EIC ESR Vacuum System Overview

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Outline

• ESR Vacuum System
  • Requirements
  • Overview
  • Layout
  • Component Details
  • Current Status
  • SynRad/MolFlow

• Interaction Region
  • Requirements
  • Overview
  • Synchrotron Radiation Studies
  • Heat Loads in Final Focusing Magnets

• Summary
# Electron Storage Ring

**New 3.8km ring**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference [m]</td>
<td>3833.94</td>
</tr>
<tr>
<td>Beam energy [GeV]</td>
<td>5, 10, 18</td>
</tr>
<tr>
<td>Max beam current [A]</td>
<td>2.5</td>
</tr>
<tr>
<td>RMS bunch length [mm]</td>
<td>~7</td>
</tr>
<tr>
<td>Max power absorbed [MW]</td>
<td>~10</td>
</tr>
<tr>
<td>Number of cells</td>
<td>96</td>
</tr>
</tbody>
</table>

![Electron Storage Ring Diagram](image)
ESR Vacuum Requirements

• Provide a sufficient aperture for the electron beam
  • 5, 10 and 18 GeV operating modes
  • 15σₓ/25σᵧ + 10/5mm for orbit distortion
  • Reverse bends required for 5GeV operations
  • Low impedance

• Maintain adequate magnet to chamber clearance

• Protect vacuum components from synchrotron radiation
  • Maximum of 10MW of SR power
  • Shielding for non-water cooled components
  • Damage to components from high energy x-rays

• Ultrahigh vacuum conditions
  • Average dynamic pressure < 1x10⁻⁸ torr
  • Beam-gas lifetime > 20 hours

• Modular installation to minimize in tunnel work
ESR Overview

- Ring is divided into several sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Qty</th>
<th>Length [m]</th>
<th>Total [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcs</td>
<td>6</td>
<td>257</td>
<td>1542</td>
</tr>
<tr>
<td>Straights</td>
<td>12</td>
<td>123</td>
<td>1476</td>
</tr>
<tr>
<td>IRs</td>
<td>6</td>
<td>136</td>
<td>816</td>
</tr>
</tbody>
</table>

- Multipole and dipole chambers
  - 80mm x 36mm aperture
  - OFS copper
  - BPMs mounted on MP chambers
- ~700 RF bellows
ESR Vacuum Valves

- 30 vacuum sectors (~128m)
- RF shielded gate valves
- All metal roughing valves

<table>
<thead>
<tr>
<th>RF shielded GVs</th>
<th>Location</th>
<th>Valves/sect.</th>
<th># sect.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcs</td>
<td>3</td>
<td>6</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Straights</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Roughing valves</th>
<th>Location</th>
<th>Valves/sect.</th>
<th># sect.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcs</td>
<td>3</td>
<td>12</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Straights</td>
<td>2</td>
<td>20</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>
ESR Vacuum Pumps, Monitoring and Control

- Ion pumps, TSP, NEG
  - One IP and TSP every half cell in arcs
  - Distributed NEG pumping
- Standard gauging layout
  - Three CCGs/vacuum sectors (90)
  - One TCG/vacuum sector (30)
- 1 wire temperature monitoring
  - ~1200 sensors
- RGAs in special sections
- Support equipment
  - 40 turbo carts
  - 10 leak detectors

Diagram:
- Arc sector
  - NEG strips or NEG coating
  - IPs and TSPs in MP (16 per sector)
- Straight sector
  - NEG strips or NEG coating
  - IPs and TSPs in MP (3 per sector)
  - IP in every other drift pipe (6 per sector)
- IR sector
  - 3 Cold cathode gauges
  - 1 Pirani gauge
  - 8 temperature sensors
ESR Arc Layout

SECTION D-D
SEXTUPOLE

SECTION E-E
QUADRUPOLE

1.917 [48.7 mm]

1.575 [40.0 mm]

18 GeV ENVELOPE

SECTION B-B
D1/D3

2.031 [51.6 mm]

15 SIGMA + 10 mm

25 SIGMA + 5 mm

1.575 [40.0 mm]

5 GeV ENVELOPE

SECTION C-C
D2

18 GeV ENVELOPE

Electron-Ion Collider
Arc Vacuum Components

**Arc Vacuum Chambers**
- OFS copper extrusions
- High heat load components (up to 10MW)
- Low impedance geometry (zero step flanges, etc.)
- Copper to stainless steel welding
- >1000 chambers to fabricate, process and integrate
ESR RF Shielded Bellows

- Combination RF-Vacuum seal
- Water cooled flanges
- Compact footprint
- Stroke Req: -25/+10mm
  - Cell length variation: +/-5mm
  - Compression (NEG): -15mm
  - Extension: +3mm
  - Chamber length: +/-2mm
  - Alignment: +/-1mm
ESR Horizontal Collimator

- RF fingers
- Replaceable collimator tip
- Movable jaw
- Vacuum chamber adjustment independent of motion system
- TC feedthrough
- Collimator enclosure
- Water cooling line
- Wire vacuum seal
- Assembly can be completed and tested before closing the vacuum

Combination NEG/IP

Cold cathode gauge

Rigid transition 80 x 36mm to 46 x 27mm

Roughing port

Full open: 18σ (46mm)
Full insert: 12σ (16mm)
ESR Horizontal Collimator

Chamber removed for clarity

- Removable jaw assembly
- Jaw mounting plate
- Collimator enclosure mounted in chamber
- Vacuum for cooling line
- Support post
- Vacuum seal to chamber (fixed)
- Motion plate
- Linear guide system
- Independently adjustable jaws
Current Status

Stainless steel to copper weld

Prototype RCS chamber

RF-Vacuum seal after bakeout

Extra flange joint to make dipole chambers straight and length more manageable

Extra bellows for variable cell length and in situ bakeout

Extrusions on order
ESR Synchrotron Radiation Studies

Photon absorption or reflection is based on incident photon energy, surface geometry, material and surface roughness. Shadow for flange joint and bellows. Simulate photon distributions and define magnetic regions. Includes beam parameters and lattice functions.

Simplified arc chamber geometry and integrated photon absorbers. Beam channel (36 x 80mm).

Dipole triplet:
- D1
- D2
- D3

Pump ports

Beam channel (36 x 80mm)

Dipole chamber - 18 GeV

Integrated photon absorbers

Dipole chamber - 5 GeV

3850W (8.9W/mm²)

500W (1.5W/mm²)

1170W (7.3W/mm²)

2400W (3.6W/mm²)

4200W (4.2W/mm²)

1470W (7.3W/mm²)

2400W (3.6W/mm²)

3850W (8.9W/mm²)
ESR Pressure Simulation

- Operating pressure dominated by PSD
- ESR average pressure populates ‘tails’
- Need to reduce vacuum conditioning time
- NEG coating option
- Simplifies chamber, commercial options
- Requires more bellows and in situ bakeout
Interaction Region Overview

- Central detector chamber
- Forward cryostat
- Rear cryostat
- RCS By-pass
- Hadrons
- Electrons

Central detector chamber
Interaction Region Requirements

- Provide clearance for the particle beams as well as the SR fan
  - Large beam sizes through strong focusing quads near IR
- Detectors must be placed as close as possible to IP
- Minimize wake fields and longitudinal impedances
- Accommodate shallow crossing angle (25mrad)
- Minimize high energy photons hitting the central beryllium pipe
- Reduce residual gas pressure to minimize beam-gas interactions
  - High pressure results in high background
- Minimize interaction between beam pipe and collision products
- Accommodate various ancillary detectors near the IP
- Average dynamic pressure < 1x10^{-9} torr
Interaction Region Main Detector Chamber

- Tapered aperture for SR fan
- Central beryllium section (1.47m)
- Large exit flange for forward spectrometer
- Working closely with detector group to sequence installation and removal steps

Diagram:
- Hadrons
- Electrons
- Vacuum chamber
- Forward spectrometer
Synchrotron Radiation Simulations

See tech note by C. Montag for more detail on transverse beam tail and beam lifetime studies.
Photon Distribution on Detector Chamber

Simulated photons imported into Geant4

Photons > 5keV

Total Flux: $2.7 \times 10^{14}$ ph/sec

Power absorbed: 0.3W

($\sim 3.0 \times 10^6$ ph/crossing)
Beam interactions with residual gas molecules generate high energy photons and scattered electrons which result in high backgrounds.
Heat Loads in Forward Magnets

Working with magnet division on heat management strategies
Summary

• Preliminary layouts for complicated vacuum areas have been completed
• Electron storage rings with similar parameters have been built (B factories)
• Interaction region layout is progressing and looks promising
• Vacuum R&D is underway to retire significant risks prior to baselining
  • RF shielded components (bellows, flange joints, GVs)
  • Chamber prototyping (ESR, central detector)
  • Movable collimators
  • Central detector chamber prototype
• Close collaboration with beam physics, magnets and detector groups
• Eager to open active collaborations with other institutions

Thank you for your attention