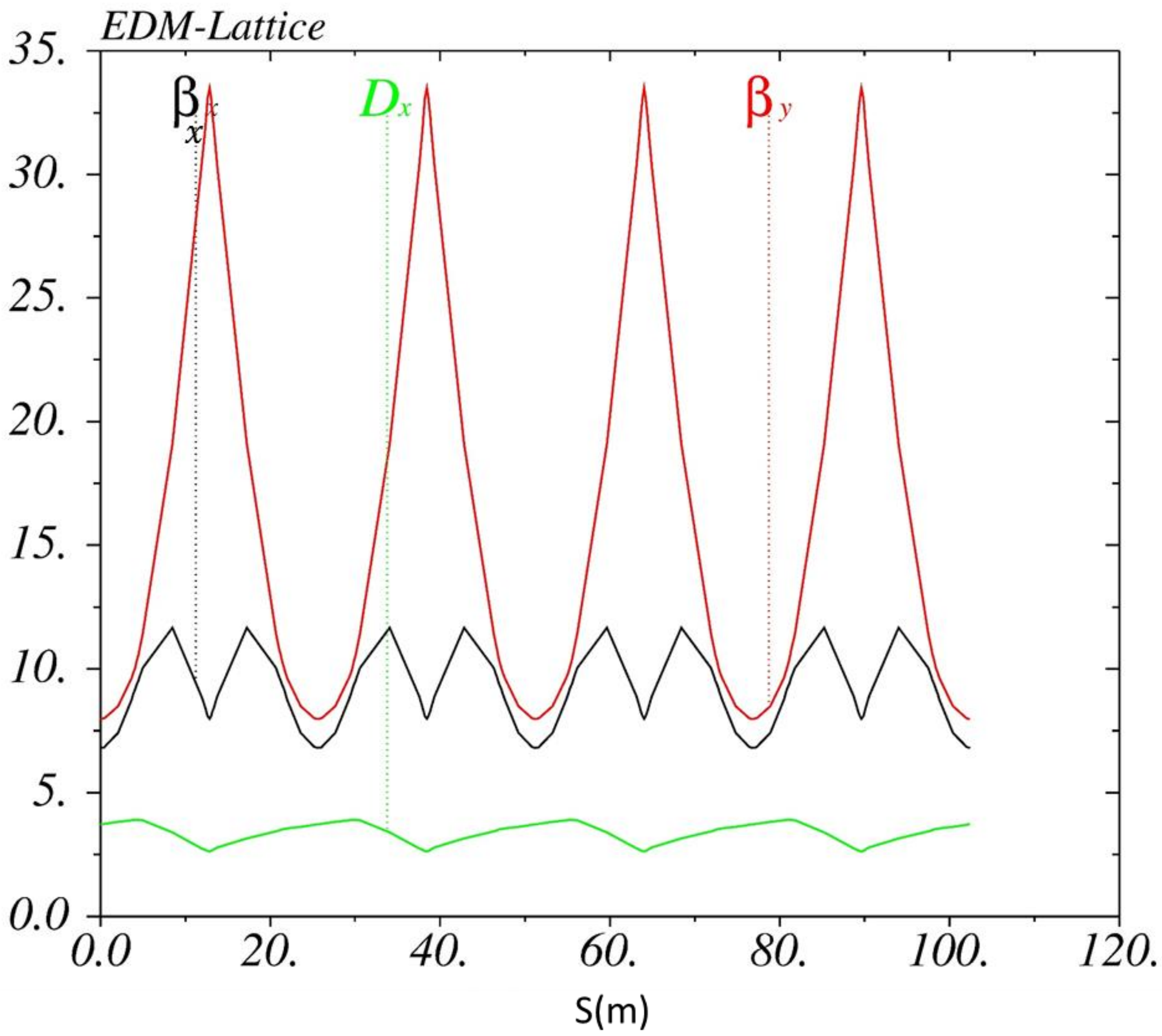
- Typical beta functions with betatron tunes

  Qx = 1.75

  Qy = 1.22

  βx-max = 11 m

  βy-max = 33 m



TUNE VARIABILITY

- Betatron tunes can be varied over a large range.

Betatron tune

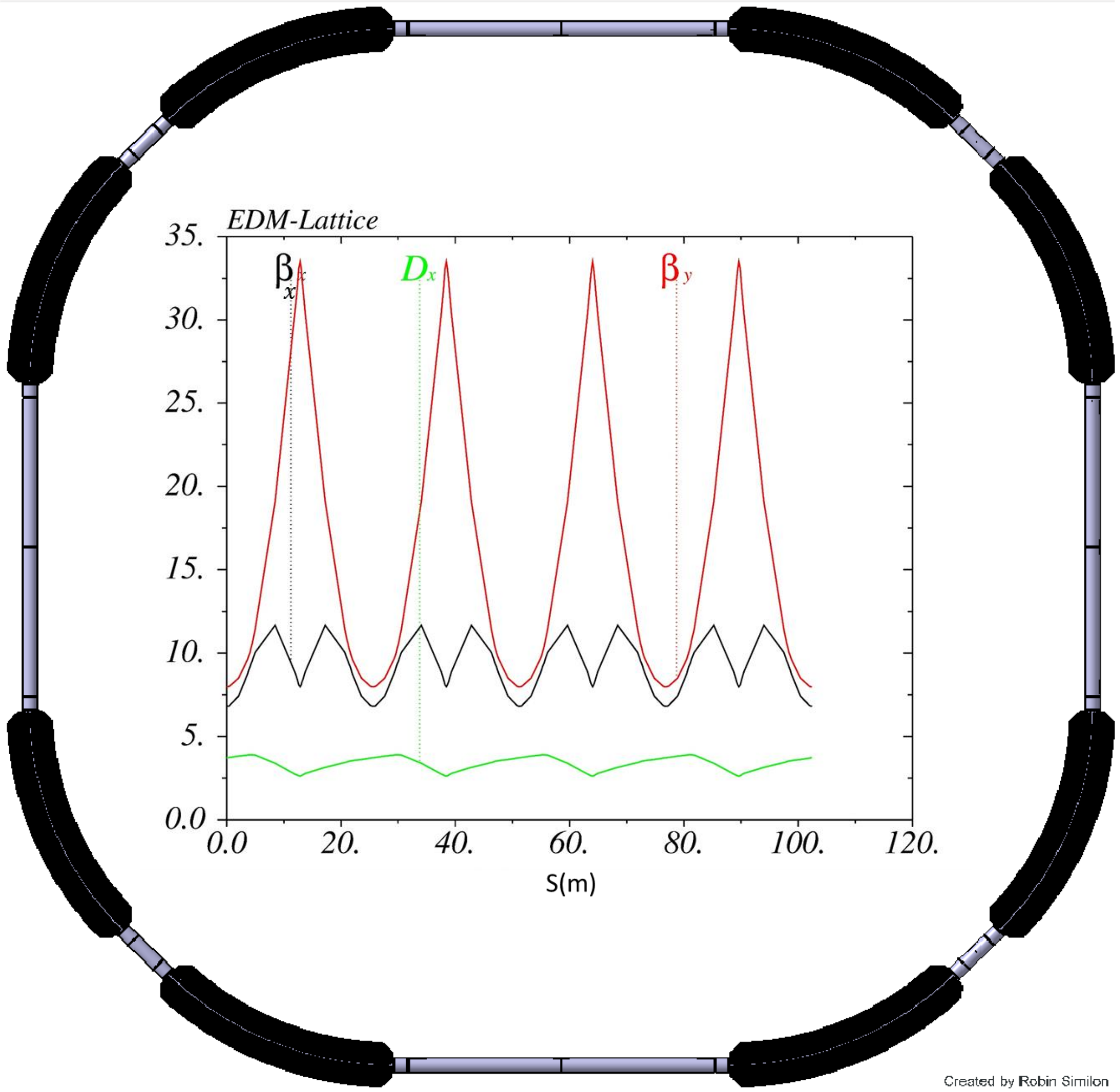
$$0.9 \leq Q_x \leq 2$$
$$0.1 \leq Q_y \leq 1.5$$

- Lattice can be adjusted for ultra-weak to moderate focusing

Betatron amplitude

$\beta_x \leq 20\,\mathrm{m}$

$\beta_y \leq 200\,\mathrm{m}$



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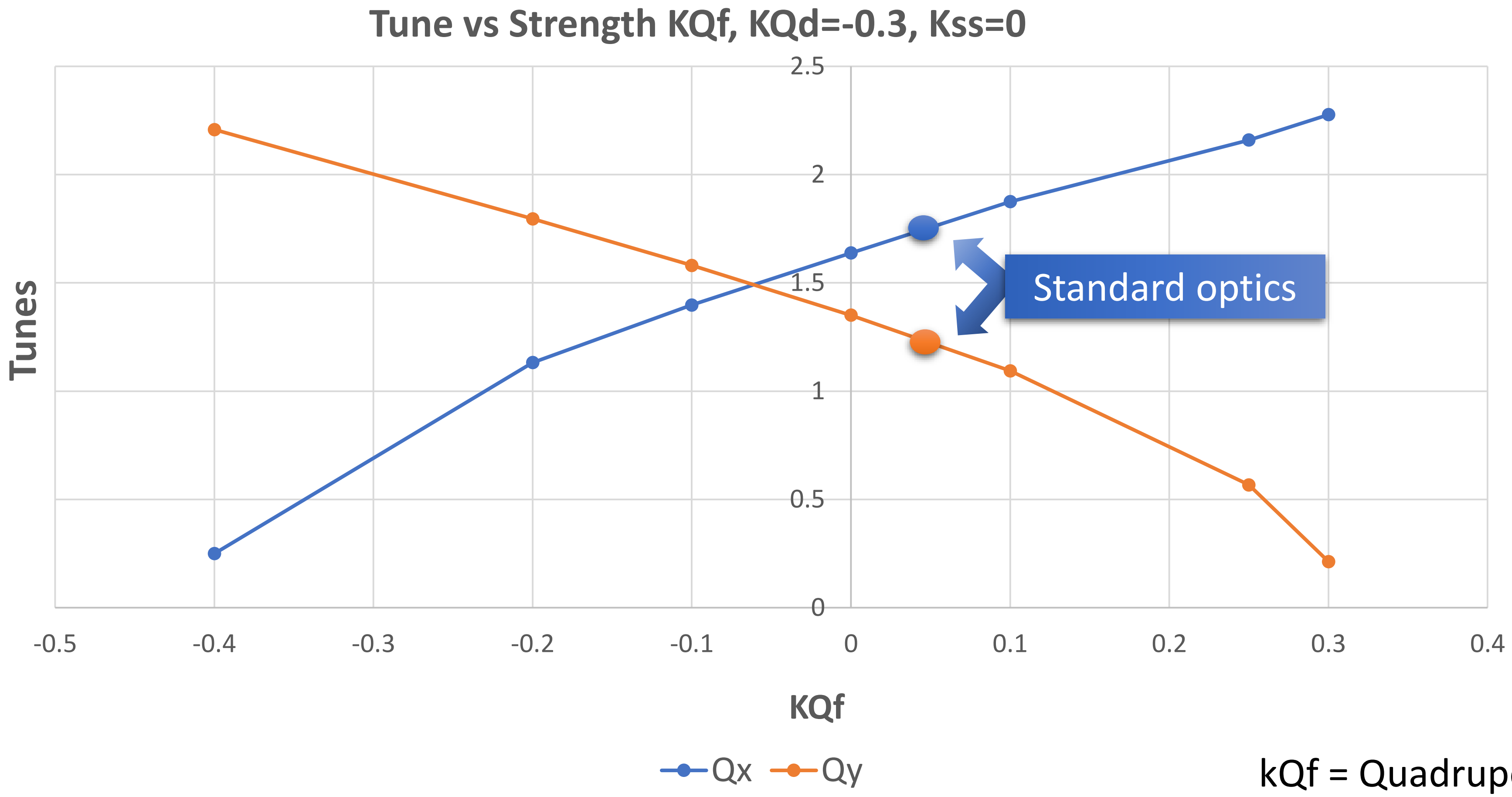
TUNE VARIABILITY



The marked points are continued in next Figure.

kQf = Quadrupole focusing strength
kQd = Quadrupole defocusing strength
Kss = Quadrupole straight section strength

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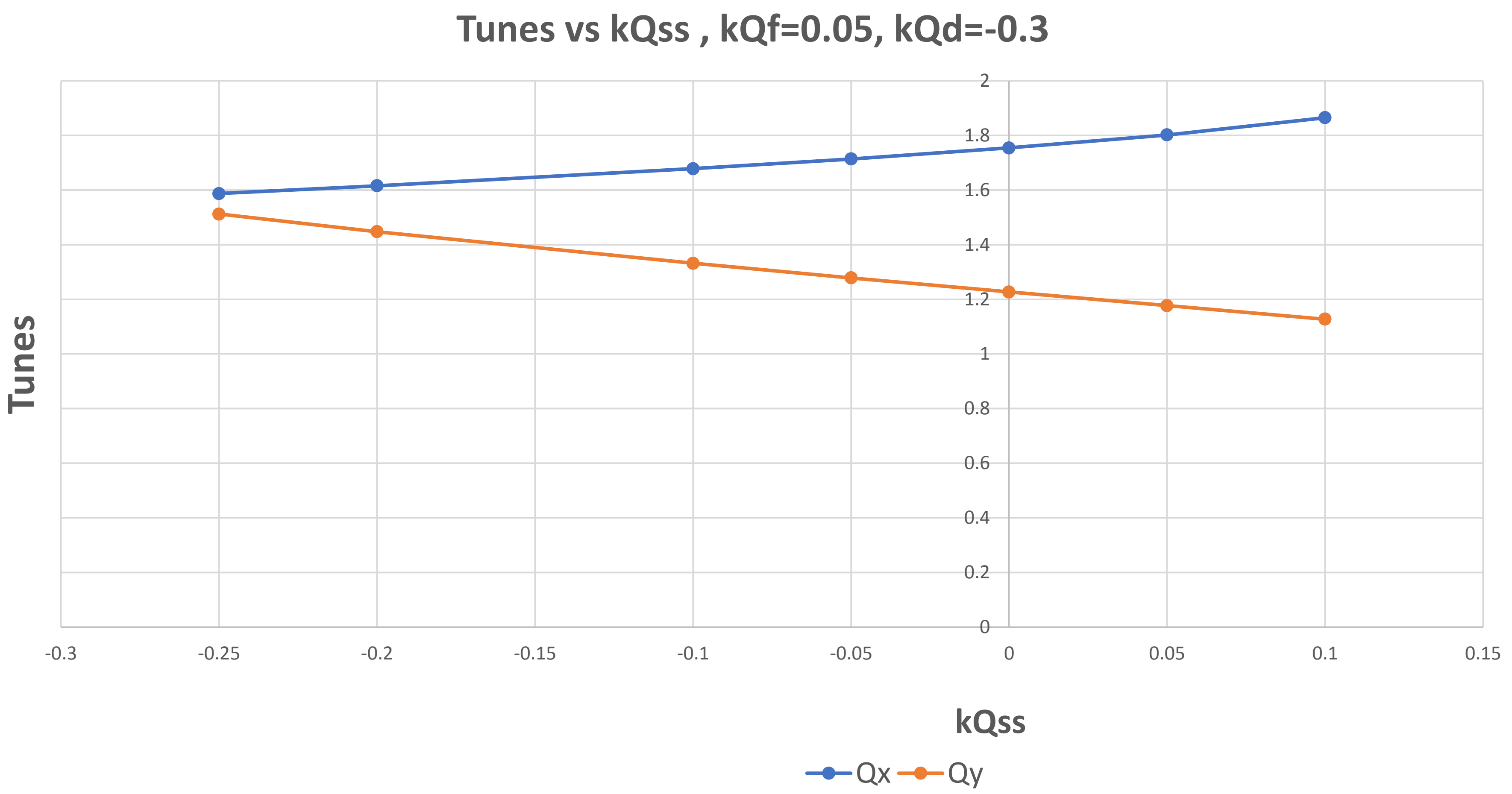
TUNE VARIABILITY



Optimization of lattice → Best Compromise b/w systematic errors and beam lifetime

BEAM LIFETIME

Main beam losses effects

- **Hadronic interaction**
  - Polarimeter
  - Target thickness
- **Single coulomb scattering**
  - Rest gas scattering
  - Transverse acceptance
- **Energy loss straggling**
  - Polarimeter and rest gas scattering
  - Longitudinal acceptance
- **Intrabeam scattering (IBS)**
  - Longitudinal acceptance
  - Phase-space density

CONCLUSION

Summary:

- Preliminary design of Prototype EDM Ring
- Optics Simulations MADX

Outlook:

- Benchmarking of simulation
- Optimization of optics
- Beam lifetime estimates in progress

THANK YOU